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Fisheries Impacts on North Atlantic Ecosystems: Catch, Effort and National/Regional Data Sets

Fisheries Centre, University of British Columbia, Canada

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edited by

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Director's Foreword

Who would have thought that every single one of the major international agencies set up with such hope in the 1950s and 1960s to manage fisheries on North Atlantic fish populations would have been found, by 2000, to have totally failed in their mandate. This series of reports presenting the output of the first two-year phase of the *Sea Around Us* project, presents a detailed and solid case for this spectacular and depressing failure.

Two questions immediately arise. Why did this happen? What can we do in future?

A search for causes raises many further questions. Were stock assessments misleading or did they miss the big picture by ignoring ecosystem effects? Were unreported catches large enough to cause declines invisible to conventional stock assessment? Was the ability of fish population age structures to buffer climate fluctuations ignored? Did political pressure cause quotas approved by scientists to be raised? Was industry locked into serial depletion by area, species and habitat? Was industry driven by a perverse economic investment ratchet? Was industry seduced by subsidies that turned money-losing fisheries into money-makers? It is quite likely that all of the above apply, and the work reported here addresses many of these questions.

But how can a major industry have caused disaster on such a scale? If we understand this meta-question we may be able to find a solution. The first phase of the project has largely been devoted to documenting the problem. So, for answers as to what to do about it, we await the results of the next two-year phase of the *Sea Around Us* project.

The Fisheries Centre at the University of British Columbia supports research that first clarifies, and then finds ways to mitigate, the impacts of fisheries on aquatic ecosystems. Only with such insight of how whole aquatic ecosystems function can management policies aim to reconcile the extraction of living resources for food with the conservation of biodiversity, with the maintenance of ecosystem services, with amenity and with other multiple uses of aquatic ecosystems. Indeed, the present dire state of marine ecosystems and their fisheries around the globe signals a pressing need for what may be termed an 'ecosystem imperative'.

Although ecosystem agendas of this kind have recently become embodied in the legislative goals of many nations, and are an integral part of the FAO *Code of Conduct for Responsible Fisheries,* in practice there have been few attempts to work out how it might actually be done. In sponsoring the *Sea Around Us* project, the Pew Charitable Trusts of Philadelphia, USA, have devoted a significant amount of funding to an ambitious pilot project aiming to address this question. The research team[1] of senior scientists, postdoctoral research fellows, graduate students, consultants and support staff commenced work in late 1999.

The first two-year phase has focused on the fisheries and ecosystems of the North Atlantic. In addition, a book for the general public is being published[2]. Members of this team have been excited and challenged by the unprecedented scope of the research work. Most of the methods used to tackle the problem are new[3], and many of the measures developed by the team have been translated into a revolutionary new mapping system.

These reports are the latest in a series of *Fisheries Centre Research Reports*. A full list is shown on our web site at *www.fisheries.ubc.ca*, and the series is fully abstracted in the *Aquatic Sciences and Fisheries Abstracts*. The research report series aims to focus on broad multidisciplinary problems in fisheries management, to provide a synoptic overview of the foundations and themes of current research, to report on research work-in-progress, and to identify the next steps that research may take. *Fisheries Centre Research Reports* are distributed to all project or workshop participants. Further copies are available on request for a modest cost-recovery charge. Please contact the Fisheries Centre by mail, fax or e-mail to 'office@fisheries.ubc.ca'.

Tony J. Pitcher

Professor of Fisheries
Director, UBC Fisheries Centre

[1] A list of team members may be found in Annex 1

[2] See Maclean, J. and Pauly D., Island Press, Washington: "In a Perfect Ocean, Fisheries and Ecosystems in the North Atlantic" , Preface.

[3] See Pauly, D. and Pitcher, T. (2000) Methods for Evaluating the Impacts of Fisheries on North Atlantic Ecosystems. Fisheries Centre Research Reports 8(2), Preface.

Preface and Acknowledgement

The contributions included in this report form part of the scientific output of the first phase of the *Sea Around Us* project (1999-2001), targeting the data-rich North Atlantic[1]. This project was initiated and is funded by the Pew Charitable Trusts, Philadelphia, USA, and designed to investigate the impacts of fishing on marine ecosystems. To this aim, the project collect and analyze catch data and ecosystem information, and has developed a suite of new analytical tools during its early phase[2]. This task is undertaken in collaboration with a global network of scientists providing data, expertise and peer review[3]. An important feature of the approaches and methods used to produce these results is that they do not compete with the elaborate single-species methodology traditionally used in fisheries management. Thus, we are able to build on the findings of conventional fisheries science in an effort to complement traditional approaches.

The following report, available as electronic PDF free of charge from our web-site (*www.fisheries.ubc.ca*), contains four sections:

1. A section on basin scale analyses, presenting findings based on the synthesis approach of the data and information documented in the geographic sections and outside sources, such as the FAO fisheries database;
2. A section covering data on catches, discards, effort and ecological information for the north-eastern Atlantic, including Iceland, Norway, Russia, Faroe Islands, Germany, British Isles, and the Netherlands;
3. A section concerning catches of the fisheries of the south-eastern North Atlantic, including French, Spanish, Portuguese, Moroccan, Azores and Canary Islands fisheries; and
4. A section on the western North Atlantic covering the US Atlantic coast, and French, Spanish and Portuguese fisheries off the Newfoundland coast.

We thank the Pew Charitable Trusts for their ongoing support of the *Sea Around Us* project, and the project team for their dedication. We would also like to thank all the external collaborators and colleagues for their willingness to work with us, and for their efforts at delivering data and information on time.

Dirk Zeller, Reg Watson and Daniel Pauly

December 2001

[1] The present report is the first in a series of reports on the North Atlantic, with others covering ecosystem models and analyses, and policy evaluation.

[2] See Pauly, D. and Pitcher, T. (2000) Methods for Evaluating the Impacts of Fisheries on North Atlantic Ecosystems. Fisheries Centre Research Reports 8(2), 195 pp.

[3] See Annex 1

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PART I: BASIN SCALE ANALYSES

MAPPING FISHERIES LANDINGS WITH EMPHASIS ON THE NORTH ATLANTIC

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ABSTRACT

Fisheries landing statistics from broad statistical reporting areas were mapped as catches with a resolution of 30 minutes of longitude x 30 minutes of latitude. The procedure involved the progressive disaggregation of the statistics, firstly to provide poorly defined records with a better taxonomic identity, and secondly by using a rule-based process involving databases of known distributions of taxa, oceanographic features and of the areas where reporting countries are permitted to fish, in order to spatially disaggregate the data. Maps prepared for reporting years 1950 until 1999 showed trends in the spatial distribution of fisheries catches, provided a valuable means of examining other questions such as interactions between fishing and marine mammals, and provided descriptions of the global catch from large marine ecosystems. Catch maps prepared for the North Atlantic are illustrated and were used in the formation of ecological models and in the preparation of maps of catch value.

INTRODUCTION

Official statistics of fisheries landings are provided to the *Food and Agricultural Organization* of the U.N. (FAO) annually by member countries. These are reported for a range of species and aggregated taxa for each of FAO's statistical areas. Use of fisheries landings data in spatial models usually requires statistics on a finer spatial and taxonomic scale than typically reported to FAO. The shortcuts taken by reporting countries, whether due to their limited resources or other motivations, causes problems for users of the data. Most reporting countries break down the major portion of their statistics to the genus or species level of identification. This level of description is highly desirable if knowledge of the fish's distribution and habitat needs is to be used to aid the spatial disaggregation of statistics. Unfortunately, some countries provide the majority of their fisheries statistics broken down only to highly aggregated categories such as 'miscellaneous marine fishes'.

In the spatial disaggregation of these statistics a two-stage process is therefore required. The first attempts to disaggregate the statistics provided into taxa of lower levels such as families, genera or species. This process allows greater success with the second stage that combines aspects of the fish's biology and known distribution with the reporting country's documented access to fishing locations to produce a fine-scale spatial disaggregation of the reported landings. This process builds global maps of annual catches as each country's landing records are processed. The process described below is proving extremely useful in producing better information for modeling a variety of processes including changes in values of marine extractions, interactions between marine mammals and fishing operations, and in charting changes in marine ecosystems.

METHODS

Spatial resolution and spatial cell size

The process described in this report seeks to disaggregate landings from FAO's statistical areas to smaller units that can be used in a statistical model using oceanographic parameters. To facilitate this, spatial units of ½ degree latitude by ½ degree longitude were used. These will be referred to as spatial cells. The choice of this size was a balance between larger cells that would average many depths and other characteristics, and provide only a crude model of distribution, and a finer structure that would require intensive computing power and data at a scale not widely available. Over the world's seas and oceans the selected cell size requires a matrix with approximately 180,000 cells. Note the difference between the term 'area', which refers to the spatial extent of one of these cells (which are smaller nearer the poles), and 'statistical areas' or 'FAO areas', by which we mean FAO's statistical reporting areas.

Data sources

Fisheries landings

The fisheries data used were supplied by FAO (with one exception – see below). For all but annual tuna and billfish landings FAO's FishStat *(www.fao.org/fi/statist/FISOFT/FISHPLUS.asp)* was consulted. Landings of tuna and billfish were taken from FAO's Atlas of Tuna and Billfish Statistics (*www.fao.org/fi/atlas/tunabill/english/home.htm*). The totals were used unaltered. A documented process of taxa disaggregation, however, was used (described

below) to allow landings to be identified sufficiently to facilitate the use of known distributional and biological information in the spatial disaggregation process. Only records of fishes and marine invertebrates were used in the analysis, i.e., data on marine mammals and algae were not considered. Data supplied were for 'official' reported landings only, and do not include discarding, nor do they make any attempt to correct for unreported, misreported catches or other errors. This will be done later, using the approach outlined in Watson *et al.* (2000) and Pitcher and Watson (2000). Landings data from the Canadian arctic, exclusively arctic char (*Salvelinus alpinus*), were taken from Crawford (1989).

Fish taxonomy, biology and distribution
FishBase (Froese and Pauly, 2000; *www.fishbase.org*) was used for information on fish taxonomy, their biology and distribution. This provided a framework for our databases and assisted with the process of spatial disaggregation by providing actual distributions or information on the limits to the distribution of many fish taxa.

Depth
Sea-floor elevations data were taken from the ETOPO5 dataset available on the U.S. National Geophysical Data Center's 'Global Relief' CD (*www.ngdc.noaa.gov/products/ngdc_products.html*) that provides elevation in 5-minute intervals for all points on Earth. Elevations below sea level (depths) were averaged for each spatial cell used in our database**.**

Primary productivity
Primary productivity data ($g \cdot C \cdot m^{-2} \cdot year^{-1}$) were provided by the Joint Research Centre (JRC), of the European Commission Space Applications Institute (SAI) Marine Environment Unit (ME) *(www.me.sai.jrc.it/me-website/contents/shared_utilities/frames/index_windows.htm*).It was developed using the Behrenfeld and Falkowski (1997) model that includes NOAA's satellite data on sea temperatures, chlorophyll a levels and light irradiance. The data were available on a spatial scale of approximately 0.176 degree and was averaged into ½ degree spatial cells. The time period averaged was for readings taken during 1999, and was taken to represent a basic climatology of primary productivity.

Coral reefs
Modeled data (Kleypas *et al.*, 1999) on the presence or absence of coral reefs globally were made available from Reefbase (*www.reefbase.org)* on a 5-minute resolution which was accumulated into our ½ degree spatial cells to provide a reef spatial coverage index. This was used to locate catches of taxa whose life-history requires the presence of a coral reef.

Sea mounts
The gazetteer provided on the U.S. National Geophysical Data Center's 'Global Relief' CD (*www.ngdc.noaa.gov/products/ngdc_products.html*) was used to count the number of known sea mounts in each of the ½ degree global spatial cells. These were used to provide the basis for the distribution of taxa known to occur only in the proximity of sea mounts.

Permanent ice coverage
Data from the U.S. National Snow and Ice Data Centre, Boulder, Colorado (*nsidc.org/index.html*) provided the monthly limits of sea ice coverage. These were used to determine which spatial cells would not be available for fishing due to nearly permanent ice coverage.

Exclusive economic zones
Boundaries of Exclusive Economic Zones (EEZ) and declared national fishing zones were taken from the Global Maritime Boundaries CD (Veridian Information Solutions, 2000) (*www.maritimeboundaries.com/main.htm*) which uses existing claims and accepted rules to delineate these zones, even though several are still unresolved.

Fishing agreements
A database of fisheries agreements between countries (FARISIS), was made available by FAO (Anon., 1998). The search facility of this resource was enhanced by importing the contents to a Microsoft Access database, a process that required parsing the exported text file using a Microsoft Visual Basic program. This database allows the fishing agreements between countries to be listed so that the rules of fishing access required in the spatial disaggregation process could reflect current or historical arrangements.

Taxonomic disaggregation
Taxonomically highly aggregated landings statistics are problematic for any analysis including spatial modeling. Some countries report the majority of their landings under the 'miscellaneous marine fishes', 'miscellaneous marine crustaceans' and 'miscellaneous marine molluscs' categories (Table 1). Some of these countries, notably China, combine a large fraction of highly aggregated categories with large reported landings, to top the list with the total tonnage reported in this format. According to FAO statistics, China has reported approximately

Table 1. Countries reporting landings in taxonomically highly aggregated groups based on totals from FAO statistics from 1950 to 1998. Listed are the top 20 countries ranked by the total tonnage (million tonnes) of landings including 'miscellaneous marine fishes' (MM Fishes), 'miscellaneous marine crustaceans' (MM Crust.) and 'miscellaneous marine molluscs' (MM Moll.). The term 'miscellaneous marine' is abbreviated as MM. The average of all countries over the same period is also shown.

	Landings	Landings MM				% MM			
Country	**marine total**	**Fishes**	**Crust.**	**Moll.**	**Total**	**Fishes**	**Crust.**	**Moll.**	**Total**
China, Main..	200.0	74.4	16.5	22.2	113.1	37.2	8.2	11.1	56.6
Korea, DPR	36.1	35.4	0.3	0.0	35.7	98.1	0.7	0.0	98.9
Thailand	68.2	32.2	0.0	0.1	32.3	47.2	0.0	0.2	47.3
Japan	375.2	21.6	0.3	0.0	21.9	5.8	0.1	0.0	5.8
Vietnam	24.0	19.1	0.0	0.6	19.7	79.5	0.0	2.6	82.1
Myanmar	18.3	18.1	0.0	0.0	18.1	98.9	0.0	0.0	98.9
Indonesia	64.1	10.3	0.1	0.0	10.3	16.0	0.1	0.0	16.1
Former USSR	209.9	8.1	0.1	0.6	8.8	3.9	0.1	0.3	4.2
India	67.5	7.7	0.6	0.1	8.4	11.5	0.8	0.1	12.4
Malaysia	26.1	7.7	0.2	0.0	7.9	29.3	0.7	0.1	30.0
Mexico	31.2	6.6	0.0	0.1	6.6	21.0	0.0	0.2	21.2
Korea, Rep.	68.0	5.7	0.0	0.3	6.1	8.4	0.0	0.4	8.9
Bangladesh	6.3	4.4	0.3	0.0	4.6	69.9	4.1	0.0	73.7
Brazil	21.9	4.3	0.0	0.2	4.5	19.6	0.1	0.7	20.4
Taiwan	29.5	4.2	0.0	0.1	4.3	14.1	0.0	0.3	14.4
Spain	56.0	3.4	0.2	0.2	3.8	6.0	0.3	0.4	6.7
Italy	16.9	3.0	0.1	0.3	3.5	18.0	0.8	2.0	20.8
USA	171.0	3.3	0.0	0.2	3.4	1.9	0.0	0.1	2.0
Iran	4.0	3.0	0.0	0.0	3.0	75.6	0.0	0.3	76.0
Hong Kong	6.4	2.4	0.0	0.1	2.5	37.5	0.0	2.0	39.5
Average all countries	**-**	**-**	**-**	**-**	***1.2***	***19.6***	***0.3***	***0.3***	***20.3***

113 million tonnes of marine landings this way since 1950, nearly three times that of any other country.

Because statistics supplied by China to FAO are such a large part of landings reported in FAO statistical areas 61 and 71 (34% since 1990) it was necessary to attempt to disaggregate these reported landings based on the more detailed records from neighboring states, namely Taiwan and South Korea. Though close to China, and undoubtedly sharing many taxa in its' fisheries catches, North Korea was not included in this analysis as it provides even less taxonomic detail for its landings than China does.

Disaggregation of landing records proceeded separately for each broad taxonomic category and were defined as fishes, crustaceans and other (mostly mollusc) taxa. Within each category the percent of the total landings that was assigned to the 'miscellaneous' category was assigned to more specific taxa based on the breakdown of landings reported by neighboring countries. This procedure was performed independently for each statistical reporting year.

In 1998, for example, China reported 27% of its total landings as 'miscellaneous marine fishes'. This same year the average proportion of total landings reported by its neighbors for this same aggregated taxa group was only 10%. Therefore, initially the procedure assigned 17% (the difference) of the Chinese 'miscellaneous marine fish' landing statistic to fish taxa identified at more specific levels than as 'miscellaneous' in the Chinese statistics or in those of its near neighbors. This difference was assigned step-wise in small fractions using a rule-based approach. The rules were that:

- China's proportion of landings assigned to any identified taxa would never be reduced regardless what neighboring states reported;
- the fraction of the difference remaining being assigned to a taxa during each iteration was in proportion to the difference between the proportion reported by China and that reported by its neighbors;
- all taxon levels were considered equally, i.e., fish families were treated the same as fish genera or species; and
- all taxa reported by neighbors could be used for reporting Chinese landings even if a taxon was not specifically reported in official Chinese landings statistics (but could be presumed to be a hidden portion of the 'miscellaneous' category).

In our example, this process continued until the additional 17% of 'miscellaneous' fish fraction reported by China but not by its neighbors had been assigned to nominated fish taxa.

Once this first stage was completed, the remaining proportion of Chinese landings still identified as 'miscellaneous marine fishes' were assigned to nominated fish taxa within the Chinese statistics in proportion to their presence at that stage. In this way all fish landings were assigned to taxa more informative than the 'miscellaneous' segment.

The same procedure was used for crustaceans, and for all remaining unidentified fractions (mostly molluscs). When completed, the total landing statistics for China for any year was unchanged overall and for each broad category (fishes, crustaceans, and others). These 'taxonomically disaggregated' landing records were used in the subsequent spatial disaggregation processes. Results of this procedure are presented in Watson and Pauly (2001). At the time of writing, the taxonomic disaggregation procedure had been applied only to landings reported by China; in the future it will be applied to landings from all countries.

Taxa distribution

The process of spatial disaggregation of fisheries statistics required a database of the global distribution of all taxa reported to FAO. The term 'taxa' is used in consideration that despite the process of taxonomic disaggregation described above, only a portion of the world's landings are reported by individual species, much of it is reported at higher or more general taxonomic levels of aggregation. For each taxon, the proportion of the world's known distribution was mapped to the spatial cells represented in the database. This information is provided in two ways. The first and preferred method, was to use maps of distributions prepared by experts. Many excellent texts such as Muus and Dahlstrøm (1974), Scarratt (1982) and Cohen *et al.* (1990) provide global distributional maps that augment the extensive set of distributions available from FAO (Anon., 2001). Some were provided to us as geographical information systems (GIS) compatible files. Most distributions, however, were available only as bitmaps (rasterized images) and had to be scanned, re-projected and otherwise processed before they could be added to our database. Most sources produce distributional maps using knowledge of fisheries landings, museum collections and generalized depth and temperature ranges of the exploitable ages and life history stages.

What is referred to here as 'depth' is the depth of water over which the species can be taken rather than the depth in the water column at which the species occurs. The reason for this is to allow generalizations on distributions from global bathymetry. This definition means that for taxa such as 'large pelagic fishes' there are no depth limits as these species may be found over the deepest parts of the world's oceans (though actually only occuring in the top hundred or so meters). If depth limits for a taxon were known then these were used in conjunction with distributional maps to restrict the distribution to a subset of the ocean's spatial cells when the spatial database record was created. That is, individual spatial cells included in broad distributional statistical areas on maps were not included if they were outside the known depth range for the taxa.

The database describing the distribution of marine taxa is not simply presence/absence for each spatial cell but rather the proportion of the world's distribution to be found in that cell. In this, it was assumed that regions that had a greater general primary productivity level would on average support greater populations of most marine fauna. Thus, spatial primary productivity data were used to apportion the distribution of each fauna between the cells that fall within the distributional limits.

Other methods were used when distributional maps were not available. The first was used exclusively for taxa identified to the genus level. Each of these used mapped distributions (if they existed) for any species in these genera that our database contains. Otherwise, like all other taxonomic levels, tabular limits to distribution were used next if these were available. There are several excellent sources of tabular information available describing the known distributions of marine fauna, notably FishBase (Froese and Pauly, 2000). This database includes contributions from global experts, and provides latitudinal and depth ranges for many species. Also included is the presence/absence of each species by FAO statistical areas. FAO's SpeciesDAB (Coppola *et al.*, 1994) was also used as a source of tabular distributional information and also covers marine invertebrates.

When tabular limits were used to construct distributions, the maximum and minimum depths were used as more than absolute limits. Rather, it was assumed that the maximum

abundance occurred at depths $^1/_3$ of the way between the minimum and maximum depths, and a triangular distribution was assumed to calculate the proportions of the distribution found at each intervening depth. In a similar way the maximum distribution of taxa with latitudinal limits was taken to occur at a midpoint in the range, with a triangular distribution assumed.

The tentative distributional range, based on any known depth or latitude limits, was then further reviewed when presence/absence by FAO statistical data was available. That is, if a species had a wide distribution described by a range of depth and latitude but was not known to occur in FAO statistical area 21 then its distribution in our database would reflect this known limit, and spatial cells within FAO 21 were removed from its range.

Therefore, the final distribution of fauna for which maps were not preexisting, reflected the known limits imposed by depth, latitude and presence/absence, with a distributional gradient within reflecting the distributions assumed for depth, latitude and gradients of primary productivity. Reviews of this database of distributions by a number of experts have improved its reliability.

Fishing access

Each of the ocean's spatial cells was assigned to a country if the center of that cell occurred within the boundaries of the EEZ for that country according to the Global Maritime Boundaries database (Veridan, 2000). Cell that were not assigned to the EEZ of a country were considered to be on the high seas, and accessible to fleets of all countries.

Rules were developed to allow fishing access to the EEZ cells of one country by another. Initially only the country itself was allowed to access the cells assigned to its own EEZ. This was modified as more information became available on that country's fishing practices and the access rights it grants to other countries. 'Guilds' of fishing countries were defined, within which each guild country was presumed to have mutual access to the EEZ cells of all other countries within the guild. Such an arrangement (albeit with many specific limitations) exists between fishing vessels of the European Union. There are also many examples where countries with historical ties (former colonies or territories) allow fishing access to another country. On a case-by-case basis, and in consultation with national experts, the database of fishing access that is used in the spatial disaggregation process was extended by granting 'permission' to allow fishing access to the spatial cells defining the EEZ of one country by other countries.

The fishing access database was further enhanced by consulting with the FAO's FARISIS database (Anon., 1998), which records fishing agreements, and allows non-historical and distant-water fishing access rights to be included in our 'rules' of fishing access.

At present our rules for fishing access are static, and the transition from 12-mile territorial sea claims to the current 200-mile EEZ has not been included. Maps presented here assume that EEZ claims existed and were in force for the whole time series. These limitations will be addressed in future versions which will better reflect historical access arrangements. Similarly, in our current fishing access database, there is no detail on which specific fishing resources may be accessed by outside countries, which may only be limited to large pelagic species. This detail will be addressed by future enhancements.

Spatial disaggregation

Using landing records that were taxonomically disaggregated where necessary, a rule-based process was used to spatially disaggregate the landings statistics from their original large FAO statistical areas to a subset of much smaller spatial cells within that statistical area (Figure 1).

The official landings records for all countries fishing within the reporting year, as determined by FAO statistics (A in Figure 1), were processed as a set of database records by first disaggregating the large generalized group statistics into lower taxonomic records (B in Figure 1 – described above). These records were then processed individually though the spatial disaggregation process (C in Figure 1, detailed in Figure 2).

Each taxon described in a landings record was looked up in the database of taxonomic spatial distributions (produced by methods described above). This yielded a subset of the spatial cells of the worlds oceans and the proportion of the world's distribution that had been estimated for each cell. The country reporting (fishing) was used with the database of fishing access (described above) which records which spatial cells are available for that country to fish in (including the EEZ of other countries where arrangements exist). The FAO statistical area from which the landing was reported provided a third set of spatial cells, those that are within the nominated statistical area. These three sets of

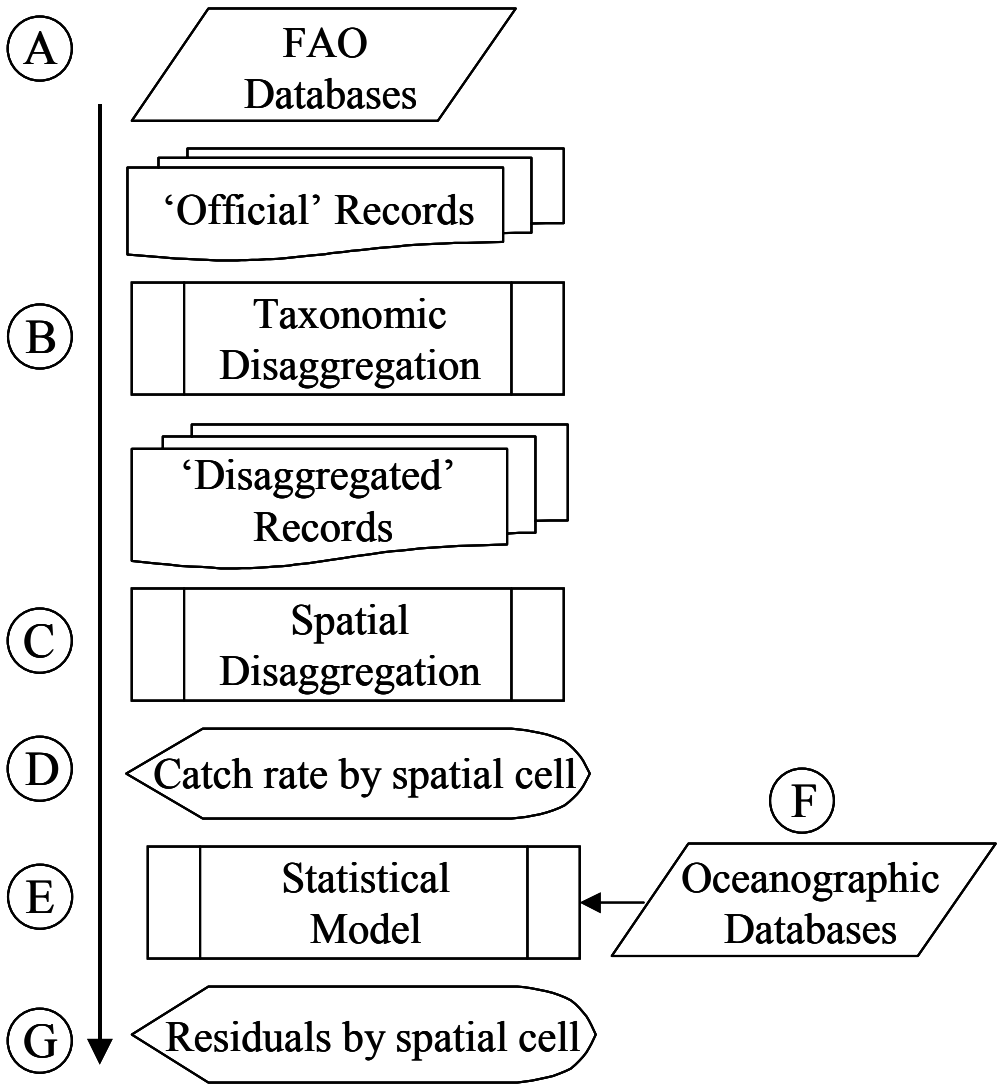

Figure 1. Schematic diagram of the data processing procedures used to produce landing rate maps.

spatial cells were then compared. If there was no overlapping cells then the landing was not allocated to spatial cells and an 'error' report was logged (Figure 2); otherwise the landing reported was assigned proportionally amongst the overlapping cells based on their areas (available in a general spatial database). In this way catches (t km^{-2} $year^{-1}$) were accumulated in each spatial cell as each record was processed.

Logging allocation errors proved very instructive in reviewing whether species distributions and country fishing access ranges were consistent with landings' records. This process allows for constant improvement of the underlying databases. At the time of writing approximately 5% of global landings records could not be mapped to a set of spatial cells because no overlap existed between the taxa's distribution, the reporting country's fishing access, and the statistical area for which the landing was reported. These 'unallocated' records, however, accounted for less than 1% of reported landings by weight. Some of these errors will be eliminated when access arrangements for fishing countries have been made more specific in time and by taxa, and when taxa distributions have been fully reviewed by experts. This process has already required a shift from the predominately depth-determined species distributions that FAO provides, which do not always allow catches in statistical areas where they are frequently reported (often these problems failed to be identified by experts in the fisheries involved).

Sometimes errors originate because countries do not report catches for all FAO areas they fish in, but simply report all the landings for their major statistical fishing areas or they may even report distant-water catches from closer fishing locations. Because the statistics more closely approximate landings rather than catches, sometimes what is reported incorrectly is the statistical area which encompasses the port where the catch was unloaded, rather than the statistical area in which the fish were caught.

Fortunately, for about 95% of landings statistics, there is an overlap between the species' distribution, the countries fishing access, and the range of the FAO statistical area the landings were reported from. Each of these overlapping spatial cells was then allocated a proportion of the reported landing, depending on their area (cells nearer the poles are smaller than those on the equator). In this way a grid map of catches is build up as each landing record is processed (D in Figure 2). Though each record is processed for the taxonomic level it is reported at (after disaggregation processes), for generalized output the results are usually re-aggregated and reported in 12 major groups: these being anchovies, herrings (defined as non-anchovy clupeiformes), perches (all perciformes taxa), tuna and billfish, cods, smelts, flatfishes, scorpionfishes (scorpaeniformes), sharks and rays, crustaceans, molluscs, and 'others'. However, for brevity the present report only presents the aggregate total of these 12 reporting groups.

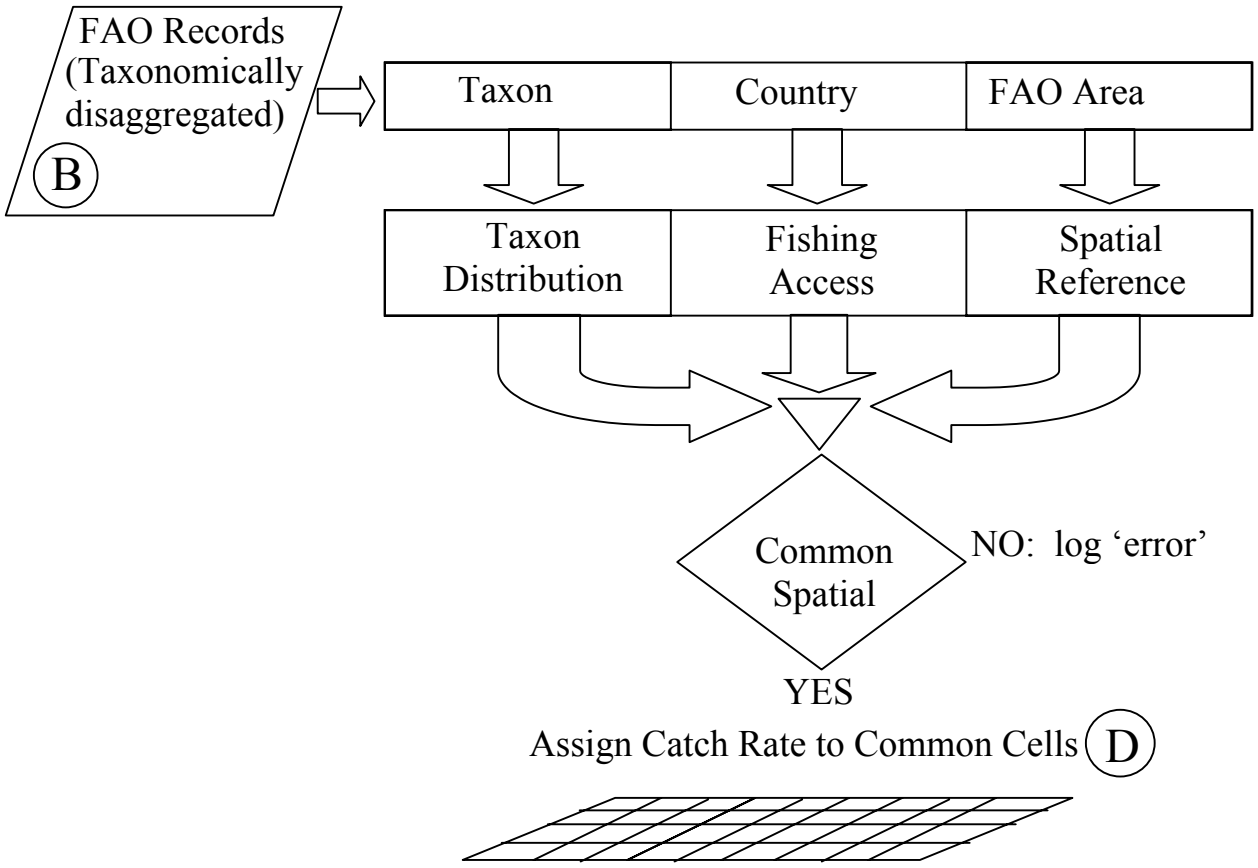

Figure 2. Schematic diagram of the spatial disaggregation process.

RESULTS AND DISCUSSION

The spatial disaggregation of FAO landings into ½ degree spatial cells allows for the totals for the 'North Atlantic', as defined in our project, to be calculated. The breakdown of the landings for the North Atlantic by group appears in Figure 3. Maximum landings were reported in the 1970s. In the late 1980s and early 1990s there was a significant reduction in cod catches which was mostly responsible for reduced landings in subsequent years.

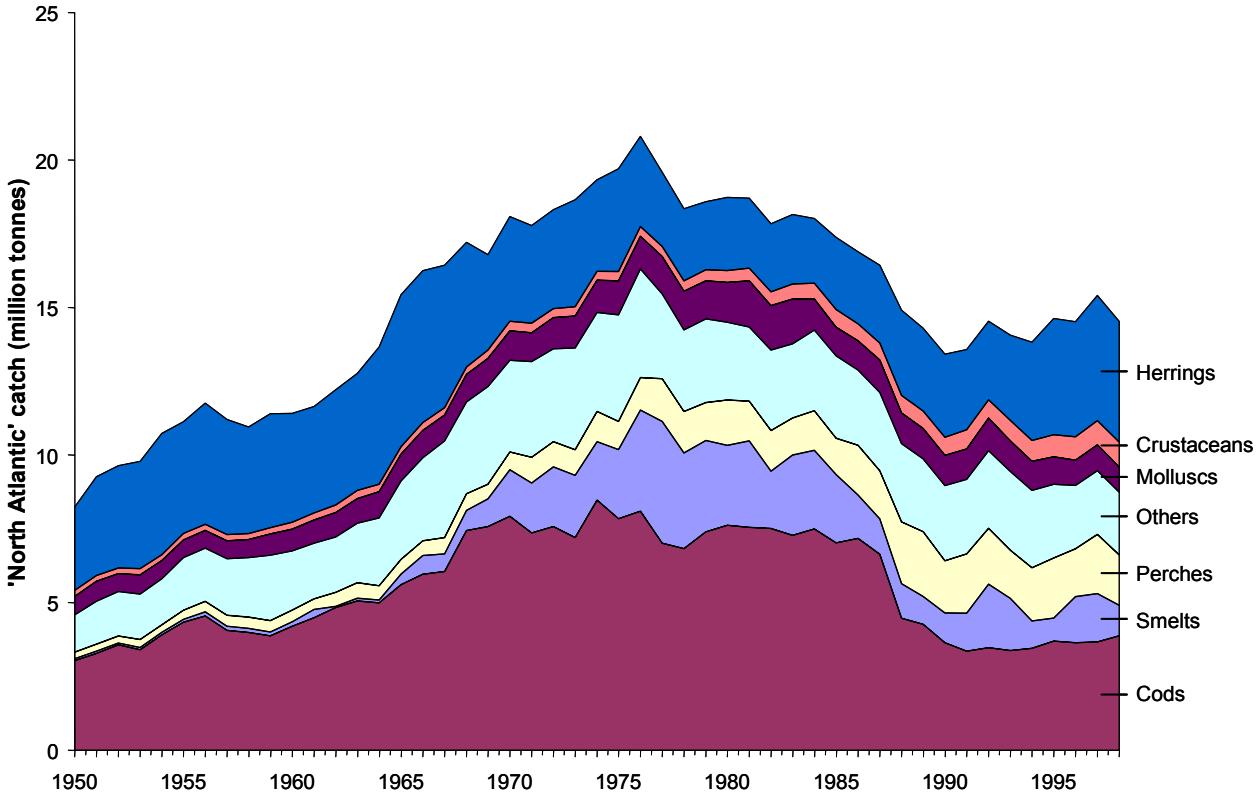

Figure 3. Annual landings of major fish groups for the North Atlantic area based on disaggregated FAO statistics. The online version of this graph is in color (see *www.fisheries.ubc.ca/Projects/SAUP*).

Results from the disaggregation of annual FAO landings data were averaged by decade for the 1950s, 1970s and the 1990s. The spatial pattern of fisheries catches evident in all decades is the very large proportion of landings that come from coastal shelf areas particularly the Scotian, Newfoundland, and Labrador shelves in the western North Atlantic, and the North Sea in the eastern North Atlantic (Figures 4 - 6). By the 1970s (Figure 5), the spatial cells with higher catches had extended along the eastern seaboard of the U.S., and to greater areas around Iceland and west of the U.K. in the eastern North Atlantic. There was also an area of the eastern Barents Sea north of Norway where there were notably high catches. By the 1990s (Figure 6) productive fishing areas were just as extensive, however, catches were generally lower particularly in areas where cod was the primary species taken.

Artifacts in the maps point out limitations which in part stem from those in the data reporting system. For example, abrupt changes in catch densities at statistical boundaries (Figure 6 in the mid Atlantic) are unlikely to represent changes in fishing practices or success, but result from a failure on some countries part to prorate catches by all statistical areas fished. Assumed jurisdictional boundaries to fishing, such as EEZs, resulted in a halo-like zone of higher catch rates around some countries (Figure 6 around Portugal). Better knowledge on fishing access would likely have exposed that there is more cross-border fishing, legally or not, than we have currently recognized in our analysis. There are large polar regions were the catch rates are zero. This is not unexpected given the year-around presence of pack ice in some of these areas, however, in Canada's Hudson's Bay, no catches are reported to FAO even in the summer. Those shown here were based on a specific report in the

literature (Crawford, 1989), one of the few additions to FAO's landing database used at this time. In fact there were only a handful of landings reported from FAO's Arctic area (18) since 1950 and all were reported by the former Soviet Union. This indicates other limitations to the current landing records. Thus, this approach could prove very useful to agencies involved in gathering and interpreting fisheries data.

The present maps use mostly unadjusted landing records from FAO. The *Sea Around Us* project has, however, been continuously refining fisheries data from a number of regional and national sources. For example, data from European countries, reports from stock assessment working-groups, and reports we have commissioned from in-country consultants, have allowed us to augment landing statistics produced by the regional authorities, such as the *International Council for the Exploration of the Sea* (ICES). We have documented unreported landings (legal or otherwise) and discards allowing us to produce well-documented 'adjusted' catch statistics, which better reflect total marine resource extractions. As the statistical areas reported on by ICES correspond to FAO's statistical area 27, in future, we can substitute these adjusted ICES landings for FAO data from this area in our analysis. As ICES statistical reporting areas are only a fraction of the size of the FAO statistical area, future maps will reflect both a fuller and a more precise account of catch rates from this region. A similar procedure is underway for other regions of the North Atlantic, and will be extended step-wise globally.

Mapped landings produced through this process proved a very useful contribution to other studies within our project particularly those dealing with interactions between marine mammals and fishing (Kaschner *et al.*, this volume), fisheries economics, and estimates of biomass (Christensen *et al.*, 2001). Incorporating the trophic levels of landings in future analysis will produce maps of change in the trophic level of landings. It is very likely that many other uses for this information will be found.

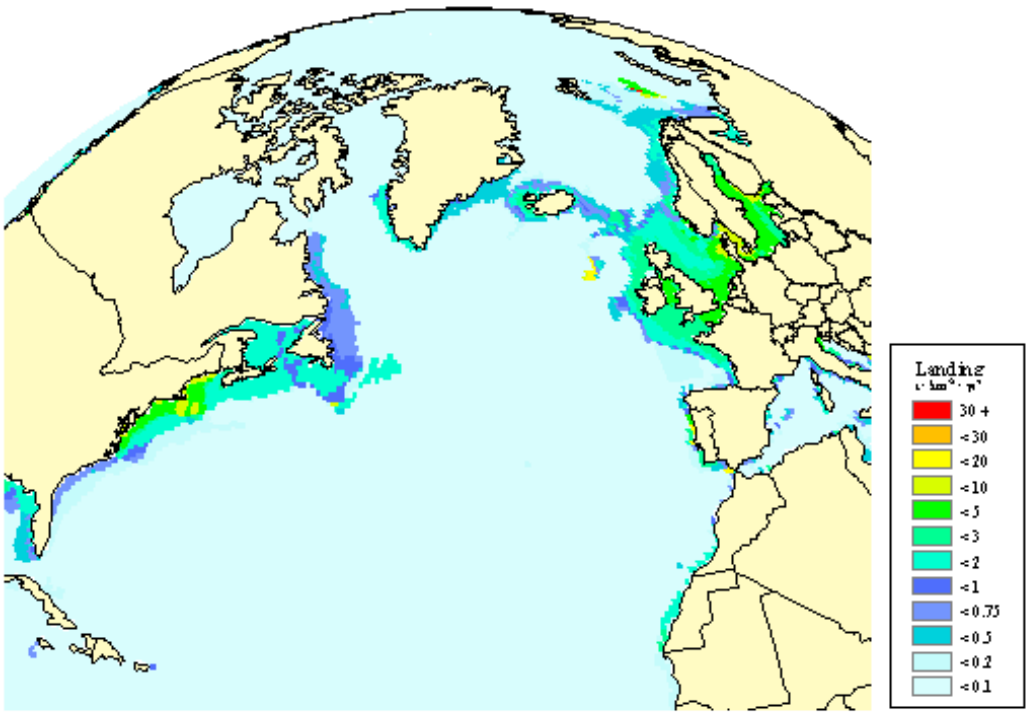

Figure 4. Map of average landed catch (t km^{-2} year^{-1}) of all taxa combined for the 1950s. The online version of this graph is in color (*see www.fisheries.ubc.ca/Projects/SAUP*).

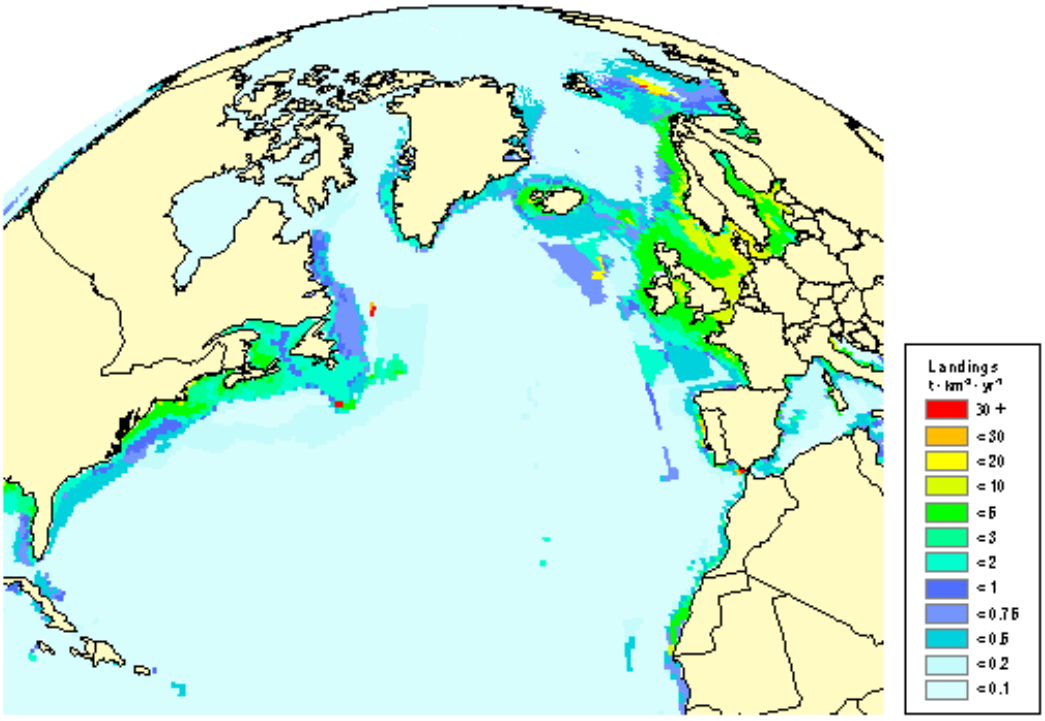

Figure 5. Map of average landed catch (t km^{-2} year^{-1}) of all taxa combined for the 1970s. The online version of this graph is in color (see *www.fisheries.ubc.ca/Projects/SAUP*).

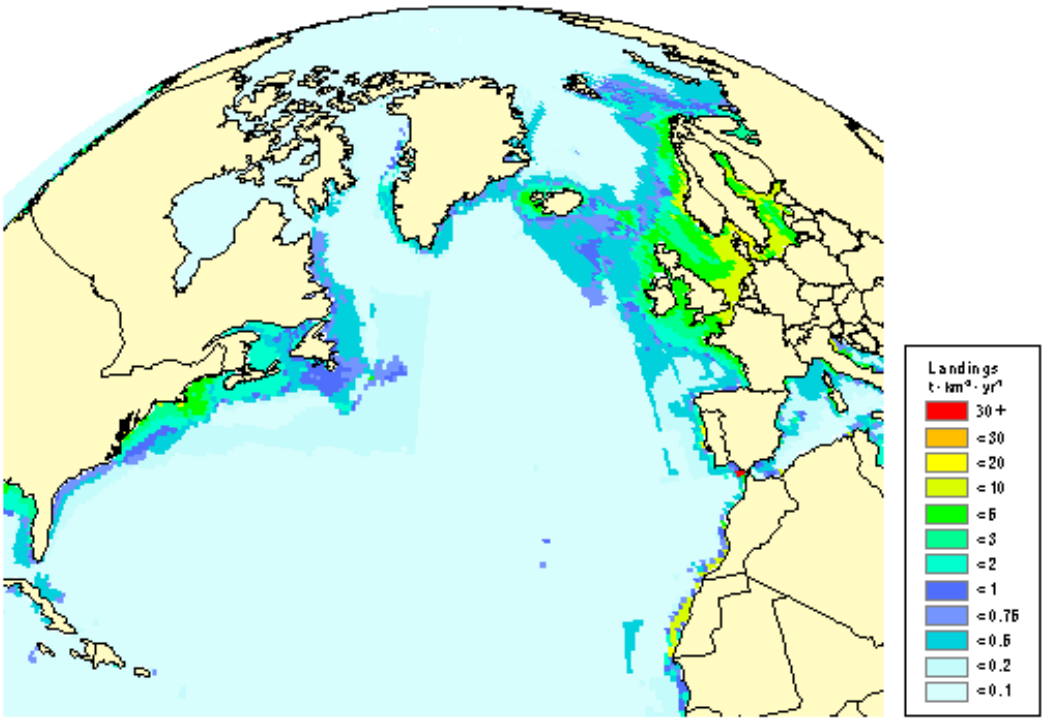

Figure 6. Map of average landed catch (t km^{-2} year^{-1}) of all taxa combined for the 1990s. The online version of this graph is in color (see *www.fisheries.ubc.ca/Projects/SAUP*).

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ENERGY CONSUMED BY NORTH ATLANTIC FISHERIES

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ABSTRACT

As part of the *Sea Around Us* project at the University of British Columbia, research was undertaken to quantify the fuel energy consumed by North Atlantic fisheries. Where possible, this included evaluating both the contemporary situation and changes in direct fuel inputs to fisheries over time. Two distinct methods were employed in estimating both the total fuel consumed and the energy intensity of specific fisheries and fishing fleet sub-sets. The first method involved soliciting relevant data directly from fishing companies. The second technique combined estimates of the generic rates at which fishing vessels consume fuel in relation to their main engine horsepower, as derived from real-world vessel performance data, with detailed catch and fishing effort data. Ultimately, a total of 58 analyses were conducted representing 54 distinct North Atlantic fisheries or fleet sub-sets. Based in five countries, these 54 fisheries together accounted for total annual landings, as of the late 1990s, of over 5.2 million live weight tonnes of fish and/or shellfish, and encompassing a range of fishing gears, vessel sizes and primary target species. Moreover, for almost half of the fisheries analyzed, time series estimates of energy intensity and total fuel consumption were possible for periods ranging up to 21 years. For the most recent years in which data were available, the results indicate that these 54 fisheries together consumed just over 1 billion litres of fuel annually. Amongst the 29 groundfish fisheries analyzed, energy intensities ranged from a low of 230 litres/tonne to just over 2,700 litres/tonne. When taken together, however, these 29 fisheries experienced a mean energy intensity of about 510 litres/tonne of groundfish and associated bycatch species landed. In contrast, amongst the twelve fisheries targeting small pelagic species analyzed, contemporary energy intensities ranged from 19 to 159 litres/tonne of fish landed and averaged just 62 litres/tonne. The single relatively small fishery for large pelagic species analyzed had an energy intensity of 1,740 litres/tonne of tuna and swordfish landed. Amongst the invertebrate fisheries evaluated, the average energy intensity of the eight fisheries targeting shrimp was 918 litres/tonne while the two scallop fisheries had an average energy intensity of just 347 litres/tonne landed, and the single crab fishery evaluated had an energy intensity of about 330 litres/tonne. Finally, the lone fishery for Norway lobster analyzed, had an energy intensity of 1,025 litres/tonne of total landings.

INTRODUCTION

As with all human activities, commercial fishing entails the dissipation of matter and energy in support of their primary activity, the harvesting of aquatic organisms. While these biophysical 'costs' are less obvious and consequently receive less attention than the direct impact that fishing has on targeted stocks and associated marine ecosystems, it is precisely the availability of abundant energy that enables most contemporary fisheries to continue even when stocks are in decline. Moreover, the consumption of industrial energy, and in particular fossil energy, has a real, if indirect, ecological impact on marine ecosystems in and of itself through the effects of global climate change. Finally, from a management perspective, industrial energy consumption provides a means of comparing fishing effort between fisheries, and changes in effort over time within fisheries.

Following the oil price shocks of the 1970s, a wave of research was undertaken to evaluate the energy intensity of a variety commercial fisheries (Wiviott and Mathews, 1975; Rochereau, 1976; Leach, 1976; Rawitscher, 1978; Lorentzen, 1978; Ágústsson *et al.*, 1978; Ragnarsson, 1979 & 1985; Nomura, 1980; Brown and Lugo, 1981; Hopper, 1981; Veal *et al.*, 1981; Allen, 1981; Watanabe and Uchida, 1984; Ishikawa *et al.*, 1987; Sato *et al.*, 1989; Watanabe and Okubo, 1989). The results of this and more recent research indicate that:

- Direct fuel energy inputs to fisheries typically account for between 75 and 90% of the total culturally mediated energy inputs. The remaining 10 to 25% of the total is comprised of direct and indirect energy inputs associated with vessel construction and maintenance, providing fishing gear, and labor (Wiviott and Mathews, 1975; Rochereau, 1976; Leach, 1976; Edwardson, 1976; Rawitscher 1978; Lorentzen, 1978; Allen 1981; Watanabe and Uchida, 1984; Watanabe and Okubo, 1989; Tyedmers, 2000);
- Energy intensity can vary considerably depending on the fishing gear used. In general, trawling tends to be more energy intensive than seining, purse seining or more passive techniques such as gillnetting, and trapping. (Wiviott and Mathews, 1975; Leach, 1976; Edwardson, 1976; Lorentzen, 1978; Rawitscher, 1978; Nomura, 1980; Hopper, 1981; Watanabe and Okubo, 1989). An exception to this relative

energy intensity pattern occurs with respect to longlining, a passive fish harvesting technology which typically requires relatively large energy inputs relative to the tonnes of fish landed, particularly when used to catch high value pelagic species such as tuna, and billfish (Rawitscher, 1978; Nomura, 1980; Watanabe and Okubo, 1989);

- In many instances, energy intensity has been found to increase with vessel size within a given gear sector and fishery (Wiviott and Mathews, 1975; Rochereau, 1976; Edwardson, 1976, Lorentzen, 1978; Watanabe and Okubo, 1989;). However, exceptions to this have also been found (in particular, see Figure 1 in Edwardson, 1976); and
- The energy intensity of a fishery can change dramatically over time as the abundance of fisheries resources change, fleets expand, the average size of vessels increase, vessels travel further to fish, and become more technologically advanced. For example, Brown and Lugo (1981) estimated that between 1967 and 1975, while the fuel consumed by the U.S. fishing fleet (excluding vessels under 5 GRT) increased from 150 to 319 million gal/year, the catch did not increase accordingly. As a result, the fossil energy input to edible protein energy output ratio for the U.S. fleet increased from 8:1 to almost 14:1 over the same period. Similarly, Mitchell and Cleveland (1993) found that between 1968 and 1988, the fuel energy input to edible protein output ratio of the New Bedford, Massachusetts fleet rose from ~6:1 to over 36:1.

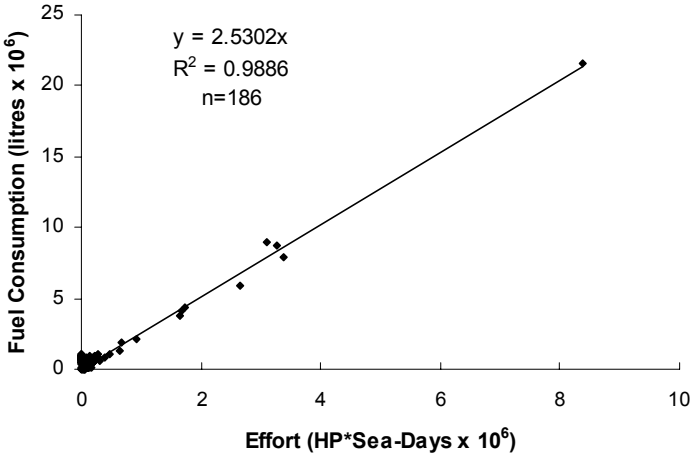

Figure 1. Fuel consumption relationship for all gear types combined.

An analysis of the culturally mediated energy inputs to fisheries would ideally encompass:

- direct fuel energy inputs;
- direct and indirect inputs to build and maintain fishing vessels;
- direct and indirect inputs to provide fishing gear 'consumed' in the process of fishing; and
- the energy required to sustain the fishing labor inputs.

However, because of the large number of fisheries being considered in this analysis, the heterogeneity that exists both between and within the fleets involved, and the general difficulty accessing reliable representative data, this analysis focused exclusively on the direct fuel energy inputs to contemporary North Atlantic fisheries.

When initially undertaken, the objective of this project was to quantify, with as much resolution as possible, the fuel energy consumed by all contemporary North Atlantic fisheries. However, given the limited data available at the time that this part of the *Sea Around Us* project was completed, analyses were only possible for approximately 54 fisheries or fleet sectors representing five countries: Canada, the United States, Iceland, Norway, and Germany. The fisheries for which analyses were conducted, however, together account for over 5.2 million tonnes (live weight) of fish and shellfish landed annually and encompass a range of fishing gears, species, and relative product values. Moreover, for almost half of the fisheries analyzed, time series estimates of energy intensity and total fuel consumption have also been possible for periods ranging up to 21 years.

MATERIALS AND METHODS

For each fishery for which an energy analysis was conducted, the primary output was an estimate of its contemporary energy intensity, or the litres of fuel consumed per round weight tonne of fish and/or shellfish landed. Two techniques were used to estimate energy intensity.

Direct solicitation of data

Annual fuel consumption, landings and temporal fishing effort (both in terms of fishing days and days at sea) data together with the physical characteristics of the associated vessels were solicited from fishing companies actively engaged in North Atlantic fisheries (Table 1).

Table 1. Summary of North Atlantic fishing vessels for which detailed catch, vessel characteristic and performance data were acquired.

Target species and fishery location	Gear type	Vessel size (Tonnage/HP)	Number of vessels represented	Annual catch by vessels (round tonnes)	Fishing seasons represented
Shrimp - NW Atlantic	Trawl	2,290/4,023	1	~4,200	1993 to 1999
Atlantic menhaden - US Atlantic coast	Purse seine	540/1,800 to 750/2,000	13	~175,000	1998 & 1999
Ground fish - NW Atlantic	Trawl	540/1,300 to 802/2,400	8	~10,000	1999
Ground fish - NW Atlantic	Trawl	790/2,400 to 990/2,000	4	~4,000 to ~16,000	1986 to '89 & 1996 to '99
Cod - NW Atlantic	Danish Seine	545/1,250	2	~1,000	1999
Scallops - Georges Bank	Dredge	309/765 to 330/990	5	~5,500	1998 & 1999

From the data provided by fishing companies, energy intensities were calculated using Equation (1).

$$I_i = Q_i / L_i \qquad ...1)$$

Where I_i is the energy intensity of the *i*-th fishery; Q_i is the total quantity of fuel consumed, in litres, by all vessels for which data were available for the *i*-th fishery; and L_i is the total round weight landings of all species, in tonnes, by the vessels for which data were available for the *i*-th fishery.

While soliciting data directly from fishing companies yields accurate estimates of the energy intensity of the vessels from which the data were derived, it has two drawbacks. The vessels represented by the data, and more specifically their fuel performance, may not be representative of the fisheries of which they are a part. Secondly, direct solicitation of data from fishing companies is a slow, labor-intensive process. As a result, a second method was employed to estimate fuel consumption and energy intensity for entire fisheries/fleet sectors.

Inferring fuel consumption from fishing effort data

Based on the rationale that fuel consumption is largely a function of an engine's size and the length of time that it is operated, a methodology was developed that uses fishing effort and catch data to estimate fuel consumption, and ultimately energy intensity, for entire fishing fleets. Specifically, the total fuel consumed by a given fishing fleet was estimated using Equation (2).

$$Q_{ij} = R_{ij} * (H_{ij} * T_{ij}) \qquad ...2)$$

where Q_{ij} is the total quantity of fuel consumed by the *i*-th fleet using the *j*-th type of fishing gear; R_{ij} is the generic rate of fuel consumption, in litres/HP*sea-days, by vessels using the *j*-th type of fishing gear; H_{ij} is the average main engine horsepower of all vessels in the *i*-th fleet using the *j*-th fishing gear; and T_{ij} is the total aggregate effort, in days at sea, expended by the *i*-th fleet using the *j*-th fishing gear.

Once the total fuel consumed by a specific fleet was estimated using the method outlined in Equation (2) and described in detail below, its energy intensity was determined using Equation (1).

Determining generic fuel consumption rates

In applying the technique outlined in Equation (2), it was first necessary to estimate *R*, the standardized rate at which fishing boat engines burn diesel fuel regardless of the species being targeted or the total resulting catch. This was done by first assembling detailed vessel characteristic, fuel consumption and fishing effort data from a variety of sources. In addition to data from the 33 North Atlantic vessels outlined in Table 1, data were also drawn from:

1. two fishing companies engaged in fisheries outside the North Atlantic region;
2. the results of a detailed economic study of 95 pelagic longliners in Hawaii (pers. comm. April, 2000 Dr. Mike Travis, NOAA);
3. and four published sources (Table 2).

For each of the 186 vessels for which detailed performance data were available, an integrated measure of fishing effort was calculated as the product of main engine horsepower and total days at sea. These values were then plotted against the total litres of fuel consumed by each vessel and a best fit line through these points and the origin was determined (Figure 1; note that the best fit line was forced through the origin based on the simplifying

Table 2. Summary of additional sources of data used to establish the relationship between fuel consumption and fishing effort.

Data source	Target species and fishery location	Gear type	Vessel size (Tonnage/HP)	Number of vessels represented	Fishing seasons represented
This research	Gulf menhaden - US Gulf coast	Purse seine	540/1,800 to 750/2,000	40	1998 & 1999
This research	Pollock - Alaska	Trawl	1,600/3,000 to 2,500/8,000	2	1999
Dr. Mike Travis, NOAA (Pers. comm.)	Swordfish & Tuna - Hawaii	Longline	19/145 to 187/1,050	95	1993
Ágústsson *et al.* (1978)	Groundfish - Iceland	Trawl	578/1,800 to 975/2,170	2	1977
Ágústsson *et al.* (1978)	Capelin - Iceland	Purse seine	450/600 to 700/2,100	7	1977
Eiríksson (1978)	Groundfish - Iceland	Trawl	969/2,820	3	1976 & 1977
Veal *et al.* (1982)	Shrimp - US Gulf coast	Trawl	n.a./275 to n.a./520	3	1980
Wiviott and Mathews (1975)	Groundfish - Washington State	Trawl	86/300	1[a)]	1971 & 1972 [a)]

[a)] Data reported for Washington State groundfish trawlers by Wiviott and Mathews (1975) represents the average of 11 vessels.

assumption that without an engine, no fuel will be consumed). The slope of this line provides a first approximation estimate of *R*, the generic rate at which fishing vessels consume fuel per HP*sea-day of effort.

In conducting this part of the analysis it became apparent that fishing gear-specific sub-sets of the vessels for which data were available, have slightly different rates of fuel consumption. In other words, two vessels with the same main engine horsepower operating for the same period of time but deploying markedly different types of fishing gear, say trawl versus purse seine gear consume fuel at different average rates as a result of the relative periods of time that their main engines are operated at various levels of output. This observation, that the rate of fuel consumption is influenced by the ways in which specific fishing gears are deployed, is supported by the analysis of Watanabe and Okubo (1989 and Figure 1). As a result, in order to refine the subsequent energy analyses of various fisheries, fishing gear-specific fuel consumption rates were determined for five sub-sets of vessels:

1. vessels using either trawl or dredge gear (Figure 2);
2. vessels using Danish seine or related mobile seine gear (Figure 3);
3. all purse seiners (Figure 4);
4. only 'standard' purse seiners (Figure 5); and
5. longliners (Figure 6).

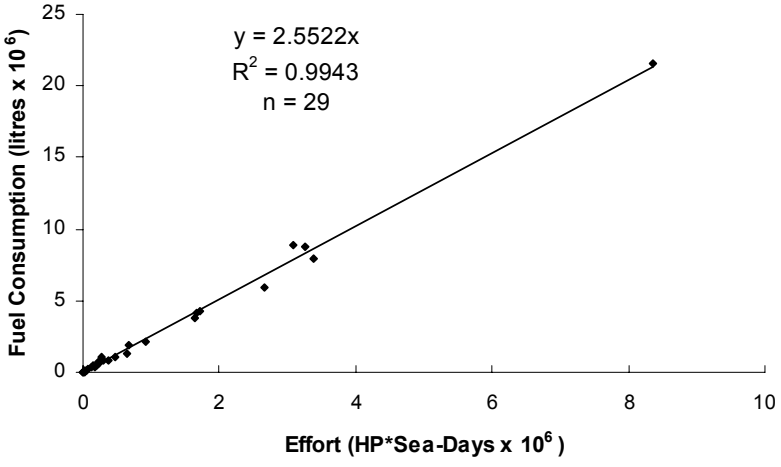

Figure 2. Fuel consumption relationship for trawlers and draggers.

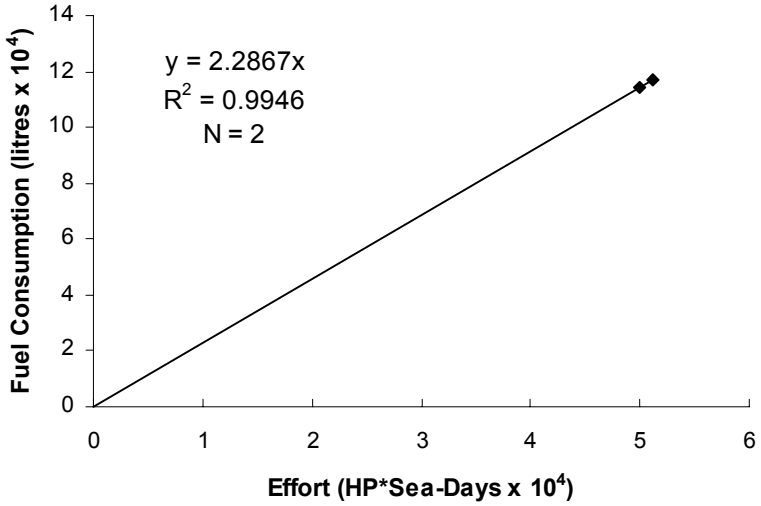

Figure 3. Fuel consumption relationship for vessels using mobile seine gear.

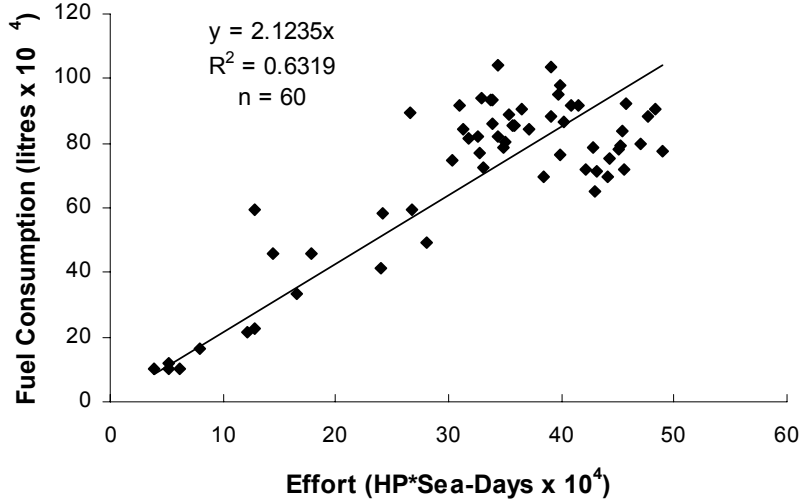

Figure 4. Fuel consumption relationship for all purse seiners.

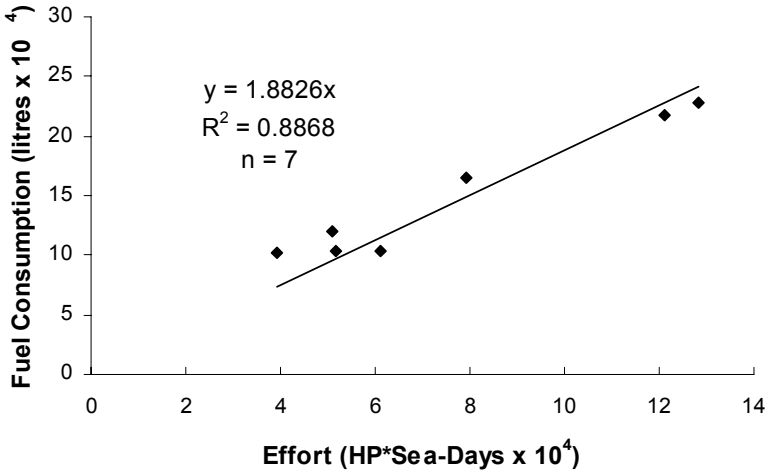

Figure 5. Fuel consumption relationship for 'standard' purse seiners.

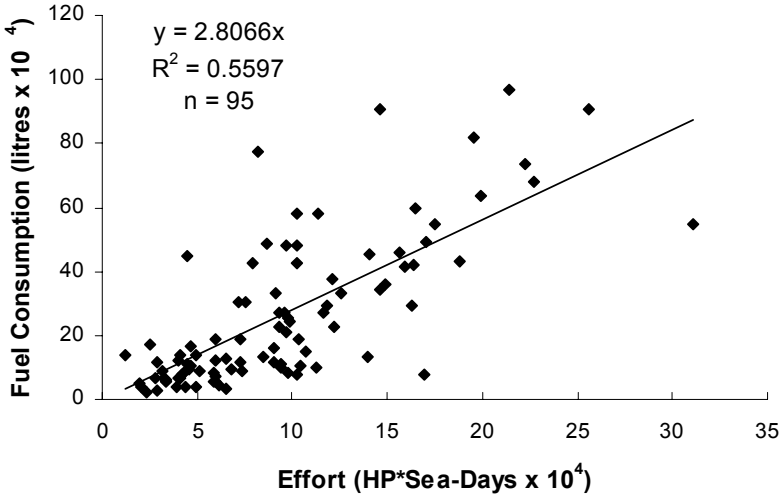

Figure 6. Fuel consumption relationship for longliners.

The estimated rates of fuel consumption per HP*sea-day of effort for all vessels combined and for the five gear-specific sub-sets are summarized in Table 3.

Two fuel consumption rate estimates were made for purse seiners (Table 3). The first represents all vessels deploying purse seine nets while the second represents what may be called 'standard' purse seiners. This distinction was made because 53 of the 60 vessels included in the first estimate (Figure 4) are menhaden (*Brevoortia tyrannus*) fishing vessels that appear to be unique in the way they deploy their nets. Whereas on a standard purse seiner, the vessel's main engine is used to maneuver while the net is deployed from the stern of the vessel, in menhaden boats, their nets are deployed using a pair of independently powered purse boats (Smith, 1991). Functionally, this difference means that menhaden fishing operations will likely burn fuel at a higher rate, relative to the horsepower of the mother ship's main engine, than will a standard purse seiner. This is borne out by the fuel consumption rate estimates in Figures 4 and 5. As a result, throughout the subsequent analyses of energy inputs to purse seine fisheries, I have used the fuel consumption rate associated with standard purse seiners, or 1.88/HP*sea-day, so as to err on the conservative side.

Table 3. Summary of generic fuel consumption rate estimates.

Gear type	Fuel consumption rate (Litres/HP*sea-day)	Sum of squares	Number of vessels represented
All vessels combined	2.53	0.99	186
Vessels deploying trawl or dredge gear	2.55	0.99	29
Vessels deploying mobile seine gear	2.28	0.99	2
All purse seiners	2.12	0.63	60
"Standard" purse seiners	1.88	0.89	7
Longliners	2.81	0.56	95

It should also be noted that for some fishing gears commonly in use in the North Atlantic, including gillnet, handline, and traps, no gear-specific fuel consumption rate estimates were possible, given the vessel performance data available. Consequently, where fuel consumption rate values were required to estimate the energy inputs to a fishery employing one of these gears, the rate associated with all fishing vessels combined was used (Figure 1), or a value of 2.53 l/HP*sea-day of effort.

Fishing effort and catch data

To estimate the total fuel consumption, and energy intensities for specific fisheries or fleet sectors using the technique outlined in Equation (2), it was also necessary to assemble the following data, in addition to generic gear-specific fuel consumption rates:

- average horsepower of all vessels engaged in a particular fishery;
- total number of days at sea of all vessels engaged in the fishery; and
- total resulting catch of all species, ideally broken down by species, by all vessels engaged in the fishery.

Using the *Sea Around Us* project's network of in-country collaborators and consultants, these types of information were sought for most North Atlantic fishing countries. Ultimately, detailed information in the forms outlined above were obtained from four countries: Canada, Iceland, Norway, and Germany.

Canada

For all Atlantic Canadian fisheries over the period from 1986 to 1999 inclusive, catch and associated effort data, including information on gear type, primary fishery target, vessel size class, average horsepower of vessel class, total fishing days, and total days at sea. These data were compiled by Paul Fanning of the Department of Fisheries and Oceans Canada and Sylvie Guénette of the *Sea Around Us* project. For the purposes of this energy analysis, an output was generated from the resulting database that allowed catch and to be correlated with HP*sea-days of effort for a total of 15 fishing gear and primary fishery target combinations. Unfortunately, in the case of six of the 15 gear type/fishery target combinations, the catch and effort output generated were either incomplete or the resulting energy analyses yielded implausible results. For example, the catch and associated effort data for the Atlantic Canadian lobster (*Homarus americanus*) trap fishery yielded apparent energy intensity values that varied wildly from year to year, spanning at least three orders of magnitude.

Of the nine gear type/fishery target combinations for which data were largely complete and yielded results that were both internally coherent and in general accord with similar fisheries, four targeted

groundfish species, three targeted invertebrates, and small and large pelagic species were targeted by one fishery each.

Iceland

Catch along with corresponding effort data, expressed in terms of HP*sea-days, were compiled by Hreidar Valtýsson of the Marine Research Institute of the University of Akureyri, for 23 distinct Icelandic fisheries or fleet segments for the period from 1977 to 1997 inclusive. Of these, four fisheries did not warrant further analysis, either because of their infrequent occurrence or the extremely small landings involved. Of the 19 fisheries for which analyses were ultimately conducted, they together accounted as of 1997 for over 2,000,000 live weight tonnes, or 99% of the total Icelandic fisheries landings that year.

Up to three criteria are used to define these 19 fisheries. The primary basis for differentiation is the size class of the vessels involved. Specifically, the Icelandic fleet is broadly divided into three types of vessels: undecked boats, decked boats and trawlers. The second criteria used to define these fisheries is the fishing gear that is deployed. Finally, the primary species or group of species targeted were used to define each fishery (Table 4).

Table 4. Icelandic fisheries for which energy analysis were conducted.

Vessel class	Gear used	Primary target	Number of vessels	Total landings in 1997[a] (tonnes)
Undecked boats	Gillnet	Groundfish	95	1,763
Undecked boats	Handline	Groundfish	538	24,031
Undecked boats	Longline	Groundfish	243	12,858
Decked Boats	Gillnet	Groundfish	145	57,864
Decked Boats	Handline	Groundfish	38	3,250
Decked Boats	Longline	Groundfish	136	44,582
Decked Boats	Danish seine	Groundfish	123	46,302
Decked Boats	Bottom trawl	Groundfish	49	38,958
Decked Boats	Bottom trawl	Norway pout	0	0
Decked Boats	Bottom trawl	Shrimp	88	32,614
Decked Boats	Bottom trawl	Lobster	20	5,704
Decked Boats	Mid-water trawl	Pelagic species	5	69,173
Decked Boats	Purse seine	Capelin	40	1,288,693
Decked Boats	Purse seine	Herring	14	249,344
Decked Boats	Driftnet	Herring	0	0
Decked Boats	Dredge	Scallops	13	10,404
Trawlers	Bottom trawl	Groundfish	67	196,241
Trawlers	Bottom trawl	Shrimp	37	42,359
Trawlers	Mid-water trawl	Redfish	9	35,073

[a] The last year for which an energy analysis could be conducted.

Norway

Drawing data from the results of a detailed Norwegian government survey of the profitability of its fishing industry in 1998, Gjert Dingsør of the Department of Fisheries and Marine Biology, University of Bergen, compiled catch, effort, and vessel characteristic data for 29 fisheries or distinct fleet subsets representing most Norwegian vessels over 8 meters in length. Unfortunately, both average vessel horsepower and days at sea data were only available for fleet segments comprised of vessels over 13 meters in overall length. As a result, 7 of the 29 fleet segments included in Mr. Dingsør's summary could not be included in the energy analysis. The 22 fleet subsets for which an energy analysis was possible, however, together account for approximately 2,500,000 live weight tonnes, or 86% of the total Norwegian catch of all species by all vessels in 1998.

The first criteria used to differentiate these fisheries and fleet segments is the primary target of the fishery. Next, the fisheries or fleet segments are further defined based on the fishing gear employed. Finally, either vessel size or the location of the fishery may be used to categorize vessels even further. Table 5 summarizes the 22 Norwegian fisheries for which energy analyses were conducted.

Germany

Catch and corresponding fishing effort data, expressed in terms of kW*sea-days (converted to HP*sea-days by multiplying by 1.341), were compiled for German commercial fisheries by Ms. Kristin Kaschner for the years 1995 to 1998 inclusive (Kaschner *et al.*, this volume). Of the eight fleet segments recognized by German fisheries managers as of 1998 (Kaschner *et al.*, this volume), energy analyses were conducted on the five largest, that together account for approximately 95% of all German landings. The five for which analyses were conducted are all trawl based fisheries targeting mainly groundfish, flatfish or small pelagic species (Table 6).

Table 5. Norwegian fisheries for which energy analyses were conducted.

Primary target	Gear used	Vessel size and/or fishery location	Number of vessels	Total landings in 1998 (tonnes)
Gadoid species	Gillnet and Handline	13 to 20.9m in length - North Norway	186	57,177
Gadoid species	Longline	13 to 20.9m in length - North Norway	80	20,698
Gadoid species	Longline	> 28m in length - All counties	58	87,819
Gadoid species	Danish seine	13 to 20.9m in length - North Norway	113	46,990
Gadoid species	Danish seine	21 to 27.9m in length - North Norway	39	41,232
Gadoid species	Unspecified	13 to 20.9m in length - South Norway	100	22,096
Gadoid species	Unspecified	21 to 27.9m in length - All counties	45	49,127
Gadoid species	Unspecified	> 28m in length - All counties	11	10,099
Gadoid species	Trawl	< 250 GRT/500 GT	47	80,843
Gadoid species	Trawl	> 250 GRT/500 GT (freshfish)	39	84,174
Gadoid species	Trawl	> 250 GRT/500 GT (factory trawlers)	21	86,268
Pelagic species	Purse seine	Smaller purse seiners	34	231,794
Pelagic species	Purse seine	Larger purse seiners	16	125,857
Pelagic species plus Blue Whiting	Purse seine	Very large purse seiners	41	863,439
Pelagic species	Mobile seine	13 to 21.34m in length	66	80,310
Pelagic species	Mobile seine	> 21.35m	42	95,637
Pelagic species	Trawl		54	412,873
Shrimp	Trawl	< 50 GRT/80 GT & >13m in length	97	5,185
Shrimp	Trawl and other	< 50 GRT/80 GT & >13m in length	55	7,904
Shrimp	Trawl	Vessels fishing around Greenland with cold storage	9	13,450
Shrimp	Trawl	Vessels fishing in areas other than around Greenland with cold storage	15	22,117
Shrimp	Trawl	> 50 GRT/80 GT without cold storage	31	18,136

Table 6. German fisheries for which energy analyses were conducted.

Gear used	Primary target	Major fishing grounds	Number of vessels	Total landings in 1998 (tonnes)
Beam trawl	Flatfish and crustaceans	Unspecified	306	8,959
Beam trawl	Flatfish	North Sea	7	2,045
Bottom trawl	Groundfish	North & Baltic Seas	133	30,895
Unspecified trawl	Groundfish	NAFO, NEAFC, EU and others	8	61,869
Mid-water trawl	Pelagic species	EU waters	4	109,247

Expressing the results

The primary output of this research are estimates of the energy intensity of various North Atlantic fisheries, expressed in terms of the litres of diesel fuel burned per live weight tonne of fish and/or shellfish landed (see Table 7 for a variety of useful conversions). However, in order to facilitate comparisons with other food production systems and help conceptualize the results, they were also expressed in terms of:

- resulting greenhouse gas emissions;
- the ratio of the edible protein energy output by a fishery divided by the industrial energy input; and
- the energy input relative to the economic value of the catch.

Greenhouse gas emissions

Direct greenhouse gas emissions associated with the routine operation of marine engines amount to the equivalent of 2.66 kg CO_2/litre of fuel burned (calculated from data presented in Lloyd's Register Engineering Services 1995, Table 5, p. 17). In addition, indirect greenhouse gas emissions that result from the production, transmission, refining, distribution and dispensing of diesel fuel amount to the equivalent of an additional 0.50 kg CO_2/litre of fuel consumed (calculated from Delucchi 1997, Table 7, p. 191). Therefore, total greenhouse gas emissions associated with North Atlantic fisheries were estimated by multiplying fuel consumption (in litres) by 3.16 kg CO_2 equiv./litre.

Table 7. Volumetric and other conversion factors for diesel fuel

	US gallons	US Barrels
To convert from 1 litre	= 0.264	= 0.00629
In addition, 1 litre of diesel:	- releases 36.036 MJ of energy upon combustion - has a density of 0.840	

Source: Rose and Cooper 1977.

Edible protein energy return on industrial energy invested ratios

In order to contextualize the performance of fisheries *vis-à-vis* other food production systems, a common basis of comparison is required. Traditionally within analyses of agriculture, aquaculture and fisheries systems, this has been done by calculating either their industrial energy input to edible food energy output ratio or its inverse, the edible energy return on industrial energy investment ratio (see for example Wiviott and Mathews, 1975, Pimental and Terhune, 1977; Folke, 1988; Folke and Kautsky, 1992; Ackefors *et al.,* 1993; Mitchell and Cleveland, 1993; Pimentel *et al.,* 1996; Berg *et al.,* 1996; Pimentel, 1997; Tyedmers, 2000).

As the nutritional importance of fish and shellfish is largely a reflection of their protein content, in this analysis edible protein energy output was used as the basis for comparison. Consequently, edible protein energy return on investment ratios ('protein returns') were calculated for each of the fisheries analyzed, for each year in which data were available. In doing so, however, it was first necessary to convert landings data, on a species-specific basis, into estimates of the edible protein output (in tonnes) and edible protein energy yield (in Joules) for each of the fisheries considered. This was done by first assembling published data regarding:

1. the maximum fraction that is generally considered edible for each species. (In the case of finfish, this was assumed to correspond to the fraction of the animal's live weight that is muscle); and
2. the fraction of the edible proportion that is protein.

Where published species-specific values were unavailable, appropriate default values were used. For example, in the case of finfish species, the default maximum edible fraction was assumed to be 55% of live weight. Similarly, in the absence of appropriate species-specific data, it was assumed that protein constituted 19% of the edible portion, regardless of the type of organism. The maximum tonnes of edible protein potentially available from a given fishery was then calculated using Equation (3).

$$M_i = \sum_k^n (L_{ik} * E_k * P_k) \qquad ...3)$$

where M_i is the maximum edible protein, in tonnes, potentially available from the i-th fishery consisting of n species; L_{ik} is the landings, in tonnes, of the k-th species in the i-th fishery; E_k is the maximum potential edible fraction of the k-th species; and P_k is the mean protein content of the edible portion, itself expressed as a fraction, of the k-th species.

Maximum edible protein energy yield from each fishery was then calculated by multiplying the maximum potential tonnes of edible protein output from the fishery by 17.6 GJ/tonne, the energy content of protein (Wiviott and Mathews, 1975). Finally, edible protein returns for each fishery were calculated by dividing the edible protein energy yield by the fuel energy input, both expressed in Joules.

RESULTS

Energy intensity of fisheries as of the late 1990s

Using either the direct solicitation method or the technique in which fuel consumption and energy intensity is inferred using generic fuel consumption rates together with catch and effort data, a total of 58 energy analyses were conducted representing 54 unique North Atlantic fisheries or fleet subsets. When considering the most recent year for which analyses were possible in each of these fisheries (either 1997, 1998 or 1999), they together accounted for just over 5.2 million tonnes of total annual landings and consumed slightly more than 1 billion litres of diesel fuel. In doing so, they released greenhouse gases equivalent to approximately 3.2 million tonnes of CO_2 into the atmosphere.

In order to facilitate comparison amongst these fisheries, the most recent year's results have been arranged in the following four primary target groups: groundfish, small pelagic species, large pelagic species, and invertebrates.

Fisheries targeting groundfish

A total of 31 energy analyses were conducted representing 29 distinct fisheries in which

groundfish species were targeted (Table 8). When taken together, the annual landings by these 29 fisheries, in the most recent year for which data were available, amount to just over 1.2 million tonnes. Of this total, Atlantic cod (*Gadus morhua*) accounted for approximately 36%, saithe (*Pollachius virens*) 14%, haddock (*Melanogrammus aeglefinus*) 10%, redfish species (*Sebastes* spp.) 10%, herring (*Clupea harengus*) 8%, and Greenland halibut (*Reinhardtius hippoglossoides*) 3%. The remaining approximately 19% for the total catch by these 29 fisheries was comprised of almost two dozen species.

In landing these 1.2 million tonnes of fish, these 29 fisheries consumed a total of approximately 615 million litres of diesel resulting in an overall weighed average energy intensity of approximately 510 litres/tonne or 18.4 GJ/tonne. Consequently, their mean greenhouse gas emission intensity was 1.6 tonnes CO_2 equiv./tonne.

When considered individually, the energy intensity of these fisheries varied from a low of 230 litres/tonne, for a Canadian mobile seine fishery for cod, to a high of 2,724 litres/tonne for a German trawl fishery targeting flatfish species (Table 8). In the case of two-thirds of the North Atlantic groundfish fisheries analyzed, however, the resulting energy intensity fell between 400 and 700 litres/tonne.

On a country-specific basis, the eleven Norwegian fisheries represented in Table 8 landed a total of 587,000 live weight tonnes in 1998 and consumed approximately 266 million litres of fuel, for a weighted average energy intensity of 453 litres/tonne (16.3 GJ/t) - the lowest combined average of the four countries represented. Next most efficient are the ten Icelandic fisheries that together accounted for approximately 461,000 tonnes in 1997 and consumed about 233 million litres of fuel, for a weighted average energy intensity of 505 litres/tonne (18.2 GJ/t). The four Canadian fisheries, with combined landings of only 63,000 tonnes and fuel consumption of approximately 38 million litres in 1999, had the second highest weighted average energy intensity at approximately 600 litres/tonne (21.6 GJ/t). Finally, the four German fisheries that together landed 104,000 tonnes and consumed an estimated 78 million litres of fuel had an average energy intensity of approximately 750 litres/tonne (27.0 GJ/t).

Amongst those fisheries in Table 8 for which only a single fishing gear is specified, the three gillnet fisheries had the highest weighted average energy intensity at almost 640 litres/tonne (23.1 GJ/t). When considered together, the two handline fisheries had the next best average energy intensity at approximately 580 litres/tonne (20.9 GJ/t) while the eleven dedicated trawl fisheries had an average energy intensity of about 530 litres/tonne (19.1 GJ/t). The five-longline fisheries in combination enjoyed the second lowest gear-specific energy intensity at approximately 490 litres/tonne (17.6 GJ/t) while the four fisheries in which mobile seine gear was used performed the best with an average energy intensity of approximately 440 litres/tonne (15.9 GJ/t).

With respect to the relatively poor energy performance of gillnet and handline fisheries, it should be kept in mind that these are both gears for which the non-gear-specific overall generic fuel consumption rate had to be used when calculating the total fuel consumed in these fisheries. In other words, when inferring the amount of fuel consumed based on the horsepower*sea-days of effort expended in these fisheries, the generic fuel consumption rate associated with all vessels was employed (Figure 1).

Fisheries targeting small pelagic species

Energy analyses were conducted on twelve North Atlantic fisheries, encompassing five countries, in which small pelagic species were targeted (Table 9). For the most recent years in which analyses were possible, these fisheries together accounted for total annual landings of approximately 3.8 million live weight tonnes. While the catch composition varied widely between fisheries, when taken together, capelin (*Mallotus villosus*) accounted for approximately 37% of the total, herring 27%, blue whiting (*Micromesistius poutassou*) 15%, sandeels (*Ammodytes* spp.) 8%, mackerel sp. (*Scomber* sp.) 5%, and Atlantic menhaden 4%. In catching these 3.8 million tonnes, these 12 fisheries together consumed a total of almost 234 million litres of fuel for an overall average energy intensity of 62 litres/tonne or 2.2 GJ/tonne. The resulting average greenhouse gas emission intensity amounted to the equivalent of only about 200 kg CO_2/tonne of fish landed.

When considered individually, the massive Icelandic purse seine fishery targeting capelin had the lowest overall energy intensity at just 19 litres/tonne. At the other extreme, the Norwegian mobile seine fishery targeting herring experienced an energy intensity of 159 litres/tonne (Table 9).

On a country-specific basis, the comparatively small Canadian fishery for small pelagic species caught a total of just under 120,000 tonnes in 1999 and burned just 2.39 million litres of fuel for an energy intensity of just 20 litres or 0.72 GJ per tonne (Table 9). Almost as efficient, however, are the three very

Table 8. Summary of energy analyses of North Atlantic fisheries targeting groundfish. (All but the first two cases relied on indirect methods (see text).)

Country	Year	No. of vessels	Average GRT	Average length (m)	Gear type	Top four species landed (by weight)				Total landings (tonnes)	Fuel burned (litres)	Energy intensity (l/t)	Edible protein return
Canada	1999	12	724	44.5	Trawl	Redfish	Flatfish	Cod	Gr. Halibut	17,340	6,424,177	370	0.130
Canada	1999	2	544	38	Mobile seine	Cod	-	-	-	1,005	231,326	230	0.250
Canada	1999	n/a	n/a	n/a	Gillnet	Cod	Saithe	Gr. Halibut	White hake	9,164	13,102,592	1,430	0.031
Canada	1999	n/a	n/a	n/a	Mobile seine	Plaice	Witch	Cod	-	3,154	1,198,277	380	0.120
Canada	1999	n/a	n/a	n/a	Longline	Cod	Haddock	White hake	Tusk	14,652	7,168,053	489	0.093
Canada	1999	n/a	n/a	n/a	Trawl	Silver hake	Haddock	Saithe	Cod	36,168	16,404,779	454	0.110
Norway	1998	186	28	15.4	GN & HL	Cod	Herring	Saithe	Haddock	57,177	24,580,276	430	0.110
Norway	1998	113	44	17.8	Mobile seine	Cod	Herring	Haddock	Saithe	46,990	22,470,664	478	0.099
Norway	1998	39	105	23.9	Mobile seine	Herring	Cod	Saithe	Haddock	41,232	12,275,447	298	0.170
Norway	1998	80	24	15.1	Longline	Cod	Haddock	Herring	Gr. Halibut	20,698	11,830,644	572	0.079
Norway	1998	58	243	37.7	Longline	Cod	Ling	Tusk	Catfishes	87,819	33,504,939	382	0.130
Norway	1998	100	25	14.9	n/a	Cod	Herring	Saithe	Mackerel	22,096	13,009,412	589	0.085
Norway	1998	45	119	23.8	n/a	Herring	Cod	Saithe	Ling	49,127	12,206,742	248	0.220
Norway	1998	11	172	34.4	n/a	Cod	Saithe	Herring	Ling	10,099	4,111,744	407	0.120
Norway	1998	47	214	33.8	Trawl	Saithe	Cod	Herring	Haddock	80,843	35,072,904	434	0.110
Norway	1998	39	330	46.9	Trawl	Cod	Saithe	Haddock	Shrimp	84,174	41,696,137	495	0.088
Norway	1998	21	754	60.7	Trawl	Cod	Saithe	Redfish	Haddock	86,268	55,206,428	640	0.070
Iceland	1997	95	6	n/a	Gillnet	Cod	Plaice	Haddock	Redfish	1,763	2,701,121	1,532	0.029
Iceland	1997	145	53	n/a	Gillnet	Cod	Saithe	Haddock	Porbeagle	57,864	27,931,125	483	0.093
Iceland	1997	538	5	n/a	Handline	Cod	Saithe	Redfish	Haddock	24,031	13,692,120	570	0.078
Iceland	1997	38	7	n/a	Handline	Cod	Saithe	Catfish	Redfish	3,250	2,115,994	651	0.069
Iceland	1997	243	6	n/a	Longline	Cod	Haddock	Catfish	Tusk	12,858	6,918,738	538	0.084
Iceland	1997	136	63	n/a	Longline	Cod	Catfish	Haddock	Tusk	44,582	29,182,739	655	0.071
Iceland	1997	123	6366	n/a	Mobile seine	Cod	Dab	Plaice	Haddock	46,302	24,425,833	528	0.086
Iceland	1997	49	164	n/a	Trawl	Cod	Haddock	Saithe	Redfish	38,958	18,909,242	485	0.092
Iceland	1997	67	602	n/a	Trawl	Cod	Redfish	Saithe	Haddock	196,241	91,825,793	468	0.092
Iceland	1997	9	930	n/a	Trawl	Redfish	-	-	-	35,073	15,496,059	442	0.093
Germany	1998	306	n/a	n/a	Trawl	Cod	Plaice	Haddock	Sole	8,958	24,404,930	2,724	0.016
Germany	1998	7	n/a	n/a	Trawl	Plaice	Sole	Cod	-	2,045	4,741,768	2,319	0.018
Germany	1998	133	n/a	n/a	Trawl	Cod	Saithe	Sprat	Flounder	30,894	23,513,788	761	0.060
Germany	1998	8	n/a	n/a	Trawl	Redfish	Bl Whiting	Herring	Capelin	61,869	25,559,345	413	0.110

much larger Icelandic fisheries that together landed approximately 1.607 million tonnes in 1997 and consumed just over 32.2 million litres of fuel for a weighted average energy intensity of only 24 litres/tonne (0.86 GJ/t). The United States, represented by the Atlantic menhaden fishery with an energy intensity of 32 litres/tonne, had the next most energy efficient national fishery for small pelagic species.

The six Norwegian fisheries for which analyses were conducted had the second worst national average energy intensity. Together they landed a total of 1.81 million tonnes in 1998 and burned approximately 176 million litres of fuel for an average energy intensity of 97 litres/tonne (3.5 GJ/t). Finally, Germany's trawl fishery for small pelagics had the highest national average energy intensity at 112 litres/tonne (4.0 GJ/t).

Amongst the fisheries analyzed, only three fishing gears were used to target small pelagic species (Table 9). Of these, purse seining accounted for the lion's share of total landings at just over 3 million tonnes and enjoyed the lowest average gear-specific energy intensity at 50 litres/tonne (1.8 GJ/t). The three trawl fisheries for small pelagic species together accounted for about 590,000 tonnes and experienced an average energy intensity of 97 litres/tonne (3.5 GJ/t). Finally, the two mobile seine fisheries landed a total of approximately 176,000 tonnes and had the highest average energy intensity at 145 litres/tonne (5.2 GJ/t).

Fisheries targeting large pelagic species

Only one North Atlantic fishery targeting large pelagic species was analyzed (Table 9). The 1999 Canadian longline fishery for swordfish (*Xiphias gladius*) and tuna required almost 2.1 million litres of fuel to land approximately 1,200 tonnes of fish for an energy intensity of 1,740 litres/tonne or the resulting equivalent of about 63 GJ/tonne. This fishery's greenhouse gas emission intensity amounts to the equivalent of approximately 5.5 tonnes of CO_2/tonne landed.

Fisheries targeting invertebrates

A total of fourteen energy analyses were conducted representing twelve distinct fisheries or fleet sectors in which invertebrate species were targeted (Table 10). Given the peculiarities of these fisheries, aggregating them, either on a country or gear specific basis (beyond the principal species targeted), was not warranted.

Of the twelve invertebrate fisheries analyzed, eight were directed at shrimp and/or prawn (Table 10). When taken together, these fisheries landed a total of approximately 166,000 tonnes of shrimp along with an additional 17,000 tonnes of fish bycatch, and burned just over 168 million litres of diesel resulting in an average energy intensity of 918 litres/tonne (33.1 GJ/t). Interestingly, because almost all of the fish bycatch associated with these eight fisheries was concentrated in just three of the five Norwegian fleet subsets that targeted shrimp, it was also possible to evaluate the energy intensity of a typical contemporary 'clean' shrimp fishery. Accordingly, of the five directed shrimp fisheries in which fish bycatch accounted for less than 20% of the reported landings, a total of approximately 136 million litres of fuel was burned in the process of landing 149,000 tonnes of shrimp. The resulting energy intensity of 913 litres/tonne (32.9 GJ/t) associated with these 'clean' shrimp fisheries turns out to be essentially the same as the average of all eight fisheries taken together. In terms of greenhouse gas emissions, these eight fisheries released, on average, the equivalent of 2.9 tonnes of CO_2/tonne of shrimp and bycatch landed.

After shrimp, the next largest tonnage of invertebrates represented in the fisheries analyzed are those for scallops (Table 10). Specifically, two dredge/plough fisheries, one Icelandic and one Canadian, were analyzed. Of the two, the 1997 Icelandic fishery had the lower energy intensity at 293 litres or 10.6 GJ per live weight tonne landed. In contrast, the 1999 Canadian scallop fishery experienced an energy intensity of 358 litres/tonne (12.9 GJ/t). When taken together these two fisheries accounted for a combined total of almost 70,000 tonnes of scallops and burned approximately 24.3 million litres of fuel for a weighted average energy intensity of 347 litres/tonne (12.5 GJ/t) and a greenhouse gas emission intensity of 1.1 tonnes CO_2 equiv./tonne.

The next largest invertebrate fishery for which data were available was the 1999 Canadian crab trap fishery. In this case, approximately 6.8 million litres of fuel were consumed in the process of catching 20,600 live weight tonnes of various crab species. The resulting energy intensity of this fishery was 331 litres or the equivalent of 11.9 GJ per tonne. Consequently it released the equivalent of just over one tonne of CO_2 per tonne of crabs landed. The final invertebrate fishery for which data were available was the relatively small 1997 Icelandic trawl fishery for Norway lobster (*Nephrops norvegicus*; Table 10). This fishery, in which only 1,200 tonnes of lobster were taken together with approximately 4,500 tonnes of various species of fish, consumed a total of almost 5.85 million litres of fuel for an energy intensity of 1,025 litres/tonne (36.9 GJ/t) and a greenhouse gas emission intensity of approximately 3.2 tonnes of CO_2 equiv./tonne of all fish and shellfish landed.

Table 9. Summary of energy analysis of North Atlantic fisheries targeting small pelagic species (first 12 cases) and large pelagics (13th case). (All but the first case relied on indirect methods (see text).)

Country	Year	No. of vessels	Average GRT	Average length (m)	Gear type	Top four species landed (by weight)				Total landings (tonnes)	Fuel burned (litres)	Energy intensity (l/t)	Edible protein return
U.S	1999	13	595	52.4	Purse seine	Menhaden	-	-	-	153,717	4,980,822	32	1.67
Canada	1999	n/a	n/a	n/a	Purse seine	Herring	Capelin	Mackerel	-	119,877	2,378,611	20	2.66
Norway	1998	66	67	18.8	Mobile seine	Herring	Saithe	Mackerel	Cod	80,310	12,801,082	159	0.33
Norway	1998	42	110	25.1	Mobile seine	Herring	Saithe	Mackerel	Cod	95,637	12,761,887	133	0.40
Norway	1998	54	199	35.2	Trawl	Sandeels	Herring	Blue whiting	Norway pout	412,873	39,358,284	95	0.54
Norway	1998	34	396	46.7	Purse seine	Herring	Sandeels	Mackerel	Capelin	231,794	22,244,150	96	0.56
Norway	1998	16	668	59	Purse seine	Herring	Mackerel	Capelin	Sprat	125,857	15,819,770	126	0.42
Norway	1998	41	1,427	64.1	Purse seine	Blue whiting	Herring	Mackerel	Capelin	863,439	73,168,078	85	0.59
Iceland	1997	5	656	n/a	Trawl	Capelin	Herring	Blue whiting	-	69,173	5,636,814	81	0.60
Iceland	1997	14	480	n/a	Purse seine	Herring	Capelin	-	-	249,344	7,995,359	32	1.66
Iceland	1997	40	551	n/a	Purse seine	Capelin	Herring	-	-	1,288,693	24,575,780	19	2.24
Germany	1998	4	n/a	n/a	Trawl	Mackerel	Herring	Rnd Sardine	Pilchard	109,247	12,259,706	112	0.51
Canada	1999	n/a	n/a	n/a	Longline	Swordfish	Bigeyetuna	Bluefin tuna	-	1,204	2,095,406	1,740	0.034

Table 10. Summary of energy analysis of North Atlantic fisheries targeting invertebrates. (All but the first two cases relied on indirect methods (see text).)

Country	Year	No. of vessels	Average GRT	Average length (m)	Gear type	Top four species landed (by weight)				Total landings (tonnes)	Fuel burned (litres)	Energy intensity (l/t)	Edible protein EROI
Canada	1999	1	2,290	60.0	Trawl	Shrimp	-	-	-	4,281	3,100,598	724	0.041
Canada	1999	5	298	34.0	Dredge	Scallops	-	-	-	5,462	1,852,298	339	0.025
Canada	1999	n/a	n/a	n/a	Trawl	Nrthn prawn	Aesop shrimp	-	-	55,158	29,299,017	531	0.057
Canada	1999	n/a	n/a	n/a	Dredge	Sea scallop	Surf clam	-	-	59,331	21,234,021	358	0.027
Canada	1999	n/a	n/a	n/a	Trap	Queen crab	Rock crab	Jonah crab	-	20,601	6,814,461	331	0.057
Norway	1998	97	27	15.5	Trawl	Shrimp	-	-	-	5,185	12,142,597	2,342	0.014
Norway	1998	55	27	15.7	Trawl	Shrimp	Herring	Mackerel	Cod	7,904	11,853,363	1,500	0.031
Norway	1998	31	97	23.9	Trawl	Herring	Shrimp	Cod	Saithe	18,136	6,840,203	377	0.127
Norway	1998	15	387	39.8	Trawl	Shrimp	Cod	Saithe	Haddock	22,117	13,826,120	625	0.059
Norway	1998	9	699	54.0	Trawl	Shrimp	-	-	-	13,450	17,608,722	1,309	0.023
Iceland	1997	88	129	n/a	Trawl	Shrimp	-	-	-	32,614	29,415,952	902	0.033
Iceland	1997	37	552	n/a	Trawl	Shrimp	-	-	-	42,359	47,363,491	1,118	0.027
Iceland	1997	13	59	n/a	Dredge	Scallops	-	-	-	10,404	3,044,429	293	0.035
Iceland	1997	20	98	n/a	Trawl	Cod	Nrwy Lobster	Redfish	Witch	5,704	5,845,099	1,025	0.039

Changes in energy intensity over time

It was possible to evaluate changes in energy intensity through time for the nine Atlantic Canadian and 19 Icelandic fisheries for which data were available. Specifically, 14 years of data, spanning 1986 to 1999 inclusive, were available in the case of the nine Canadian fisheries, and 21 years of data, spanning 1977 to 1997 inclusive, were available for each of the 19 Icelandic fisheries.

Canadian fisheries

Changes in the energy intensity of the four Canadian groundfish fisheries analyzed are plotted in Figure 7. While there is a great deal of inter-annual variability in the energy intensity of three of the four Canadian groundfish fisheries illustrated in Figure 7, in general the energy intensity of all four has increased over the period from 1986 to 1999. Interestingly, and perhaps not surprisingly, the period of greatest variability in energy intensity for most of these fisheries coincides with the years immediately prior to, and during the collapse of Canada's northern cod stock. Finally, it is worth noting that for almost the entire interval analyzed, the mobile seine fishery experiences the lowest energy intensity of the four fisheries illustrated in Figure 7.

Changes in the energy intensity of the three Canadian invertebrate fisheries analyzed are plotted in Figure 8. Over the period from 1986 to 1999, the Atlantic Canadian shrimp fishery experienced marked changes in its energy intensity (Figure 8). After a period of steady decline through the late 1980s, its energy intensity increased rapidly from approximately 600 litres/tonne in 1989 to over 1,800 litres/tonne just four years later. Through the late 1990s, however, the trend again reversed itself to the point that by 1998, the fishery was once again consuming less than 600 litres of fuel per tonne of shrimp landed. In contrast, both the Atlantic Canadian crab and scallop fisheries have displayed much less dramatic changes in energy intensity over the period from 1986 to 1999 (Figure 8). Specifically, through the first half of the interval, the crab fishery enjoyed a general reduction in its energy intensity reaching a low of just under 200 litres/tonne in 1993. Since then, however, this fishery's energy intensity has been slowing trending upwards once again. Finally, while the scallop fishery's energy intensity has been the least volatile of the three Atlantic Canadian invertebrate fisheries considered, it has been slowly trending upwards, with only a few minor reversals, throughout the period from 1986 to 1999 (Figure 8).

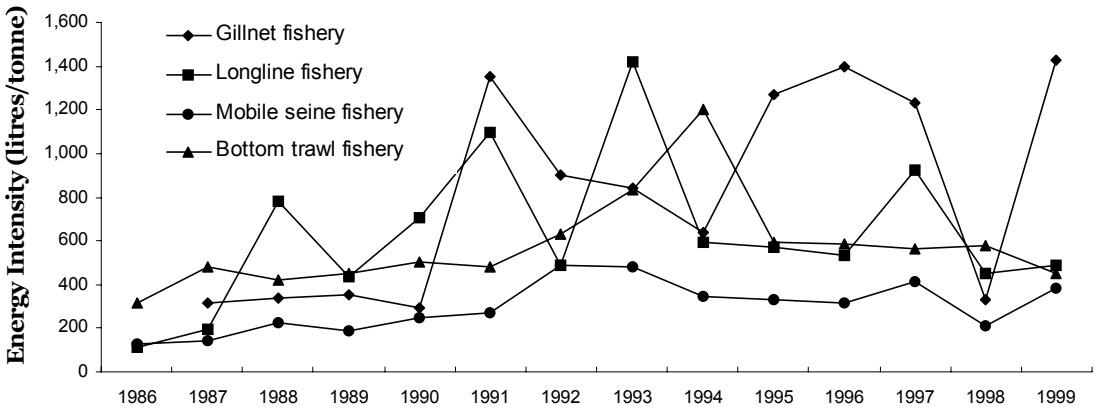

Figure 7. Changes in the energy intensity of Atlantic Canadian groundfish fisheries from 1986 to 1999.

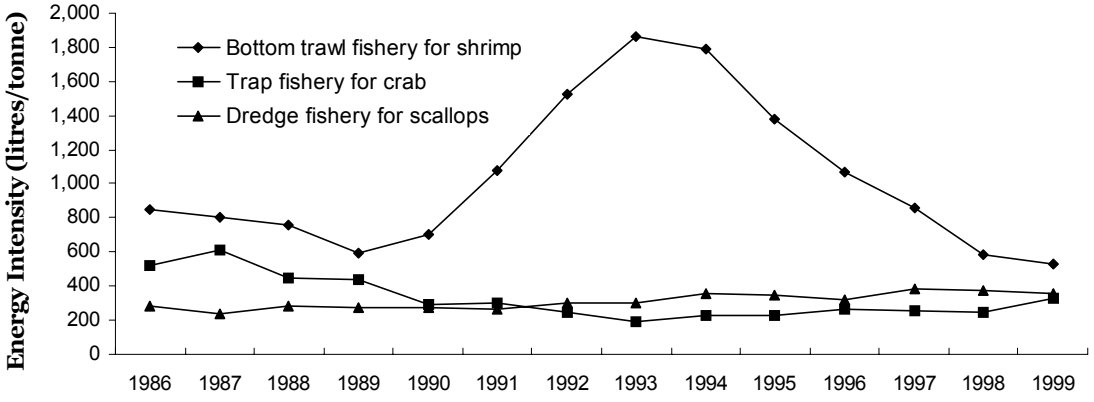

Figure 8. Changes in the energy intensity of Atlantic Canadian invertebrate fisheries from 1986 to 1999.

Changes in the energy intensity of Atlantic Canada's purse seine fishery for small pelagic species are illustrated in Figure 9. Although this fishery for small pelagic species is consistently the least energy intensive of all the Atlantic Canadian fisheries considered, it experienced approximately a doubling of its energy intensity over the period from 1986 to 1999 (Figure 9).

Changes in the energy intensity of Atlantic Canada's longline fishery for large pelagic species are illustrated in Figure 10. In addition to being the smallest fishery analyzed, with annual landings of typically under 2,000 tonnes, the longline fishery for large pelagic species is not only the most energy intensive of all the Canadian fisheries analyzed in most years, it also has the dubious distinction of achieving the highest one time energy intensity of any fishery considered in this analysis of just over 3,800 litres/tonne in 1996 (Figure 10).

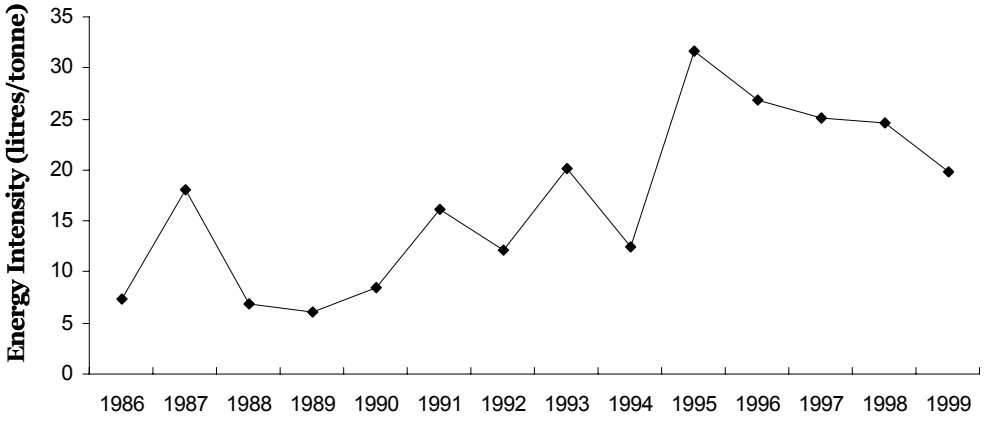

Figure 9. Changes in the energy intensity of Atlantic Canada's purse seine fishery for small pelagic species from 1986 to 1999.

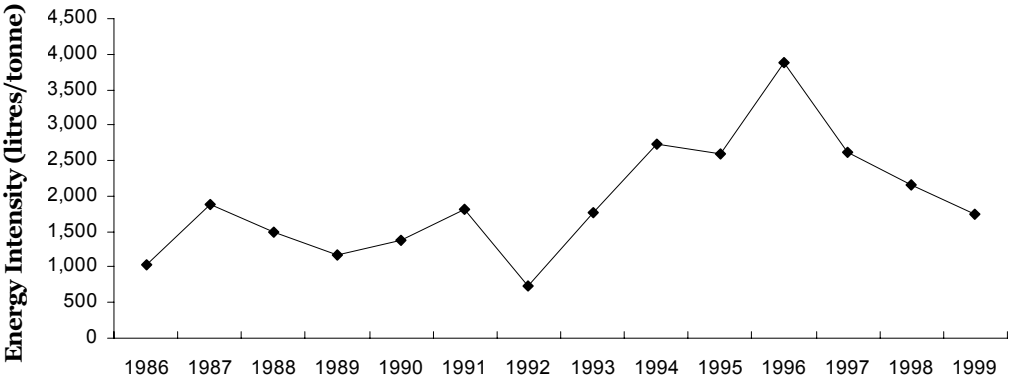

Figure 10. Changes in the energy intensity of Atlantic Canada's longline fishery for large pelagic species from 1986 to 1999.

Finally, changes in the total amount of fuel consumed annually by the nine Atlantic Canadian fisheries analyzed are illustrated in Figure 11.

What is most striking about the temporal changes in the total fuel consumed by the nine Atlantic Canadian fisheries considered, is the dramatic reduction that has occurred since 1991, coinciding with the collapse of the Northern cod stock (Figure 11). From a peak annual consumption of over 400 million litres of fuel in 1991, of which groundfish fisheries accounted for fully 80%, total fuel consumption has dropped to just 100 million litres in 1999.

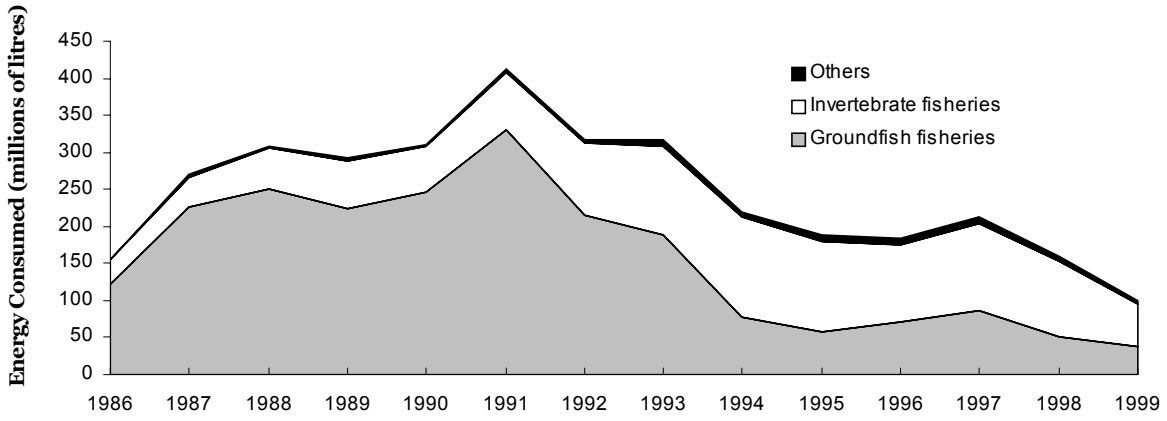

Figure 11. Changes in the total fuel consumed by nine Atlantic Canadian fisheries from 1986 to 1999.

Icelandic fisheries

Changes in energy intensity through time of nine Icelandic fisheries targeting groundfish species are illustrated in Figure 12.

Upon close inspection, a number of very interesting patterns emerge from the data presented in Figure 12. First, after an initial period of general decline through the late 1970s, the energy intensity of almost all of the groundfish fleet subsets illustrated in Figure 12 increased throughout much of the 1980s and early 1990s. Since then, however, all fleet subsets except one, the undecked boats deploying gillnet gear, have undergone a more or less pronounced decrease in their energy intensity. Second, the three fleet subsets composed of the smallest fishing vessels in the Icelandic groundfish fleet (i.e., undecked boats that are all demarcated by dashed lines in Figure 12) which were the least energy intensive at the beginning of the period illustrated in Figure 12, became the most energy intensive fleet segments throughout the 1990s. In contrast, trawlers, the fleet segment composed of the largest groundfish fishing vessels used in Iceland (demarcated by the heavy solid line in Figure 12), experienced a mid-range energy intensity through the late 1970s and early 1980s. However, since 1983 they have consistently been one of, if not the least energy intensive groundfish fleet subsets in operation in Iceland. Finally, many of the fleet subsets illustrated in Figure 12 display a sharp increase in their energy intensity in 1983. Interestingly, this was the last year before an individual transferable quota (ITQ) system was introduced by Icelandic management authorities to better manage its groundfish stocks (Hreidar Valtýsson, University of Akureyri, Iceland, pers. comm.) and it is possible that the marked energy intensity increases in 1983 reflect the extra lengths that fishers were willing to go to in trying to secure a larger fraction of the total quota allocation under the ITQ system starting in 1984.

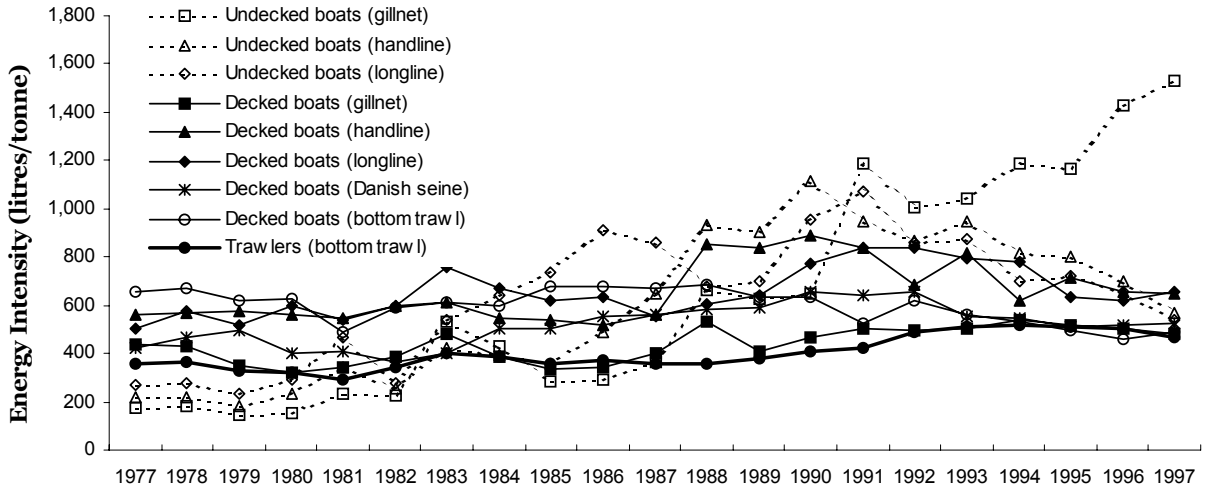

Figure 12. Changes in the energy intensity of Icelandic groundfish fisheries from 1977 to 1997.

Changes in the energy intensity of the three Icelandic fisheries targeting small pelagic species are illustrated in Figure 13. In years in which it has been conducted, the mid-water trawl fishery is not only the smallest, in terms of tonnes landed, of the three Icelandic fisheries directed at small pelagic species, it is typically the most energy intensive (Figure 13). Of the two fisheries for small pelagic species conducted continuously through the period from 1977 to 1997, the purse seine fishery for herring has been markedly more energy intensive in most years than the purse seine fishery for capelin. What is most remarkable about this latter fishery has been its consistently low energy intensity through time. Specifically, only once in the 21 years for which data were available has the purse seine fishery for capelin experienced an energy intensity of over 30 litres/tonne.

Changes in the energy intensity through time of the four Icelandic fisheries targeting invertebrates are illustrated in Figure 14. Of these Icelandic invertebrate fisheries, the two bottom trawl fisheries for shrimp employing either decked boats or trawlers, are typically the most energy intensive (Figure 14). Interestingly, while there were often large differences in the energy intensity experienced by these two size classes of vessels fishing for shrimp prior to 1988, since then their energy intensities have both been very similar and have largely declined over time. Over the period for which data were available, the relatively small tonnage fishery for Norwegian lobster has experienced a relatively consistent though generally high-energy intensity of between 800 and 1,300 litres/tonne (Figure 14). As was the case in the Canadian scallop fishery, the energy intensity of the Icelandic scallop fishery varied little from year to year but generally trended upward over the period from 1977 to 1994.

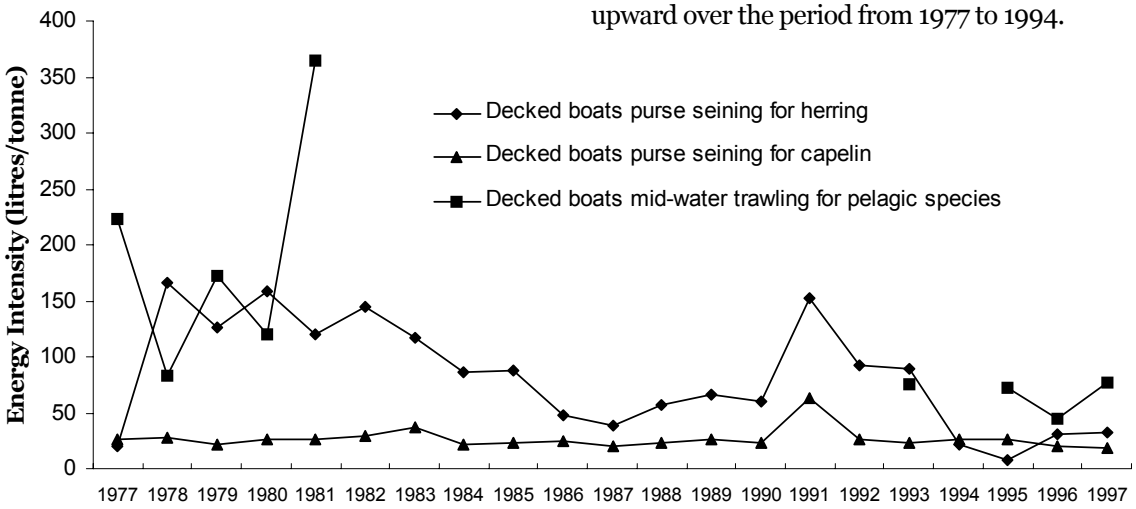

Figure 13. Changes in the energy intensity of Icelandic fisheries for small pelagic species from 1977 to 1997.

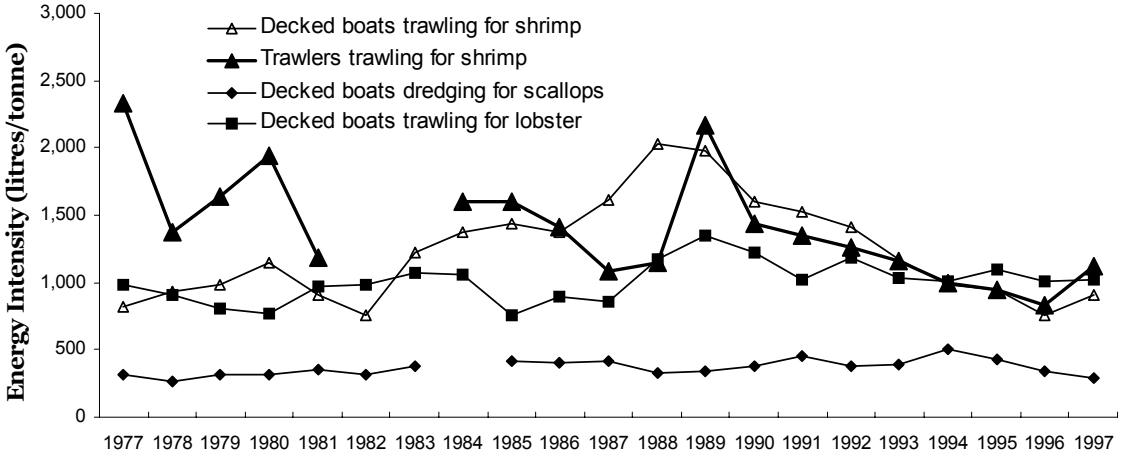

Figure 14. Changes in the energy intensity of Icelandic invertebrate fisheries from 1977 to 1997.

Finally, changes in the total amount of fuel consumed annually by the entire Icelandic commercial fishing industry are illustrated in Figure 15. Except for a minor reversal in 1984-85, the total amount of fuel consumed annually by all Icelandic fisheries increased steadily through the period from 1977 to 1991 when it peaked at almost 450 million litres. Between 1991 and 1996, however, the total annual energy inputs to Icelandic fisheries declined steadily, only to increase once again in 1997. On a broad sectoral basis, the combined Icelandic groundfish fisheries account for the lion's share of total fuel inputs in any given year. Interestingly, however, since 1982, when groundfish fisheries accounted for 90% of the total fuel consumed, their proportion of the total has slowly been reduced over time to the point that in 1997, they only represented 65% of the total. The one broad fishing sector whose total annual energy inputs have consistently increased over the period from 1977 to 1997 has been the invertebrate fisheries.

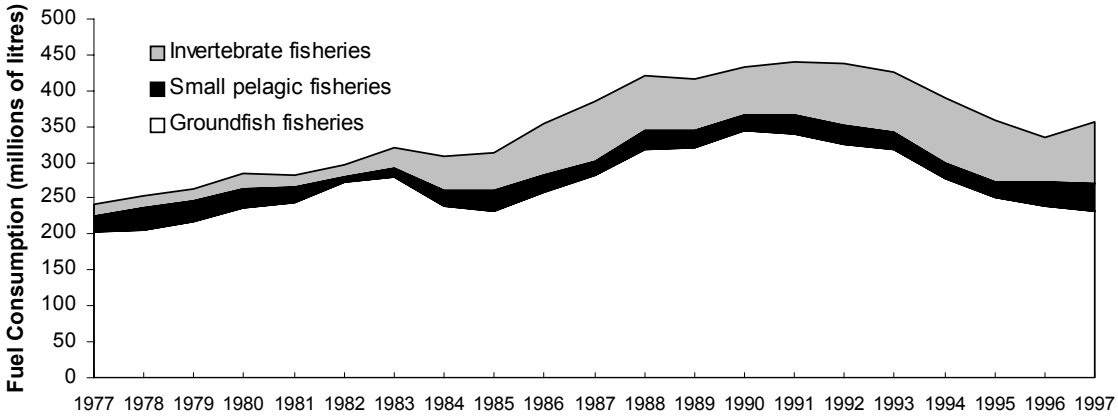

Figure 15. Changes in the total fuel consumed by Icelandic fisheries from 1977 to 1997.

Edible protein energy returns on investments

Of the four major types of fisheries analyzed, those targeting small pelagic species consistently had the highest edible protein returns, ranging from 0.33 to over 2.6 (Table 9). Taken together, the overall mean edible protein returns of these 12 fisheries was about 1.3. In other words, contemporary North Atlantic fisheries for small pelagic species yield, on average, 1.3 times as much potentially edible protein energy than is contained in the fossil fuel consumed for catching it. A very important point to note, however, is that the vast majority of the landings by these fisheries is destined for reduction to fishmeal and oil and not for direct human consumption. As a result, only a tiny fraction of the edible protein that they yield is ultimately available for human consumption.

Amongst fisheries whose catches are destined for direct human consumption, those targeting groundfish had protein returns ranging from just under 0.02 to a high of 0.25 (Table 8). Taken together, the mean edible protein return of all 29 groundfish fisheries, in the most recent years for which data were available, was 0.095. In contrast, the mean edible protein return of all invertebrate fisheries considered was 0.039. However, between individual fisheries, values varied from 0.014 to almost 0.13 (Table 10).

Recent temporal changes in the edible protein returns of Icelandic and Canadian groundfish and invertebrate fisheries are illustrated in Figures 16 and 17 respectively. Of note, there has been a more or less steady decline in the edible protein return of both country's groundfish fishing sector over the periods for which data were available. In contrast, although the mean edible protein returns of invertebrate fisheries in both Iceland and Canada are markedly lower than those of the groundfish sector, they have remained much more consistent over time, and in recent years have improved in both countries.

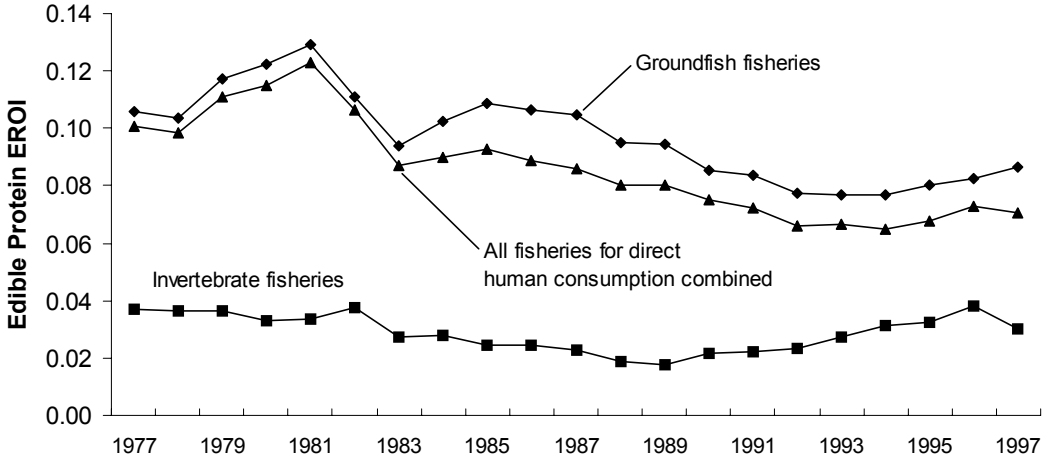

Figure 16. Changes in the edible protein returns of Icelandic groundfish and invertebrate fisheries from 1977 to 1997.

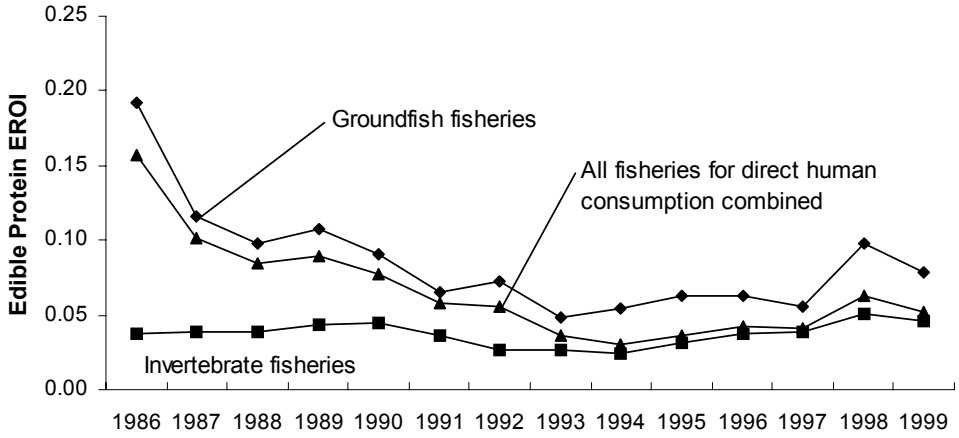

Figure 17. Changes in the edible protein returns of Canadian groundfish and invertebrate fisheries from 1986 to 1999.

DISCUSSION

Validating the methods used

Given the novelty of the technique used to quantify energy inputs to most of the fisheries analyzed (as outlined in Equation 2), I was anxious to confirm or 'ground truth' my results where possible. Such an opportunity arose within the context of the energy inputs to Icelandic trawlers. In a report prepared for the Fisheries Association of Iceland and the Icelandic Ministry of Fisheries, Ragnarsson (1985) provides estimates of the total litres of fuel consumed annually by Icelandic side and stern trawlers over the period from 1972 to 1984. By summing these estimates and plotting them beside the total annual energy input estimates that I derived for all Icelandic trawlers, regardless of the species group targeted, I found an extremely good agreement for all the years in which the two time series overlap (Figure 18).

Thus, the methods used in this analysis appear appropriate, particularly when:

- there are sufficient real world vessel performance data from which gear-specific fuel consumption rate estimates can be based; and
- data are available that accurately reflects average vessel horsepower and total days at sea for any fleet or fleet sub-set of interest.

Comparing contemporary North Atlantic fisheries with other commercial fisheries

Gear-specific mean energy intensities for each major targeted groups were calculated and tabulated along with the results of previous energy analyses for comparison of the energy performance of contemporary North Atlantic fisheries with those in other parts of the world (Table 11). In general, the energy intensities of contemporary North Atlantic fisheries are broadly consistent with those of similar fisheries conducted elsewhere in the world.

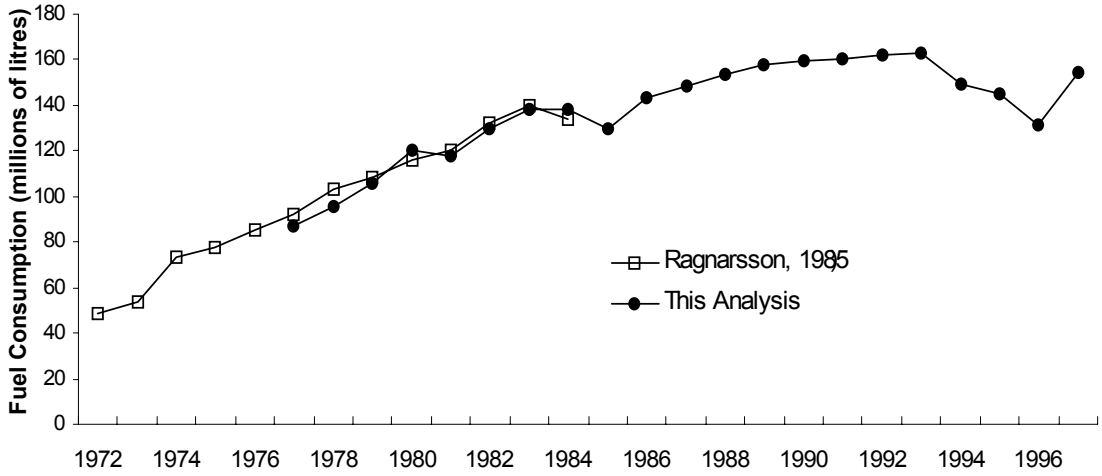

Figure 18. Total fuel consumed annually by Icelandic trawlers as determined by Ragnarsson (1985) and in the present study.

Comparing contemporary North Atlantic fisheries with other protein producing sectors

Using mean edible protein returns, it is possible to compare the energy performance of contemporary North Atlantic fisheries with other protein producing sectors (Table 12). While the protein energy output of contemporary North Atlantic fisheries for direct human consumption is only a small fraction of the fossil fuel energy that they consume, they fall well within the range of other protein producing sectors. In fact, even the two poorest performing North Atlantic fishing sectors, those targeting invertebrates and large pelagic species, have better protein returns than many livestock and intensive aquaculture systems.

Reflecting both their size and highly industrialized character, contemporary North Atlantic fisheries are major consumers of energy and emitters of greenhouse gasses. The relative significance, however, of fisheries as energy consuming sectors within economies, varies widely amongst North Atlantic countries. For example, Iceland's fishing industry accounts for fully one third of the entire nation's fossil fuel consumption and greenhouse gas emissions (Árnason and Sigfússon, 2000). This contrasts with larger, highly diversified economies such as the United States and Germany, where fishing accounts for only a small fraction of total national energy consumption and greenhouse gas emissions.

Of much greater significance and concern, however, than the relative scale of commercial fishing as an energy consuming sector within North Atlantic economies, is the fact that for many fisheries there are very clear signs of ever increasing dependence on fossil fuels and decreasing yields per unit of energy expended. Amongst those North Atlantic fisheries analyzed, this trend is particularly evident in both Icelandic and Canadian groundfish and scallop fisheries, and Canadian fisheries targeting small and large pelagic species. Even though this general pattern has been documented previously in other fisheries, in other parts of the world (Brown and Lugo 1981, Watanabe and Uchida 1984, Sato *et al.,* 1989, Mitchell and Cleveland 1993), it is deeply troubling given the state of many of the world's fish stocks, the finite nature of fossil energy resources (Duncan and Youngquist, 1999, 2001) and the ever increasing scarcity of industrial energy availability per capita globally (Duncan, 1993).

ACKNOWLEDGEMENTS

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Table 11. Comparison of commercial fishery energy intensities.

Fishery (home base or location)	Energy intensity (GJ/t)	Analysis includes energy inputs to	Source
Purse seining for capelin (Iceland)	0.7	Fuel	Ágústsson (1978)
Purse seining for small pelagics (N. Atl.)	**1.8**	**Fuel**	**This study**
Purse seining for herring (Maine, U.S.)	2.2 to 2.4	Fuel, gear, vessels	Rawitscher (1978)
Set nets for various species (Japan)	2.9	Fuel	Nomura (1980)
Trawling for small pelagics (N. Atlantic)	**3.5**	**Fuel**	**This study**
Mobile seining for small pelagics (N. Atl.)	**5.2**	**Fuel**	**This study**
Purse seining for herring (B.C., Canada)	5.8	Fuel, vessels	Tyedmers (2000)
Trawling for pollock (Japan)	7.5	Fuel	Nomura (1980)
Trawling for perch (Maine, U.S.)	6 to 8	Fuel, gear, vessels	Rawitscher (1978)
Jigging for squid (Japan)	7.2 to 72	Fuel	Sato *et al.* (1989)
Trapping crabs (Maryland, U.S.)	8 to 10	Fuel, gear, vessels	Rawitscher (1978)
Purse seining for pelagics (Japan)	10	Fuel	Nomura (1980)
Trawling for groundfish (Wash. U.S.)	10	Fuel, vessels and other	Wiviott and Mathews (1975)
Trapping crabs (N. Atlantic)	**12**	**Fuel**	**This study**
Dredging for scallops (N. Atlantic)	**13**	**Fuel**	**This study**
Gillnetting pink salmon (Washington, U.S.)	13 to 19	Fuel, gear, vessels	Rawitscher (1978)
Mobile seine for groundfish (N. Atlantic)	**16**	**Fuel**	**This study**
Purse seining for salmon (B.C., Canada)	17	Fuel, gear, vessels	Tyedmers (2000)
Longlining for groundfish (N. Atlantic)	**18**	**Fuel**	**This study**
Trawling for cod (Massachusetts, U.S.)	18 to 20	Fuel, gear, vessels	Rawitscher (1978)
Trawling for groundfish (N. Atlantic)	**19**	**Fuel**	**This study**
Trawling for flounder (Rhode Island, U.S.)	20 to 22	Fuel, gear, vessels	Rawitscher (1978)
Jigging for squid (Japan)	20 to 44	Fuel	Nomura (1980)
Handlining for groundfish (N. Atlantic)	**21**	**Fuel**	**This study**
Trawling for pollock (Japan)	21 to 84	Fuel and other	Watanabe and Uchida (1984)
Gillnetting for groundfish (N. Atlantic)	**23**	**Fuel**	**This study**
Purse seining for tuna (California, U.S.)	31 to 62	Fuel, gear, vessels	Rawitscher (1978)
Trawling for shrimp (N. Atlantic)	**33**	**Fuel**	**This study**
Trawling for croaker (Japan)	33 to 75	Fuel and other	Watanabe and Uchida (1984)
Gillnetting for salmon (B.C., Canada)	34	Fuel, gear, vessels	Tyedmers (2000)
Trolling for salmon (B.C., Canada)	34	Fuel, gear, vessels	Tyedmers (2000)
Trawling for Norway lobster (N. Atlantic)	**37**	**Fuel**	**This study**
Trawling for shrimp (Australia)	38	Fuel, vessels	(Leach 1976)
Trawling for groundfish (Japan)	38	Fuel	Nomura (1980)
Trawling for haddock (Massachusetts, U.S.)	34 to 42	Fuel, gear, vessels	Rawitscher (1978)
Pole & line for skipjack (Japan)	42	Fuel	Nomura (1980)
Driftnetting for salmon (Japan)	44 to 68	Fuel	Nomura (1980)
Longlining for halibut (U.S.)	48 to 51	Fuel, gear, vessels	Rawitscher (1978)
Trawling for groundfish (Japan)	52	Fuel, vessels and other	Wiviott and Mathews (1975)
Longlining for swordfish/tuna (N. Atlantic)	**63**	**Fuel**	**This study**
Trolling for chinook salmon (Washington, U.S.)	82 to 87	Fuel, gear, vessels	Rawitscher (1978)
Longlining for tuna (Japan)	84 to 134	Fuel	Nomura (1980)
Trapping lobster (Maine, U.S.)	141 to 145	Fuel, gear, vessels	Rawitscher (1978)
Trawling for shrimp (Texas, U.S.)	270 to 312	Fuel, gear, vessels	Rawitscher (1978)
Trawling for shrimp (U.S.)	358	Fuel	Leach (1976)

Table 12. Protein returns for various food production systems

Food production system	Edible Protein EROI	Source
Carp farming (Indonesia)	0.70	Ackefors *et al.* (1993)[a)]
Kapenta fishery (Zimbabwe)	0.25	Michélsen (1995)[b)]
Groundfish trawl fishery (Washington State - 1970's)	0.17	Wiviott and Mathews (1975)
All commercial fishing (New Bedford Mass., 1968 to 1988)	0.17 declining to 0.03	Mitchell and Cleveland (1993)
Salmon purse seine fishery (British Columbia)	0.14	Tyedmers (2000)
Tilapia farming (Africa)	0.11	Ackefors *et al.* (1993)[a)]
Mussel farming (Scandinavia)	0.10	Folke and Kautsky (1992)[b)]
Contemporary North Atlantic groundfish fisheries	**0.095**	**This study**
Carp farming (Israel)	0.084	Ackefors *et al.* (1993)[a)]
Sea ranched Atlantic salmon (Sweden)	0.083	Folke and Kautsky (1992)[b)]
Turkey (USA)	0.077	Pimentel (1997)[c)]
Milk (USA)	0.071	Pimentel (1997)[c)]
Salmon gillnet fishery (British Columbia)	0.068	Tyedmers (2000)
Salmon troll fishery (British Columbia)	0.068	Tyedmers (2000)
Tilapia farming (Israel)	0.066	Ackefors *et al.* (1993)[a)]
Tilapia semi-intensive pond culture (Zimbabwe)	0.060	Berg *et al.* (1996)
Swine (USA)	0.056	Pimentel (1997)[c)]
Cod fishery (USA - 1970's)	0.050	Folke and Kautsky (1992)[b)]
Contemporary North Atlantic invertebrate fisheries	**0.039**	**This study**
Egg production (USA)	0.038	Pimentel (1997)[c)]
Contemporary North Atlantic longline fishery (large pelagics)	**0.034**	**This study**
Catfish - intensive pond culture (USA)	0.030	Pimentel *et al.* (1996)
Chicken (USA)	0.029	Ackefors *et al.* (1993)[a)]
Tilapia - intensive cage culture (Zimbabwe)	0.025	Berg *et al.* (1996)
Atlantic salmon - intensive cage culture (British Columbia)	0.025	Tyedmers (2000)
Shrimp- semi-intensive culture (Colombia)	0.020	Larsson *et al.* (1994)
Chinook salmon - intensive cage culture (British Columbia)	0.020	Tyedmers (2000)
Lamb	0.020	Pimentel (1997)[c)]
Atlantic salmon - intensive cage culture (Sweden)	0.020	Folke and Kautsky (1992)[b)]
Beef (USA)	0.019	Pimentel (1997)[c)]
Seabass - intensive culture (Thailand)	0.015	Pimentel *et al.* (1996)
Shrimp - intensive culture (Thailand)	0.014	Pimentel *et al.* (1996)

Note: a.) Ackefors *et al.* (1993) do not cite the original sources of these data. In addition, as they only provide energy inputs per gram of protein produced, these were converted to protein return ratios based on protein's energy density of 17.9 kJ/gram;
b.) As cited in Berg *et al.* (1996);
c.) Energy inputs to contemporary US livestock production systems as reported by Pimentel (1997) only include the energy needed to provide feed inputs (Dr. David Pimentel, pers. comm. 1999).

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MODELING AND MAPPING TROPHIC OVERLAP BETWEEN MARINE MAMMALS AND COMMERCIAL FISHERIES IN THE NORTH ATLANTIC

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ABSTRACT

The impact that fishing operations may have on marine mammals and other components of marine ecosystems is a major concern today. Fisheries, in addition to causing by-catch mortalities, affect marine mammals through direct and indirect competition for the same food sources. Our goal was to assess the potential trophic impact of fisheries on mammal populations in the North Atlantic by quantifying the overlap in resource exploitation in space and time using high-resolution modeling and mapping.

We developed a relatively simple model to estimate feeding requirements (specified by food type) and population biomass of all North Atlantic marine mammal species. Main model input parameters were population abundance, sex-specific mean body mass, standardized diet compositions, and weight-specific feeding rates. A spatial model was constructed using a geographic information system to link annual food consumption estimates to the corresponding species-specific, rasterized distributional ranges. Spatially explicit food intake (expressed as proportions of total food intake per ½ degree latitude/longitude square) was further refined by incorporating information about habitat preferences and feeding patterns. Superimposing the geographically matching fisheries catches (generated by a similar rule-based model) allowed the calculation of overlap between fisheries catches and marine mammal consumption. The model indicates that, in the North Atlantic, total food consumption of marine mammals in the 1990s was three times higher than total fisheries catches. However, spatially disaggregating consumption and specifying intake by food type showed actual resource overlap to be quite low. Areas of high overlap in the North Atlantic are concentrated along the East coast of North America (35° – 53° N) and in European shelf waters.

This visualization of geographical 'hotspots' of marine mammal-fisheries interactions may help to identify areas of conflict, realized or potential. Hence the meta-analysis approach taken here may serve as a useful management tool in the context of defining marine mammal critical habitat and efficient MPAs design.

INTRODUCTION

Marine mammals are generally located near or at the top of marine food webs (Pauly *et al.*, 1998) and it has been suggested that, being apex predators, some species may have or have had considerable impact on the structuring of pelagic ecosystems (Merrick, 1997). Hence, the status of marine mammal populations may reflect the state of an ecosystem (Timoshenko, 1995) and may serve as an indicator of the sustainability with which it is being managed. As a result, many studies have attempted to qualitatively and quantitatively assess the ecological role of marine mammals (e.g., NAFO, 1997; Trites *et al.*, 1997). The influence of marine mammals on the ecosystem, however, is difficult to describe by any single feature, or indeed even several features. Nonetheless, modeling some aspects of marine mammal ecology may help delineate ranges, test hypotheses, and describe patterns qualitatively (Bogstad *et al.* 1997; Stenson *et al.* 1997).

In the past fifty years the majority of marine mammal populations have been reduced to very low levels and, despite extensive management efforts, have failed to recover in many cases. It has been speculated that human fishing activities may be one of the major factors affecting recovery rates (Bowen, 1985; Crespo *et al.*, 1997). Mortality may occur through incidental entanglement of marine mammals in fishing gear (Northridge, 1984, 1991) or through competition for food resources (Bowen, 1985; Trites *et al.*, 1997). Understanding the mechanisms and the extent to which fisheries are competing with marine mammals would greatly facilitate management decision regarding conservation measures to protect endangered marine mammal populations.

To quantify the degree of overlap between two of the top predators in marine food webs (marine mammals and humans), estimates of food resource utilization for both predators are required. Available fisheries catch data have numerous shortcomings, lack of spatial resolution and reliable quantification of discards first amongst them. Nonetheless, quantification of global fisheries catches is, for obvious reasons, more reliable than any direct attempts to

determine the total intake of a very large and diverse group of free-ranging animals. Modeling feeding requirement has therefore been recognized as the only avenue to estimate marine mammal consumption (Bogstad *et al.*, 1997).

A multitude of approaches, varying greatly in complexity and detail, have been applied to the problem of modeling food consumption. Approaches differ in three main respects: geographic scale, number of species included and model complexity, i.e., the number of parameters taken into account. However, until now, most studies have focused on small numbers of species in limited geographic areas (e.g., Doidge and Croxall, 1985; Stenson *et al.*, 1997; Nilssen *et al.*, 2000) and included sex- and age-specific information for each input parameter as well as specifying seasonal changes (Bogstad *et al.*, 1997). Some of these have also integrated explicit spatial and temporal changes in food requirements (Sigurjonsson and Vikingsson, 1997; Potelov *et al.*, 2000).

The few models encompassing larger areas and higher taxonomic groupings generally assume homogenous geographic distribution and feeding patterns, which positions them at the other end of the scale with respect to model complexity (Hinga, 1979; Trites *et al.*, 1997; Tamura and Ohsumi, 1999, 2000; Young, 1999). Furthermore, these highly simplified models assume uniform feeding rates across all age classes within a given species, ignoring the effect of individual size or sex on food requirements as well as spatial and seasonal differences (e.g., Tamura and Ohsumi, 1999).

While the danger of simplistic models is well known, it must also be realized that over-parameterization may also reduce model precision due to the accumulation of uncertainties (Stenson *et al.*, 1997). Problems related to the estimation of detailed input parameter values are certainly likely for a large proportion of marine mammal species, considering the dearth of reliable information about life history, growth curves and feeding ecology.

The importance of choosing the appropriate analytical scale when modeling ecological systems has been stressed by numerous researchers (Legendre and Fortin, 1989; Levin, 1992; Jaquet, 1996; Jaquet and Whitehead, 1996; Logerwell *et al.*, 1998; Pauly and Pitcher, 2000). When temporal and spatial scales are too small relative to the processes of interest, high parameter variation will overwhelm the model's ability to detect patterns (Jaquet, 1996). Although comparatively small geographic scales will suffice when studying certain marine mammal species, a large number of species is highly migratory, and range globally or hemispherically. Similarly, modern fishing fleets cover long distances, roaming the world's oceans. Due to feeding patterns, availability of prey species or management decisions, exploitation of the resources sustaining both groups may be highly irregular over the course of a year. A model should, therefore, be global in scale and cover time spans of, at least, a year to capture the interactions between the two groups. Adding more species is also desirable, as it will increase the model's scope.

Resolution is another critical consideration (Jaquet, 1996). Investigators have suggested that a consistent ratio between marine mammal biomass and primary production may exist, indicating these top predators may be very efficient in the utilization of available food web energy (Trites *et al.*, 1997). Such basin-scale patterns may only be detectable at very large scales through cross-ecosystem comparisons. However, if the resolution of data is too coarse, details are averaged and patterns are masked. Storing input parameters at a high resolution allows for studying broad scales, while preserving detail, thus allowing for analysis on multiple scales (Jaquet, 1996)

METHODS

Marine mammal food consumption model

A relatively simple generic model, developed by Trites *et al.* (1997), was used to generate estimates of feeding requirements, specified by food type, and population biomass of all 47 North Atlantic marine mammal species (excluding West Indian manatee and polar bear):

$$Q_i = \sum_s N_{is} W_{is} R_{is} \qquad ...1)$$

where N_{is} is the number of individuals by sex s of species i, W_{is} is the mean individual weight by sex and species; and R_{is} is the daily ration (by sex and species) for an individual of weight W_{is}.

The main advantage of this model is that it can be applied to the numerous species of marine mammals about which very little is known. Unknown parameter values can be inferred through empirical relationships, e.g., those of Innes *et al.* (1987), or Trites and Pauly (1998),

wherein required parameters are estimated based on other, often more readily available data.

Main model input parameters were species-specific abundance estimates, mean body mass (specified by sex), standardized diet compositions and weight-specific feeding rates, which have been compiled in a global marine mammal database. Below is a brief description of the approach taken for each input parameter.

Species abundance and sex ratio

As the areas covered by surveys are usually limited, abundances are generally estimated only for a fraction of the total population, such as sub-species or sub-populations, or for a limited geographical stratum. To obtain an estimate of the total North Atlantic abundance of a species, the following approach was taken. Abundance estimates were taken from primary data sources, wherever possible (e.g., Oeien and Oeritsland, 1993; Jefferson, 1996; IWC, 1997; Jefferson and Schiro, 1997; Waring *et al.*, 2000) supplemented by secondary sources (e.g., Riedman, 1990; Reijnders *et al.*, 1993; Ridgway, 1994, 1999) when necessary. All available regional estimates were compiled in a database, jointly with information about the time period and geographical area covered by the estimate, the method used to obtain it, and the associated uncertainties. Estimates were then assigned to specific standardized areas and time periods and ranked based on the reliability of the surveying technique and the estimate itself, as judged by the first author. (Surveys explicitly devoted to population/abundance estimation are relatively rare and, in many cases are conducted with a frequency of over a decade. Consequently, the most recent abundance estimate available was classified as a 1990s estimate and all historic estimates predating the 1970s were classified as 1950s (including so-called 'pre-exploitation' estimates). In cases were no historic estimate could be found, a conservative approach was taken, assuming no change in population abundance during the past 50 years).

Default model input parameter values, i.e., the total North Atlantic abundance estimates for each species, were then derived through summation of the most reliable regional abundance estimates available or via extrapolation to the total distributional range of a species.

Population sex ratios were assumed to be balanced, except in cases where explicit information on other population ratios was available (including closely related species with similar life histories).

Mean body mass

The estimation of mean individual body mass, required to calculate total population biomass, is comparatively simple if life tables and growth curves are available. Unfortunately, this information is unobtainable for many species. Based on the strong correlations between growth rate, survival, longevity and maximum length, Trites and Pauly (1998) developed a method allowing the estimation of mean body masses of marine mammals from maximum body length. The functional relationship between the two parameters can be expressed as:

$$W_{is} = a_{is} L_{\max_{is}}^{b_{is}} \qquad ...2)$$

where W_{is} is the mean body mass of an individual of the species i and the sex s, $L_{\max_{is}}$ is the corresponding maximum length reported for such an individual. Variables a_{is} and b_{is} are sex-specific regression coefficients varying for different high-order taxonomic groups, established by regressing (log) maximum length against (log) mean body mass in 30 marine mammal species with known growth curves and life tables (see Trites and Pauly (1998) for details and for the species-specific body mass estimates for North Atlantic marine mammal species thus obtained).

Daily rations and diet composition

Food consumption of marine mammals have been studied extensively using direct observations of consumption and scat analysis as well as using indirect approaches, such as isotope ratios (Todd *et al.*, 1997). Feeding rates have been estimated based on direct measurements of food intake or maximum stomach contents (Innes *et al.*, 1987; Lockyer, 1987). Alternatively, feeding rates can be derived from calculated energy budgets using bioenergetic models (Lockyer, 1981). These models are based on certain assumptions about physiological parameters, the feeding requirements of a specific individual (e.g., Klumov, 1963; Innes *et al.*, 1986) or standard metabolic rates of the species (Sigurjonsson and Vikingsson, 1997). Here, daily food rations were estimated from the empirical model of Innes *et al.* (1987), as modified by Trites *et al.* (1997; see below).

Diet composition of marine mammals is difficult to obtain, and most dietary information is only available in the form of qualitative summaries (e.g., Riedman, 1990), thus precluding its direct use in trophic modeling studies. However, by combining scattered quantitative studies with qualitative summaries mentioned in the literature, Pauly *et al.* (1998) were able to obtain

standardized diet compositions for the overwhelming majority of marine mammal species, consisting of the proportion of eight prey types (see Table 1). Thus, total food consumption by food type can here be estimated by substituting R_{is} in the basic food consumption equation with:

$$R_{is} = \sum_{j=1}^{8} pDC_{ijs} * (0.1 * W_{is}^{0.8}) \qquad ...3)$$

where pDC_{ijs} is the proportion of food type j in the diet of species i and the sex s and the second part of the product describes the weight specific energy requirements or feeding rate of an individual with W_{is} as the mean body weight of an individual in kg. The exponent of this equation was derived by Innes *et al.* (1987), whereas the multiplicative term was adjusted by Trites *et al.* (1997) to account for the difference between consumption for growth and for maintenance.

Table 1. Correspondence between the eight marine mammals food groups used here (left column) and groups reported in the fisheries catch databases.

Food group[a)]	Taxa included	ISSCAAP Group[b)]
Benthic invertebrates	All crustaceans (except krill), seasquirts, bivalves, gastropods, octopus	42 –45, 47, 52-56, 58, 75-77
Large zooplankton	Krill (especially *Euphausia superba*)	46, 74
Small squid	Mantle length < 50 cm; e.g., Gonatidae	Part of 57
Large squid	Mantle length >= 50 cm; e.g., Onychoteuthida	Part of 57
Miscellaneous fishes	*FishBase*[c] habitat attributes: demersal; benthic; benthopelagic; bathydemersal; reef-associated (max. size so far: all); pelagic (max. size: >= 80 cm)	21-25, 32-34, 36-39
Mesopelagic fishes	*FishBase*[c)] habitat attributes: bathypelagic (max. size: all)	Not covered
Small pelagic fishes	*FishBase*[c)] habitat attributes: pelagic (max. size < 80 cm)	Part of 35

[a)] From Pauly et al. (1998);
[b)] From FAO's International Standard Statistical Classification of Aquatic Animals and Plants;
[c)] See Froese and Pauly (2000).

Spatially explicit food consumption model

Distributional ranges of species

As a next step, the species-specific estimates of food consumption generated by the model were linked to the corresponding distributional ranges of each species.

Delineation of geographical ranges of marine mammals is greatly hampered by difficulties in defining the limits of the distribution of these elusive and often highly mobile animals. Due to the vastness of the marine environment, surveys designed for estimating population sizes usually cover only a small fraction of the distributional ranges of most species (e.g., Waring *et al.*, 2000). Also, a substantial proportion of marine mammal species were described based only on a few stranded specimens or sightings (e.g., some of the beaked whales). For these, determining distributional ranges other than 'ocean-wide' is presently not possible. (Note that the low population numbers assigned to these rare species preclude their biasing the results presented below.)

In consequence, delineation of a species range is mostly based on the professional judgment of experts rather than actual quantitative analysis (e.g., Riedman, 1990; Reijnders *et al.* 1993), except in a few cases where unusually large and regionally stratified sighting data are available (e.g. Townsend, 1935).

We used the distributional ranges of pinniped species as compiled in Reijnders *et al.* (1993), who based their delineations on direct consultation with experts for the individual species. Geographic ranges of the other taxonomic groups of marine mammals (cetaceans, sirenians, marine otters and polar bear) were plotted based on the distribution maps in Jefferson *et al.* (1993). All ranges describe the maximum limits of the geographical distribution of a species over the course of a whole year, i.e., including all areas covered during the annual migrations. Levels of confidence in the distributional range, ranked by the authors based on information provided by Jefferson *et al.* (1993) and Reijnders (1993) have been included in the

model to reflect the origin and reliability of the information and only the most reliable distributions were used.

Species geographic ranges were manually digitized as shapefile polygons using the ArcView GIS tools. Ranges were subsequently re-expressed as presence/absence grid cells in the raster database of ½ degree longitude/latitude squares used by the *Sea Around Us* project (see Watson *et al.*, this volume). The total area of the geographic extension A_i of a species i was calculated using:

$$A_i = \sum_{c_i} a_{c_i} \quad ...4)$$

where a_{c_i} is the area of a grid cell c_i in which a species i is present. Assuming a homogenous distribution of the animals, food consumption densities qD_i in each cell for individual species can be estimated from:

$$qD_i = Q_i / A_i \quad ...5)$$

where Q_i is the total food consumption of a species i divided by its distributional range A_i.

Specific fractions of total species abundances, biomass and food consumption can then be assigned to individual grid cells.

Incorporation of habitat preferences
Obviously the assumption of a homogenous distribution does not reflect well the real distribution of population, biomass and food consumption. Studies have shown that distributions of some species of marine mammals are closely correlated with certain biological and physical environmental parameters, such as depth, slope, sea surface temperature, ice cover and zooplankton distributions (Jaquet and Whitehead, 1996; Griffin, 1997; Moore and DeMaster, 1997). These factors can thus be used as indicators to predict the preferred habitats of a species within its total range of occurrence and some of them were therefore integrated into the model to spatially refine biomass distribution for those species for which the information is available.

Here, specific depth ranges and association with ice edges were encoded for each of the marine mammal species considered in this model, to allow use of the depth information and ice coverage index that are attributes of the ½ degree spatial cells in the SAUP database (see Watson *et al.*, this volume). An algorithm was then developed, using a trapezoid probability distribution, which converted these parameters into 'weighting factors', describing the probability of occurrence of a member of a given species in a particular cell, which would be highest within its preferred range of habitat parameters and lower if the depth and ice attributes of a cell diverge from this optimum. Multiplication of the initial portions of biomass and food consumption densities with the weighting factors of a each spatial cell and a subsequent normalization procedure resulted in realistic spatial distribution of the marine mammal species in question.

Fisheries catches
Annual fisheries landings from FAO and other sources were adjusted for misreporting, underreporting, etc. following the procedures in Pitcher and Watson (2000), then taxonomically disaggregated and re-assigned into spatial cells of ½ degree of longitude by ½ degree of latitude using the rule-based procedure described in Watson *et al.* (this volume). The catches were then regrouped into the eight marine mammal food categories mentioned above (Table 1).

This led to maps of fisheries catches, expressed in $t \cdot km^{-2}$ $year^{-1}$, with a resolution of ½ degree latitude/longitude, in which the fisheries catches were expressed in the same eight categories also used to describe the food composition of marine mammals, thus allowing computation of an overlap index.

Resource overlap/fisheries impact index
As the assessment of overlap with fisheries is more sensible at higher taxonomic levels, marine mammal species were grouped into suborders (pinnipeds, odontocetes, mysticetes), with the exception of the beaked whales, here defined as a group distinct from the other odontocetes due to their life history, oceanic distribution, and specialized diet composition. Food intake and diet composition of all marine mammals belonging to the same taxonomic group were averaged within each cell, to obtain an average diet composition and food consumption representative of a given group within each cell.

The estimation of overlap between marine mammal food consumption and fisheries catches by ½ degree cell was initially performed using a modified version of an ecological niche overlap index, based on an equation derived by MacArthur and Levins (1967). However, this index, which only considered the qualitative overlap of marine mammal diet vs. catch composition, produced misleading results, as it did not account for the quantities involved. To

incorporate the quantitative aspect, the original index was modified, leading to:

$$a_{jl} = \left(\left(\frac{2\sum_k p_{lk} p_{jk}}{\sum_k p_{lk}^2 + p_{jk}^2} \right) * \left(Q_l * C_j \right) \right) \Big/ (NF) \quad \ldots 6)$$

where α_{jl} describes the quantitative overlap between a fishery j and a marine mammal group l in each cell, and the first term of the numerator expresses the overlap in diet/catch composition between a marine mammal group l and fisheries sharing the resource k, with p_{lk} and p_{jk} representing the proportions that each of the k resources contributes to the average diet of this mammal group l or the catch composition of the fisheries j. This term is multiplied with the product of the total average food consumption of the mammal group l and the total fisheries' catches within each cell and subsequently normalized using a normalization factor NF, which is defined as the product of the total food consumption of the marine mammal group and total catches (summed over all cells), adjusted by division by a scaling factor of 10^9.

RESULTS AND DISCUSSION

Figure 1 presents, for the North Atlantic, our estimate of food consumption, by marine mammal group in 1950s and the 1990s, compared with the corresponding fisheries catches. In bulk, marine mammals presently consume about three times as much as the fisheries catches, a figure similar to that estimated for the Pacific Ocean (Trites *et al.*, 1997) and for the world ocean as a whole (Tamura and Oshumi, 1999, 2000). This value was higher in the 1950s, when there were more marine mammals and fisheries catches were lower (Figure 1).

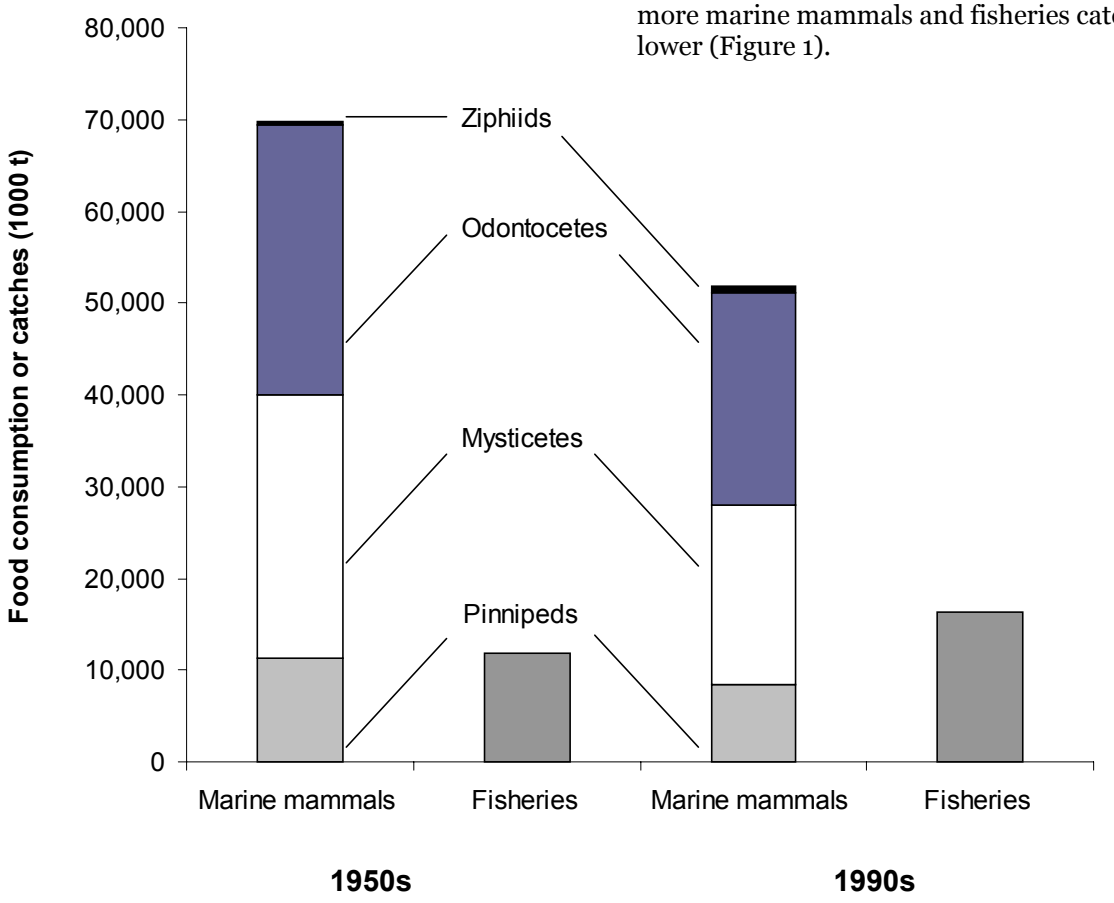

Figure 1. Overall marine mammal food consumption specified by marine mammal groups in the 1950s and 1990s, compared with total fisheries catches during the same decades.

This overall figure, however, masks important differences between mammal groups, of which several, with high consumptions (notably the toothed whales), consume preys not exploited by fisheries. Our new maps make this abundantly clear.

Figure 2 shows the spatial distribution of marine mammal food consumption in the 1990s. The highest consumptions ($t \cdot km^{-2}$ $year^{-1}$) occur along the shelves, particularly so in Arctic waters, and along the East coast of North America. However, it is the large area of oceanic waters, inhabited by toothed whales (sperm and beaked whales, porpoises and dolphins) that lead, in the aggregate, to large overall consumption figures by marine mammals.

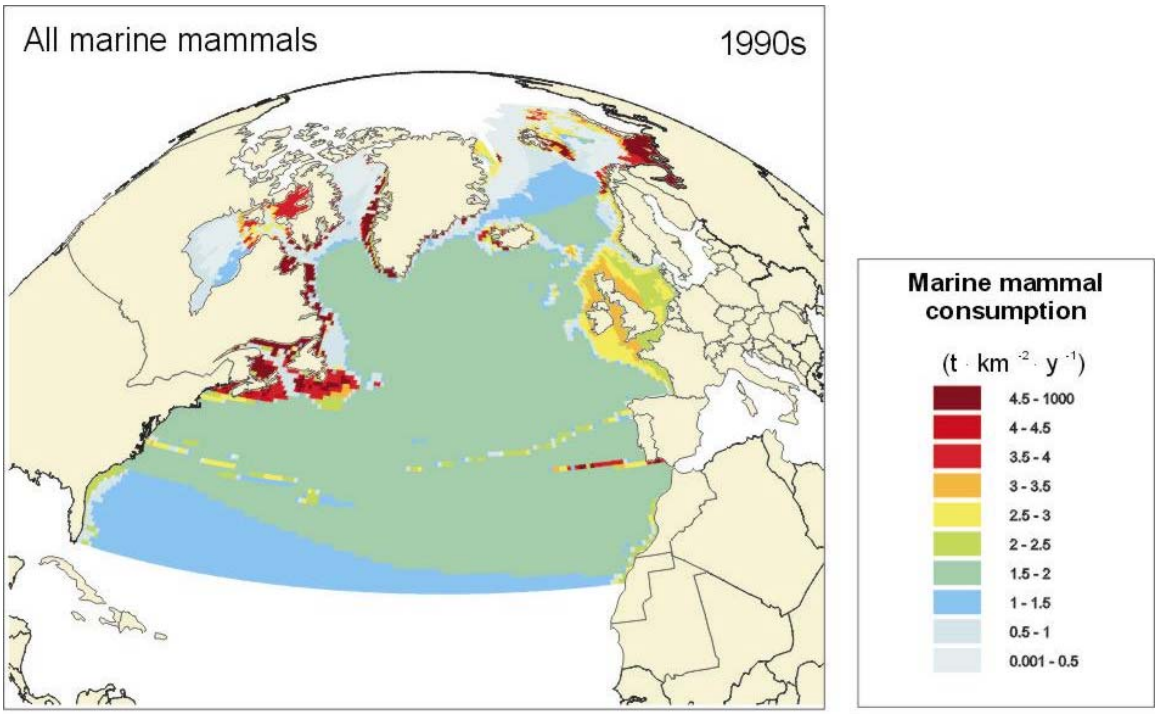

Figure 2. Distribution of marine mammals food consumption rates in the North Atlantic (1990s). The online version of this graph is in color (see *www.fisheries.ubc.ca/Projects/SAUP*).

This is confirmed by Figure 3, a map of spatial diet overlap between marine mammal and fisheries. Overlap 'hot spots' occur mainly on, or along the edges of shelves, particularly along the coast of North America, from 34° – 52° North, and in the North Sea and adjacent waters. Not surprisingly, these are also the areas from which most reports of fishing-mammal interactions originate, e.g., marine mammals getting entangled in fishing nets, or fishing boats ramming whales etc.

The information in Figure 3 can be refined by presenting the data by group of marine mammal (Figure 4). This shows, that:

1) Marine mammal diet/fisheries overlap is highest for pinnipeds, notably around the British Isles, Newfoundland, the Bay of Fundy and the Gulf of Maine;
2) There is almost no overlap between toothed whales and fisheries;
3) The baleen whales show intermediate overlap.

Regarding item (3), we should perhaps add that we believe the overlap to be biased upward, because the baleen whale group is presently dominated by Minke whales, which have a higher biomass than all other species combined, and which have been here classified as a 'shelf species', an assignment which some experts will contest. This is a theme that will have to be revisited. Such reviews will also have to consider the sub-population structure of marine mammals (to the extent as they are known), and especially seasonal migration and feeding patterns, so far ignored, and which will have to be modeled explicitly.

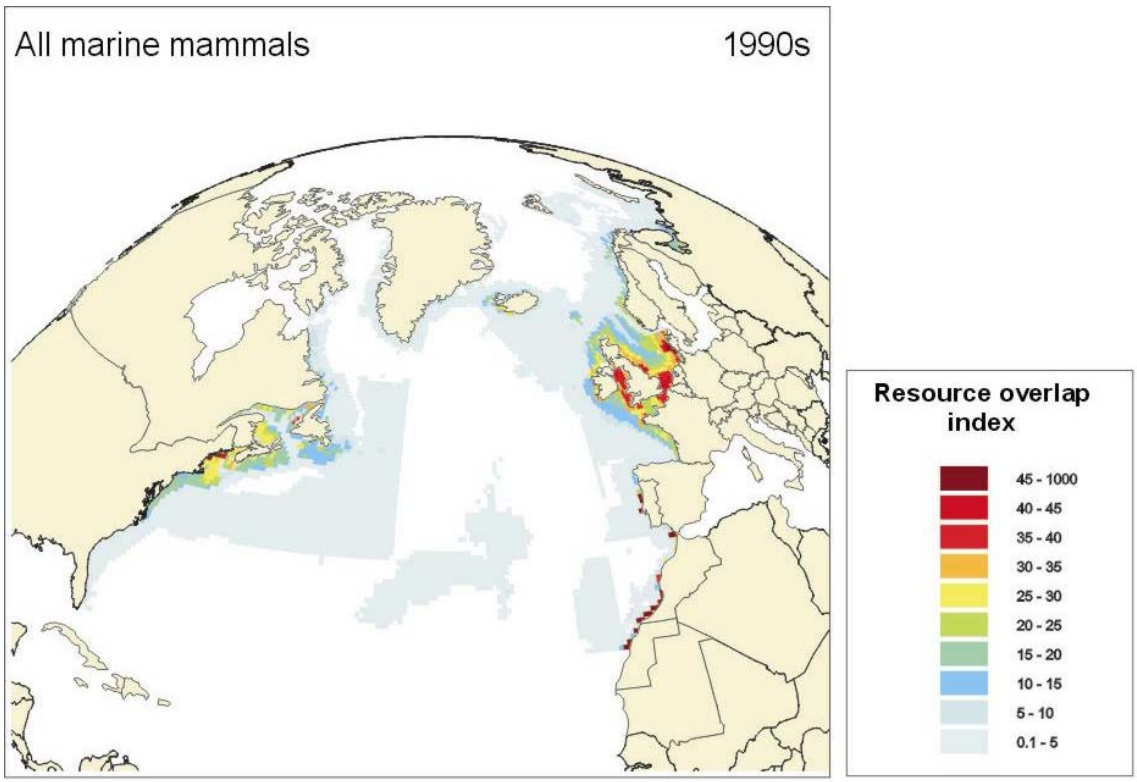

Figure 3. Distribution of overlap between all marine mammal food consumption and fisheries catches in the North Atlantic (1990s). The online version of this graph is in color (see *www.fisheries.ubc.ca/Projects/SAUP*).

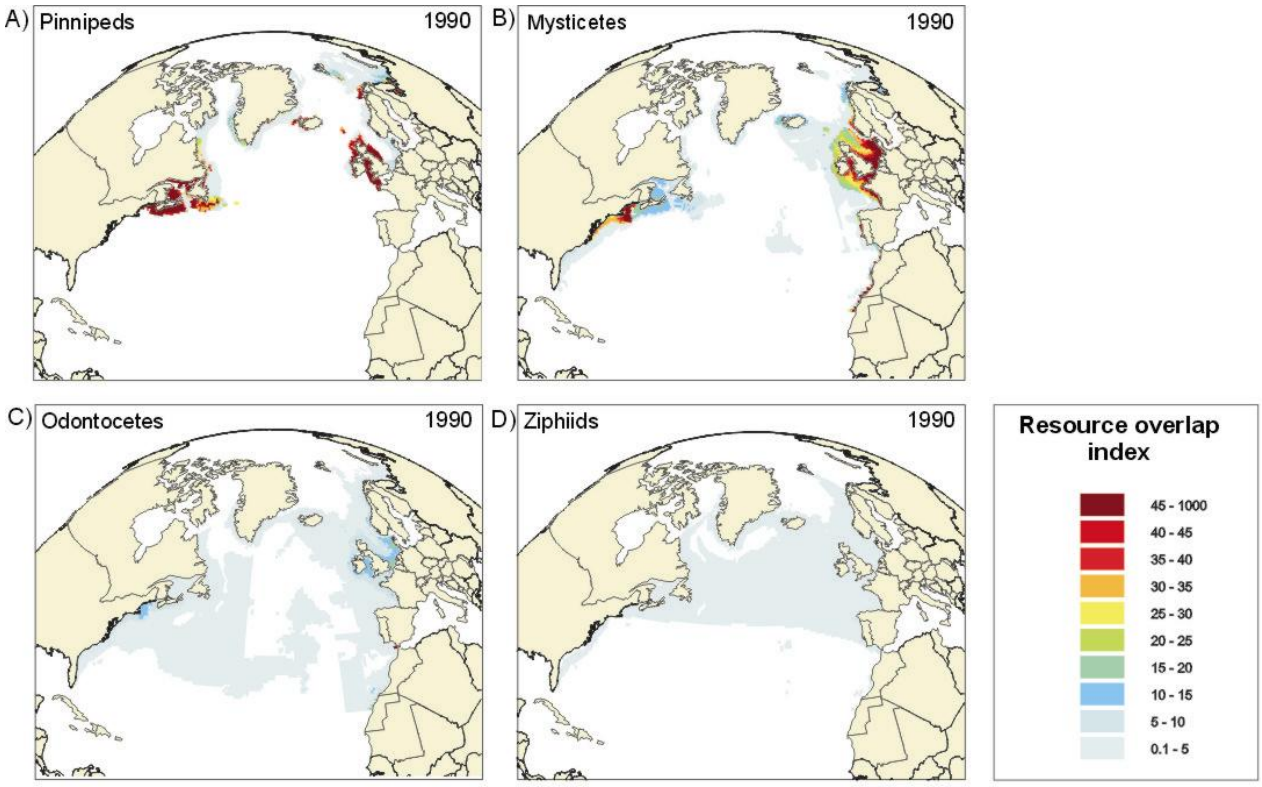

Figure 4. Distribution of overlap between individual marine mammal groups and fisheries catches (1990s). **A:** Pinnipeds; **B:** Baleen whales; **C:** Toothed whales (excl. Beaked whales); **D:** Beaked whales. The online version of this graph is in color (see *www.fisheries.ubc.ca/Projects/SAUP*).

However, we believe our key result to be the demonstration that our goal, the mapping of marine mammal food consumption, and its overlap with fisheries catches, could actually be reached, despite the lack of detailed data often alleged to preclude approaches of this sort. Clearly, if it is useful to publish maps of species distribution, estimated population numbers, and diet composition, then it is useful, as well, to combine such information into maps such as presented here. Indeed, there is no reason to assume that the uncertainty inherent in the components will render the synthesis useless. For example, many of these uncertainties pertain to local features of the basin-wide distributions that we emphasize here. Moreover, there is no reason to assume that, e.g., the food consumption rate, or mean diet composition of the mammal species considered here would all be biased in the same manner. Indeed, we assume the opposite to be the case, i.e., that errors in a few species will tend to be compensated by errors in the opposite direction in other species.

We conclude this by pointing out the potential of whale watching as a non-extractive activity that may provide market incentives for encouraging the rebuilding of marine mammal populations. Table 2 provides indicators that the industry presently generates 80 million US$ in direct expenses, and about 350 million US$ when indirect expenses are considered. As it appears, this industry is rapidly growing, including in countries – such as Iceland - which officially maintain its option to re-initiate whaling. We consider this an interesting development, as it may contribute to mitigate some of the issues of overlap between fisheries and marine mammals discussed here.

Table 2. Direct and total expenses by whale watching tourists, in 1998, both boat- and land-based[a)]

Area	Direct expenses (US $ '000)[b)]	Total expenses (US $ '000)[b)]
Western North Atlantic		
Atlantic Canada	18,336	127,086
St Pierre & Miquelon (France)	16.4	94
New England (USA)	30,600	107,250
Eastern USA	500	1,500
Bermuda	13	20
Bahamas	2,700	2,970
Eastern North Atlantic		
Norway	1,632	12,043
Iceland[c)]	2,958	6,470
Greenland	832	2,750
United Kingdom	1,884	8,231
Ireland	1,322	7,119
France (Mainland)	41	51
Spain (Mainland)	55	192
Canary Islands (Spain)	17,770	62,195
Gibraltar (UK)	225	1,350
Portugal (Mainland)	31	87
Azores Islands (Portugal)	582	3,370
Subtotal Atlantic	**79,497.4**	**342,778**
Global expenses	**299,509**	**1,049,057**

[a)] All estimates adapted from Hoyt (2001).
[b)] Values scaled to North Atlantic by removing British Columbia from Canadian returns, and assuming the following North Atlantic % components for totals that include the Mediterranean: France: 10%; Spain 10%, Gibraltar 50%.
[c)] In Iceland, as of July 2001, one of eight tourists goes whale watching and total expenses range from $ 10-13.5 millions.

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ESTIMATING DISCARDS FROM CATCH SPECIES COMPOSITIONS

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ABSTRACT

This contribution presents a procedure for estimating discards based on the log-normal abundance model using observed catch data. The method is programmed as a Dynamic Link Library (DLL) in Borland Delphi (a version of Pascal). The DLL procedures can be accessed from a variety of programs. Accessing the DLL from VBA in MS Excel is only dealt with here. The method was tested on simulated data drawn from a log-normal probability distribution. The method was also tested on one year's Canadian observer data. These data consisted of 52 categories of which 21 were landings. The categories were empirically found to be approximately log-normally distributed, a necessary pre-requisite. In general, the approach works as long as the underlying distribution of catches is log-normal, the number of categories (species, genera, etc.) are known and there are an adequate number of observations. However, the accuracy of the method when applied to real data, including its bias, is untested as yet.

INTRODUCTION

Catches in capture fisheries are fundamentally removals from ecological communities. Depending on the selectivity of the gear, it might be expected that catches will reflect underlying patterns in the community which is being fished.

The most widely used approach to modeling communities has been to fit species abundance models. It has been demonstrated empirically that most, it not all, communities follow a consistent pattern (Magurran, 1988). Species abundance models form the basis for the study and interpretation of species diversity and are often used to measure human impacts on species communities.

The log-normal abundance model has been found to fit the widest variety of ecological communities (Magurran, 1988). Most of these models are justified on the division of niche space (May, 1975; Sugihara, 1980), but agreement is not universal, particularly over the application of the log-normal (Ugland and Gray, 1982). The least selective gears are trawls, which have been shown in one case at least to be log-normal (Magurran and Abdulquadar, unpubl. data cited in Magurran, 1988).

Methods to fit species abundance models have assumed that the collection method of animals is not selective (e.g., Bulmer, 1974). This is inadequate for many applications, including the analysis of species composition data in fisheries. In many cases, and particularly fisheries, it is the variability in selectivity that is most of interest. Either the gear is selective in what it catches or significant catch is discarded and never recorded. It is the last issue that is addressed here.

Whether the log-normal is a result of the ecology or statistics, the pattern can be used to estimate discards. If we know that we have observed only a proportion of catches drawn from a log-normal, the gaps in the distribution should add up to the discards, so the area under the curve is the total catch. In practice, the only requirement is that the distribution is a log-normal. Therefore, catch categories need not strictly be species, but can be categories based on size or other criteria.

METHODS

Many methods for fitting distributions treat observations as independent draws of a random variable from a probability distribution. Although this is an approximation, it can lead to reasonable results as long as the data are good quality and there are few missing data. If data are missing, as in discarding, this approach must assume only the rarest are discarded ('veil line'), otherwise the best estimate is that all missing categories come from the mean of the distribution. This approach can be improved upon by recognizing that the distribution is followed as deterministic model, and therefore the abundances are not independent, but that each catch category must occupy a separate rank in the distribution.

If the rank of each observed catch (i.e., landings) in the ordered list of total catches is known, fitting the log-normal is simple. If the rank is not known, but all observations are present, the abundance rank can be assumed to be rank of each observed catch in the sorted list, ignoring the possible effect of observation error. Unfortunately, this simple method is not available where discarding occurs, and therefore another approach is required.

The natural solution is to allow each catch category the possibility of occupying each rank and sum the likelihood over all possibilities. Given an abundance distribution as an array with an abundance in each rank, each catch category can be allocated to a separate rank to obtain a likelihood for that particular permutation. Summing over all permutations, the marginal likelihood can be obtained for the abundance distribution parameters. The maximum likelihood estimates can then be found using standard numerical techniques.

Generating the abundance distribution

The abundance distribution is generated from the log-normal distribution so that abundances are set to mid-points of equal areas under the curve. For example, if there are S categories, the z points $0.5/S$, $1.5/S$,... $(S\text{-}0.5)/S$ are found using the inverse standard normal function. These are rescaled as $x = \exp(\mu+z\sigma)$ to get the log-normal distribution.

Generating a likelihood for each observation

Each landings observation is assumed to be log-normally distributed (this should not be confused with the abundances, which are also log-normally distributed). The log-normal error distribution assumes that coefficient of variation is constant and catches are greater than zero. The likelihood can be written:

$$L = \frac{\left(\ln(x_i) - \mu_r\right)^2}{\sigma_{obs}^2} - \ln\left(\sqrt{2\pi}\ \sigma_{obs}\right) \qquad ...1)$$

where x_i is the observed catch in category i, μ_r is the expected log catch in rank r obtained from the abundance distribution, and σ_{obs} is the error distribution scale parameter. Therefore, for any log-normal abundance parameters, μ and σ, the log-likelihood that an observed catch comes from a particular abundance rank can be calculated.

The log-likelihood for species groups can be calculated from the sum of abundance ranks. Note that this requires all combinations of ranks to be considered, rather than simply considering each single rank as for a single species. This general approach is also used to estimate missing catches (i.e., discards), which are included in the likelihood as through an EM algorithm approach.

Summing permutations

Summing directly over all permutations is impractical for any reasonably large number of species. The problem can be reduced from a permutation to a combinatorial problem by using a dynamic programming approach. This recognizes that once a rank in the abundance distribution is filled, we do not have to know which catch category filled it. The information maintained during the procedure is the 'state' of the system, simply the set of filled ranks. Each category in turn is applied to all current states to generate a new set of states for the next catch category. New states are generated by taking each current state and filling in turn each of the empty ranks with the current category. The likelihood is calculated as the procedure progresses (see Appendix 1 for technical details). The same procedure applies if there is more than one category making up an observation, but multiple empty states are filled in this case. For example, a reported landing may consist of several categories, as is mostly the case with discards.

From a data point of view, discards are missing observations. The general approach of fitting maximum likelihood models where data are missing is the EM algorithm. This method is iterative. The missing data are replaced by their expected value to estimate parameters. The estimated parameters are used to calculate a new expected value for the missing data and the process repeated until convergence. For calculating discards, the estimate arose naturally during the likelihood calculation. The expected discards can be calculated from the states after all available observations have been applied. For each state, the sum of the remaining empty ranks equals the discards. Each state has a likelihood, which can be used as the weight in obtaining a weighted average of the discards. This can then be used as the expected value in calculating the final likelihood. The estimation of discards and likelihood is thus simultaneous.

Even reducing the problem to one of combinations can rapidly lead to practical problems where the number of catch categories is high. The maximum number of combination paths followed in the dynamic programming procedure can therefore be capped, so only the paths with the highest log-likelihood are maintained. This involved organizing the states in binary trees so that the smallest likelihood can be found and removed easily. The log-likelihood range (difference between the largest and smallest) gives some indication of the loss of possible permutations from the calculation. A small range indicates significant likelihood is

being lost to the procedure due to the capping. A large range suggests likelihood being lost is not significant and the procedure is probably accurate.

Minimization
The log-likelihood can be minimized using *Solver* in *Microsoft Excel* or any other appropriate numerical routine that uses the function only, as differential of the full likelihood function is not available.

Estimating discards
Discards are estimated as the weighted average sum of the possible unfilled ranks once all data have been processed. The weight used is the likelihood (i.e., exponent of the log-likelihood). Clearly, if all categories are specified in the observations, the discards are fixed at zero.

However, with the current log-normal error model, the discards (i.e., sum of unfilled ranks) needs to be bias-corrected by the observation error parameter, as it is an arithmetic mean. If it is assumed this error is negligible or the log-normal is a poor error model, it may be better to neglect the correction altogether.

Software
The method is programmed as a Dynamic Link Library (DLL) in Borland Delphi (a version of Pascal, with capabilities of C++). The DLL procedures can be accessed from a variety of programs. Accessing the DLL from VBA in MS Excel is only dealt with here.

Trials
The method was tested on simulated data. The data were drawn from a log-normal probability distribution. The method was also tested on one year's Canadian east coast groundfish observer data. These data consisted of 52 categories of which 21 were landings. The categories were empirically found to be approximately log-normally distributed, a necessary pre-requisite. Other abundance distributions were not tested.

RESULTS AND DISCUSSION

Using simulated data, it was apparent that if the abundances are log-normally distributed and the number of categories are known, the three parameters can be fitted with reasonable accuracy. Similarly, if categories are missing (discarded), they can be estimated. Clearly, adequate data are still necessary to fit the model and the fit is best where there is a good contrast between categories, so both rare and common categories are represented.

The number of catch categories cannot be estimated using maximum likelihood. The likelihood function for this parameter is asymptotic, so the fit improves (very slightly) as the number of categories increases. It is likely that some observer data would be required to fix this parameter.

For large numbers of categories, the results are less sensitive to specifying their number. This is because the abundance distribution is more finely divided up, so the loss or gain of a category above or below the true number represents a lower percentage of the total catch.

When using real data, a number of additional practical problems had to be dealt with. The high number of categories and low proportion (<50%) which were landings are probably typical of real data and created some practical problems for the method. The techniques of:

- limiting numbers of combinations in dynamic programming method; and
- fixing the largest rank to the maximum observed catch are necessary to avoid possible poor results.

Limiting the numbers of combinations may mean a significant loss of likelihood from the full model. The likelihood is limited to those combinations where landings categories are closest to the rank most similar to their value. Where observation error is high, excluded ranks may still possess a relatively large likelihood, although they are excluded on computation grounds only.

For this pilot data set, the estimate of discards appeared to be robust to this problem (Table 1). Even when the observation error parameter was estimated from the data and the likelihood range was small (approximately covered a likelihood range of a factor of 2), the results did not vary much from a fixed error parameter. The discard estimate uncorrected for bias was closer to the observed value, although the corrected estimate was worse. As this is only one data set, it is not possible to draw too many conclusions from this.

It is not clear how much of a problem estimating observation error is when the number of paths being followed in the dynamic programming procedure is capped. Increasing the observation error scale results in a lower likelihood range indicating likelihood is lost during the calculation. This will affect the maximum likelihood estimate biasing it towards smaller values.

Poor results were obtained if the maximum landing category was not assumed to be the maximum catch. Depending on the start parameters, very high estimates of discards could be obtained from fitting the model. This is because without information capping the missing discards and with only a small proportion of categories in the landings, it was possible that discard categories could include very high values (note it is a log scale). With the exception of some fisheries (including shrimp trawls), such high discarding is uneconomic. In addition, you would have to be very ignorant of the fishery not to have some idea of the commonest category in the catch. This seems therefore a reasonable piece of information to supply and greatly improves the estimate.

In general, the approach works as long as the underlying distribution of catches is log-normal, the number of categories (species etc.) are known and there are an adequate number of observations. However, the accuracy of the method when applied to real data, including its bias, is unknown.

The number of categories affects the fitting method. A large number of catch categories is likely, particularly where data are combined from many vessels over a year or more. The approach, limiting the number of dynamic programming paths, means that only a small proportion of the most significant paths are followed. It is possible that by changing the order in which categories are processed, different results might be obtained. It is not expected that these differences would be large, but this has not been tested. Other methods, perhaps based on random sampling combinations, have not yet been considered.

The maximum rank needs to be fixed to the maximum landings. This is reasonable where the commonest species is known. However, this does raise the issue of depletion and its affect on the species abundance model. Currently the model is statistical and makes no allowance for the potential impact of fishing on the community. This issue could be explored with time series data to check whether parameters and goodness-of-fit of the model varies as exploitation increases.

Fitting the observation error parameter may not be possible in practice. This parameter may be biased by the procedure in many cases, so that estimates from other sources may be better. For example, it could be estimated from the variance of individual trip observer reports.

Given the complexity of the model, probably the best way to estimate parameter standard errors and correlations and discard confidence intervals, would be to use a parametric bootstrap based on the estimated parameters. Within a spreadsheet, it would be time consuming, but technically simple, to estimate confidence intervals using a bootstrap procedure. Given the log scale, it might be expected confidence intervals will be quite high.

Table 1. Parameter estimates from fitting the model to the Canadian observer landings data. The discards are generally over estimated. The much smaller log-likelihood range for the estimated observation error parameter suggests many likely combinations were lost through the dynamic programming procedure capping the number of states, in this case, to 500. This range can be increased, but results in a significant decrease in the speed of the routine.

	Observation error	
	fixed	**estimated**
Mean μ	4.743	4.772
Scale σ	3.115	3.108
Observation Error Sigma	0.100	0.260
Log-likelihood Range	7.185	1.071
Estimated Discards (with bias correction)	14,545.14	15,435.57
Estimated Discards (no bias correction)	13,160.99	11,897.52
Observer Discards	***10,569.53***	

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APPENDIX 1: DYNAMIC PROGRAMMING METHOD

Assuming the abundance rank of each catch category is unknown, we can sum the likelihoods of all permutations of categories amongst the different ranks to obtain a total likelihood for the abundance model parameters. The number of permutations is the factorial of the number of categories. For any reasonable number of categories, it would not be possible to work through all permutations. For this reason, a dynamic procedure was used which reduces the permutation problem to one of combinations.

To describe the dynamic programming procedure, states and state transitions need to be defined. A state is the likelihood ($\mathbf{G_{iR}}$) together with the set of rank positions ® already filled by catch categories. The state level is defined as the number of ranked positions filled and is the same as the number of categories processed (**i** of a total of **S** categories). The maximum number of states in existence would never be more than maximum number of state combinations needed for the transition ($2\ {}^{S}C_{(S/2)}$). A state transition occurs when a category, **i**, fills a rank position not already occupied, so that the new state set includes the new rank which has been filled. The new state likelihood is defined as: $\mathbf{G_{i+1,B}} = \mathbf{G_{i+1,B}} + \mathbf{G_{iA}}\ \mathbf{L_{ri}}$ where set **B** contains all ranks in **A** as well as the single rank **r** (i.e. $\mathbf{B}=\mathbf{A}\cup\mathbf{r}$). Initially all likelihoods are zero ($\mathbf{G_{i+1,B}}=0$), except for the null set $\mathbf{G_{o\varnothing}}=1$. The total likelihood can now be calculated with the algorithm:

1. Define the abundance at each rank using the abundance model. There are as many ranks as categories. For the log-normal, the probability density was split into **S** partitions, each with 1/**S** probability mass. The expected catch was calculated within each partition, forming the **S** ranked catches.

2. Calculate the likelihood matrix for each category in each rank ($\mathbf{S}^2$ calculations). The likelihood of observed catches of each category **i** in each rank, **r**, can be calculated as $\mathbf{L_{ri}} = P_i(\mathbf{N_{ro}},\mathbf{q_i})$. Likelihoods in practice are stored as log-likelihoods, but converted to likelihoods for addition. Note that for groups containing more than one category, the matrix cannot be used and likelihoods have to be calculated for each category group combination.

3. Start with one initial state at level 0, with no rank positions filled, and a likelihood of 1 ($\mathbf{G_{o\varnothing}}=1$). If the highest catch is assumed to be in the highest rank, these values are replaced by the appropriate likelihood, and the initial state has the highest rank filled.

4. Choose the next category from the set of categories that have not been processed.

5. For each state at level **i**, apply category **i**+1 to each open rank (or combination of open ranks if it is a group category) to generate a state of level **i**+1. If likelihoods ($\mathbf{G_{i+1,B}}$ and $\mathbf{L_{ri}}$) are different to the limit of the computer precision (tested on the log-likelihood), the smallest likelihood can be discarded, otherwise we add the new likelihood to the existing state likelihood. This automatically calculates the likelihood for all combinations of previous categories up to that level.

6. Procedures 4 to 6 are repeated **S** times until all the ranks are filled. Note that the last rank may be a group category of discards. At this point there is one state which holds the full parameter likelihood ($\mathbf{G_{S\Omega}}$).

Where data are missing (discards), the expected sum of missing ranks is used in the likelihood calculation (i.e. EM algorithm). In this case, the discard group is processed last. The expected discards is the sum of open ranks averaged over all combinations weighted by the likelihood. The expected discards can then be used to calculate the final set of likelihoods to obtain the full parameter likelihood ($\mathbf{G_{S\Omega}}$).

APPENDIX 2: SOFTWARE DOCUMENTATION

The DLL functions can be accessed in a spreadsheet using VBA user-defined functions. There are three functions available:

The **CombLogLikelihood** function calculates the log-likelihood for abundance distribution parameters. The **LogNormal** function generates an array of abundance values for the specified log-normal distribution. The **FitLogNormal** function obtains maximum likelihood fits for the parameters using the simplex method of Nelder and Mead. In practice, an external minimizer such as *Solver* was found to be more flexible and less error prone. The function is still provided here for completeness.

The functions can be accessed in Visual Basic by declaring the functions within the module where they are used. The DLL is called '**CombDLL1.DLL**' and should be placed in the current directory (or a directory in the windows path string). The functions can be declared as follows in a visual basic module:

```
Declare Function CombLogLikelihood Lib "CombDLL1" (DataRange As Variant, GroupSize As Variant, mu As Variant, sigma As Variant, SigmaObs As Variant, AllSp As Variant, TreeSize As Variant, ResultArray As Variant) As Boolean
Declare Function LogNormal Lib "CombDLL1" (XLMu As Variant, XLSigma As Variant, XLNSP As Variant, Dist As Variant) As Boolean
Declare Function FitLogNormal Lib "CombDLL1" (DataRange As Variant, GroupSize As Variant, mu As Variant, sigma As Variant, SigmaObs As Variant, AllSp As Variant, TreeSize As Variant, ResultArray As Variant) As Boolean
```

where the parameters are as follows:

DataRange the input data range

GroupSize the number of species in each group.

mu is the mean parameter of the abundance log-normal

sigma is the standard deviation parameter of the abundance log-normal

SigmaObs is the standard deviation parameter of the observation error model (also log-normal)

AllSp The total numbers of species in the composition (Sum of GroupSize plus discard species)

TreeSize Limit on the number of combinations which are followed in the dynamic programming calculation

ResultArray The array which is returned with the results.

XLMu is the mean parameter of the abundance log-normal

XLSigma is the standard deviation parameter of the abundance log-normal

XLNSP is the number of species in the distribution

Dist is the distribution returned in an array

A VBA function to calculate the log-likelihood and return the discards could be:

```
Function CombLL(mu As Double, sigma As Double, SigmaObs As Double, AllSp As Double, MaxCombin As Integer, ByVal DataRange As Range, Optional ByVal GpSizeRange As Variant) As Variant
Dim i As Integer, NoofData As Integer, DataInColumn As Boolean
ReDim ResultArray(3)
'Volatile (False)
NoofData = DataRange.Columns.Count
If NoofData = 1 Then
 NoofData = DataRange.Rows.Count
 DataInColumn = True
End If
ReDim GpSize(NoofData), Data(NoofData)
If DataInColumn Then
 If IsMissing(GpSizeRange) Then
  For i = 1 To NoofData
   Data(i) = DataRange.Cells(i, 1)  'note array base is 1
   If Data(i) = 0 Then Exit Function 'bomb out as sheet is recalculating
   GpSize(i) = 1 'Default values
  Next i
 Else
  For i = 1 To NoofData
   Data(i) = DataRange.Cells(i, 1) 'note array base is 1
   If Data(i) = 0 Then Exit Function 'bomb out as sheet is recalculating
   GpSize(i) = GpSizeRange.Cells(i, 1)
  Next i
 End If
Else
 If IsMissing(GpSizeRange) Then
  For i = 1 To NoofData
   Data(i) = DataRange.Cells(1, i)  'note array base is 1
   If Data(i) = 0 Then Exit Function 'bomb out as sheet is recalculating
   GpSize(i) = 1 'Default values
  Next i
 Else
  For i = 1 To NoofData
   Data(i) = DataRange.Cells(1, i) 'note array base is 1
   If Data(i) = 0 Then Exit Function 'bomb out as sheet is recalculating
   GpSize(i) = GpSizeRange.Cells(1, i)
  Next i
 End If
End If

If CombLogLikelihood(Data, GpSize, mu, sigma, SigmaObs, AllSp, MaxCombin, ResultArray) Then
 CombLL = ResultArray
Else
 CombLL = "Function failed"
End If
End Function
```

where

mu and *sigma* are parameters of the abundance distribution

SigmaObs is the scale parameter for the log-normal error distribution

AllSp is the total number of catch categories

MaxCombin the maximum number of combinations allowed in the dynamic programming procedure

DataRange is the Excel range of the observed landings

GpSizeRange is the optional Excel range of numbers of categories for each datum - all assumed 1 if not present.

The function returns a variant array, which can be displayed in a spreadsheet using the array command ({}). This is achieved by selecting three columns in a row, typing in the function and pressing Ctrl-Enter. The function displays the log-likelihood, the estimated discards and the maximum log-likelihood range. The last value is there to see what range the combinations data structure covers and is there for error monitoring only.

The parameters can be fitted by maximizing the log-likelihood (target cell) through changing the parameters (changing cells) using *Solver* in *Microsoft Excel*.

PART II: NORTH-EASTERN NORTH ATLANTIC

THE SEA AROUND ICELANDERS: CATCH HISTORY AND DISCARDS IN ICELANDIC WATERS

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ABSTRACT

This paper aims to give and overview of the fisheries 'around Icelanders' and explains the methods involved in constructing a database on these fisheries. This refers to fisheries 'around Icelanders' because information is given both for fisheries of all countries in the waters around Iceland and for fisheries conducted by Icelandic boats in distant waters. The introductory section will include and overview of these fisheries, descriptions of the fishing grounds, a history of fisheries management in Icelandic waters and a description of the sources of data used to reconstruct the catch and effort database. The second section introduces the fishing fleets operating in Icelandic waters. Icelandic fleets are discussed by fishing gear and foreign fleets by country. Information on how the effort history was reconstructed and information on the engine power of the Icelandic fleet is also included in this section. Reconstruction of catch history and discard estimates is explained in the third section, which also includes a brief summary of all species harvested in Icelandic waters. Finally, some primary results and a discussion are presented.

INTRODUCTION

Few people in the world are as dependent on fisheries as Icelanders. Marine resources around the island, particularly cod, are the foundation of the country's export earnings. While fishing and fish processing represent 15% of GDP, fisheries account for 75% of the total export earnings, with cod representing 25% of the 75% (*www.hagstofa.is/talnaefn/Lh_1999/Lh_1999.htm*). Thus, a good knowledge of the history of the fisheries is vital for the country.

Here catch and effort information from the Icelandic fishing grounds since 1950 and some of the main factors concerning the Icelandic fisheries are discussed. Obviously, not all of these factors can be fully covered in the limited scope of this report, but references are given to other more detailed sources of information. A great amount of literature is available about Icelandic fisheries from a wide variety of data sources; however, large gaps are still found and many inconsistencies exist between sources. These gaps in the records can be partly filled in with careful historical analysis of old documents (which was not possible within the framework of this project). Although many of the gaps or inconsistencies may never be fully resolved, attempts were made to leave no gaps and therefore, when information was lacking, indirect clues were used to give the best estimate possible.

The contribution of this report on Icelandic Fisheries to the *Sea Around Us* project (SAUP) is a database which contains all the information on fisheries in Icelandic waters, as well as for fisheries conducted by Icelandic boats in distant waters. This database will function as the main Icelandic input in order to direct further studies within the SAUP project (Pauly and Pitcher, 2000). The aim of this specific paper is to primarily describe the methods used to analyze and reconstruct these fisheries and, secondly, to provide a short history of these fisheries. The resulting database is not given in this document since it is too large and will be published separately in electronic formats (*www.fisheries.ubc.ca/projects/SAUP*). However, the tables within this database are explained in detail in Appendix I.

The Fishing Grounds

The geographic boundaries of the Icelandic fishing grounds have changed with time. Originally, the grounds consisted of the waters above the continental shelf, which then changed to the International Council for the Exploitation of the Sea (ICES) fishing area 'Va'. Most recently, the grounds have been extended to the 200 nm economic exclusive zone (EEZ) (Figure 1). These boundaries do, however, overlap to a large degree. All of the continental shelf above 400 m depth is both within ICES Va and the 200 nm EEZ, as is most of the shelf above 600 m depth. The minor exception is the Iceland-Faroe Ridge, which does not go below a depth of 600 m. This means that until around the 1970s most fisheries carried out in Icelandic waters were within these zones. The only part of the ICES area Va that is outside the 200 nm EEZ is an area east of Greenland that does not sustain large fisheries. However, the 200 nm EEZ also includes deep water north, east, south and west of Iceland that is not included within the boundaries of ICES Va. Also, some of the Faroese grounds (ICES Vb) are

located within the Icelandic 200 nm EEZ. Generally, the Icelandic 200 nm zone covers most of the ICES Va, but also includes parts of ICES XIVa, IIa, Vb, XIII and XIVb.

The period since 1950 has seen large changes in the size of the Icelandic EEZ (Figure 2.). In the beginning it consisted of a 3 nm extension from the coastline. The northern boundary of the EEZ was extended to 4 nm in 1950, including all bays, while the EEZ in all other regions remained at 3 nm. All trawl, Danish seine fisheries (including Icelandic) and foreign herring (*Clupea harengus*) fisheries were forbidden to operate within the EEZ. In 1952 the EEZ was extended to 4 nm all around Iceland. At this time the foreign fleets did not go beyond or protest the extension. In 1958, the Icelandic government extended the EEZ from 4 nm to 12 nm and severely limited trawl and Danish seine fisheries within this area. This time the foreign fleets refused to comply since large parts of their major fishing grounds became off limits. British naval destroyers entered the zone to protect their fishing vessels and their confrontation with Icelandic vessels, which became known as the first modern 'cod war' (*Gadus morhua*), lasted until 1961. This restricted both foreign and Icelandic trawler operations and was, in fact, a major contributor to the stagnation and decline of the Icelandic trawler fleet during that period. These actions also meant that Danish seine fisheries were almost non-existent until 1960 when they were once again allowed within limited areas.

The next extension of the EEZ was to 50 nm in 1972 and at that time Icelandic trawlers were excluded from the restrictions. This meant that cod was virtually off limits to foreign fleets and they could only sustain their catches within this zone when under the protection of their navies. The 50 nm limit was only a temporary measure by the Icelandic government until they could extend it to 200 nm. They did this in 1975 promoting the third and last modern cod war. Icelanders were eventually successful in laying claim to the extension of the EEZ boundary to 200 nm and the British fleet left Icelandic waters in 1976 followed by the West German fleet in 1977. However, Belgian, Faroese and Norwegian boats were allowed to continue fishing limited amounts.

Currently, Iceland has maritime boundaries with Greenland, Faroe Islands and Norway (Jan Mayen). The boundary with Jan Mayen is 200 nm north of Iceland; since the islands are uninhabited, the Norwegians did not lay claim to a boundary set equidistant between the two countries in this region. However, some parts of the Icelandic EEZ overlap with parts of EEZs claimed by Greenland and the Faeroe Islands.

Most fisheries in Icelandic waters take place within all of the aforementioned areas (Icelandic continental shelf, ICES Va and 200 nm EEZ). These fisheries consist of haddock (*Melanogrammus aeglefinus*), catfish (*Anarhichas* spp.), plaice (*Pleuronectes platessus*[a)]), scallop (*Chlamys islandica*), lobster (*Nephrops norvegicus*) and many more species. Other species such as cod, Icelandic summer spawning herring, golden redfish (*Sebastes marinus*), saithe (*Pollachius virens*) and shrimp (*Pandalus borealis*) migrate to some extent to other waters or have small trans-boundary stocks however, these are minor or infrequent and therefore can be ignored. Problematic stocks, are stocks that either migrate regularly to Icelandic waters or have large trans-boundary components. These stocks include:

- Capelin (*Mallotus villosus*)-found in ICES Va and XIVa, Icelandic, Norwegian and Greenlandic EEZs;
- Oceanic redfish (*Sebastes mentella*)-found in ICES Va, Vb, XII and XIVb, Icelandic, Greenlandic EEZs and international waters;
- Greenland halibut (*Reinhardtius hippoglossoides*)-found in ICES Va, XIVb, IIa and Vb, Greenlandic, Icelandic and Faroese EEZs;
- Norwegian spring spawning herring-found in ICES Va, I, IIa and IIb, Russian, Norwegian, Faroese, Icelandic EEZs and international waters; and
- Blue whiting (*Micromesistius poutassou*)-found in ICES Va, VIII, VII, VI, Vb and IIa, EC, Faroese, Icelandic, Norwegian EEZs.

A few other species are occasionally found in Icelandic waters but usually in low quantities and include mackerel (*Scomber scombrus*), horse mackerel (*Trachurus trachurus*), turbot (*Psetta maxima*), bluefin tuna (*Thynnus thynnus*), pollack (*Pollachius pollachius*) and squid (*Loligo* spp.).

Management of the fisheries

Except for the limits on trawl and Danish seine fisheries mentioned above, little was done for a long time to restrict the Icelandic groundfish fisheries. After the expulsion of the foreign fleets, Icelandic groundfish fishing capacity grew

a) The correct scientific name for the European plaice, often called *Pleuronectes platessa*, is *P. platessus*. All scientific names in this report are based on FishBase (www.fishbase.org).

considerably and quickly reached the same level as all the fleets combined in previous years. Icelanders had only temporarily managed to steer away from serious overfishing of groundfish species. Effort restrictions were enforced in 1977 so that each boat could only fish a limited number of days per year. However, there were no limits of entry into the fishery. This system was only used until 1982 as it proved to be economically wasteful (Arnason, 1996). The prototype of the Individual Transferable Quota (ITQ) was introduced into the groundfish fisheries in 1984. Initially, under this new management system some boats were allowed to go for effort quotas and boats less than 10 Gross Registered Tones (GRT) were not included. This management system was largely abolished in 1990 when a uniform quota system was established for all important species.

The first fishery to be managed by a quota system in Iceland was the herring fishery, which experienced a total stock collapse, resulting in a moratorium being put in place in 1972. The fishery was partly resumed in 1975 and boats were given individual non-transferrable quotas. Due to economic reasons this was changed to fully transferable quotas in 1979. The other large pelagic fishery, the capelin fishery, followed a similar trend later. Individual quotas were introduced in 1980 and made transferable in 1986.

Although it is not within the scope of this study to evaluate the Icelandic ITQ system, its effects on the fisheries are hard to ignore. Of direct interest to our analysis is the fact that the system promoted a reduction of discarding of certain species and an increase in discarding of other species. Species that did not have a Total Allowable Catch (TAC) were now retained or targeted specifically instead of being discarded (most likely dead) as they had been in the past. Hence, the landing statistics show an increase in landings for these species, which does not necessarily reflect the same increase in fishery-induced mortality due to the discarding activity in the past. On the other hand, the ITQ system encouraged discarding of small individuals from species that now had a TAC (high-grading).

It is, however, an over-simplification to describe the Icelandic fishery management as a pure ITQ system. The fisheries are also managed by various other methods, such as gear restrictions, minimum mesh sizes and mandatory use of sorting grids in some fisheries. Large nursery areas are permanently closed to fisheries, and spawning areas for cod are closed during the main spawning season. Temporary area closures are also used extensively if the catch is found to have a high number of juveniles. Of these fisheries, those using trawlers are generally more restricted than other fisheries. For example, trawlers (with some exceptions) are not allowed to operate within 12 nautical miles from the coast.

Subsidies have played a part in the management of Icelandic fisheries. Money earned in good years was used to subsidize fisheries in bad years, or, probably more often, loans were used for subsidies in the hope that future revenues and taxes from fisheries could re-pay them. Taxation and subsidies also differed between fisheries. Exchange rate manipulation was also often used. This was particularly extensive after the Second World War through the 1970s (Runolfsson, 1997), but has diminished substantially since then. The remaining subsidies are in the form of personal income tax breaks whereby fishers can withhold a certain amount from taxes for each day registered at sea. This has been estimated to be about US $23 million per annum in lost revenues for the government. Indirect government expenditures related to the fishing industry has been estimated to be approximately US $38 million. This includes fishery related education, various monitoring and research institutions related to the fishing industry (including marketing), the Ministry of Fisheries and part of the operations for both the Ministry of Environment and Ministry of Foreign Affairs (Agnarsson, 2000). Of this amount, expenditures directly aimed at managing the marine stocks Marine Research Institute, Coast Guard, Ministry of Fisheries, Directorate of Fisheries) have been estimated at around US $16 million per annum. In turn the government receives about US $8.5 million per annum from the fisheries from various fees and licenses.

Information sources

All Icelandic fishing boats (except those fishing for lumpfish *Cyclopterus lumpus*), are required to get their catches weighed (by species) at ports of landings by government certified officials. These reports are collected by the Fisheries Association of Iceland (*Fiskifélag Íslands*) in order to get the total landings. The information from the Fisheries Association is in variable format. *Útvegur* (Fisheries Association of Iceland 1978-1998 and Statistics Iceland 1999-2000) provide excellent information on effort and catch by gear from 1977 to 1999 also some information on total landings since 1968. This report also provides information on various aspects of Icelandic fisheries such as the size and capacity of the fishing fleet, effort by

fishing gear, landings and catch value of the fishing fleet by fishing gear or port of landing. The Fisheries Association also provided a file on the distribution of catches by fishing fleets since 1982. This is from the database behind the information provided by *Útvegur*. There are, however, slight differences between the two. In cases of discrepancy the information on the file was used since it is continuously updated as new information becomes available.

Using these two sources of data, the period from 1977 is well covered by the landing information provided by fishing gear, effort by each fleet and fishing capacity. Records prior to 1977 are much more problematic and patchy. These records include annual reports from 1957 to 1976 on the fisheries by Icelandic boats in *Ægir* (Elísson 1957 to 1969, Anon., 1970 to 1977), a journal published monthly by the Fisheries Association. There are also special reports in the same journal on the trawler fleet (Elísson 1956, Björnsson 1958, Árnason 1959, 1959a, 1960 to 1964, Steinsson 1969, 1969a, 1969b, 1970, 1970a, 1971), the herring fleet (Anon 1963, 1963a, 1965 to 1969) and the winter season groundfish fleet (Anon 1958 to 1962 (incl. a and b), 1963b, 1963c, 1964, 1966c, 1966d, 1967b, 1968b, 1966a to 1972a). These reports provided vital information, but suffered from various problems. These problems included changes in format between years, different information given for different periods, and inclusion of catch from distant waters in some years (i.e., the numbers were often not directly comparable between years and could not be used without prior standardization).

The *Bulletin Statistique des Pêches Maritimes* published by ICES (1905-1990), provides vital information on fisheries in Icelandic waters until 1987 and is the almost exclusive source of information on the distant water fleets in Icelandic waters. The *Bulletin Statistique* also provides valuable information on the Icelandic fisheries by gear from 1966, supplementing information provided by *Ægir*. This information is far from being perfect and it had to be used with caution. The *Bulletin Statistique* also provided vital information on Icelandic catches in distant waters since catch was generally not separated by grounds in Icelandic sources. Information on distant water fleets in Icelandic waters after 1987 was taken from a database provided by ICES (STATLANT).

Nytjastofnar sjávar (Anon. 2000) is an annual report published by the Marine Research Institute in Iceland. This provided numbers for total catch each year for many species. This information agreed reasonably well with *Bulletin Statistique* and *Útvegur*, but there were always some differences. *Nytjastofnar* only provides total catch information on the most important commercial species, and it does not give information on effort. However, it does give information on various aspects of the biology of the stocks such as stock size, growth and maturity. The time periods for which catch data were reported varies between species; cod has information since 1905, haddock, saithe and other important species since 1950 and other species of lesser importance have records for shorter time periods.

Hagskinna is a single publication by Statistics Iceland (Jónsson and Magnússon, 1997). It is a collection of various historical statistics for Iceland, stretching back many centuries. However, most of the information on fisheries in *Hagskinna* is from the Fisheries Association or ICES *Bulletin Statistique*, although parts have been corrected from contemporary sources. *Hagskinna* does not provide catch information or effort by fishing gear, but does provide some information on categories such as the total catch by trawlers, total number of boats, and average weight of trawlers and decked boats. The effort is given in sea-days for the trawlers, but these numbers were not directly useable because they included number of sea-days in distant waters. The same applies to catch numbers. As well, the foreign catch was not separated to species except for capelin and herring. *Hagskinna* was thus only useful for our analysis for comparison to other sources and provided valuable information for periods prior to 1950.

Additional information was found in databases from the *Food and Agriculture Organization* of the United Nations (FAO) and the Northwest Atlantic Fisheries Organization (NAFO, *www.nafo.ca/science/stats/index.htm*). The information provided by NAFO was used to find the Icelandic fisheries in the N.W. Atlantic, since this was not provided in *Bulletin Statistique*. The FAO information was only used for comparison with other sources, since it only provides information on the whole of Northeast Atlantic and specific to grounds.

Below is a summary of the data sources used and how they are cited in the text:

- *Útvegur*, annual report since 1977, cited as *Útvegur*;
- *Ægir*, monthly journal published for the whole period here, many articles, cited with authors name or cited as *Ægir* when talking about in general;

- *Hagskinna*, one publication on historical statistics, cited as *Hagskinna* or Jónsson and Magnússon (1997);
- *Bulletin Statistique*, annual publication on fisheries from 1903 to 1987, cited as *Bulletin Statistique* or ICES;
- ICES database, a follow up on *Bulletin Statistique*, cited as ICES;
- *Nytjastofnar sjávar*, annual report by the MRI, cited as *Nytjastofnar* or Anon. (2000);
- FAO database on worldwide catches since 1950, cited as FAO; and
- NAFO database on the catches in the N.W. Atlantic since 1950, cited as NAFO.

More detailed texts in English about the fisheries in Icelandic waters are to be found in Jakobsson (1992), Jónsson (1994), Schopka (1994), Thor (1995), Arnason (1996), Baldursson *et al.* (1996), Halliday and Pinhorn (1996), Hannesson (1996), Runolfsson (1997), Vilhjálmsson (1997), Jakobsson and Stefánsson (1998), Valtysson (1998), and Guðmundsson and Scopka (1999). Good information is also found in Jónsson (1984), Þorsteinsson (1980), Jónsson (1988), Jónsson (1990) and Gunnarsson *et al.* (1998), but these are all in Icelandic. Other information is to be found on the web sites listed in Appendix II.

THE FISHING FLEET

Fisheries have a long history in Icelandic waters. There are references to fishing in the age of Settlement (874 to 930 AD). The importance of fisheries increased during the 14th century and has been a considerable part of the economy since. Until the 19th century fisheries by Icelanders were almost exclusively conducted by open rowing boats. These proved efficient since the fishing grounds were usually close to shore. Decked sailing vessels were first used in Greenland shark fisheries and, to a limited degree, in cod fisheries from the beginning of the early 19th century. It was only after 1880 that decked sailing vessels became an important part of the cod fishery. However, their heydays were short-lived and they declined in numbers after 1907 and were phased out altogether by 1928. By that time rowing boats were also becoming rare and very few of them seem to have survived past 1950. The reason for the decline of these boats was, of course, the motor. The first motor was put into an Icelandic fishing boat in 1902 and the first all-Icelandic owned steam trawler was bought in 1904.

The Icelandic fishing fleet has traditionally been split into 3 groups; trawlers, decked boats, and undecked boats. However, the divisions among these are not always clear. The trawler group is split into side trawlers used from 1905 to 1978 and stern trawlers used since 1970. The decked boat category is by far the most diverse. It ranges from small boats (smaller than many undecked boats) to large purse-seiners and large multipurpose boats. The separation of decked boats and trawlers is not very clear since many decked boats use trawl gear. Many of the decked boats are also structurally identical to stern trawlers, and some of the old side trawlers were converted to purse-seiners, which put them into the decked boat class. This classification is in fact a kind of an anachronism from the times when boats were much smaller than trawlers. This started to change around 1960 when large purse-seiners began operating. Since Icelandic data sources always separate between these classes and the amount of information on each is very different, they cannot, except in a few cases, be combined. Examples where they could be combined include trawlers and decked boats using gillnets, and decked boats and undecked boats using scallop dredges. In these cases, the trawlers and undecked boats are added to the decked boat class because the fisheries by these gear type are insignificant compared to the decked boats. This was not possible in most other cases where the boat categories used a common fishing gear on a larger scale, such as trawlers and decked boats using trawl and undecked and decked boats using handline, longline and gillnets.

Nowadays, radar, fish finders and global positioning system (GPS) are standard equipment on most small and large Icelandic fishing vessels. Icelandic fishers were, in fact, the first in the world to put some of this equipment in their fishing boats (Óskarsson, 1991). The trawler *Ingólfur Arnarson* (named after the first settler in Iceland), which came newly built to its Icelandic owners in 1947, was the first fishing boat in the world with radar. By 1950, almost the entire trawler fleet was equipped with radar and automatic sounders and was considered, at that time, the most modern trawler fleet in the world. This equipment greatly increased the fishing capacity of the trawlers, helping them find the fishing grounds and almost unexpectedly, find the fish with the sounders. The herring fleet was also at the forefront of the use of new technology. The first Icelandic purse-seiners were experimenting with sonar in 1954, and the powerblock in 1959. By 1961, the whole purse-seine fleet was equipped, and this technology had almost completely replaced traditional drift netting (Jakobsson, 1980). Another primary example of

this rate of dissemination was when the Icelandic trawler fleet changed from being outfitted with side trawlers to a fleet composed entirely of stern trawlers within a span of 9 years. More recently the handline fleet has changed almost completely from traditional handlines to automatic, computerized jigging reels.

The evolution of the Icelandic fisheries can therefore best be described as punctuated equilibrium. As has been demonstrated above, changes in the Icelandic fisheries are usually rapid. From the first use of new equipment, techniques or approaches, only a few years pass until the entire fleet is following suit. The main factors influencing the Icelandic fisheries are given in Appendix III. Furthermore, it should be noted that most boats use two or more types of fishing gear. They regularly switch between lobster trawl and longlines, between shrimp trawls and Danish seines, between purse-seines and shrimp trawls, between pelagic trawls and bottom trawls, etc.

Engine capacity

The standardized unit used for effort is Horsepower-sea-days. There is no source that gives this unit directly per fishing gear fleet, therefore HP and sea-days had to be acquired or estimated independently.

All information on the engine power is from *Útvegur*. It gives the number of boats and total HP per size classes of boats in 1970, 1975, 1980 and after 1982. Information on the HP by fishing gear is not available, but information on the weight (GRT) of boats using each fishing gear is available for all the fleet after 1975 and for trawlers from 1950 onwards (*Ægir* and *Hagskinna*). Hence, we estimated the average HP of each fleet after finding the relationship between boat weight and HP. The average HP of each fishing gear fleet was calculated with a power function

$$HP = aGRT^{b} \qquad ...1)$$

The parameters a and b are estimated for each year by minimizing the sum of squares of the difference between observed and predicted numbers. There seems to be a rather consistent linear increase in parameter a from 1970 to 1985 and then a shift towards an even steeper linear increase after that (Figure 2). Parameter b, however, seems to be stable until 1985 but then begins to decrease. These changes in the parameters indicate that the boats are getting more powerful per weight with time, but the increase is faster in smaller boats than in larger ones. Given these trends, it is quite simple to estimate the parameters for years when information was not available, simply by fitting a line between known years. There was no information available on engine power before 1970. It was therefore decided to use the 1970 value for all the years from 1950 to 1970.

There is no information readily available on the average weight of undecked and decked boats by fishing gear use prior to 1976. However, there is information available on the total number of boats and their total weight (*Bulletin Statistique*). The average weight (W_{xy}) of boats by fishing gear category prior to 1976 was estimated by calculating how the known average weight in 1976 ($W_{1976,y}$) for each gear category changed based on proportional breakdown of fleet by geartype.

$$W_{xy} = \frac{W_{1976,y} \sum W_{x,y}}{\sum W_{1976,y}} \qquad ...2)$$

where W_{xy} is average weight, x is the year and y is fishing gear category. From this we get estimates on the average weight of fleet categories prior to 1976 assuming that changes are the same for all the fleets.

Handline

This is the traditional fishing gear in Icelandic waters, used since ancient times. It is the primary fishing gear of the undecked boats, but also used by decked boats. Although the handline is a traditional fishing gear, it has gone through many changes. The line itself has changed from wool, to hemp to nylon and the hook has also evolved and become more effective. By far the most revolutionary change in handline technology has been the invention of the computer-driven electronic jigging reel, whose development was much influenced by an Icelandic firm. Consequently the majority of the Icelandic handline fleet are now equipped with electronic jigging reels. The difference in efficiency from the old days (before the mid-1980s) where one fisher would be at each line doing everything manually to the current way is immense. By having a computer control the jigging activity, one man can now easily operate many handlines. In addition to electronic jigging reels, many modern undecked boats (and probably all decked boats and trawlers) are equipped with fishfinders, radar and GPS. This, of course, means that the catch per day per boat is much higher for modern boats given the same amount of fish in the sea. The handline is mostly used to catch cod but also, to a

much lesser extent, other groundfish species. A version of the handline is also used to fish for squid.

Data on effort by the decked boat fleet are well covered by *Útvegur* after 1975, where sea-days for each gear category are well documented. *Ægir* is the main source of effort data from 1972 to 1975 and *Bulletin Statistique* from 1966 to 1971. There was no information on the total effort by decked boat fleets from 1950 to 1965, but information was available on catch by gear and total effort in the winter fishery from 1958 to 1972 (*Ægir*). This was used to estimate the effort from 1958 to 1965. However, the catch by gear is not separated by species, but it is mostly cod. From this we can estimate the annual effort spent by the handline, longline and gillnet fleets for the period from 1958 to 1965. This was not a simple task for many reasons. The first was because effort by decked boats was given in number of trips until 1965 and between 1969 and 1972, but in sea-days between 1966 and 1972 (both sea-days and number of trips were given between 1969 and 1972). Therefore, the pre-1966 numbers had to be converted to sea-days using information from years where both effort units were known. However, boats were much smaller in 1958 than in 1969, and therefore probably did not spend as much time at sea per trip. This problem was solved by assuming that the number of sea-days per trip increased from 1.67 in 1958 to 1.80 in 1965; for comparison, the average from 1969 to 1972 was 2.02. With this we can calculate the total number of sea-days in the winter fishery for the missing years. The next problem was to convert the number of sea-days for the winter fishery to total sea-days for the whole year. On the average 55% of the total annual effort was spent during the winter fishery between 1966 to 1969 and this number was used to convert sea-days in the winter fishery for the missing years to sea-days spent during the whole year. The next problem, and probably the most complicated, was to assign this effort to fishing gear. Total effort (*E*) by gear *(g)* was estimated as

$$E_g = e_g \sum E_g \Big/ \sum e_g \qquad ...3)$$

where total annual effort in sea-days ($\sum E_g$) is known and *e* is relative effort calculated by

$$e_g = \frac{C_{g,winter} \sum E_{g,winter}}{q_g \sum C_{g,winter}} \qquad ...4)$$

where $C_{g,\ winter}$ is catch, and q_g is a proportionality parameter, calculated by

$$q_g = \frac{'C_{g,winter} \sum 'E_{g,winter}}{'E_g \sum 'C_{g,winter}} \qquad ...5)$$

These equations cannot be simplified because the parameters needed in Equation (3) are estimated from later years, while the parameters in Equation (1) and (2) available for each year. The proportionality constant q_g was estimated as 0.04 for handline, 0.18 for longline and 1.18 for gillnets. Gill netters have the highest value since they have the highest catch during the winter fishery.

The effort in each year (E_y) prior to 1958 was assumed to be proportional to total number of decked boats (*Hagskinna*), i.e.,

$$E_y = E_{y+1} N_y \big/ N_{y+1} \qquad ...6)$$

where N_y is number of boats and *y* is year. No other more detailed effort unit was available for these years. Effort by undecked boats is not as well documented as the decked boat category. Total effort for undecked boats is known for 1969, 1970, and after 1975 from *Útvegur*, and by gear after 1982. The effort between 1970 and 1975 was assumed to be the average from 1969, 1970, 1975, 1976 and 1977, or 45,000 sea-days. The sea-days from 1963 to 1968 were assumed to be 43,000. The sea-days before 1963 were assumed to be proportionally the same as the number of reported open boats (the 1962 number was set to 43,000 sea-days for calibration), which is only available until 1962 (Statistics Iceland 1967) and after 1975 (*Útvegur*). The effort by gear until 1982 was assumed to be the same as the average proportions from 1982 to 1992.

Longline

Longlines are much more effective than handlines, but more difficult and expensive to operate. They are therefore used on larger boats, mainly decked vessels. The longline was the most popular groundfish fishing gear by the decked boats until the 1960s, when gillnets were increasingly used during the spawning season. Longlines are, however, still more popular during other parts of the year. The line is usually set close to the bottom, except for minor fisheries targeting porpeagle (*Lamna nasus*; from 1959 to 1962) and bluefin tuna (since 1997). The longline fishery has become increasingly mechanized in recent years, e.g., baiting is now commonly done at sea by machines. The longline fishery can be split into shallow and deep-water fisheries. Cod is the primary target in shallow water fisheries, but

Atlantic catfish, haddock, tusk (*Brosme brosme*) and ling (*Molva molva*) are also caught, although tusk and ling are mostly found at intermediate depths. The main species fished in deep waters are Greenland halibut and redfish. The deep-water boats are much fewer, larger and more mechanized than those involved in shallow-water fisheries. Most foreign longline fisheries in Icelandic waters can be considered to occur at intermediate depths since they target species such as cod, halibut, tusk and ling, which are either found at, intermediate depths or over a wide depth range. Specialized longlines are used to target Greenland shark and halibut, as well as porpeagle and bluefin tuna. Mobile longlines (troll lines) are not used in Iceland.

The information available on effort and catch by this fishing gear is similar to that of the handline fleet and the same methods were used to fill in the missing years. However, undecked boats rarely use longlines, which makes the information on total effort more reliable.

Nets

The first recorded use of nets in Iceland was in 1753. However, this gear did not become popular until the 1950s when nylon became available. By 1961, when information on catch by gear during the spawning season became available, the gillnet catch was 100,000 t, compared to 58,000 t by longlines and 9,000 t by handline during the same season. The longline and handliners may have ended up with larger catches for the year since they are used throughout the year, whereas gillnets are more or less restricted to the spawning season.

Cod is the primary target as with so many other fishing gears, but large amounts of saithe are also fished, as well as smaller amounts of haddock and ling. Many specialized versions of bottom gillnets are used, mainly differing in mesh size. There are nets optimised for haddock (140-150 mm mesh size), lumpfish (180-270 mm), flatfish (Pleuronectiformes) (165-200 mm), Atlantic halibut (*Hippoglossus hippoglossus*) (460 mm), salmon (*Salmo salar*) (105-125 mm), trout (*Salmo trutta* and *Salvelinus alpinus*) (40-80 mm), and seals (harbor seal, *Phoca vitulina*; common seal, *Halichoerus grypus*) (280-290 mm). Common gillnets used in cod fisheries have a 139.7 to 254 mm mesh size, the former being the minimum allowed in most grounds. Common haddock, flatfish and halibut nets are included in the net category used here (the information available does not give numbers for each net type), other rules apply to the other nets. Generally they are all used in shallow waters, even freshwater, and although information is generally not available on the effort spent using these nets, they are at least not included in the gillnet category used here. Except for the lumpfish fisheries these are all very small fisheries. All of these nets mentioned are bottom gillnets. Driftnets have only been used in herring fisheries (63 mm mesh size).

Gillnets are mainly used by small to intermediate size decked boats, similar in size to longliners. The main change in gillnets was the introduction of nylon in 1954. It made the nets stronger and thinner, and recently new synthetic fibres are also being used. Another change was the introduction of lead sinkers in 1979, which replaced the use of stones. It has been estimated that this increased the catchability of cod by 20-30% (Þorsteinsson, 1980) since fewer fish escaped under the net. However, this innovation probably did not change the catchability of saithe substantially, since they are usually located higher off the ocean bottom than cod. Information available on catch and effort by bottom gillnets is very similar to that which is available for longlines and handlines, thus the same analytical methods were used.

Information on driftnets for herring is only available since 1972. However, catches were very low during the 1960´s since the purse-seines were much more efficient. Driftnets were commonly used before that, but information on effort and catch by gear is not available.

Traps

Traps are rarely used in Icelandic fisheries. They are only used in freshwater to catch eels, of which both the European and American form (*Anguilla anguilla* and *A. rostrata*) occur in Iceland, and in the sea to catch whelk (*Buccinum undatum*). From 1985 to 1987 traps were also used to catch spider crab (*Hyas araneus)* and Norway lobster (*Nephrops norvegicus*), but were discontinued. Low scale experimental trap fisheries for cod have been conducted but proved unsuccessful. Except for the freshwater fisheries for eel, trap fisheries are well documented.

Mobile seines

The Danish seine is the principal fishing gear used to target flatfish species at shallow and intermediate depths. They are also used to target cod and haddock. The boats using Danish seines are similar in size to longliners and gill-netters. In fact many boats switch between gear types seasonally. There were considerable fisheries

carried out by Danish seine from the early 1930s until 1951. However, no information is available on the catch and effort of these vessels during that time period. Therefore, they were not included when total catch was divided amongst gear types. This may have a significant effect with regard to plaice, which was the main target species of the Danish seiner, but the influence on other species should be minimal since catch by other gear was probably much higher. The Danish seine has always been a controversial fishing gear in Icelandic waters. In the past, Danish seiners had to obey the same rules as trawlers (which were also controversial), and were not allowed to operate within the EEZ when it was extended to 4 miles off the coast in 1952, and to 12 miles in 1958. This meant that there were virtually no Danish seine fisheries during those times since it was then strictly a shallow water gear. However, trawlers could still operate in deeper water areas.

By 1960 Danish seines were again allowed into some formerly restricted areas and have been operating in Icelandic waters ever since. One of the results of this controversy was that the Danish seiners were well monitored and catch and effort statistics are therefore much better than for other decked boat fleets, excluding the lobster boats. We, therefore, have information on effort and catch by species since 1961 (*Ægir* from 1961 to 1971, *Bulletin Statistique* from 1972 to 1975, and *Útvegur* after 1975). The 1960 effort was assumed to be half the 1961 effort. Current minimum mesh size of Danish seiners is 120 to 155 mm, depending on the fishing area.

Seines

The first recorded use of purse seines in Iceland was in 1904. Purse seines are used by intermediate to large decked boats, some of which are of similar size to large trawlers. Purse seines are primarily used to fish capelin and herring; bycatch of other species is low. Two main types of purse seines are the herring and capelin seine. The main difference is the mesh size, which is 31.4 mm in herring seines and 21 mm in capelin seines. Information on the effort of the herring fleet is fragmentary as with many other gear types used by decked boats. Since the capelin fishery is much more recent, more information is available (in *Ægir* and *Útvegur*). There is good information on the pelagic seine fishery from 1961 to 1965 (*Ægir* , from 1966 to 1971 in *Bulletin Statistique*). This information is given in number of trips but converted to sea-days by multiplying it by the average number of sea-days per trip (3.5) in later years when both are known (1972 to 1975 in *Ægir* and thereafter in *Útvegur*). The only other information available on effort is the total number of boats participating in the herring fishery since 1955. Each boat spent roughly 100 sea-days from 1962 to 1967 and the same was assumed for boats from 1955 to 1961. Total number of sea-days was assumed to be 13 200 from 1950 to 1954, or the same as calculated in 1955.

Cod fisheries were also conducted with seines from 1962 until 1976. These proved to be highly efficient, too efficient actually, the quality of the catch being low, it could not be processed in time and a large part of the catch was wasted. These fisheries were, therefore, restricted within a few years after they started and were banned after 1976. Information on the effort in the cod seine fishery is not available until 1972 (*Ægir*), however, it was at its peak a few years prior to records being available. The only information available from 1964 to 1971 is on the sea-days spent by boats capable of using purse seine during the winter cod. This does not necessarily mean that they used cod seine during the winter cod fishery, they could as well have used purse seines in the herring fishery but switched to gillnets or longline during the winter cod fishery. Nevertheless, this is the only clue we have on the effort spent by cod seine (or more accurately on effort spent by boats capable of using cod seine). The total annual effort was estimated by assuming that the effort in 1971 was twice the known effort in 1972 since the known catch was double in 1971. Effort by cod seine (E_{cs}) before 1971 was then assumed to be proportional to the number of purse-seine capable boats (N_{ps}) participating in the fishery

$$E_{cs} = \frac{N_{ps,y} * E_{cs,y+1}}{N_{ps,y+1}} \qquad ...7)$$

The effort in 1962 and 1963 was estimated with Equation (4) since there was information only pertaining to the catch by cod seine in the winter fishery, but none pertaining to effort.

Trawls

The first trawler to be reported in Icelandic waters was a British trawler, in 1890. There were more of them each year thereafter, and at the turn of the century it was estimated that there were around one hundred foreign trawlers operating in Icelandic waters, most of which were British. In 1904, one year before statistics on the distant water fisheries in Icelandic waters became available, there were 180 trawlers reported in Icelandic waters, 150 of them being British. For

comparison, 100 Norwegian boats fishing for herring, 150 French schooners, 100 Faroese and 130 Icelandic decked sailing vessels, and 2000 Icelandic rowing boats were also reported in the same year (Jónsson, 1984). The trawlers were very unpopular among the Icelanders, since they frequently destroyed the Icelandic fishing gear and were suspected of "destroying" the fishing grounds. The Icelanders, however, realized that their operation could not be prevented and soon began their own trawl experiments. The first Icelandic experiment with trawl was in 1901 with a sail trawler, followed by the first Icelandic steam trawler in 1904. Since then, trawlers have been in continuous use by Icelanders. Trawls are used for diverse fisheries. The 'common' trawl is used to fish for cod, haddock, saithe and other groundfish at shallow and intermediate depths, and for redfish and Greenland halibut in deeper waters. Specialized trawls are used to fish for Norway pout (*Trisopterus esmarki*), shrimp, lobster and pelagic fish.

Many species are caught as bycatch in trawl fisheries, some of which (halibut and common skate - *Raja batis*) are always retained while other close relatives such as long rough dab (*Hippoglossoides platessoides*) and starry ray (*Raja radiata*) are mostly discarded. In the past, shrimp trawlers caught large amounts of other species such as cod, haddock, redfish and Greenland halibut. However, sorting grids have been obligatory since 1996 and bycatch of these fish species has been greatly reduced. Sorting grids are not used by lobster trawlers, which therefore have large amounts of cod, redfish, haddock, monkfish (*Piscatorius lophius*) and witch flounder (*Glyptocephalus cynoglossus*) as bycatch. Boats using lobster trawl are mainly decked boats of intermediate size. The shrimpers are a much more variable fleet. Some very small undecked boats fish for inshore shrimp while large trawlers fish offshore. Trawls and purse seines were, until recently, almost the only fishing gears that Icelanders used in distant waters. A longline fishery in distant waters has also developed recently. About half of the current trawler fleet are wetfish trawlers while the other half are freezer trawlers. Beam trawls are not used in Icelandic waters.

The minimum allowed mesh size for groundfish and midwater trawls has been increased with time, from 110 mm in 1954, to 120 mm in 1963, 135 mm in 1976 and finally to 155 mm in 1977, the largest minimum mesh size in the N. Atlantic (Halliday and Pinhorn, 1996). Trawling with 135 mm is, however, still allowed in some areas in the south, mainly for redfish. The minimum mesh size in the cod and shrimp fisheries is 36 mm, and 80 mm in lobster trawls.

Extracting data from the information available for this fishing gear proved to be the most problematic. Trawlers almost exclusively use trawl, but decked boats commonly use this gear as well. Catch and effort information on the real trawler is much better then for the decked boat, but a proportionally large part of the real trawler catch is from distant waters, primarily Greenland. This is rarely separated from the catch from Icelandic waters in Icelandic data sources. The effort spent by real trawlers in Icelandic waters is available in *Útvegur* after 1976. *Ægir* has information on the effort from 1968 to 1976. Total effort is given in both sea-days and hours trawled, but effort by grounds is given in days fishing or hours trawled. These, therefore, had to be converted to sea-days. Fortunately, there were years when all effort units were used and so the conversion factors could be estimated (sea-days = 1.5 x days fishing and 8 x hours towing). Effort in sea-days by grounds is also known from *Ægir* from 1960 to 1963. However, there is no information on effort by grounds between 1964 and 1967 and before 1960, only on total effort and catch by ground. The effort by ground was estimated by assuming that the relationship between percentage of catch in Icelandic waters and percentage effort in Icelandic waters was the same for the years where effort by grounds was unknown and known. The relationship was found to be:

$$E = 1.05C^{0.91} \qquad ...8)$$

where E is percentage of effort spent in Icelandic waters and C is the known percentage of catch in Icelandic waters. *Ægir* gives separate information on effort by stern and side trawlers after 1971, but only effort by side trawlers prior to 1971. This leaves two years of missing data on stern trawler effort since the first one started operating in 1970. However, the number of stern trawlers was known for those two years and if we assume that each one of them spent 275 sea-days per year, which is to the average between 1972 and 1975, the effort can be determined. The *Bulletin Statistique* does not separate decked boats and trawlers when effort information is available, but instead separates them by size and it also gives the catch by grounds. The smaller trawlers (below 500 GRT) in *Bulletin Statistique* were assumed to be decked boats, thereby providing information from 1966 to 1971. After 1971 data were available in *Ægir* from 1972 to 1975 and from *Útvegur* after that. The effort by the larger trawlers in *Bulletin Statistique* was given in hours fishing and thus

not directly useful for data analysis. Trawling by undecked boats before 1966 is poorly documented. Presumably, trawls were also not commonly used by decked boats after 1951 when the EEZ was extended to 4 miles since decked boats were generally too small to be able to trawl outside this limit. The boats, however, became larger in the 1960s as a result of the herring fisheries, and therefore they could trawl in deeper waters outside of the herring season. Because of this, we assume there were no trawl fisheries by decked boats before 1962 (Jónsson 1984). Catches between 1962 and 1966 were estimated from catch information in *Ægir* on the winter fishery. This catch was assumed to be half the total annual catch from 1962 to 1966 (it was roughly half the total catch between 1966 and 1969). The estimated total annual catch was then divided by the average catch/effort between 1966 and 1969, assuming that catch/effort remained constant to arrive at an estimate on effort for the unknown time period (1962-1966).

The effort and catch by lobster trawlers is well documented since 1961, three years after the fishery began. Information used was from *Ægir* until 1971, from *Bulletin Statistique* from 1972 to 1975 and *Útvegur* thereafter. Effort prior to 1961 was assumed to decrease linearly from the 1961 value to zero in 1958.

Information on effort in shrimp fisheries is available from 1966 to 1975 in *Bulletin Statistique* and from *Útvegur* thereafter. Effort prior to 1961 was assumed to be directly proportional to landings.

Fisheries with Norway pout trawl are first documented in 1969. Effort and catch by this gear is known from *Ægir* between 1972 and 1975, but from *Útvegur* thereafter. Effort from 1969 to 1971 (where only catch is known from *Ægir*) was estimated based on the assumption that the CPUE was the same as the average from 1973 to 1976.

Pelagic trawls are the principal fishing gear used in oceanic redfish fisheries, but they are also used alongside purse seines for the pelagic species. The first use of midwater trawls in Iceland was in 1952 and was not for pelagic species, but rather for cod on the spawning grounds. When the EEZ was moved to 12 miles and Icelandic trawlers were excluded from this zone, this fishery stopped. However, we do not have information on the effort or catch for these fisheries, and so they are not included in the analysis. It is possible that the catch is accounted for by inclusion in the bottom trawl catch. Small amounts of pelagic species were fished with midwater trawls in 1966 and 1967 (*Bulletin Statistique*), between 1972 and 1983, and after 1990 (*Ægir* and *Útvegur*). Considerable amounts of oceanic redfish have also been fished with this gear since 1989 (*Útvegur*).

Dredges

Although there are basically four types of dredges used in Icelandic waters, ocean quahog, scallop, sea urchin and kelp dredge, there is wide variation in the design between each of them. Good information is available on the catch composition and effort of these dredge types (except for the kelp dredge) since these fisheries all began relatively recently. Scallop fisheries are the most important of these fisheries and were also the first dredge fishery to start up (1969). Information on effort and catch for these species is available since 1972 in *Ægir* and after 1975 in *Útvegur*. The effort from 1969 to 1971 was estimated based on the assumption that the catch/effort was the same as the average in 1972 and 1973. Breiðafjörður Bay in western Iceland was, and remains, the most important fishing area for scallop and kelp, while ocean quahog and sea urchin are harvested all around Iceland.

Other gears

Other fishing gear types used in Iceland are limited and used in very special cases. Fishing rods are, of course used both in freshwater and marine sport fisheries. Information on the use of fishing rods is understandably very scarce. Nowadays, salmon is mostly fished by fishing rods, as is a large portion of the trout fishery. Sport fishing on the ocean has never been popular in Iceland, although the activity has been increasing lately.

Harpoons are used to hunt whales and guns to hunt seals. However, information on the effort of these is not available. The simplest fishing gear used in Iceland is the human hand, used by a few divers to collect sea urchins, scallops and other benthic invertebrates.

Whaling has a long history in Icelandic waters. Deep-sea whaling was conducted by Basque, Dutch and French boats in the 17th and 18th century, but was largely abandoned by the late 18th century due to declining whale populations. During this time period the catches probably included right whales (*Eubalaena glacialis*), since they have a low swimming speed, and humpback whales (*Megaptera novaengliae*). Icelanders also caught whales opportunistically when they

entered the fjords and could be harpooned or driven ashore. Large-scale whaling started again in Icelandic waters in 1883, when steam vessels became available and blue (*Balaenoptera musculus*), fin (*Balaenoptera physalus*) and sei (*Balaenoptera borealis*) whales were targeted by Norwegian whaling boats in the western and eastern fjords of Iceland. Whaling was quite important economically for a short while, but like whaling in previous centuries the species were quickly overexploited. Whaling was banned in Icelandic waters in 1915 because of concerns about the whale populations, and to prevent foreigners from exploiting them. Whaling was then briefly resumed from one whaling station in Hvalfjordur ('Whale Fjord') in southwest Iceland. However, whale watching is now growing in Iceland (Kaschner *et al.*, this volume).

FOREIGN FISHERIES IN ICELANDIC WATERS

The first references to distant water fisheries in Icelandic waters are those of English boats fishing for cod in 1412. They became quite numerous in the 15th century and participated quite openly in Icelandic domestic politics (Iceland was under the Danish crown at that time). Because of this, the 15th century was dubbed "the English century" in Iceland. By the late 15th and early 16th centuries the English fisheries had declined due to conflicts with the locals, who were in part, supported by German merchants representing the Hanseatic league. Given this history of conflict, Cod wars between Icelanders and English fishers is not strictly a 20th century phenomenon (Þorsteinsson, 1976).

After the decline of the British Fleet, boats from the Netherlands became the most numerous distant water fleet in Icelandic waters surpassing English presence in the early 16th century. French boats from Brittany and Flanders replaced the Dutch as the most numerous distant water fleet from the early 19th century, until the arrival of the British trawlers. Fairly good information is available on the landings from these boats from the mid-18th century (Pálmadóttir, 1989). Until the beginning of World War II, French boats primarily used handlines on decked sailing vessels. The French fleet also conducted some limited trawl fisheries in Icelandic waters, as did most other countries. Faroese boats began fishing cod in Icelandic waters in the late 19th century, using similar boats and technology as Icelanders. Initially they were unpopular with Icelanders (as were all other distant water fleets). This animosity between Icelanders and the Faroese fleets did not last long due to the fact that the Faroese landed a large part of their catch in Iceland providing employment for Icelanders, and because information was shared by the Faroese fishers with Icelandic fishers. Faroese boats, since that time, have fished extensively in Icelandic waters and is the only distant water country with uninterrupted catch history in Icelandic waters for the entire 20th century. Norwegians have also been important players in Icelandic fisheries since the 19th century. It was primarily they who initiated large-scale whaling and herring fisheries in Icelandic waters during that century. They participated quite extensively in the herring fisheries and in the groundfish fishery to a lesser extent.

The English returned in the late 19th century with trawlers. English boats once again dominated the distant water fisheries in Icelandic waters in the 20th century, until the extension of the Icelandic EEZ to 200 miles. The main species targeted by the English fishers in the 19th century were flatfish and haddock; large amounts of cod were discarded until cod itself became the target species.

The second most important country participating in the groundfish fishery in Icelandic waters during the 20th century was Germany, mainly West Germany after the Second World War. Their total tonnage was lower than the British, and they always fished in deeper waters catching more saithe and redfish. Boats from Belgium, Denmark, East Germany, Poland, the Soviet Union, Finland, Sweden, Greenland, Japan, and United States also participated at one time or another in the Icelandic fisheries. The target species of these foreign fisheries was diverse. Belgian, Dutch and Scottish boats were fishing groundfish (Belgian boats were allowed to fish in Icelandic waters long after the EEZ had been extended to 200 miles). The Danes were fishing flatfish (although Iceland was under the Danish crown until 1944, Danish boats were never numerous in Icelandic waters). East Germans and Poles were fishing for groundfish, particularly in deep waters, targeting redfish and Greenland halibut. Vessels from the former USSR also fished in deep waters targeting redfish and Greenland halibut, but also participated in the herring fisheries. Finns and Swedes have also been involved in the fishery for herring. Recently, Greenlanders began fishing for capelin and Japanese for bluefin tuna. American boats have not been reported in Icelandic waters this century, but it is perhaps interesting to mention that schooners from Gloucester, Massachusetts, came to fish halibut in Icelandic waters in 1873. This fishery did not prove successful at that

particular time, however, they came back 11 years later and fished extensively in Icelandic waters until 1897. Boats from Portugal, Spain and Italy have also allegedly fished only small amounts in Icelandic waters. The fact that the great fishing countries, Spain and Portugal, have not been very active on Icelandic grounds in the 20th century is surprising.

The current distant water fleets fishing in Icelandic waters are: Norwegian and Faroese longliners fishing for groundfish; Norwegian, Faroese and Greenlandic purse-seiners fishing for capelin and herring; Japanese longliners fishing for tuna; and Greenlandic and European Union (British and German) trawlers fishing for redfish. Furthermore, Russian and European herring boats and Faroese boats fishing for blue whiting are allowed to fish in a certain amount in Icelandic waters. Except for the Japanese longliners, all catches are very low in comparison to catches made by Icelandic boats. The reason for these boats being allowed to fish in Icelandic waters is due to reciprocal fishing rights (groundfish, redfish), shared stocks (capelin, herring, blue whiting and redfish) or in the case of tuna, because Icelanders do not possess the knowledge to catch this species. Except for the groundfish fisheries, these all occur at the fringes of the Icelandic EEZ; redfish in the southwest, tuna in the south, herring in the east and capelin in the north.

The information on the effort and catch of the distant water fleets is almost exclusively from *Bulletin Statistique* and more recently from other ICES sources. The effort units were standardized to hours fishing. Where the effort was given in other units they were converted to hours fishing calculated from years where both units were given. This applies mainly to German boats, and to a lesser extent Scottish boats. The other source of information is from Thór (1995), which gives further information on the English fleet. Information on the effort of the foreign fleets in Icelandic waters is not available after 1977, but by that time, effort was severely reduced since the main fishing countries, Germany and Great Britain, had been expelled from Icelandic waters.

The species composition of the catch by foreign fleets is somewhat curious. Some catch is only given by group name (e.g., shellfish, flatfish or salmonids) and there are also some reported catches of species that are very rare or non-existent in Icelandic waters. Some of these questionable catches might be correctly reported, as in the case of rare species such as turbot, mackerel and squid. For other species, such as conger eel and sole, these reports are less likely, given that these fishes have never been identified by scientists in Icelandic waters. It has been assumed that these are either misidentifications or they were not fished in Icelandic waters. For example, it is conceivable that some boats did catch a few tows in their home waters after having fished in Icelandic waters, but did not report the catch separately.

ICELANDIC BOATS IN DISTANT WATERS

Iceland is a coastal fishing country and the majority of landings from Icelandic boats have always been from Icelandic waters. The first distant water fishery was an experimental fishery in Newfoundland waters which was started just a few years after the first trawler arrived. Although this fishery did not prove successful, real fisheries in distant waters were established for cod in the Barents Sea in 1934. These fisheries were on a relatively low scale until after the Second World War when they increased to about 5,000 t in 1950. During this time, the Icelandic boats had found new and better grounds in Greenlandic waters. Thus, the groundfish fisheries in the Barents Sea declined and were virtually non-existent after 1952. Although cod was always an important species, catches of redfish surpassed cod in some years. Icelandic trawlers also sought fish in North American waters in which large catches of redfish were fished in 1958 and 1959, but were significantly smaller approaching 1972. The distant water fisheries declined in importance when the side trawlers were phased out, since the stern trawlers initially preferred coastal water.

Icelandic trawlers did not really leave Icelandic waters from 1977 to 1993. However, during this time, significant quota reductions were being introduced and fishers began looking for alternative fisheries to participate in. Much to the annoyance of the Norwegians, Icelanders located an area in the Barents Sea in 1993 where cod migrated through an area that was outside any nations' EEZ. Icelanders have fished in this area ever since although an agreement with the Norwegians concerning quotas was negotiated. Icelandic trawlers also found another ground which did not fall in an EEZ. This area is known as the Flemish Cap and is located off the Grand Banks of Newfoundland. The main species fished in this area has always been shrimp. Icelandic boats have also recently sought shrimp in the Barents Sea. Prior to these two fisheries, Icelandic boats were also fishing oceanic redfish, found in Icelandic, Greenlandic and International waters.

Since this is a straddling stock, it is questionable if this can be classified as a distant-water fishery, although part of the catch by the Icelandic fleet is fished outside the Icelandic EEZ.

Herring fisheries were quite important for the Icelandic economy in the 1960s. In the mid-1960s, the Norwegian spring spawning stock started to change its migration pattern, moving further and further from Iceland. At the same time, the stock was being heavily overfished. As a result, Icelandic purse-seiners began to seek herring in distant waters after 1964. These fisheries were conducted until 1976 throughout the North Atlantic, from the North Sea to the waters off Canada. The purse- seiners withdrew into Icelandic waters at the same time as the trawlers in 1977, but did not resume a search for other opportunities until 1994. At this time, the Norwegian spring spawning herring stock had partially recovered and their migrations patterns brought them again near the Icelandic EEZ.

Other pelagic fish species have also been fished in distant waters, mainly driven by the collapse of the spring spawning herring mentioned above. Mackerel was fished in the North Sea from 1967 until 1976, horse mackerel (*Trachurus* spp.) and sardinella (*Sardinella* spp.) in West Africa in 1975, capelin in Canadian waters from 1975 to 1978, and blue whiting in Faroese waters from 1977 to 1983.

RECONSTRUCTING THE CATCH HISTORY

Estimating the annual catch of the Icelandic fleet proved to be more difficult than originally thought. It was not simply a matter of locating data and entering them into spreadsheets. The data were often found to differ between sources, in some cases very significantly, and none of the data combined or directly gave complete information on catch by species, by gear, from 1950. In general, the catch history of Iceland was reconstructed starting with the total catch. Catch numbers from different sources were compared, and catches in distant waters were subtracted where needed. The catch was then split by gear, based on available data, or estimated as explained below. *Nytjastofnar* was used as the main source information for total catch statistics prior to 1977. *Bulletin Statistique* and *Ægir* were considered less accurate because they have not been revised and updated to the same degree as *Nytjastofnar*. However, *Nytjastofnar* does not include as many species and has no information on catch by fishing gear. *Bulletin Statistique* and *Ægir* were therefore used extensively to supplement *Nytjastofnar*. After 1976, *Útvegur* is the main source of information. In some cases after 1976 the numbers from *Bulletin Statistique* and *Nytjastofnar* were preferred when they agreed on some number that was quite different from *Útvegur* (there were sometimes unexplainable differences between theses data sources). There was no information available on catch by fishing gear from 1950 to 1955, only on total catch. Catch (C) by gear (g) and year (y) was therefore estimated by:

$$C_{g,y} = \frac{E_{g,y} C_{g,y-1} \sum C_{g,y}}{(E_{g,y-1} \sum (E_{g,y-1} \sum (\frac{E_{g,y} C_{g,y-1}}{E_{g,y-1}}))} \quad ...9)$$

where $E_{g,y}$ is effort and $\Sigma C_{g,y}$ is total catch minus known catch by gear in later years where some catch by gear was known. This equation gives us catch estimated from the catch/effort of the previous year, corrected by changes in catchability (total catch/total effort). The main weakness of this approach is that catchability is assumed to change in the same manner for all gear.

Catch composition by trawlers is available in *Ægir* from 1956 to 1968, and can therefore be subtracted from the total catch that is used in equation (5). Catch by the Danish seine and lobster trawl fleets is available from the same source from 1960 to 1971. Some fragmented information is available in *Bulletin Statistique* on other gear from 1962 to 1965. However, the information in *Bulletin Statistique* was not used directly since there were large differences between these numbers and total catch. An example of this type of discrepancy is outlined for haddock in 1964. Total catch is about 57,000 t, catch by trawlers accounts for about 9,000 t, catch by Danish seine and lobster trawl about 8,000 t and the catch in distant waters is negligible. This leaves about 40,000 t unaccounted for. Catch by handline, gillnet and longline given in *Bulletin Statistique* is only about 20,000 t, leaving 20,000 t unaccounted for. The unaccounted 20,000 t could have been fished by cod seine, or decked motor boats (DMB) using trawl. However, if one compares catches from the surrounding years for the cod seine and decked motor boats when the total catch is known, it seems unlikely that these two gear types could account for the extra 20,000 t. In these types of cases the catch was divided among the fishing gear according to equation (5), and the information in *Bulletin Statistique* was essentially ignored. Good information is available from 1966

to 1976 in *Bulletin Statistique* on the most important species, i.e., cod, haddock, saithe, herring, plaice, and redfish. Most other species are problematic since information on catch by gear actually gets worse with time. There is no information on the catch of these species by trawlers after 1968, or catches of these species by lobster trawl and Danish seine after 1971. For years when the catch composition was not known we simply let the catch by gear follow a linear trend from the last year known before and the first year known after, but corrected proportionally to add up to the known total catch. Some species were, however, only assigned to one fishing gear since this gear fished the large majority in known years. Examples are blue ling (all unknown catch to trawl), herring (all to purse-seine between 1959 and 1970), tusk (all to longline), shrimp (all to DMB trawl and lobster (all to lobster trawl). After 1976 more clarity prevails in the data sources, since catch by different fleets is well documented, fisheries in distant waters are well known and they are clearly separated from catch in Icelandic waters.

It was also necessary to evaluate how to split the catch amongst boats using trawl (decked motor boats, side trawlers and stern trawlers) prior to 1977. The information in *Ægir* was considered accurate for the catch by the side trawlers (we only have to subtract the distant water catch), but the information in *Bulletin Statistique* is very flawed. It obviously does not include all trawling boats in some years since the catch by side trawlers in *Ægir* is much higher than trawl catch given in *Bulletin Statistique*. In other years the catch is given to "motor" trawlers, but a large part of the Icelandic trawlers were steam trawlers, which is a separate category in *Bulletin Statistique*. All this makes the information on trawlers in the *Bulletin Statistique* difficult to evaluate except for the values after 1971. The uncertainties in regards to splitting trawl catches, was solved by allowing the catch by side trawlers decrease linearly from 1968 to 1977 since the number of trawlers did decrease almost linearly during that time (by 1978 they were no longer in use). The catch by the stern trawlers followed their increase in number from 1970 (when the first stern trawler was brought to Iceland) up to the known 1977 number. The remaining uncertainty involves catches by decked motorboats using trawls. Their catch from 1971 to 1976 was simply found by subtracting the estimated catch by the other trawl classes from the known catch in *Bulletin Statistique*. In the process, the decked motorboat trawler category became a catch-all for unaccounted catch from 1962 until 1971 (their catch was assumed to be zero prior to 1962).

The last part of the catch history that needed to be manipulated was the catch of cod, haddock and saithe by undecked motorboats until 1981 (catch of other species was assumed to be zero for this boat class). The total catch by undecked boats was known from 1977 to 1981 and was assigned to fishing gear according to the average proportion from 1982 to 1992 (there was no consistent trend in the proportions during this period). This proportion between the fishing gears was also used for the period from 1950 onward. From 1971 to 1976 the undecked boats acted as a catch-all for unaccounted catch (and the numbers seem quite realistic). Before 1971, the catch was estimated by equation (5). Overall, there were many dangerous assumptions made in order to reconstruct catches of undecked boats. However, it is anticipated that because the undecked boats were not important players in the Icelandic fisheries, any errors in estimates will not have significant impacts on the big picture.

THE SPECIES

Below is a short description of each of the fish species, species group and landings that are included in the spreadsheet (*www.fisheries.ubc.ca/projects/SAUP*). Information on the marine fish species is mostly from Jónsson (1992) but also from Gunnarsson *et al.* (1998) and Anon. (2000). Other sources are cited in the text for each species or group.

Sharks and skates

Black dogfish (*Centroscyllium fabricii*):
Common in deep waters WSW and S of Iceland. Small amount reported in deep-water fisheries since 1992 (*Útvegur*); might have been discarded in some amounts before.

Portuguese shark (*Centroscymnus coelolepis*)
Common in deep waters WSW and S of Iceland. Small amount reported in deep-water fisheries since 1992 (*Útvegur*); might have been discarded in some amounts before.

Spiny dogfish (*Squalus acanthias*)
Not very common in Icelandic waters but still the most common shark species present. Considered a pest by Icelandic fishers in the past and probably often discarded. Retained more often in recent years but still only when encountered as bycatch in other fisheries. The first reported landings are in 1963 (*Bulletin Statistique*), there

is no catch in 1964, but landings are reported from 1965 to 1968 (*Ægir*); landings values are from *Útvegur* after 1968.

Dogfish (unidentified)
The dogfish catch of the foreign fleets is not identified to species (*Bulletin Statistique*) but was most probably spiny dogfish

Greenland shark (*Somniosus microcephalus*)
Greenland shark fisheries have most likely been conducted in Icelandic waters from the time of settlement (Júlíusson *et al.*, 1992). They reached a large scale in the 18th century, and a maximum in 1867 when 13100 barrels (each barrel contained about 62 liters) of shark oil were exported. At this time, this species was probably the most important marine resource in Icelandic waters. These were the only fisheries by Icelanders prior to the 20th century that can be described as deep-water fisheries. They were first conducted on open rowing boats, but later became the first Icelandic fisheries to use decked sailing boats. Only the liver was retained for its valuable oil, which was used for lighting up streetlights of European cities. When whale oil and fuel oil became more available the markets for the shark oil disappeared and direct fisheries for the Greenland shark were over by about 1910. Catches have been low during this century and it is now mostly caught as bycatch in other fisheries. However, a few are caught each year in direct longline fisheries and since this is the only fish species where the majority of the catch goes to local consumption (it is considered poisonous when fresh but Icelanders have a way to cure it and get rid of the poison)[a)], it is quite possible that actual catches are higher since there no incentive to report them. Landing statistics are not available for Icelandic boats until 1960, and then they apply for fisheries in the N.W. Atlantic. Statistics for Icelandic waters are available from 1962 to 1976 in *Bulletin Statistique* and in *Útvegur* thereafter. All catch prior to 1977 was assigned to trawlers. Catch for the early part of the century is only given in barrels of oil exported. Therefore, this has to be converted to live fish harvested. The conversion has to be done in several steps since no direct information is available on how to convert barrels of oil to live fish. Each barrel of oil (62 L) is estimated to consist of 1.67 barrels of liver (Guðmundsson 1977). The density of oil is assumed to be 0.95 for conversion to kg, and liver is assumed to be 25% of body weight (based on related species in Þrastarson et al 1994). This gives the conversion factor of 393.5 to convert barrels of oil to kg live shark.

Porbeagle (*Lamna nasus*)
Direct fisheries were conducted for porpeagle from 1959 to 1962 (Jónsson 1992), but no statistics are available; catch was assumed to be 10 t a year for this period. Information on catch is available in *Ægir* from 1965 to 1968 and in *Útvegur* thereafter.

Common Skate (*Raja batis*)
Used to be common in Icelandic waters, but is now overfished. This species probably provided the bulk of the reported skate and ray catches in the past, the other species either being to small to be of interest or living in deep waters out of reach to fishing gear at that time. A relatively big part of the catch goes to local consumption and is probably cured at sea by the fishers and not reported in landings. Actual catches might therefore be considerably higher than reported. This is illustrated by the large differences in landings between the different data sources that cannot be properly explained. Four possible reasons for this are: some sources might report only the weight of that portion which was retained from the skate (a relatively large part of it is cut off when gutted); a large part of the catch goes to local consumption and might not be reported, but is possibly estimated by some sources; some part of the catch might be fished in distant waters; and finally, a part of the catch might actually be another ray species. Landing statistics were used from *Bulletin Statistique* from 1950 to 1976, and from *Útvegur* thereafter.

Shagreen ray (*Raja fullonica*)
Found in rather deep waters SW and S of Iceland, probably used to be more common. Might have been part of the skate and ray catches of the past. Catches have been increasing in recent years as the trawlers go to deeper waters and it is caught as bycatch. All information on catches is from *Útvegur*.

Starry ray (*Raja radiata*)
The only cartilaginous fish that can be considered common in Icelandic water. Found all around Iceland, but usually dispersed. Has always been fished and caught as bycatch and until recently was always discarded, at least by Icelanders. The increase in landings in recent years could therefore partly be explained by increased retention. All catch information is from *Útvegur*.

Skates and rays (unidentified)
Skates and rays were not identified in the past. However most of these catches were probably

[a)] with the result tasting like overripe camenbert, but with the same texture as a shredded carpet [Note by editor #3].

common skate. The Icelandic catches in Icelandic waters were all assigned to common skate when these catches were not identified. Unidentified catches in distant grounds (*Bulletin Statistique* and NAFO) were, as the name indicates, not identified to species.

Knifenose chimaera (*Rhinochimaera atlantica*)
Found in deep waters WSW and S of Iceland. A small amount reported every couple of years since 1992 (*Útvegur*); might have been discarded in some amounts before.

Large eyed rabbitfish (*Hydrolagus mirabilis*)
Found in deep waters WSW and S of Iceland. Small amount reported in 1992 and 1995 (*Útvegur*); might have been discarded in some amounts before.

Rat-tail (*Chimaera monstrosa*)
The only Icelandic chimaera that is not confined to deep waters. Was probably discarded in the past but retained now, which would explain increasing landings. However, at times boats have targeted it (when out of quota for other more valuable species). Information on landings is from *Útvegur*.

Non-teleost fishes (unidentified)
Some countries report catches in this category. For the Icelandic fleet this was porbeagle and Greenland shark in the past, but most recently chimaeras. However, we can not find out what the foreign catch species composition is, except that it is probably not a skate species or spiny dogfish since they are clearly separate in the information source (*Bulletin Statistique*).

Pelagics

Capelin (*Mallotus villosus*)
A major fishery in Iceland, the tonnage caught in some years is as high as for all other species combined. This fishery was quite small until after the collapse of the herring stocks in the early seventies. Most of the capelin goes to reduction so price per weight is low. Capelin spawn mainly along the shore of southern Iceland and die after first spawning. Larvae and adults live in the cold waters north of the country. In some years the adult stock migrates to Norwegian (Jan Mayen) or Greenlandic waters, therefore these countries have a share in the fisheries according to an agreement between the countries. All countries are currently allowed to catch a certain share in other EEZ's. The Icelandic fishery has mostly been within the Icelandic EEZ, but also covering ICES areas Va, IIa, and XIVa. Agreements were reached with Norway in 1980 and Greenland in 1989 on the respective divisions of the TAC and reciprocal fishing rights (Vilhjálmsson 1994). The Icelandic catch in the other EEZs are minor and cannot be separated from the catch in the Icelandic zone from our sources. The catch values used from 1962 to 1976 are from *Hagskinna*. Thereafter, the picture becomes less clear (although there are no major differences between data sources), mainly because some sources round the numbers to 100s of t (*Nytjastofnar* and *Hagskinna*) and others do not separate the catch by ICES areas (*Útvegur*). This leaves ICES as the main data source used from 1977 to 1989. After 1989 the landings data from *Útvegur* are used.

Herring (*Clupea harengus*)
A big fishery in Iceland today but was most important in the 1960s. Herring fisheries began in Icelandic waters in the mid-19th century and were initiated by Norwegian fishers. Somewhat surprisingly, there are no references to Icelanders harvesting herring before that time. However, Icelanders soon began to fish herring. Initially the herring was fished with beach seines, but this changed to purse seines and driftnets just before the turn of the 20th century. The catch by these fishing gears is known since 1971, and can be assumed to be mostly by purse-seiners from 1961 to 1970 (Jakobsson, 1980). Prior to that, the division between gear types is not possible with the data sources available. We therefore assigned the catch 50/50 to each gear type prior to 1956 and gradually reduced the driftnet portion until 1959 when we assigned it all to purse-seiners. Three herring stocks were found in Icelandic waters all of which collapsed in the late 1960s. These stocks were the Icelandic spring spawning stock; the Icelandic summer spawning stock; and the Norwegian spring spawning stock. The Icelandic spring spawning stock is the only stock out of the three that have not yet recovered. Since these collapses, almost all the herring fisheries in Icelandic waters have concentrated on the Icelandic summer spawning stock. In recent years, as the stock has been migrating to international waters, Icelanders have been fishing a certain part of the Norwegian spring spawning stock according to an agreement between the countries involved (Norway, Russia, Iceland, Faroe Islands and the European Union). This fishery is almost exclusively in international waters just northeast of the Icelandic EEZ (although a small part has been caught within the Icelandic EEZ). Information on the landings of herring is apparently good owing to the fact that the herring fishery is a single species fishery and is of considerable importance. Total catch

information is from *Nytjastofnar* from 1950 to 1976, and *Útvegur* thereafter.

Sandeels Sandeels of the species *Ammodytes marinus*, *Ammodytes tobianus*, and *Hyperoplus lanceolatus* are common in Icelandic waters. Some amount was fished between 1979 and 1980 but catches have decreased since (*Útvegur*). There has been interest in resuming this fishery. Most catches were probably *A. marinus*. Lately, sandeels have been imported as bait for the haddock fisheries.

Blue whiting (*Micromesistius poutassou*)
Blue whiting is native to Iceland, however, the Icelandic stock is small and does not sustain large fisheries. Most of the fisheries are from the large stock that spawns northwest of the British Islands. This stock migrates to feeding grounds in the Norwegian Sea and can sometimes be found in large concentrations in the Icelandic EEZ. Except for the period from 1977 to 1983 and after 1996 (*Útvegur*), Icelanders have not been active in the direct blue whiting fishery. A large part of this fishery (including Icelandic boats) was in Faroese waters in the late seventies and early eighties. There was also some fisheries in Greenlandic and international waters. The fishery since 1995 has mostly been in Icelandic waters; 1999 was an exception when the fishery started on the spawning grounds west of the British Islands. Besides this direct fishery a considerable amount of juvenile blue whiting was caught as bycatch in Norway pout fisheries from 1972 to 1989 (Sveinbjornsson, 1981, *Útvegur*). This amount is not included in some data sources. Catch values used for blue whiting are from Nytjastofnar from 1972 to 1989 and from *Útvegur* after 1989.

European smelt (*Osmerus eperlanus*)
This species is not found in Icelandic waters and the reported catch by Germany in 1976 (*Bulletin Statistique*) This is either a case of misidentification (with capelin (*Mallotus villosus*) or great silver smelt (*Argentina silus*)) or was not caught in Icelandic waters.

Horse mackerel (*Trachurus trachurus*)
Horse mackerel is not native in Icelandic waters but has in some years migrated there and some low amounts reported (*Útvegur*). The catches of the foreign fleets are suspiciously high, however, and might therefore actually not have been fished in Icelandic waters. Icelandic boats did fish considerable amounts in the North Sea in 1973 and 1974 (*Bulletin Statistique*) and in the East Central Atlantic in 1975 (FAO).

Mackerel (*Scomber scombrus*)
Mackerel is not native in Icelandic waters but migrates there in some years, and small amounts have been reported (since 1991 in *Útvegur*). The catches of the foreign fleets are suspiciously high, however, and might therefore actually not have been fished in Icelandic waters. However, Icelandic boats fish considerable amounts in distant waters, especially in and around the North Sea from 1967 to 1976 (*Bulletin Statistique*) and in some unspecified grounds from 1997 onwards (*Útvegur*).

Clupeoids (unidentified)
Catch of 72 t reported in 1972 by East Germany (*Bulletin Statistique*); probably herring.

Scombriformes (unidentified)
Catch of 16 t reported by East Germany in 1979 (*Bulletin Statistique*); probably mackerel.

Bluefin tuna (*Thunnus thynnus*)
Not considered native to Icelandic waters but sometimes migrates there and is 'accidentally' caught. Recently, Japanese boats were allowed to do some experimental fisheries in the southernmost part of the Icelandic EEZ. One Icelandic boat has also been equipped for tuna fisheries in Icelandic waters (although it operates in ICES area XII). Data on landings are from *Útvegur*.

Sunfish (*Lampris guttatus*)
Found in the southern part of the Icelandic EEZ and occasionally further north and is incidentally caught there. Low amount reported approximately biannually since 1993 (*Útvegur*)

Sardinellas (*Sardinella* spp.)
Not found in Icelandic waters, but some amount was fished off West Africa in 1975 by Icelandic boats (FAO).

Splendid alfonsino (*Beryx splendens*)
Found in Icelandic waters but no catches reported there. Low amounts reported by Icelandic boats in the Western Central Atlantic in 1996 (*Útvegur*).

Alfonsino (*Beryx decadactylus*):
Found in Icelandic waters but no catches reported there. Some amount reported by Icelandic boats in Western Central Atlantic in 1997 and 1998 (*Útvegur*).

Breams (unidentified)
Rare in Icelandic waters (but see *Beryx* spp. above). Foreign catches might be misidentification or fished in other waters.

John Dory (*Zeus faber*)
Rare guest in Icelandic waters. Icelandic boats fished small amounts in unspecified distant grounds in 1997 (*Útvegur*).

Groundfish

Aggassiz' smoothhead (*Alepocephalus agassizii*)
Found in deep waters WSW and S of Iceland. A small amount reported in 1992 (*Útvegur*). Bycatch in recent deep-water fisheries; might have been discarded in some amounts.

Black scabbard fish (*Aphanopus carbo*)
Common in deep waters WSW and S of Iceland. Caught in small amounts since 1992 as bycatch in deep-water fisheries in Icelandic waters, but also in the Western Central Atlantic in 1996 and 1999 (*Útvegur*). Might have been discarded in some amounts before.

Scabbard fish (*Lepidopus caudatus*)
Rare in Icelandic waters and has never been reported in catches, however, low amounts were reported by Icelandic boats in unspecified distant waters in 1997 (*Útvegur*).

Cardinal fish (*Epigonus telescopus*)
Common in deep waters WSW and S of Iceland. Small amount reported in Icelandic waters in 1999 and in unspecified waters in 1996 (*Útvegur*). Bycatch in deep-water fisheries; might have been discarded in some amounts before.

Blackfish (*Centrolophus niger*)
Rare in Icelandic waters and has never been reported there in landings. Low amounts were, however, reported by Icelandic boats in other grounds in 1997 (*Útvegur*).

Atlantic (or common) catfish (*Anarhichas lupus*)
The most common catfish species in Icelandic waters and it provides the bulk of the catfish catch. Found on the shelf all around Iceland. Both targeted specifically when migrating from spawning grounds and is bycatch in other fisheries. Reported landings in early years do probably include spotted catfish (see under that name). From 1950 to 1972 the catch numbers in *Bulletin Statistique* were used. After 1973 the numbers in *Hagskinna* and *Útvegur* were used (The first *Útvegur* edition is from 1977, but there is some catch information available for previous years in each issue).

Spotted catfish (*Anarhichas minor*)
The spotted catfish is not infrequent in the colder waters north and east of Iceland but is always as bycatch. Probably not separated from Atlantic catfish before 1958 in the Icelandic distant water fisheries (information after 1958 is from *Bulletin Statistique*, FAO supplemented by *Ægir*) and before 1968 in fisheries in Icelandic waters (*Útvegur*). Even after 1968 it is quite probable that some of the landings were included in reports as Atlantic catfish. Catch prior to 1977 is assigned to trawlers, since they are the gear with the majority of known catches. This species is considered good for mariculture and some experiments have been conducted recently.

Arctic (or jelly) catfish (*Anarhichas denticulatus*):
Found in deep cold waters, not considered edible since flesh is jelly-like. Some boats have nevertheless reported some minor catches since 1992 (*Útvegur*). Some bycatch in fisheries for Greenland halibut and shrimp but discarded because of low value.

Catfishes (unidentified)
Foreign fleets did not separate the catfish catch between species (*Bulletin Statistique*). The catch is therefore not split between species, however, considering the area fished the large majority is probably Atlantic catfish.

Vahl's Eelpout (*Lycodes vahli*)
Small fish that is frequently caught as bycatch in shrimp fisheries. Usually discarded but some boats reported small amount in 1992 and 1993 (*Útvegur*). Found in deep waters north of Iceland.

Esmark's eelpout (*Lycodes esmarki*)
The largest of many eelpout species found in Icelandic waters. Not infrequent catch in fisheries for shrimp and Greenland halibut; usually discarded. Some boats have retained it since 1993 (*Útvegur*). Found in deep waters north and west of Iceland.

Great silver smelt (*Argentina silus*)
Common in medium depths W, SW, S, and SE of Iceland. Common bycatch in Greenland halibut and redfish fisheries but until recently mostly discarded. Recently there has also been a direct fishery for this species. Catch statistics from 1961 to 1968 are from *Ægir*, after that from *Útvegur*.

Gurnard (*Eutrigla gurnardus*):
Not infrequent in medium shallow waters W, SW, and S of Iceland. Usually discarded by the Icelandic boats due to small size and low value,

but some retained by foreign fleets. Small amounts have been reported by Icelandic boats annually since 1996 (*Útvegur*).

Lumpfish (*Cyclopterus lumpus*)
Common in all Icelandic waters. Caught in a directed fishery and as bycatch in others. The direct fishery is unique among Icelandic fisheries since they did not have to be reported to the same extent as other fisheries, although the fishers fishing for the roe have required a special permit since 1976. Some sources of information only give the bycatch from those fisheries not directly targeting this species since reporting is mandatory in these cases.

The *Marine Research Institute* does, however, estimate the total catch from reports from the lumpfish fishers. The male goes to local consumption but the roe is kept from the females and exported as (fake) caviar. The first catch statistics are available in 1966. Catches until 1970 are from *Bulletin Statistique*, from 1971 to 1989 from *Nytjastofnar*, and from *Nytjastofnar* (assumed to be the direct catch) plus *Útvegur* (the bycatch) after 1989.

Monkfish (*Lophius piscatorus*)
Common in the warmer waters around Iceland. Caught as bycatch (mostly in lobster fisheries) and recently became a direct fishery. Very valuable fish; might not have been reported specifically in early years. Catch information is available in *Ægir* from 1961 to 1964, *Bulletin Statistique* from 1965 to 1976 and *Útvegur* thereafter.

Orange roughy (*Hoplostethus atlanticus*)
Found in concentrations in some deep waters W, SW, S, and SE of Iceland. Caught as bycatch and also has occasional target fisheries. Very valuable fish. Catch information is from *Útvegur*.

Redfishes (unidentified)
The redfish species (*Sebastes* spp.) in Icelandic waters are not well known despite heavy fisheries for a long time. The species found are at least four (*S. viviparous*, *S. mentella*, *S. marinus* and *S. fasciatus*, the last one being a rare guest), but possibly six (the fifth might be the so called giant redfish which has been considered the same species as *S. marinus*, and the sixth might be a species previously considered within the *S. mentella* complex). A number of multinational studies (incl. genetic studies and acoustic surveys) are attempting to clarify these matters. Although this distinction will be of great value in the future it is much more difficult to find out what was the species proportion in the past. It is likely that the early catches in Icelandic waters were predominantly *S. marinus* since it is very common and lives in more shallow waters than the other species (but see below for each species). The stocks are found over a large area covering many ICES zones and EEZ's, and they sustain large fisheries by many countries. Redfish catch by the Icelandic boats in Icelandic waters is from *Nytjastofnar* from 1950 to 1976, after that from *Útvegur*. The split up of the catch between *S. marrinus* and demersal *S. mentella* is from *Nytjastofnar*. Icelandic catch in distant waters is from *Bulletin Statistique*, NAFO, FAO and from *Útvegur* in more recent years recently.

Redfish (*Sebastes marinus*)
This is the most common redfish species on the continental shelf around Iceland. It is usually associated with the bottom and found all around Iceland, usually above 500 m depth. It probably provided the bulk of the catches by all fleets in Icelandic waters until about 1980. It is targeted directly and is also caught in smaller amounts as bycatch. All the catch was assigned to side trawlers in years when catch by gear was not available since the majority of catches were by trawlers in years when catch by gear was known. Most of the fishable stock of this species is probably within ICES area Va and the Icelandic EEZ.

Redfish (*Sebastes mentella*, demersal)
This species (stock) is similar to *S. marinus* and for a long time they were not separated in catches. It is usually found below 500 m depth, and since the trawl fishery until the 1980s was mostly on the shelf, it was probably a small part of the total catch. The proportions in landings by the Icelandic fleet have been estimated since 1978 (Anon., 2000). The previous Icelandic fishery in Greenlandic waters probably targeted both *S. marinus* and *S. mentella* and currently it is not possible to split the past fishery according to species, however, the proportions are probably similar to those in Icelandic waters.

Redfish (*Sebastes mentella*, oceanic)
This is considered the same species as above but a distinct stock with different horizontal distribution and a pelagic lifestyle; it also looks somewhat different. The fishery for this stock is a direct fishery using mid-water trawl. Eastern European fleets were the pioneers in this fishery but the majority of the catch is now by Icelandic boats. This stock is found over the Reykjanes ridge SW of Iceland; part of the catch is within the Icelandic EEZ (Icelandic boats), part outside (many countries, including Iceland). The affinities between the demersal and oceanic

stocks of S. mentella are unclear. There seems to be some genetic difference, but there could still be some intermingling between the stocks. It has been proposed that there is a third stock of this species, a pelagic version of the demersal stock, found in the same area as the oceanic stock but living at greater depth. Catch information is from *Útvegur*.

Redfish (*Sebastes viviparus*)
Small shallow-water species. Probably discarded before because of its small size but a small target fishery has evolved recently. Catch information from *Nytjastofnar*.

Smooth head (*Alepocephalus bairdii*)
Common in deep waters WSW and S of Iceland. Caught in small amounts as bycatch in recent deep-water fisheries, might have been discarded in some amounts before. A low amount has been reported annually since 19922 (*Útvegur*).

Spine eel (*Notocanthus chemnitzii*)
Common in deep waters WSW and S of Iceland. Caught in small amounts as bycatch in recent deep-water fisheries; might have been discarded in some amounts before. Low amount reported each year since 1992 (*Útvegur*).

Cusk eel (Ophidiidae; unidentified)
Not found in Icelandic waters. Small amount reported by Icelandic boats in distant but unspecified waters in 1997 and 1998 (*Útvegur*).

Conger eel (Congridae; unidentified)
Not found in Icelandic waters, probably misidentification or fished in other waters.

Demersal percomorphs (unidentified)
There is no information available in *Bulletin Statistique* on what this category (perch-like) consists of for the foreign fleets, but when applied to the Icelandic fleet, it is always lumpfish.

Salmonids (unidentified)
Some amount reported every other year between 1964 and 1975 by East German, West German and Soviet fleets; probably great silver smelt.

Other catch (unidentified)
Catch that cannot been assigned to other groups. From 1950 to 1952 this is from *Hagskinna*, from 1953 to 1968 from *Bulletin Statistique* and from 1969 to 1999 this is the unidentified catch in *Útvegur*. Not possible to say what this is in recent years, could be species already accounted for but also other species. In earlier years it probably includes species accounted for in later years.

Groundfish, gadoids

Blue antimora (*Antimora rostrata*)
Common in deep waters WSW and S of Iceland. Catch of 2 t reported in 1996 (*Útvegur*); might have been discarded in some amount.

Blue ling (*Molva dypterygia*)
Common in deep waters south and west of Iceland. Caught as bycatch in deep water fisheries, but also support targeted fishery. There are no reported Icelandic landings of blue ling before 1961. It is possible that blue ling was not separated from common ling in those early years. There is information available on landings in *Ægir* from 1961 to 1965, *Nytjastofnar* is used from 1966 to 1976, and *Útvegur* after 1976. All catch before 1977 was assigned to side and stern trawlers since catch by other gear is low compared to trawlers. Data on blue ling catches by distant water fleets are only available since 1973, however there is no doubt that a large part of the unidentified gadoid catch prior to that is blue ling.

Cod (*Gadus morhua*)
This is by far the most important marine resource in Icelandic waters. Its economic importance has been surpassed by herring and possibly Greenland shark at times, but these periods were relatively short-lived. The Icelandic cod stock is mostly found on the Icelandic shelf, although a few tag returns have been from other waters (Jónsson, 1996). There is one major exception to this rather localized distribution pattern. The Greenlandic cod stock is largely made up of larvae drift from Icelandic spawning grounds. When this fish matures, it returns to Icelandic waters to spawn. This return has at times had major influences on cod fisheries in Icelandic waters, contributing to large increase in the landings but also to large problems in assessing the stocks. This Greenland migration has not occurred since 1990, and is not expected to occur in the near future since the Greenlandic cod stock is at extremely low levels. The cod is the major target species in handline, longline, gillnet, Danish seine and bottom trawl fisheries. There has always been some discarding of small sized cod in Icelandic fisheries. This is specially so in fisheries where large amounts are fished during a short time (e.g., during spawning time) and there is little incentive to retain the small, lower valued cod. It is intensively debated if this has increased with the introduction of the ITQ system. Good scientific studies are not available to verify this, but the many reports by fishers about discarding cannot be easily ignored (although there are also fishers who claim discards to be lower). It is assumed

that discarding has increased since the ITQ system was established and has been especially high in recent years, due to unusually high prices of quotas. Catch numbers were used from *Nytjastofnar* and *Bulletin Statistique* from 1950 to 1976 (these two sources had the same numbers), but from *Útvegur* thereafter.

Greater fork-beard (*Phycis blennoides*)
Common in deep waters WSW and S of Iceland. Small amount reported in 1994 (*Útvegur*); might have been discarded in some amounts before and after.

Grenadier (roughhead) (*Macrourus berglax*)
Common in deep waters WSW and S of Iceland. Caught in small amounts as bycatch in recent deep-water fisheries (*Útvegur*); might have been discarded in some amounts before.

Grenadier (roundnose] (*Cyrophaenoides rupestris*)
Common in deep waters WSW and S of Iceland. Caught in small amounts as bycatch in recent deep-water fisheries; might have been discarded in some amounts before. Catch Statistics are available in *Bulletin Statistique* from 1973 to 1976, but in *Útvegur* thereafter. All catch was attributed to trawlers for period before catch by gear was known.

Haddock (*Melanogrammus aeglefinus*)
Haddock is very important in fisheries around Iceland. It is fished with many types of fishing gear, but the largest amounts by trawl and longline. This is the fish that Icelanders prefer to eat. Therefore, a proportionally large part goes to local consumption (*Útvegur*), or is eaten at sea. Actual catches might therefore be higher than reported landings. There could also be some highgrading, but probably less than that for cod, since the quota value of haddock is much lower and quotas therefore easier to obtain. Catch numbers used are from *Nytjastofnar* from 1950 to 1976, but from *Útvegur* thereafter.

Ling (*Molva molva*)
Common at intermediate depths S and W of Iceland. Bycatch in many fisheries and also a target fishery. Early landing statistics might include blue ling. Catch statistics from 1950 to 1976 are from *Nytjastofnar* and thereafter from *Útvegur*

Norway pout (*Trisopterus esmarki*)
Common south and west of Iceland; has at times sustained target fisheries for reduction. A problem with this fishery was that juveniles of more economically important species such as cod and haddock were frequent bycatch. Catch information from *Bulletin Statistique* was used from 1969 to 1976 and *Útvegur* thereafter.

Saithe (*Pollachius virens*)
Found all around Iceland, more common in the south and west. Caught as bycatch and is also a target species; mainly fished with trawl and gillnets. Discarding of small saithe has probably always occurred. However, recent rumours claim that some of the reported saithe landings are actually cod, meaning that landing statistics overestimate the saithe catches and underreport cod catches. This is because the quota value of cod is much higher than that for saithe. Assessing the stock has always been problematic, recruitment into the stock has always been difficult to determine (as opposed to cod) and saithe is highly migratory. It has been proved to migrate in large quantities to and from Icelandic waters. The fisheries in Icelandic waters are, however, on the continental shelf, within ICES area Va. Catch numbers used are from *Nytjastofnar* from 1950 to 1976, but from *Útvegur* thereafter.

Tusk (*Brosme brosme*)
Tusk is common in medium depths S and W of Iceland. It is mostly fished by longline. Little information is available on catch by fishing gear before 1977, except about the minor amounts fished by side trawlers, lobster trawlers and Danish seine boats for some periods. Catch that remained when these fishing gears had been subtracted from total catch was assigned to longliners since the majority was fished with longline in years where catch by gear is known. Total catch is from *Bulletin Statistique* from 1950 to 1976, but from *Útvegur* thereafter.

Whiting (*Merlangius merlangus*)
This is a shallow water species but not very common in Icelandic waters compared to the North Sea, for example. It is possible that some of the whiting catches were misidentified as hake by the foreign fleets. Whiting is not usually fished directly in Iceland, but occurs as bycatch in shallow water fisheries. It might have been discarded in large amounts since it is usually small in size, or reported with and not separated from haddock (mostly prior to 1965). Landings are only known since 1960 and come from a variety of sources. *Bulletin Statistique* covers the years 1960, 1964 and the time period 1965 to 1976; *Ægir* covers the years 1961 to 1963; and thereafter catches come from *Útvegur*.

Bib (*Trisopterus luscus*)
Never reported in Icelandic waters by scientists. The 1 t reported by Belgium in 1977 was probably a misidentification (Norway pout) or was not caught in Icelandic waters.

Hake (*Merluccius merluccius*)
Very rare in Icelandic waters. It is therefore unlikely that the foreign fleets caught as much as they reported there. The catch was probably either misidentified or was not fished in Icelandic waters. Perhaps the trawlers took a few hauls in home waters after returning from Icelandic waters before landing and reported all the catch in Icelandic waters. Some catch reported in unspecified grounds (not Icelandic) by Icelandic boats in 1997 and 1998 (*Útvegur*).

Pollack (*Pollachius pollachius*)
Pollack is not native to Icelandic waters, but is frequently found there (usually single individuals at a time). Some distant water countries, however, reported some catches. It is unclear if this is true; it could be misidentified saithe, or not fished in Icelandic waters.

Gadoids (unidentified)
Distant water fleets operating in Icelandic waters reported some catch as unidentified gadoids. A large part of this is probably blue ling and to a lesser extent grenadiers. Icelandic boats also reported small amount of unidentified gadoids in the North Sea in 1970 (*Bulletin Statistique*).

Groundfish, flatfish

Dab (*Limanda limanda*)
Dab is a common shallow water species in Iceland. Landings were low before 1988, but thereafter the Icelandic Danish seine fleet began targeting it directly. It is possible that it was discarded before or not separated from other flatfish species. The trawler fleet was, however, not allowed to fish in the shallow waters where dab is found, and it is not caught in great quantities by shallow water fishing gears such as longlines, handlines and gillnets. Dab now sustains a target fishery (usually boats that have finished their quota for more valuable species) and is caught as bycatch in the Danish seine fisheries for plaice. Catch by gear is more or less unknown before 1977, except for side trawlers. The catch that was not by trawlers was assigned to Danish seiners. Landings were, however, very low before 1985. Catch information from *Bulletin Statistique* was used from 1950 to 1976 (except in 1957 and 1963 when *Ægir* was used because *Bulletin Statistique* gave no values), but *Útvegur* thereafter.

Greenland halibut (*Reinhardtius hippoglossoides*)
The Greenland halibut fishery is currently the most important flatfish fishery in Iceland. As opposed to most of the other flatfish species the Greenland halibut is a deep-water species found in the cold waters E, N and W of the island. Little is known about the stock but the Greenland halibut in East Greenlandic, Icelandic and Faroese waters are considered the same stock. The Greenland halibut fishery was initiated by the German fleets in the 1950s but was then taken over by the Icelandic fleet. The Icelandic catches have declined (because of declining stock size) since 1988 and Faroese and Greenlandic catches have increased (fished in their home waters). Most of the Icelandic fishery is within the Icelandic 200 nm EEZ, but also includes ICES areas XIVb (where the major spawning grounds are), Va and IIa. There are also reported Icelandic catches in the Barents Sea and in an unspecified area, probably on the Rockall grounds. The Greenland halibut was probably reported with Atlantic halibut early on and actual landings therefore underestimated. Catch statistics for the Icelandic fleet is fragmentary for the two first decades. There are reported catches in the N.W. Atlantic in 1959 (FAO) and in Icelandic waters in 1961, 1962, and 1965 to 1968 (*Ægir*), from 1969 to 1976 catch statistics are available from *Nytjastofnar* (which agree very well with numbers from other sources), after that information from *Útvegur* is used. All catch prior to 1977 was assigned to trawlers. Landing statistics on Greenland halibut in *Bulletin Statistique* are incomplete: it is either not reported, reported as unidentified flatfish or 'halibut' (hence also making the halibut statistics questionable) depending on countries and years. Information on catch statistics have, however, been reassessed from 1961 to 1996 by Hjörleifsson (1997) and from 1950 to 1960 by Hjörleifsson *et al.* (1998).

Halibut (Atlantic) (*Hippoglossus hippoglossus*):
Halibut is one of the most valuable fish in Icelandic waters and is found all around the island. The catches have been declining for a long time as the stock has been heavily overfished. There used to be target fisheries for halibut by fleets from many countries. However, due to its low stock size, the current halibut catch is mostly a bycatch of other fisheries. Because of its dispersed distribution and since it is caught in most fishing gear it is difficult to manage the

stock. A proportionally large part of the catch goes to local consumption or is eaten at sea and landing statistics might therefore be underestimates of catches. Catch information from 1950 to 1976 is from *Nytjastofnar* and after 1976 from *Útvegur*. Experimental halibut farming has been conducted in Iceland for some years, giving promising results lately. Production numbers are from Jóhannson (2000).

Lemon sole (*Microstomus kitt*)
Lemon sole is common in medium shallow waters in the warmer waters S and W of Iceland but is also found in the north. It was primarily caught as a bycatch species in trawl and Danish seine fisheries, but recently has also been targeted specifically. It is of high value and does not have a TAC, so discards are probably low. Landings have been increasing recently, but there are concerns that these might be misreports. Rumours exist that some fishers report catches of other species such as plaice or witch flounder (that have a TAC) as lemon sole (by having lemon sole at the top of the fish box but the other species below). If this is true, then this is one of the few cases where reported landings might actually be overestimates, as is the case when cod are reported as saithe. Early catches of lemon sole might not have been separated from other flatfish. Catch statistics from 1950 to 1976 are from *Nytjastofnar* and thereafter from *Útvegur*.

Long rough dab or American plaice
(*Hippoglossoides platessoides*)
This is probably the most numerous flatfish in Icelandic waters, and is found all around the country in a wide range of depths. It has always been caught as bycatch by most fishing gear and promptly discarded because of its small size and low value. Recently it has been the target of fisheries by the Danish seine fleet (by boats short of quotas for other, more valuable species). This species probably has the questionable honour of being the most discarded fish in Icelandic waters at all times and the mortality due to fisheries was, at least in the past, much higher than the landings indicated. The stock is, however, very robust and has never shown any signs of depletion. Landing statistics are from *Útvegur*, except for some minor distant water fisheries in 1964 and 1965 from NAFO.

Megrim (*Lepidorhombus whiffiagonis*)
The megrim is found at medium depths along the south shores of Iceland. It is bycatch in other fisheries such as Danish seines and lobster trawl. It is of relatively low value so it might have been discarded in some quantities in the past. Catch statistics are from *Bulletin Statistique* from 1950 to 1976 (*Nytjastofnar* gives the same numbers except in 1961, where other sources agree better with *Bulletin Statistique*).

Plaice (*Pleuronectes platessus*)
This species is very common in Icelandic waters and is found all around the island. It is also a valuable fish and has sustained considerable catches since 1950. The Icelandic catches were relatively low until 1983 when boats using Danish seines started targeting it substantially. The plaice is primarily targeted by Danish seine boats but is also a common bycatch in trawls and recently in gillnets. Early catches might include some other flatfish. Catch statistics might be underestimates in the most recent years since the TAC has been drastically reduced and some fishers claim that they are "forced" to discard it due to low quota status when fishing for other species (such as dab and lemon sole). Catch numbers used are from *Nytjastofnar* from 1950 to 1976, but from *Útvegur* thereafter.

Witch flounder (*Glyptocephalus cynoglossus*)
This species has probably been fished in Icelandic waters throughout the 20th century, but not much by Icelanders until recently. Some of the catch might be included under the lemon sole category (see above), but early catches were most likely included in 'other flatfish'. Witch is both targeted and caught as bycatch. Witch has mostly been fished by Danish seine boats since 1986, but before that by bottom and lobster trawlers. Total catch information is from *Nytjastofnar* (*Bulletin Statistique* gives the same numbers) before 1977 and *Útvegur* after 1976.

Brill (*Scophthalmus rhombus*):
This species has only once been reported in Icelandic waters and it is therefore unlikely that the foreign fleets did catch any there. The catches are either misidentification or not fished in Icelandic waters. Again, the trawlers probably took a few hauls in home waters after returning from Icelandic waters before landing and reported all the catch as coming from Icelandic waters.

Flounder (*Platichthys flesus*)
Was first reported in Icelandic waters by scientists in 2000 and was therefore either a misidentification or not caught in Icelandic waters (same as above for brill).

Sole (*Solea vulgaris*)
Has never been reported in Icelandic waters by scientists and was therefore either a misidentification or not caught in Icelandic waters (same as above for brill).

Turbot (*Psetta maxima*)
The turbot is not native to Icelandic waters but is a rather frequent visitor there; usually only one or few specimens are caught at a time. It is therefore not likely that the reported catches by the foreign fleets were actually fished in Icelandic waters. They could be misidentifications or have been fished in other waters (same as above for brill). The minor reported Icelandic catches are from *Útvegur*.

Flatfishes (unidentified)
This can be many species. Landings of flatfish prior to WW II were often not separated by species and can therefore contain many common species; however, usually halibut and plaice were reported separately. Foreign catches were also unidentified in some cases but could usually either be assigned to long rough dab (as for the English fleet) or Greenland halibut (as for the English and German fleets). For the period under consideration, most of the unidentified flatfish catches could be assigned to some species, but from 1955 to 1966 some small amounts were still left behind in the unidentified flatfish group. Unidentified flatfish were also given in *Útvegur* after 1986.

Freshwater and anadromous fish (including aquaculture)

Abalone *(Haliotis rufuscens)*
Recent experiments have been conducted on abalone in mariculture. About 8 t were harvested in 1999 and an estimated amount of 23 t in 2000 (Jóhannsson, 2000).

Salmon (*Salmo salar*)
Native to Iceland; both in aquaculture and the wild. Some gillnet fisheries were conducted for salmon until 1998. Now all of the fisheries are either sport or gillnet fisheries in rivers. The sport catch is about 28000 individuals while about 6,660 are fished with gillnets. The gillnet catch has been declining from about 20,000 individuals in 1975, while the long term average is stable in sport fisheries (Guðbergsson, 2000). Historical catch statistics are quite unreliable since catches of freshwater fishes were not mandatory. Salmon farming began in 1984 and has leveled off at around 3,000 t/year. Total catch before 1960 was estimated from known years, catch from 1960 to 1996 is from *Bulletin Statistique*, and thereafter from Guðbergsson (2000).

Arctic char (*Salvelinus alpinus*)
Native and common in Iceland; both pure freshwater and anadromous stocks. Popular in aquaculture recently. The wild catch is included in 'unidentified trout'. Tonnage harvested is from FAO until 1996, but from Guðbergsson (2000) afterward.

Brown trout (*Salmo trutta*)
Native and common in Iceland; both pure freshwater and anadromous stocks. The wild catch is included in 'unidentified trout', but the amount harvested in aquaculture is reported separately and is low compared to the other trout species involved in aquaculture.

Rainbow trout
(*Oncorhynchys mykiss*) Not native to Iceland but used in aquaculture. Some have escaped and are to be found wild in a few streams.

Trouts (unidentified)
Arctic char and brown trout. This catch is obviously only an estimate since it has been exactly the same for long periods. This is, however, the only estimate we have on the wild catch of trouts in Iceland. This is probably the total catch estimate from all Icelandic fisheries on these, either fished for sport in rivers and lakes, or fished commercially by gillnets in lakes or in shallow waters. The anadromous species are not fished with the saltwater species and it is not mandatory to report landings, as required for saltwater species. There are therefore large uncertainties about the fishery for this species. Catch information is from *Bulletin Statistique* (preferred) and FAO. The 1997 to 1999 catch is estimated from previous years.

European seabass (*Dicentrarchus labrax*)
A warm water species not native to Iceland, but recent aquaculture experiments using geothermally heated waters. Production numbers are from Jóhannsson (2000).

River eels (*Anguilla anguilla* and *A. rostrata*)
Native to Iceland; both American and European eels considered to be found. Fished in traps in streams. There have always been some catches, but probably low except in 1961 and 1962 when experiments were conducted with live eel exports (Gunnarsson *et al.*, 1998).

Freshwater fishes (unidentified)
The only freshwater species found in Icelandic waters are the species mentioned above, plus sticklebacks (*Gasterosteus aculeatus*). Germany reported 2 t of unspecified freshwater fish in 1976.

Invertebrates and algae

Spider Crab (*Hyas araneus*)
Common in shallow waters all around Iceland. This species is a frequent bycatch in other fisheries (mostly for scallop and gillnet) but is rarely retained. An experimental direct fishery was conducted between 1985 and 1987. Information on catches is from *Útvegur*.

Spiny Crab (*Lithodes maia)*
A common species in the warmer Icelandic waters. Sometimes bycatch in other fisheries and usually discarded; a small amount reported in 1994 (*Útvegur*).

Crabs (unidentified)
Small amounts of unidentified crab were reported by Germany and Belgium. Probably spider crab.

Norway lobster (*Nephrops norvegicus*)
Common in the warmer Icelandic waters. Sustains considerable fisheries and is the most valuable species in Icelandic waters by weight. The only Icelandic fishery that is partly managed by obligatory discarding since females cannot be retained (presumably they survive the handling). Most of the fishery is direct but there is also small amounts caught as bycatch in other fisheries. Experimental lobster fisheries were first conducted in 1939, but were not continued. Some low scale fisheries began in 1951, and large-scale fisheries did not begin until 1958. No information was found on the catch before 1958; presumably it was low. Total catch information is available in *Nytjastofnar* from 1958 to 1976 and from *Útvegur* thereafter.

Shrimp (*Pandalus borealis*)
This is the only commercially exploited shrimp species in Iceland. Sometimes a very small part of the catch is *Pandalus montagui*, however, they are never separated in reports. The shrimp fishery in Icelandic waters is by three distinct fisheries on separate stocks (Skúladóttir and Pétursson, 1999), consisting of stocks inshore, offshore and on the Dhorn Banks between Iceland and Greenland. Inshore shrimp is fished by small local boats in bays and fjords in northern and western Iceland. It is assumed that separate stocks are found in each bay (and separated from the offshore shrimp). Experimental fisheries for inshore shrimp began in 1924 but failed. The second attempt began in 1939 and some amount has been fished annually since. Records are, however, only available since 1955, but fisheries were low before. The offshore shrimp is fished by larger boats in deep waters north of Iceland (within Icelandic 200 mile EEZ and ICES area Va). The same boats target the Dhorn bank shrimp stock close to the Greenlandic EEZ (within Icelandic 200 mile EEZ but in ICES area XIVb). Experimental fishery for offshore shrimp began about 1976 but was low until 1983. Recently Icelandic shrimp boats have been shrimp fishing in international waters on the Dhorn banks and within Norwegian EEZ in the Barents Sea. Landings prior to 1977 are from *Nytjastofnar*, but thereafter from *Útvegur*.

Pagurus crabs (*Pagurus* spp.)
Two species are common in Icelandic waters, *P. bernhardus* and *P. pubescens*. Except for a total of 2 t reported by Belgian boats in 1966 and 1968 they have never been reported in landings in Icelandic waters. They are, however, common bycatch in scallop fisheries, but never retained.

Crawfish (*Palinurus* sp.)
Has never been reported in Icelandic waters by scientists therefore the 6 t reported by France in 1953 is either a misidentification (possibly Norway lobster) or was not caught in Icelandic waters (same as above for brill).

Horse mussel (*Modiolus modiolus*)
Common in Icelandic waters, but has only been reported in a very small amount in 1991 (*Útvegur*).

Ocean quahog (*Arctica islandica*)
Common in Icelandic waters and has been harvested substantially for export in recent years. Previously, small boasts did harvest this species for bait, but there are no data on the amount. Some is also caught and discarded by scallop boats. Catch information is from *Útvegur*.

Scallop (*Chlamys islandica*)
Common in Icelandic waters and has been harvested there since 1969, mostly in Breidafjordur Bay in W. Iceland since. The only scallop species commercially exploited in Iceland. Information on landings before 1977 is from *Nytjastofnar*, and afterwards from *Útvegur*.

Squid (unidentified)
Many cephalopod species have been reported in Icelandic waters, however they are not fished regularly. Very little is known about them and studies are scarce (Bruun 1945, Jónsson 1980, Jónsson 1998). Occasionally large amount of European flying squid (*Todaroides sagittatus*) are noticed and some is fished, mostly for bait by specialized handlines. These are not considered resident stocks, but from deeper waters outside the Icelandic EEZ. Some catches have been identified as *Loligo* spp. However, these have not

been identified in Icelandic waters by scientists, so this identification is somewhat dubious. The landings history of squid is from *Ægir* between 1955 and 1967, then there is no catch for some years, but landing statistics after 1978 are from *Útvegur*.

Whelk (*Buccinum undatum*)
Common all around Iceland and has recently been harvested with traps. Discarded in scallop fisheries. Catch information is from *Útvegur*.

Mollusks (unidentified)
Belgian boats reported 1 t of unidentified molluscs in 1972, which might be scallop.

Sea cucumber (unknown)
Most probably *Cucumaria frondosa*. Common all around Iceland and often discarded bycatch in dredge fisheries; small amounts reported in 1995 (*Nytjastofnar*).

Sea urchin (*Strongylocentrotus droebachiensis*)
Common all around Iceland and harvested for their roe in recent years. Most of the harvesting is by dredges but some smaller amounts also by divers, the latter is not reported. The fishery collapsed after 1996 due to marketing problems. *Echinus esculentus* is also found in Icelandic waters, but is not as common as *S. droebachiensis* and is not targeted. Discarded in scallop fisheries. Information on catches is from *Útvegur*.

Invertebrates (unidentified)
Catch of 83 t of unidentified invertebrates reported by German boats in 1965, could be Norway lobster.

Shellfish (unidentified)
Some small amounts reported by foreign fleets from 1953 to 1961, could be scallop, but also possibly other species.

Brown Seaweeds (*Ascophyllum nodosum*)
Harvested by farmers for various uses, but mainly food for livestock. Commercially exploited on and off since 1939, reduced and used as food for livestock and recently for algin production. Information on brown seaweed harvest is only available from FAO and *Bulletin Statistique*, the latter was preferred when data were available in both sources.

Kelp (*Laminaria digitata*)
Basically the same as brown seaweed but also often used as fertilizer. Information only available in *Bulletin Statistique*.

Marine mammals

Blue whale (*Balaenoptera musculus*)
Blue whales were a large part of the catch prior to WW II (Sigurjónsson and Hauksson 1994). Between 1948 and 1960 between 5 to 33 individuals have been caught annually, and hunting of blue whales was banned in 1960. Information on numbers caught is from *Nytjastofnar*, and the average weight used to convert this to weight is from Trites and Pauly (1998). This source was used also to estimate weight of all other marine mammals.

Fin whale (*Balaenoptera physalus*)
The fin whale was an important target species in the period after WW II. Harvested until 1989 when whaling was banned in Iceland. Information on numbers harvested is from *Nytjastofnar*.

Harbour porpoise (*Phocoena phocoena*)
These are often caught as bycatch in gillnet fisheries. A total of 3 animals were reported in 1982 and 1990 (FAO). However, the actual numbers caught is much higher.

Humpback whale (*Megaptera novaeangliae*)
A few were caught after WW II (*Nytjastofnar*), but the catches were higher prior to the war.

Killer whale (*Orcinus orca*)
The killer whale has not been hunted systematically like the large whales. A few have been caught live for aquariums however,. This is probably what happened to the 9 animals reported in 1981 and 1982 (FAO).

Minke whale (*Balaenoptera acutorostrata*)
Minke whales have been hunted during most of the 20th century, although official records are only available after 1973 (*Nytjastofnar*). Prior to this, Icelandic catch was estimated by Sigurjónsson (1982) and the Norwegian catch was estimated by Víkingsson and Sigurjónsson (1998). Minke whales were caught by small boats all around Iceland, in comparison to the hunting of other baleen whales that was done on large boats from only a few stations. Minke whaling has not been permitted since 1985.

Sei whale (*Balaenoptera borealis*)
The sei whale was targeted after WW II, catches prior to that were probably lower because of the relative small size of the whale compared to the blue and fin whale. Information on numbers harvested is from *Nytjastofnar*.

Sperm whale (*Physeter macrocephalus*):
The sperm whale has been caught in large numbers in Icelandic water during the 20th century. Only immature males are found in Icelandic waters. Numbers harvested is from *Nytjastofnar*.

Toothed whales (unidentified):
These are probably medium sized species such as the pilot whale (*Globicephala melas*) and the bottlenose whale (*Hyperoodon ampulatus*), or possibly even dolphins (*Lagenorhynchus albirostris* and *Lagenorhynchus acutus*). They are not harvested systematically but for some reason a total of 10 animals were reported in 1989 and 1990 (FAO).

Seals (several species)
Only 2 species of seals are native to Iceland, grey seal (*Halichoerus grypus*) and common seal (*Phoca vitulina*). Greenland seal (*Phagophilus groenlandicus*), ringed seal (*Phoca hispida*), and hooded seal (*Cystophora cristata*) are frequent guests in the winter, while bearded seal (*Erignathus barbatus*) and walrus (*Odobenus rosmarus*) are rarer. The number of seals are split into different species and also pups and adults. However, they are all combined when the biomass in catches is calculated. It is not unlikely that more seals were killed than accounted for here, since reporting them was not mandatory until recently. All the information on seal kills is from *Nytjastofnar*.

DISCARDS AND UNREPORTED CATCH

Discards are a very controversial issue in Iceland and no conclusive scientific quantifications are available on their magnitude. However, much can be derived from the history of Icelandic fisheries. For example, species living in deep waters have been subjected to very few fisheries until recently, therefore, we can assume that discards and misreporting are relatively non-existent in early years. When effort began to move to deeper waters and there was still no reported landings on these species, they must have been discarded. This has changed in recent years given that some catches have been reported so discarding has probably been reduced.

Many shallow water species, especially long rough dab and starry ray, have always been discarded in large amounts due to their low value. However, with the implementation of the ITQ system they were retained more since they did not have a TAC. The ITQ system has therefore reduced discarding or even created target fisheries on species without a TAC. The effect is opposite on those species with a TAC, especially if they are also of high value. Since the value of quota is high for many species and some boats have much more fishing capacity than allowed by quotas, they tend to highgrade the catch: small fish are discarded (which is illegal) or some species are falsely reported as others. There are rumors going around ranging from virtually no discarding by some fleets to thousands of tonnes annually by others. There are also a few cases where boats have been caught discarding, or are strongly suspected of doing so from indirect clues (such as comparing the catch with and without on-board observer).

Fish species in which a proportionally large part is used for local consumption are a special case. These are mainly haddock, halibut, skate and Greenland shark (*Útvegur*). These are all eaten by the fishers at sea and therefore not reported, which probably causes minor underestimates of actual catches. The fishers can also take some amount home for the family, usually one bag of fillets However, some of them take more, and some have even been caught in the act. These amounts are not reported in any landing statistics (both before and after the ITQ system was established). It is therefore quite possible that the part that goes to local consumption is underestimated and actual landings are higher than reported. Estimates of this form of local consumption can be made by assuming that the 5,000 fishers land 50 times per year, each taking 20 kg of ungutted haddock home. This makes a total of 5,000 t/y or about 12.5% of the total reported haddock catch. The part that goes to export, which is more than 99% for most species, is much better monitored, from the place of landing, through processing to the final exporting of the product.

From this knowledge, each species was given an estimate of discarding by decade. These estimates were categorized as low, low/med, med, med/high and high (Pitcher and Watson, 2000). The problem was then to assign some numbers (percentages) to these categories in order for this to be useful in stock assessment. The percentages used (Table 1) were based on several studies on discarding in Icelandic waters (Agnarsson 2000, see Appendix IV). These are percentages of the average catch and were assumed constant from 1950 onwards.

It is mandatory to report all landings in Icelandic waters and Icelandic registered boats are mandated to report all of their catches in distant waters. Government officials and official weights at all ports of landing ensure this, and this also

ensures that illegal fishing is minimal. The only exceptions from this mandated reporting are the lumpfish fisheries and fisheries for anadromous species in very shallow marine waters or in freshwater. Except for lumpfish, these numbers are low, but should still be evaluated with caution. All species have to be identified when landed; nevertheless there is always catches reported as unidentified, or as a group, such as flatfish or shellfish. There is no information on what these groups contain, but they might include species fished in low quantities during each trip. If they contain the commercially important species the amounts can be ignored since the values are low. However, if they contain species whose reported catches are low, they can skew the picture since they would be a large portion of the actual catch.

Table 1. Assigned percentage discards (range and mean) by estimated discard category, based on Agnarsson (2000).

Category	Discard range (%)	Average discard rate (%)
Low	0-5	2.5
Low/Med	5-10	7.5
Med	10-15	12.5
Med/High	15-25	20
High	25	50

RESULTS

Although it is beyond the scope of this paper to analyze in detail the data that have been gathered, preliminary results are presented and discussed in order to illustrate some general trends in the fisheries in Icelandic waters.

There has been a general increase in effort from 1965 to 1990 (Figure 3), reflecting a two to threefold increase in total number of days spent at sea by Icelandic boats, and a doubling of engine power spent per day at sea (see also Tyedmers, this volume). Around 1950 about half of the effort was spent by trawlers. This decreased during the 1960s when purse-seiners accounted for most of the effort. After the collapse of the herring stocks the trawlers took over again as the predominant boat type, especially after the stern trawlers began operating after 1970. Horsepower-sea-days also increased for other gear categories as the boats became larger and more powerful (Figure 4). There is also a sharp increase in horse power-sea-days by the smallest boats (handliners), after 1986 (Figure 5).

At first glance, the trend in total catch in Icelandic waters seems to fluctuate quite strongly (Figure 6). This is largely due to only two species; herring and capelin. Trends in catch for other species are relatively smooth. Catches of small pelagics increased after 1960, during the herring years. After the herring stock collapsed it took some years for the capelin fishery to establish itself. The capelin stock does fluctuate widely, mostly due to variability in recruitment and its short lifespan (catch is usually only based on two year classes).

Catch of other species has been remarkably constant since 1950. Before 1975 Icelandic boats took more than half of the cod catch in Icelandic waters, but foreign boats took more than half of the catch of other species. After the extension of the EEZ the foreign catch declined to low numbers, but Icelanders increased their catches to amounts similar to all foreign catches combined.

Icelandic catch in distant waters fluctuates greatly (Figure 7). Cod and redfish fisheries in distant waters were extensive in the first decade because trawl fisheries were limited by regulation in Icelandic waters. Herring fisheries were considerable in distant waters from 1965 to 1975, due to the collapse of the stocks in Icelandic waters. This was followed by a period when Icelandic boats did not venture beyond Icelandic waters. Their outward expansion, however, began again around 1995, when severe measures to reduce the effort in Icelandic waters were implemented.

The total catch per total effort is actually about the same in 1950 and 1997 (Figure 8). However, this is misleading due to the influence of herring and capelin. When these species are excluded, a downward trend, especially for cod, becomes obvious. If we look at catch/effort by species and fishing gear (Figure 9), the changes with time are more variable. The declining trend is obvious for gear fishing cod. However, most effort in the early years was directed towards cod, whereas in later years when the ITQ system was put in place, many boats fished for other species and actively avoided cod, which makes their effort for cod impossible to separate from the total effort for that gear type in the data available. There is also a decline in haddock and saithe catch/effort. However, this is less clear since many fishing gears do not show any obvious trend. Redfish show a very different trend in that catch/effort increases for many fishing gear types in more recent years. Halibut shows an obvious decline in catch/effort by most fishing gears. There is also a decline in catch/effort of the plaice before 1970, which then fluctuates after that year. The high catch/effort before 1970 might reflect more the uncertainty in assigning the catch by gear and estimating the effort for those early years.

DISCUSSION

The species mentioned above show differing trends, and direct us to different aspects of the data that should be questioned. Does the catch/effort trend of cod really reflect stock size? Why is the catch/effort trend by fishing gear so different for haddock and saithe? Why such a big difference in catch/effort for plaice before and after 1970? These questions are not addressed in the present report as this paper is only meant to explain the making of the database and to give a short overview on the subject.

In the beginning of the period under consideration (1950 to present), the fisheries around Iceland were already well developed. Trawlers had been operating there for more than 50 years, Icelandic boats had already ventured to distant waters, and foreign fleets had been fishing in Icelandic waters causing conflicts for more than 500 years. To extend this analysis to the early years of the 20th century, and even further to earlier centuries, would be extremely interesting, although resource intensive. It can also be argued that it would be more important to get more accurate information for the period after 1950 before earlier years are visited. Several gaps in knowledge have been identified. For instance, we do not know effort and catch by gear for major species before 1966 (with exceptions), we do not know catch by gear for species of lesser importance before 1977, and we do not know the total catch of many minor species for long periods. Furthermore, we have very little reliable information on discarding. Information on discards and other unaccounted mortalities due to the fisheries would be like locating an undiscovered stock of herring. This type of information is probably not available in printed format, and would therefore be difficult to estimate. The most promising way is probably to interview old fishers on what actually happened in the past. However, this too would be time consuming and costly.

Time consuming and costly or not, it is vital for a country as dependent on fisheries as Iceland to have access to information and a good understanding about its past fisheries. Information on fluctuations of catch, effort and catch/effort from days gone by are directly useful for today's stock assessment and can only help to improve our fisheries management. I would argue that this is especially important today given that new generations of fishery scientists are taking over who otherwise might lack the understanding and knowledge of past stock structure, biomass, fisheries and ecosystems.

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APPENDIX I: EXPLANATION OF TABLES PRESENTED IN DATABASE (AVAILABLE FROM AUTHOR AND *WWW.FISHERIES.UBC.CA/PROJECTS/SAUP*)

Icelandic effort

This worksheet provides information on various aspects of the Icelandic fishing fleet, such as effort, weight of boats and engine power. Many tables are provided but the first (Table 1.1) should be of primary concern. It separates the fleet into several categories based on the type of fishing gear used and by type of boat. Tables should be self-explanatory.

Table 1.1
Represents HP-sea-days, estimated directly or indirectly from other tables.

Table 1.2
Sea-days for the same boat categories. Numbers are either directly from the data sources or estimated from others.

Table 1.3
Average weight of boats in these categories, also either directly from the sources or estimated indirectly.

Table 1.4
Engine power by boat category. This number is not given directly in any source but estimated from the average weight and a function on HP vs. weight of boats.

Table 2.1
Number of boats in various size and type categories, sometimes this had to be used to estimate effort since no other information was available.

Table 2.2
Total weight of the boats in the same categories as table 2.1.

Table 2.3
Calculated average weight per boat from Tables 2.1 and 2.2.

Table 2.4
Sum of Tables 2.1 and 2.2.

Table 3.1
Information available on number of trips per boat/gear type.

Table 3.2
Effort in sea-days given in *Bulletin Statistique*.

Table 4.1
Total engine power in HP of each boat size class as given in *Útvegur*.

Table 4.2
Average HP per boat (table 4.1 divided by table 2.1).

Table 4.3
Same information as table 1.4, using a different function (this was however not used further.

Table 4.4
Calculations used to find the best functions in for tables 1.4 and 4.3.

Table 5.1
Information on crew-sea-days as stated in *Útvegur*. This was not used further (as per Table 4.3).

Table 5.2
Information on the average age of the fleet by size category.

Table 5.3
Information on the number of boats that used each fishing gear.

Table 5.4
Information on the manpower in the fishing sector.

Table 5.5
Information on effort.

Table 5.6.
Information on the total tonnage of size classes adapted from *Ægir* .

Table 5.7
Information on the number of boats in the same classes.

Table 5.8
Information from *Ægir* on the herring and winter (cod) fisheries. These were used to estimate the effort and catch by gear of the fleets. Calculations are also shown.

Table 5.9
Information on effort.

Icelandic Catch

This worksheet contains information on the landings of the Icelandic fleet.

Table 1
Summary of catches by Icelandic boats in Icelandic waters, and the numbers used in subsequent analysis.

Table 2
Summary of catches by Icelandic boats in distant waters.

Table 3
Data obtained from the various data sources, which were used to construct Tables 1 and 2. Catch by gear in Table 1 is either directly from given sources or when information was not available, estimated from known years. Cells where the numbers were estimated are orange as opposed to the normal yellow. The majority of groundfish catches in distant waters are fished by trawlers (not decked boats), while the pelagic catch is

fished by decked boats using both purse-seines and mid-water trawls. The information in each column is:

Column

1 Common name of the species.
2 Fishing gear.
3 Boat type, UMB = undecked boats, DMB = decked boats, SDT = side trawler, STT = stern trawler, OB = other boats such as research vessels, and all = all boats combined.
4 Group name according to the SAUP.
Information source (Y = summary of catch in distant waters, Z = summary of catch in Icelandic waters). Fiskifélag is both information in *Ægir* (pre 1977) and *Útvegur* (after 1976). Bull Stat is from total catch tables in *Bulletin Statistique*, but Bull Stat (effort) is from tables on catch by gear.
5 The 200 NM EEZ fished in, catches in the past are given in the EEZ that they would have been in today, although at the time they occurred in international waters.
6 This is the area code according to ICES, NAFO or FAO, the FAO code was only given when there was not possible to identify according to ICES or NAFO code.
7 Notes

The data sources in Table 3 did not agree on numbers in many cases. Landing numbers that differed substantially from numbers used were colored orange, number that differed somewhat were colored gray and numbers that agreed (give or take a few %) were not colored. Note that many Icelandic sources give the total catch in all grounds and therefore numbers are higher than when catch is only given for Icelandic grounds. These were not colored unless they still differed from the catch in Icelandic grounds after the catch in distant waters was subtracted (these calculations are not shown). The sum of all the fishing gear in tables 1 and 2 always gives the total landings.

The species names are rather straightforward, and if there are some uncertainties about them the scientific names are given below under the heading "Species-information". However, some of them have to be clarified. Some similar species were not separated in catches until recently (e.g., the catfish species, redfish species, skates and herring stocks). In these cases the group name is given first, and the species identification name in brackets following (e.g., catfish (spotted), redfish (Sma)). The meaning of the abbreviations for herring stock and redfish species are as follows: Herring stocks: Ic = Icelandic, Nss = Norwegian spring spawning, all = Ic and Nss, o = other (such as the North Sea and Newfoundland stocks). Redfish stocks and species: Smo = *Sebastes mentella* oceanic, Smed = *Sebastes mentella* demersal, Sma = *Sebastes marinus*, Sv = *Sebastes viviparous*, dem = *Sebastes mentella* demersal *and Sebastes marinus*, all = all species or unknown.

Foreign fleet

In this worksheet all information is gathered on the effort of the foreign fleets operating in Icelandic waters, as well as on the engine power and gross tonnage of the fleets. The effort units used are in the yellow lines in the table and numbers within these that are estimated from other effort units are coloured orange.

Foreign catch

This worksheet contains a table on landings by foreign fleets in Icelandic waters, by fishing gear when available. These are from *Bulletin Statistique* and later from ICES, except for some corrections by Hjörleifsson (1997) and Hjörleifsson et al (1998). *Bulletin Statistique* contains two tables on catch, one is total catch the other is catch by known effort. The catch numbers used are either the known catch by gear or total catch minus the known catch by gear. It is therefore possible to sum up the numbers in this table. The catch by gear in this table corresponds to the given effort in the 'For-eff' sheet.

Countries fishing are according to *Bulletin Statistique*. 'Germany' includes West Germany prior to reunification as well as complete Germany after reunification. East Germany is reported separately, their catches were much lower. USSR is the Soviet Union and Russia, fleets from other former Soviet states have not been reported in Icelandic waters, although boats from the Baltic states are now fishing for oceanic redfish just outside the Icelandic 200 mile EEZ.

Species groups (e.g., shellfish, flatfish or salmonids) are colored in yellow for clarification. Dubious species, i.e., species that are not found in Icelandic waters, or are rare guests are colored green for clarification.

Species Information

Listed below is the information on the species or species groups by column.

Column

1 Common name.
2 Icelandic name.
3 Scientific name.
4 Species numerical code Number according to the Marine Research Institute in Iceland.
5 Status: native, questionable, introduced or not present (Fishbase nomenaclature).
6 Commercial importance (Fishbase nomenaclature).
7 Aquaculture (Fishbase nomenaclature).
8 Regulations (Fishbase nomenaclature).
9 TAC: When a TAC was first established on the species.
10 Abundance (Fishbase nomenaclature).
11 Price per kg: All catches, from *Útvegur* in Icelandic krónur.
12-16 Estimates on human induced mortalities other than given in landings.
17-20 Average depth range from annual trawl survey conducted since 1985

Some information in this worksheet is highly subjective, such as when considering if a species which is commercially important is highly commercial or just commercial, or if the species is considered to be fairly common, common or abundant. There are no formal studies on these (to clarify these qualitative terms). Perhaps some type of index could be made, to objectively evaluate these issues, but this would require much more work and this is outside the scope of this project. Therefore at present, the numbers are only based on the authors' options and experience both as a fisher and as a fishery scientist. The same is also true for the estimates of discards.

Oil Consumption

This worksheet is a summary of various studies on the oil consumption of the Icelandic fishing fleet (see also Tyedmers, this volume).

Various

This worksheet contains various auxiliary tables that were useful for this analysis. They are included here for completeness.

APPENDIX II: SOURCES OF FURTHER INFORMATION ON THE WEB

www.fauna.is Pictures of Icelandic fish species, as well as other animals.

www.fiskifrettir.is (Fishing news): A newspaper on Icelandic fisheries; available in Icelandic only.

www.fiskistofa.is (Directorate of fisheries): Information on various aspects of the Icelandic fishery system, available in Icelandic and English. However, the Icelandic is more detailed, which, among other things, provides up to date information on all landings in Iceland.

www.hafro.is/hafro (The Marine Research Institute): Information on various aspects of the marine environment and fisheries in Iceland. In Icelandic and English, however the Icelandic r is more detailed. Information on the latest stock assessments can also be found here (www.hafro.is/hafro/Radgjof/2000/summary.html) as well as a searchable database on articles by scientists at the institute (www.hafro.is/hafro/Bokasafn/heimildir.e.cgi).

www.hi.is (University of Iceland): The largest university in Iceland's website address. Many of the departments in this university deal with various aspects of fisheries. It also has a graduate program in fisheries science (Fisheries Research Institute). Most information is only in Icelandic.

www.kvotathing.is Information on quota prices Icelandic only.

www.mar.is Information source, Icelandic only.

www.rfisk.is (The Icelandic Fisheries Laboratories): Information on research in the Icelandic fishing and processing industry

www.rsf.is (Fish markets): Up to date information on sales (amount and value) and availability in Icelandic fish markets since 1992. Both in Icelandic and English

www.sigling.is (The Icelandic Maritime Administration): Information on ships, lighthouses, harbours, etc. Mostly in Icelandic.

www.statice.is (Statistics Iceland): Very good site with statistical information from Iceland, includes among other things detailed information on fisheries in 1998 and 1999. Both Icelandic and English, although the Icelandic site is more detailed.

www.stjr.is/sjr (The Ministry of Fisheries): Information on various aspects of the Icelandic fishery system, in Icelandic (more details) and English. Fishery regulations can be found in the Icelandic version. The Ministry has sites with basic information on fisheries (www.fisheries.is/index.htm and www.stjr.is/interpro/sjavarutv /english.nsf/pages/front-c)

*www.ths.is*_(National Economic Institute): Information on various aspects of the Icelandic economy. Both Icelandic and English, the Icelandic is more detailed.

www.unak.is (University of Akureyri): A university situated in Northern Iceland. It is unique in Iceland since it offers an undergraduate program in fisheries science (Faculty of Fisheries). Mostly in Icelandic.

www.veidimalastjori.is (Directorate of Freshwater Fisheries): Information on freshwater fisheries and aquaculture, mostly in Icelandic.

www.verdlagsstofa.is Information on fish prices, Icelandic only.

APPENDIX III: MAJOR CHANGES IN CATCHABILITY OF FISH IN ICELANDIC WATERS (TIMELINE)

Below is a summary of circumstances that have influenced the catchability of fish in Icelandic waters. Some of them decreased the catchability, such as the extension of the EEZ, while others increased it, such as improvements in fishing gear design. In many cases the exact year they were first used is unclear, but they are given a year thought to be close to when they were first used. In addition there have been many and constant changes in the design of fishing gears. Many of these are probably gradual and therefore difficult to pinpoint in time, others are probably not. Further studies would be needed to pursue this problem further.

1950 Radar and sounders become common in use by trawlers; positive influence on catchability of groundfish since grounds became easier to find. EEZ extended to 4 miles along the north coast. This acted as a negative influence on foreign fleets and Icelandic trawl and Danish seine fleets since many grounds became off limits.

1952 EEZ extended to 4 miles all around Iceland; a negative influence on catchability of foreign fleets and Icelandic trawl and Danish seine fleets since many grounds became off limits.

1954 Nylon commonly used in trawl and gillnet fisheries; positive influence on the catchability of groundfish since the gear was lighter and much more reliable. 110 mm minimum mesh size enforced in trawl and Danish seine fisheries, negative influence for on the catchability of groundfish.

1957 Nylon commonly used in purse seines, positive influence on catchability of herring, since the gear was lighter and much more reliable.

1958 EEZ extended to 12 miles, a negative influence on foreign fleets and the Icelandic trawl and Danish seine fleets, since many grounds became off limit.

1961 Sonars and Powerblocks became widely used by purse seiners, positive influence on catchability of herring.

1963 120 mm mesh size enforced. Negative influence on catchability by trawl and Danish seine, since smaller fish escaped.

1972 EEZ extended to 50 miles, negative influence on catchability by foreign fleets since many major grounds became of limit.

1975 EEZ extended to 200 miles, most foreign fleets were expelled from Icelandic grounds.

1976 135 mm mesh size enforced. Negative influence on catchability by trawl and Danish seine, since smaller fish escaped.

1977 155 mm mesh size enforced in most grounds. Negative influence on catchability by trawl and Danish seine, since smaller fish escaped.

1978 Loran navigation system positive influence on catchability of most species since grounds were easier to find.

1979 Lead used instead of stones to sink gillnets, leading to 20 – 30% increase in catchability of cod, no increase for saithe.

1983 Computerized jigging reels, positive influence on handline fisheries.

1984 ITQ in groundfish fisheries, negative influence on catchability of species that do have a TAC (due to highgrading), but positive on species that do not have a TAC (species retained more).

1988 Rockhoppers, positive on bottom trawl fisheries since they could operate on rougher grounds and less time had to be spent fixing damages gear.

1991 Computers (MACSEA), positive on most species since it became easier to find grounds and store data on where good fishing took place.

1993 GPS, positive on most species, especially groundfish since it became easier to find grounds.

1993 D-graphic of the sea bottom on a computer screen.

APPENDIX IV:
STUDIES ON DISCARDING IN ICELANDIC WATERS

Summary of Results (roughly translated from Agnarsson, 2000)

1982 Study by the Marine Research Institute on decked boats comparing vessels fishing in the same area: 2/3 of undersize cod was discarded, this equals 6% of catch tonnage.

1987 Study by the Marine Research Institute on trawlers (same method as above): Similar as above or 5%.

1992 Study by the *Marine Research Institute* on Ocean redfish trawlers. 16-17% of catch discarded.

1994 Study by the *Marine Research Institute* on Ocean redfish trawlers. Similar as above.

1995 Study by a commercial fishing company (Venus) on Ocean redfish trawlers. Similar as above. (This species is mainly discarded since it frequently has a parasite that makes it low value, the parasite is much rarer in other species-

1990 Questionnaire to fishers by SKÁÍS : Questions to 900 fishers (300 on trawlers, 300 on decked boats, 300 on undecked boats), 591 answers back. From this it was estimated that about 40 thousand tonnes of groundfish (consisting of all species grouped into this category) were discarded in 1989. This represents about 6% of total groundfish catch. Discarding of cod and haddock was 2 times higher in trawlers than.

1992 Catch composition compared in gillnet boats with and without observers: 1 to 2% discards by weight (0.92% average). (This has been considered unrealistically low).

1992 Fishermen asked (confidentially) about discarding (occurrences/practices) on trawlers: Discarding of groundfish was 4.1% by weight, highest for redfish (12.9%), lowest for cod and saithe (0.4 and 0.2%, respectively). Other species: haddock 2.2%; Greenland halibut 2.2%; plaice 2.4%; other flatfish 17 tonnes and various catch 72 t (no percentage is given for the last two). Redfish was not identified to species in this study (however this is not Oceanic redfish as above). Only small redfish were discarded, they might have been small sized commercially exploited species (*Sebastes marinus* and demersal *S. mentella*), but were more likely *S. viviparous* which is a small species not utilized until more recent years.

2000 Catch composition compared in 4 gill netters and 4 Danish seiners with and without observers: Fewer small sized fish of the same species were encountered on those boats without observers, no quantitative results.

LANDINGS AND EFFORT IN NORWEGIAN FISHERIES

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ABSTRACT

The present report documents official Norwegian fisheries catches (tonnage and value) from 1950-1999 for principal commercial species, based on data from the Directorate of Fisheries, Norway. Some information on broad spatial breakdown of catches are also available. Furthermore, fishing effort by major gear types, listing number of sea-days, average vessel length and tonnage, and number of vessels are also summarized, although temporal coverage varies by gear type and only starts in the late 1960s.

INTRODUCTION

The main component of this report are the data files (*www.fisheries.ubc.ca/projects/SAUP*) which contain annual Norwegian landings and fishing effort. The landing data are from 1950 onward, while the effort data are more limited and start in the late 1960s. The following text assesses the reliability of these data. Given that the data have been divided into landings and effort, we will maintain this distinction through-out the discussion.

Fisheries data are often thought of as being unreliable because there are often substantial incentives to cheat. These incentives change over time due to the situation that the fishers are in. For instance, fishers might over-report landings to establish a track record, but might under-report landings if they are bound by a quota. As well, data are rarely collected without a purpose, this purpose might influence both the resources spent to obtain the data, and the reliability of the data.

While we will discuss factors that influence the reliability of data in the different sections, a few general trends are useful to note. Fishing has always been important along the Norwegian coast. Because of this, sporadic records of landings, and effort, for some of the main fisheries can be found from several centuries back. However, the longest unbroken record, to our knowledge, is from the 1950s onward. The early records have little direct use, as the resources spent on collecting them were limited. To a large extent, this also holds true well into the 1960s. Because of the limited jurisdiction even of coastal waters, and because fish stocks appeared unlimited, management was not an issue. The invention and rapid introduction of the power block changed this, as it was quickly shown that one could fish down the herring stocks. During the 1950s and 1960s, the North Sea herring and then the Norwegian Spring Spawning herring were fished down by local fishers and international fleets (for overview of herring fisheries see Bjørndal *et al.*, 1999). Because the records had limited direct use until the late 1960s, they most likely are relatively reliable, because there was little incentive to misreport. In 1973 a licensing scheme was introduced for the purse seine gear, and after the extension of the EEZ to 200 miles in 1977, management schemes were introduced in most fisheries. Initially, these schemes were mostly a combination of limited entry and group quotas which then increased to tighter individual vessel quotas during the 1990s. As these management schemes made it more profitable to misreport, it is likely that the reliability of the landings data became poorer from the late 1970s. However, to some extent this may be countered by more resources being spent collecting the data.

Government support of fisheries also has a long history, and at least dates back to the temporary measures implemented in the Lofoten fishery in the 1930s. In the late 1960s these support measures became more permanent and continued into the 1970s and 1980s before almost disappearing in the early 1990s. Systematic collection of effort data is related to these measures and also started in the late 1960s. However, because these data had specific aims, and were mostly based on self declaration, there may have been incentives to misreport.

Catch

For the landings, we have used the official Norwegian data (for description see Appendix 1.1). The numbers for 1996-1999 are preliminary numbers. These figures include all landings by Norwegian fishers in Norway or abroad, independent of fishing area or vessel size. Catch value is the amount paid to the fishers for the catch (1 Kroner = US$ 0.11, 25-September 2001). This amount includes freight and price subsidies and mandatory production tax but does not include fees to the sales union or value added tax.

The Norwegian Directorate of Fisheries is responsible for the collection of the data. However, since the late 1930s, the fishers' sales organizations, who are entitled by law to take over and sell practically all species of fish on landing, have to an increasing extent, assumed the role of suppliers of fishery statistics. These organizations also set minimum prices for different species, which is the most likely source of inaccuracies in the data before the 1970s. The reason for this is that the report of each transaction must have a price that is not less then the minimum price. However, if one does not record the full quantity landed, the buyer pays a lower price, and recorded landings will be lower then actual landings.

In 1977, the 200 mile Exclusive Economic Zone (EEZ) became internationally accepted, giving the authorities the right to regulate beyond the coastal fisheries. This resulted in tighter regulations of all fisheries in cooperation with the European Union (EU) in the North Sea, and with the Soviet Union (later Russia) in the Barents Sea. Regulations were first introduced in the most valuable fisheries for vessels with the most powerful gear types, but have successively been introduced into new vessel groups. While restrictive quota regulations were introduced in the ocean going fleet relatively early, the process moved much slower for the cod fishery of the coastal fleet. From the beginning of 1980, certain restrictions concerning gear and short period closures of the fisheries were imposed on this fleet, but other than this, the group enjoyed free fishing. In 1989, the coastal fleet was put under stricter quota regulations. All these regulations have been on a group basis, creating 'race to fish' fisheries and overcapitalization. In 1990 individual vessel quotas were introduced for large purse-seines and cod trawlers to tackle these problems. However, this also increased the incentives for fishers to underreport landings and also to high-grade their catches, leading to increased discarding.

In the transition from a management scheme with group quotas to a scheme with individual vessel quotas, track records become important because quotas are allocated based on track record. This is demonstrated in Norway where there were incentives to overstate landings in some fisheries particularly around 1990. This issue might also be of importance in fisheries which occur in unregulated international waters during the period before a regional management body is set up. These quotas are often allocated between countries based on track records.

Since 1975 , the size of catches has been measured by the weight of the fish when caught. Prior to 1975, the catch was measured by the weight of the fish when delivered ashore. The weight of fish that is landed in gutted condition as fillet or salted etc., is then converted into live weight. The size of catches measured by the weight of the fish when caught exceeds the weight when delivered ashore by between 7 to 10 percent for whole fish, but with up to three times as much for fillets. In combination with the vessel quotas this gives increased scope for high-grading for the (few) vessels with onboard production. This is because one can keep only the best part of the fillet. Because the true live weight equivalent is much higher then the one used, this will also lead to recorded catches being lower then actual catches.

A last issue is that official Norwegian landings sometimes differ from the numbers reported to ICES. This seems related to the fact that the official landings should not exceed the Norwegian quota, and hence, when they do, the official numbers are corrected.

Generally, it is clear that most incentives are towards under-reporting the landings, and hence, the official statistics understates the actual catches. There are no official or published estimates of how much fish is landed and unreported or how big the high-grading problem is. Estimates of unreported landings tend to vary between nearly zero to approximately 20%, although one can also find higher estimates.

Fishing Areas

The landings presented by fishing areas (for description see Appendix 1.2) include landings by Norwegian fishers in Norway and abroad. Unfortunately, the landings are only divided into main groups of fish (i.e., cod, other whitefish, herring, other pelagics, and other fish) and we have not been able to obtain a better separation. The figures for 1951-1972 include only fishing in distant waters, whereas the second period (1972-1999) includes all fisheries (coastal and offshore).

Between 1973 and 1976 the catch was not divided into coastal fisheries and fisheries in distant waters. The Norwegian Directorate of Fisheries rearranged the statistics from 1977, making it possible to draw a clear distinction between coastal fisheries and ocean fisheries. Offshore fishing includes all fishing outside the 12 nm zone, whereas coastal fishing includes all fishing inside the 12 nm zone.

Effort Data

The effort data presented are based on annual surveys of Norwegian fishing vessels with overall length of 13+ m operating on a whole year basis (see Appendix 1.2).

The following criteria have to be met by the vessels participating in the survey:

- The vessel has been fishing for at least 30 weeks a year;
- The vessel has a motor no older than 25 years; and
- The vessel has operated in specific fisheries or combinations of fisheries.

In addition, the vessel needs to have the equipment and motor power typical for this fishery or combination of fisheries, it must have operated in specific geographical regions and fit into specific categories describing size.

Although completion of this survey is mandatory for all fishers who match these criteria, completion of the survey is not strictly enforced, and therefore participation rate varies substantially. In general, the number of participants have been rather low, and it is difficult to judge how representative the results are for the complete fleets. Generally, the response rate has been as high as 30%, but in 1997 only 27% of the fleet population were included in the survey. Also, as the surveys are filled in by the fishers themselves, this may introduce biases. Of the variables that we are reporting here, days of fishing are the one most likely to be misreported. However, given the type of regulations, it is hard to see what one can achieve by cheating here and thus it can only be speculated that perhaps fishers that do not fish very often may overstate the number of fishing days to remain on the record.

Until 1979, the foot was used as the unit of measurement, whereas the metric system has been in use from 1980 onwards. Conversion of feet to meters was done using 1 foot = 0.33 meters.

Changes to these categories are made from year to year and consist of adjusting the size of the vessels included, fishing gears, the fishing grounds and the type of fisheries the vessels participate in. The most important changes are stated in the footnotes in the tables (see data files). However, minor changes from year to year have been ignored. Changes in categories have also added to the difficulties in grouping, especially those categories for off-coast (offshore) fisheries with long-line, gillnet etc. and miscellaneous coastal fisheries which are composed of several vessel groups.

Up to and including 1967 the numbers presented in the column for number of vessels are vessels included in the survey, whereas from 1968 this is the number of boats in the population. In Norway, horsepower has not been used as a measure of effort. It has therefore not been possible to obtain data concerning this variable.

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APPENDIX 1: DESCRIPTION OF DATA TABLES

The tables listed below will be available at: *www.fisheries.ubc.ca/projects/SAUP*

1.1 Catch data

Catch (t) and value (Norwegian Kroner; 1 Kroner = US$ 0.11, 25-September 2001) by year from 1950 to 1999 for principle commercial species. No area breakdown of catch is included. Principle species list: Capelin (*Mallotus villosus*), Salmon and sea trout (smelts), Halibut (*Hippoglossus hippoglossus*), Greenland halibut (*Reinhardtius hippoglossoides*), Plaice (*Pleuronectes platessus*), Witch (*Glyptocephalus cynoglossus*), Tusk (*Brosme brosme*), Haddock (*Melanogrammus aeglefinus*), Spawning cod (*Gadus morhua*), Finmark young cod (*G. morhua*), Other cod (*G. morhua*), Norway pout (*Trisopterus esmarki*), Saithe (*Pollachius virens*), Ling (*Molva molva*), Blue ling (*Molva dypterygia*), Winter herring (*Clupea harengus*), Fat herring (*C. harengus*), Redfish (*Sebastes* spp.), Catfish (*Anarhichas* spp.), Dogfish (e.g., *Squalus acanthias*), Porbeagle (*Lamna nasus*), Crab, Lobster, Deep water prawn, Other fish and by-products (Directorate of Fisheries, Norway).

1.2 Spatial data

Fisheries Catches allocated by broad geographic areas:

A) Fisheries catches (t) in distant waters, 1951-1972, including Iceland, North Sea and West Africa.
B) Quantity of catch (t) by fishing grounds, 1972-1999, including North of Latitude 62^{o} N, North Sea, Iceland/Faroe, West of Scotland, East of Greenland, NAFO areas, other areas.

1.3 Effort data

Fishing effort by major gear types, listing number of sea-days, average vessel length and tonnage, and number of vessels. Years covered varies by gear type (period in brackets): Factory trawlers (1968-97), fresh-fish trawlers (1968-97), small trawlers (1975-97), industrial trawlers (1971-97), ocean trawling for shrimp (1974-97), seining (1970-97), shrimp trawling (1955-97), shrimp trawling in combination with other gears (1968-97), purse seine (1965-97), off-shore long-liners and gillnet (1968-97), coastal gillnet and hand-lines and Danish seine (1968-97), large seine (1974-96), large trawl (1953-66).

NORWEGIAN UN-MANDATED CATCHES AND EFFORT

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ABSTRACT

This contribution presents unreported catches for selected fisheries and species from Norwegian waters, with particular emphasis on cod (*Gadus morhua*) in the Barents Sea between 1950 and late 1990s. Estimated discard rates ranged from over 20% in the 50s to approximately 10% of reported landings in the 90s. Additional species covered include redfish (*Sebastes* spp.), blue whiting (*Micromesistius poutassou*), haddock (*Melanogrammus aeglefinus*), whiting (*Merlangius merlangus*) and saithe (*Pollachius virens*). Some information on shrimp (*Pandalus borealis*) and marine mammals is also presented.

INTRODUCTION

Historically, the Norwegian fisheries were based on small vessels fishing along the Norwegian coast. After World War II offshore fisheries developed rapidly, vessels became larger and technological development in the 1950s and 1960s revolutionized the fisheries. Some of the technological developments that increased the efficiency and the capacity of fishers were the use of synthetic fibers for trawls and seines; larger vessels; increased horsepower; 'power blocks' in seine fisheries; and echo-sounders which made it easier to locate the fish and find new fishing grounds. These improvements led to record catches of, among others, cod (*Gadus morhua*), herring (*Clupea harengus*) and shrimp (*Pandalus borealis*). The increased catches led to overexploitation of many stocks, and the population of Norwegian spring spawning herring collapsed towards the end of the 1960s, which led to a fishing ban for Norwegian spring spawning herring in 1972. Appendix 1 provides information on Norwegian catch and effort data.

The depletion of fish stocks and the increased fishing capacity of the fleet led to the exploitation of other species and new locations. In the late 1960s and early 1970s several new fisheries were started. The fisheries for capelin (*Mallotus villosus*), herring in the North Sea, shrimp in the Barents Sea, the industrial fishery for Norway pout (*Trisopterus esmarki*) and sandeels (*Ammodytes* spp.) were all developed in the early 1970s. The government took control over the management of the most important fish species in the 1970s and the first total allowable catch (TAC) was imposed for capelin in 1974; this was followed by a TAC for demersal fish in 1975. ICES has given management advice regularly since the early 1960s. Increased mesh size, catch quotas (TACs), closed areas and reduced effort have been some of the recommendations made by ICES (Nakken, 1998). National economic zones (Exclusive Economic Zones EEZ) were introduced in 1977, and Norway and the USSR agreed on an equal sharing of the cod stock in the Barents Sea. Fishing by other countries within the EEZ and Barents Sea was reduced gradually (Jakobsen, 1993). The fishery for Norwegian spring spawning herring was reopened in the late 1970s, but under stricter control.

Efficiency and fishing capacity continued to increase in the 1980s and 1990s. In the early 1980s by-catch limitations in the shrimp fishery were introduced and increase in mesh size and an area closure system were implemented in the fisheries for gadoid species in the Barents Sea. Under the area closure system, an area is closed to fishing when the number of undersized fish of the targeted species in the catches exceeds 15%. In the mid-1980s a 'collapse' of the cod, haddock (*Melanogrammus aeglefinus*) and capelin stocks occurred in the Barents Sea. As a result, the capelin fishery was closed in 1986 and reopened only in 1991. Cannibalism was substantial in the cod stock because of the lack of food for cod. The fisheries were characterized by a substantial increase in discarding until the late 1980s when a discard ban was introduced. At first the discard ban applied only to cod, haddock and saithe (*Pollachius virens*), but now it applies to most species. Its effectiveness is uncertain.

Norwegian pelagic whaling for big whales was stopped in 1972. The International Whaling Commission (IWC) banned all whaling in 1987, but Norway opposed this decision. According to the IWC rules, Norway was not obliged to abide by the whaling moratorium. The Norwegian government stopped commercial whaling for small whales in 1987 and reopened it in 1993. However, catches between 1987 and 1993 continued under the banner of scientific whaling.

Since the 1990s, a considerable amount of research has focused on improving gear selectivity. The use of sorting grids (also called by-catch reduction devices) in the Barents Sea shrimp fishery were made compulsory by Norway

and Russia in 1993. The sorting grids proved to be very effective and a sorting grid system has been compulsory in the bottom trawl fishery for gadoid species in the Barents Sea since 1997. Ongoing research is being conducted for the use of sorting grids on purse seine vessels involved in the mackerel and saithe fishery.

Since 1950, Norwegian fisheries have followed a trend of decreasing numbers of fishers and vessels as the catch capacity of the fleet increases. Furthermore, as operating expenses have increased, fishing organizations have applied pressure on management to increase quotas. In recent years, this has resulted in the overexploitation of the Northeast Arctic cod stock.

Northeast Arctic cod

Garrod (1967) estimated discards of northeast arctic cod in the English, Barents Sea cod fishery. Garrod, as well as others, showed that discarding was a big problem in the trawl fishery for Northeast Arctic cod. I have also estimated the discards of this fishery and looked at some effects of this bias in catch statistics. (Dingsør, in prep).

The discards of northeast arctic cod are originally the estimated discards of three, four and five year-olds in the bottom trawl fishery. The numbers at age discarded were converted into weights using the Arctic Fisheries Working Group (AFWG) weight-at-age relationships (Anon., 2000a), these weights being fixed for the years 1950-1982. However, there is reason to believe that the stock weights at age in the 1950s and 1960s were actually lower, causing the estimated biomass to be too large. The weights may have been lower when the stock was larger and intraspecific food competition was potentially greater.

The discards at age were estimated by taking the age proportions of the cod stock for each year, simulating a fishery of the stock with the mesh sizes used and their selection curves for the respective years. The catches of three to five year-olds were then adjusted according to the age proportions of the estimated catches; catches were only adjusted upwards. The age proportions of the stock for the years 1950-1982 were gathered from the AFWG stock numbers at age, estimated by standard Virtual Population Analysis (VPA; Anon., 2000a). Since the catch numbers at age have a large influence on the results of the VPA, the adjusted catch numbers were used in the VPA to estimate new stock numbers at age. These new stock numbers were then used to re-adjust the catches. This procedure was performed twice. For the years 1983-1998, the Norwegian bottom trawl surveys were used to find the age proportions of the stock. The estimated discards were found by subtracting the AFWG catch numbers from the adjusted catch numbers.

Norwegian, Russian (USSR), English, West German, and a group composed of other countries' discards were estimated for the period 1950-1976 for ICES areas I and IIb. Catches in area IIa were not adjusted since most of these are from the fishery on the fish migrating to the spawning grounds and very few 3-5 year-old cod occur in this area. Russian and the 'group of other countries' catches in area I and IIb were adjusted for the years 1982-1998. Norwegian catches in area I and IIb were adjusted for the years 1982-1984. Total Norwegian trawl catches at age, summed for areas I, IIa and IIb, were adjusted for the years 1985-1998. The available Norwegian catch data were stratified by gear only, not area.

No catch-at-age data by country and area are available for the years 1977 – 1981. Total catch numbers at age, nominal catch (tonnes) by countries and total nominal catch (tonnes) by trawl and other gears for each area are available (Anon., 2000a). Catch numbers at age were divided into Norwegian catches and catches by the remaining countries. It is assumed that only Norway uses other gear types and therefore the Norwegian catches were divided between trawl catches and catches by other gear types. The Norwegian trawl catches and catches by remaining countries were then adjusted as explained previously.

However, the method used may inaccurately estimate the discards in some cases. These cases arise from applying the same age proportions across all gear types, from a strong year class entering a fishery, or if a new technology was introduced which limited bycatch.

Since the age proportions applied were the same for Norwegian trawl, other gear types and other countries, the estimated discards may be inaccurate. The nominal discards for 1981 may also be inaccurate since they seem too large in comparison to surrounding years. However, this anomaly may have resulted from a cold-water intrusion into the Barents Sea in 1980 and 1981, which shifted the stock to an extreme westward distribution. This would have resulted in low catches for Russian vessels and a high proportion of Norwegian catches taken by other gear types. Since the vessels in the other gear type category usually catch a smaller proportion of small fish

than a trawl does, an overestimate of discards could have occurred.

Discard rates for other year classes may be overestimated when a strong year class enters the fishery. This occurred, for example, in the Russian cod fishery in 1973 when the strong 1970 year-class entered the fishery and high discards of four and five year-olds, rather than of three year-olds, occurred. The reason for this is not quite clear since Norway and England both have high discard rates of three year-olds. It may be an effect of the distribution of the year-classes, as it is known that cod has a more westerly distribution by age; young cod are distributed further to the east than older cod (Nakken and Raknes, 1987).

Estimated discards in the 1990s may also have been overestimated since the use of sorting grids, which improves gear selectivity, was voluntary in the mid-1990s and compulsory since 1997. The closure of fishing locations, which have too large a proportion of small fish in catches, would also be a source of overestimation.

The results show that average discards by percentage of total catch decreased for all countries combined (Table 1). The decrease was probably due to increases in mesh size (Table 2). There is some variation of discard amounts between countries although Norway generally has less discards than the other countries. This is because discards are not estimated for conventional gear types, which catch approximately two-thirds of the Norwegian quota, and also because of larger mesh size used by Norway in comparison to the other countries.

Table 1. Estimated cod discards in % of total catch, averaged per decade.

Decade	Discards
1950s	22
1960s	14
1970s	9
1980s	9
1990s	10

In some cases it may be better to assign the estimated values of discards as 'un-mandated' catches. During the heydays of the former Soviet Union, it was always assumed that discards were zero/non-existent. Results show that this was not true and may, in fact, support suggestions that Soviet vessels caught and landed a lot of small fish that never showed up in the catch statistics.

Table 2. Cod end mesh sizes (mm) used in Northeast Arctic cod (*Gadus morhua*) fisheries. The mesh sizes apply to nylon since 1967. Mesh sizes of 135 mm apply to all vessels in Norwegian EEZ and to Norwegian vessels in the Grey zone (the area under joint Russian and Norwegian jurisdiction). Mesh sizes of 125 mm apply to all vessels in the Russian EEZ and to Russian vessels in the Grey zone.

Year	Norway	Other countries
1946	80	80
1954	110	110
1963	130	120
1982	135	125

Redfish

By-catch of fish, especially small redfish (*Sebastes* spp.) in the Barents Sea shrimp fishery has been substantial. By-catch-induced discards in the shrimp fishery during the years 1983-1986, which were estimated by the Norwegian Institute of Marine Research, are believed to be among the most extensive ever (Table 3, Figure 1). The by-catch was estimated in numbers and was converted to weights by assuming that the mean weight was 100 gram. However, the by-catches of redfish have been successfully reduced starting with the introduction of a sorting grid in 1989 which was made compulsory from 1993 in both Norwegian and Russian EEZ, as well as in the areas around Svalbard (Isaksen, 1997).

Table 3. Estimated by-catch of small redfish (*Sebastes* spp.) in the Norwegian and foreign shrimp fishery north of 60°N, and reported landings of redfish for the same area and period.

Year	By-catch (tonnes)	Landings (tonnes)
1983	13,800	4,651
1984	23,900	2,027
1985	78,300	2,932
1986	33,500	5,411
1987	22,300	3,124

Blue whiting (Poutassou)

The Norwegian industrial trawl fishery catches a considerable amount of blue whiting (*Micromesistius poutassou*). However, official catches for most years are considerably smaller than the estimated catches, which are considered to be more accurate and are used by the ICES Working Group (Anon., 2000b). The fishing vessels and the landing stations report the catches to the Norwegian Directorate of Fisheries, which in turn reports to ICES. In addition, a control agency samples catches when landed and estimates the round weight of blue whiting in the catches. The un-mandated catches reported in this report are the differences between the

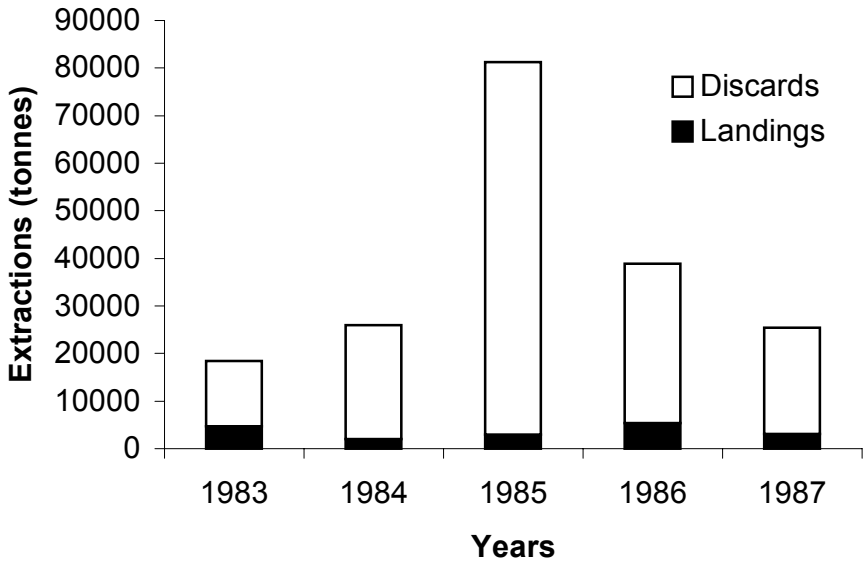

Figure 1. Total extractions of redfish (*Sebastes* spp.) from ICES area I, broken down into reported landings and discards by the shrimp fishery.

estimated catches and official catches. In the fishery for Norway pout and blue whiting, it has been common in recent years to register the catch as the species that represents at least 50% of the delivery. This over-reporting of target species and under-reporting of incidental by-catches causes negative values in the years 1997-1999 for target species. The over-reported catches were all allocated to haddock, saithe, whiting and other species. The industrial by-catches are estimated by the Working Group on the assessment of demersal stocks in the North Sea and Skagerrak (Anon., 2000c).

Haddock, whiting and saithe in the North Sea

The un-mandated catches of haddock, whiting (*Merlangius merlangus*) and saithe include discards and industrial by-catch. The saithe data also include unreported catches. The total annual international discard estimates of haddock and whiting in the North Sea were derived by extrapolation from Scottish data (Anon., 2000c). The Working Group (WG) estimated the by-catch of haddock, whiting and saithe in the Norwegian and Danish industrial fishery for Norway pout and sandeels in the North Sea. The unreported catches of saithe are the differences between the official statistics and the information provided by members of the WG. In some years, French catches belonging to area IIa are included in the official statistics of area IVa and IIIa. These catches are subtracted from the unreported catches and cause negative values.

Northeast Atlantic mackerel and horse mackerel

Only the Netherlands has provided information on discards in the mackerel (*Scomber scombrus*) and horse mackerel (*Trachurus trachurus*) fisheries in recent years (Anon., 2000d). This does not imply that The Netherlands is the only country that has discards, but that it is the only country that records and reports discards to the ICES WG. The information on discards is not applied to any other countries and it is not specified to which countries the earlier discards belong. The area-misreported catches of mackerel are catches caught in area IVa and reported in area VIa. For the years 1995, 1996 and 1998 some of the IVa catches reported are in area IIa. WG members have submitted the information on area-misreported mackerel catches. The unallocated mackerel and horse mackerel catches are adjustments to the official catches, performed by the WG, made from any special knowledge about the fishery such as under- or over-reporting for which there is firm external evidence (Anon, 2000d). Over-reporting and area-misreporting caused the negative unallocated catches of horse mackerel in the present report. The area-misreported horse mackerel catches are not specified to area, but the sum of all the area-misreported catches should be zero.

The un-mandated catches of herring (*Clupea harengus*) south of 62° N are available, although discard information is only available for some unspecified countries (Anon., 2000e). Area misreporting is estimated by the WG. The catches

that are misreported are caught in area IVa, but reported as catches in area VIa.

Shrimp

During the sieving procedure, when the shrimp are sorted by size on board the vessel, it is believed the smallest size fractions of shrimp (proportions below 15-mm carapace length) are discarded in the Swedish and Norwegian shrimp fishery in the ICES areas IIIa and IVa east (Anon., 2000f).

Whales

The whale catches are divided into two groups, big whales and small whales. The big whales were caught during 'pelagic whaling' which mainly took place in the Antarctic, but some whales were also taken in the North Atlantic. Norwegian pelagic whaling was stopped in 1972 and the catch records are collected from *International Whaling Statistics* (1961, 1964, 1970 & 1974). Small-whales were first caught in the 1920s with small boats along the Norwegian coast. In the 1950s and 1960s the vessels increased in size and the catch area expanded to the Barents Sea, Greenland and Newfoundland. The 1950-1953 catches are collected from Statistics Norway, the 1954-1985 catches from *International Whaling Statistics* (1961, 1964, 1970, 1974, 1981 & 1988) and the 1986-1999 catches from *Havets Ressurser* (Toresen *et al.*, 1999 and 2000). All reported catches include whales caught for scientific purposes. The data for whales will be incorporated in the *Sea Around Us* Marine Mammal database (see Kaschner *et al.*, this volume).

Seals

The catches of seals are collected from the *Report of the joint ICES/NAFO Working Group on Harp and Hooded seals* (Anon., 1992, 1999), the Norwegian Directorate of Fisheries (Fiskeridirektøren) and *Havets Ressurser 2000* (Toresen *et al.*, 2000). The catches include incidental catches along the Norwegian coast and catches from scientific sampling conducted by Norway. The data for seals will be incorporated in the *Sea Around Us* Marine Mammal database as well.

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APPENDIX 1
THE NORWEGIAN CATCH AND EFFORT DATA

The Norwegian catch and effort data were obtained from a survey of Norwegian fishing vessels (The Norwegian Directorate of Fisheries, 1999). The fishing vessels included in this survey were those which had an overall length of 8 meters or more and operated on a whole year basis in 1998. These vessels caught 89% by weight of the total official catches. Vessels below 8 meters caught 12,374 tonnes. Vessels between 8 and 12.9 m and the vessels above 13 m that were not included in the survey caught 55,221 and 222,517 tonnes, respectively. No effort data are available for the vessels that were not included in this survey.

The vessels in the Norwegian fisheries are divided into three main groups:

- Vessels fishing for gadoid species;
- Vessels fishing for shrimp;
- Vessels fishing for pelagic species.

The vessels in these three groups are then divided into classes depending on gear and size of vessel (Tables 4-6, see *www.fisheries.ubc.ca/projects/SAUP*). The available fleet characteristics, fleet effort and landings were tabulated. The Norwegian Directorate of Fisheries (NDF) provided the fleets average main engine power. Information that was not available from NDF is marked 'N.A.'. Un-mandated catches are not included in the table, except for blue whiting in vessel class 023.

References (Appendix 1)

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Table 4. Vessels fishing for gadoid species**.**

Code	Vessel type	Area of operation	Vessel length (m)	Vessel tonnage (GRT)
001	Fisheries with gillnet, and hand-line	North-Norway	8-12.9	-
002	Fisheries with gillnet, and hand-line	North-Norway	13-20.9	-
003	Fisheries with Danish seine	North-Norway	8-12.9	-
004	Fisheries with Danish seine	North-Norway	13-20.9	-
005	Fisheries with long line.	North-Norway	8-12.9	-
006	Fisheries with long line	North-Norway	13-20.9	-
007	Miscellaneous coastal fisheries for cod	South-Norway	8-12.9	-
008	Miscellaneous coastal fisheries for cod	South-Norway	13-20.9	-
009	Fisheries with Danish seine	North-Norway	21-27.9	-
010	Miscellaneous coastal fisheries for cod	All counties	21-27.9	-
011	Fisheries with long line	All counties	≥ 28	-
012	Miscellaneous coastal fisheries for cod	All counties	28	-
013	Freshfish trawlers	-	-	≥ 250 GRT
014	Factory trawlers	-	-	≥ 250 GRT
015	Other trawlers and small trawlers fishing for saithe, cod (Without quotas or limited quotas)	-	-	-

Table 5. Vessels fishing for shrimp.

Code	Vessel type	Vessel size (tonnage (GRT), length (m))
016	Shrimp trawling	Vessels under 50 GRT, 8-12.9 m (Without shrimp trawl license)
017	Shrimp trawling	Vessels under 50 GRT, ≥ 13 m (without shrimp trawl license)
018	Shrimp trawling in combination with other gears	Vessels under 50 GRT, 8-12.9 m (without shrimp trawl license)
019	Shrimp trawling in combination with other gears	Vessels under 50 GRT, ≥ 13 m (without shrimp trawl license)
020	Ocean trawling for shrimps. Vessels which have participated in fishing for shrimps in the Greenland area. Vessels with cold storage plant	-
021	Ocean trawling for shrimps. Vessels which not have participated in fishing for shrimps in the Greenland area. Vessels with cold storage plant	-
022	Ocean trawling for shrimps Vessels without cold storage plant	Vessels > 50 GRT

Table 6 .Vessels fishing for pelagic species.

Code	Vessel type	Vessel size (m) or load capacity (hl)[a)]
023	Trawling for Norway pout, sandeels, capelin. (Also vessels with North Sea trawl license)	-
024	Seining for saithe, herring, mackerel, sprat etc	8-12.9 m
025	Seining for saithe, herring, mackerel, sprat	13-21.34 m
026	Seining for saithe, herring, mackerel, sprat	21.35 m and above
027	Purse seining for capelin, herring, mackerel	Loading capacity up to 7.999 hl
028	Purse seining for capelin, herring, mackerel	Loading capacity ≥ 8.000 hl
029	Purse seining for capelin, herring, mackerel. With blue whiting season	-

[a)] 1 hl (hectoliter) = 100 liters

UNREPORTED CATCHES IN THE BARENTS SEA AND ADJACENT WATERS FOR PERIODS FROM 1950 TO 1998

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ABSTRACT
Catch data for the northeast Atlantic with an emphasis on Norwegian fisheries are provided. The focus is on discards, by-catch, unreported, misreported and unallocated catches. Sixteen commercial fish and invertebrate species are represented with unreported catches exceeding 25% of the total catch for five of these species. Particular emphasis is drawn to Atlantic cod (*Gadus morhua*), redfish (*Sebastes* spp.) and haddock (*Melanogrammus aeglefinus*).

INTRODUCTION
This report evaluates information on the unreported catches of commercial fish and invertebrate species in parts of the northeast Atlantic Ocean. The trends presented here are based on data provided by Dingsør (this volume), who reported on discards, by-catch, unreported, misreported and unallocated catches, with an emphasis on Norwegian fisheries. Here, 'unreported catches' are defined as unreported with regards to the official ICES database ('STATLANT'). The areas considered in the present paper include ICES Fishery Statistical areas I (Barents Sea), IIa and b (Barents Sea/Norwegian Sea), IIIa (Kattegat and Skagerak), IV (North Sea), VI (the Northwest coast of Scotland and Ireland), and VII (Irish Sea and the English Channel). For a map of ICES Fisheries Areas, see Figure 1.

The official, reported catch data included in the present report are based on the official ICES landings database (STATLANT, year 2000 version). In the case of a few species (Atlantic cod (*Gadus morhua*), horse mackerel (*Trachurus trachurus*), and North Sea whiting (*Micromesistius poutassou*)), the ICES data were adjusted by ICES Working Group estimates of catches. This was necessary because the ICES STATLANT data required for the present estimations and summaries were missing or were incomplete. All calculations of the 'percent unreported catches' documented in this report represent the percentages based on the total catch (total catch = official ICES STATLANT catch + unreported catch).

Of the sixteen commercial fish and invertebrate species for which some estimates of unreported catches were available (Table 1, also see Dingsør, this volume), the unreported catch exceeded 25 % of the total catch (total catch = official ICES catch + unreported catch) for five species at least some of the time for the areas considered here – redfish (*Sebastes* spp.), haddock (*Melanogrammus aeglefinus*), horse mackerel (*Trachurus trachurus*), witch flounder (*Glyptocephalus cynoglossus*), and European hake (*Merluccius merluccius*). In addition to these five species, the estimated unreported harvest of North Sea herring (*Clupea harengus*) and Atlantic cod (*Gadus morhua*) was assessed for periods with available information (Table 2).

The present report focuses on three species for which total catch estimates are of particular interest: Atlantic cod in the Barents Sea and Norwegian Sea (1950-1998), redfish in the Barents Sea during parts of the 1980s, and haddock in the North Sea (1963-1998). Figures and data of official and unreported catches for the 12 species not specifically addressed in this report are available on the *Sea Around Us* project web site (*www.fisheries.ubc.ca/projects/SAUP*). Attention is drawn to specific details and history of the present examples in a report by Dingsør (this volume).

Table 1. Species and time periods covered by report.

Common Name *(Species Name)*	**Time Period**
American plaice (*Hippoglossoides platessoides)*	1984-1998
Atlantic mackerel (*Scomber scombrus)*	1978-1998
Blue whiting (*Micromesistius poutassou)*	1977-1998
Cod (*Gadus morhua)*	1950-1998
European hake (*Merluccius merluccius)*	1984-1998
European ling (*Molva molva)*	1984-1998
European plaice (*Pleuronectes platessus)*	1985-1998
Haddock (*Melanogrammus aeglefinues)*	1963-1998
Herring (*Clupea harengus)*	1984-1998
Horse mackerel (*Trachurus trachurus)*	1984-1998
Redfish (*Sebastes* spp.*)*	1983-1987
Saithe (*Pollachius virens)*	1970-1998
Shrimp (*Pandalus borealis)*	1985-1998
Whiting (*Merlangius merlangus)*	1960-1998
Witch flounder (*Glyptocephalus cynoglossus)*	1984-1998
Yellowtail (*Limanda limanda)*	1984-1998

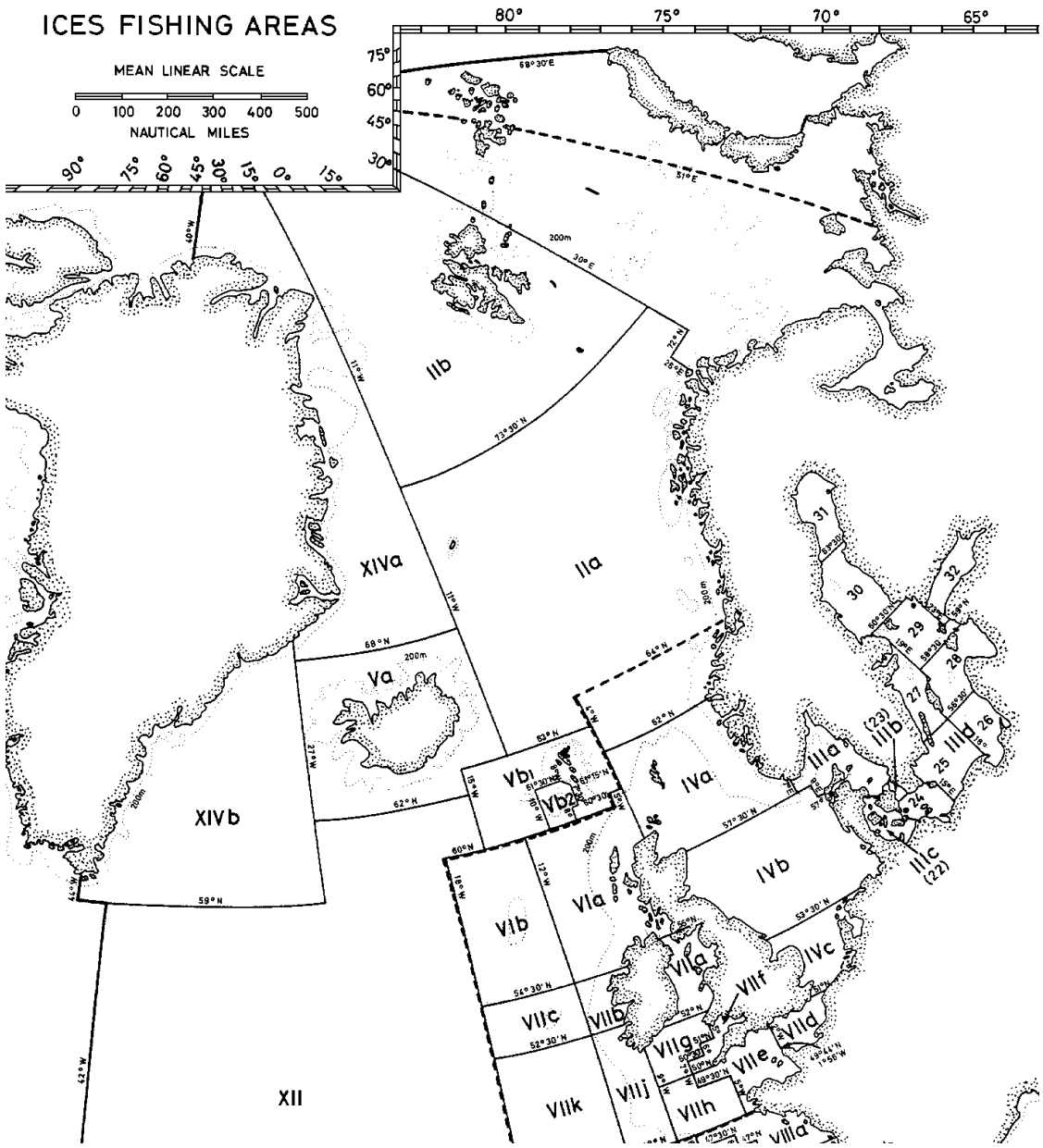

Figure 1. ICES Fisheries Statistical Areas mentioned in this report: I (Barents Sea), IIa and IIb (Barents Sea/Norwegian Sea), IIIa (Kattegat and Skagerak), IV (North Sea), VI (the Northwest coast of Scotland and Ireland), and VII (Irish Sea and the English Channel). For a complete map of ICES Areas, see *www.ICES.dk/globec/data/fisharea.gif*.

Table 2. Actual extractions of selected species from the Barents Sea and adjacent waters.

Species	Area and countries	Time period	Official catch (t)	Unreported catch (t)	Total catch (t)	% Unreported
Cod	I, IIa and IIb: All countries	1950-59	7,681,958	2,407,700	10,089,658	23.9
		1960-69	7,442,286	972,423	8,414,709	11.6
		1970-79	8,205,008	366,615	8,571,623	4.3
		1980-89	4,050,224	295,876	4,346,100	6.8
		1990-98	5,232, 95	387,547	5,619,742	6.9
Redfish	I: All countries[a)]	1983-87	18, 45	171,800	189,945	90.4
Haddock	IIIa and IV: All countries	1963-69	1,704,494	1,603,694	3,308,188	48.5
		1970-79	2,228,827	1,726,795	4,015,022	43.0
		1980-89	1,396,920	742,319	2,139,239	34.7
		1990-98	627,219	570,459	1,197,678	47.6
European hake	IV: Denmark	1984-89	5,108	1,852	6,960	26.6
	IV: Denmark and Norway[b)]	1990-98	11,427	6,956	18,383	37.8
Herring	IV, VIIa and VIa: All countries	1984-89[c)]	3,121,737	5,544	3,127,281	0.1
		1990-98	3,832,008	40,031	3,872,039	1.0
Horse mackerel	IV: Denmark and Norway	1984-89	312,471	88,741	401,212	22.1
		1990-98	1,028,276	59,756	1,088,032	5.5
Redfish	I: All countries[a)]	1983-87	18,145	171,800	189,945	90.4
Witch flounder	IV: Denmark and Norway	1984-89	2,879	1,251[d)]	4,130	30.3
		1990-98	4, 62	3,522[e)]	7,984	44.1

[a)] Based on countries fishing for Pandalus borealis.
[b)] Norway data are included for the years 1995-1998 only.
[c)] Only includes unreported catches in areas IVb, IVc, VIId and VIa for 1989.
[d)] Only includes Norway's unreported catch for years 1984, 1985 and 1989.
[e)] Only includes Norway's unreported catch for years 1990, 1991 and 1992.

ACCOUNTS BY SPECIES

Atlantic Cod (*Gadus morhua*, Barents Sea and Norwegian Sea)

Atlantic cod are fished by several countries in the region encompassed in this study (ICES areas I, IIa and Iib, Figure 1). The key countries are Norway and Russia (formerly USSR), and to a lesser extent, the United Kingdom. In terms of landings, the North Atlantic cod fishery is the largest of all the fisheries in the region (average official landings per year between 1950-1998 was over 665,000 tonnes/year, Table 2). Therefore, despite the relatively moderate proportions of unreported catch of cod (mean across all decades: 10.4%, Figure 2), the average annual unreported catch itself is rather large (over 90,000 tonnes per year).

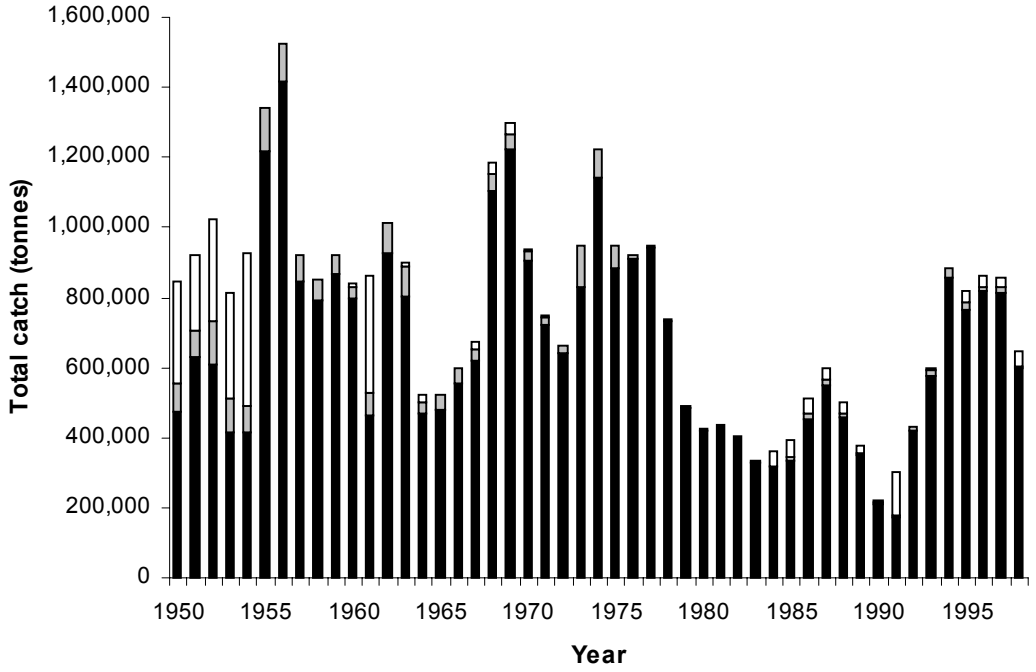

Figure 2. Total extractions (total catch) of cod by all countries in ICES I, IIa and IIb. Black: official landings from ICES STATLANT. Grey: Discards as estimated by Dingsør (this volume). White: unreported catches as estimated by Dingsør (this volume).

With the exception of the 1990s, the unreported proportion of cod caught by all countries combined appears to have declined across the decades since the 1950s (Table 2). One of the periods in which a decline in unreported catch occurred was in the late 1970s, just prior to a precipitous decline in total catches which occurred in the early 1980s (Figure 2; for data see: *www.fisheries.ubc.ca/projects/SAUP*). During this period of very low total harvest in the 1980s, the average total catch by all countries was approximately 430,000 tonnes·year^{-1}, down from 840,000-1,000,000 tonnes·year^{-1} in the previous three decades (Table 2). Several factors related to decreasing catches may have contributed to the observed drop in discard rates in the late 1970s (Figure 3). Cold water in the Barents Sea in 1979-1981 led to an extreme westerly distribution of the cod stock (Nakken and Raknes, 1987), which in turn led to low trawl catches in ICES areas I and IIb. Further, the establishment of Exclusive Economic Zones (200 mile EEZ) in 1977, combined with a splitting of the cod stock between Norwegian and Russian responsibility may have led to better management of the cod stock compared to earlier periods (Jakobsen, 1993).

However, there are two reasons to expect that the unreported catches documented here for the Atlantic cod are underestimated. First, Norway's average discard rates for cod of 2.5% of the total catch appears generally lower in comparison to the discard rates for other countries (Figures 4 and 5). This occurred because estimates of discards were available only for the bottom trawl gear type while the official ICES landing data used for our calculations includes all gear types without gear differentiation. Approximately $^2/_3$ of the Norwegian cod fleet is composed of gear types other than bottom trawl. Thus, our unreported/discard estimates (which only apply to trawl gear) are clear underestimates of total Norwegian unreported and discarded catch. This contrasts with catches of cod from other countries in the Barents Sea, which is almost exclusively by

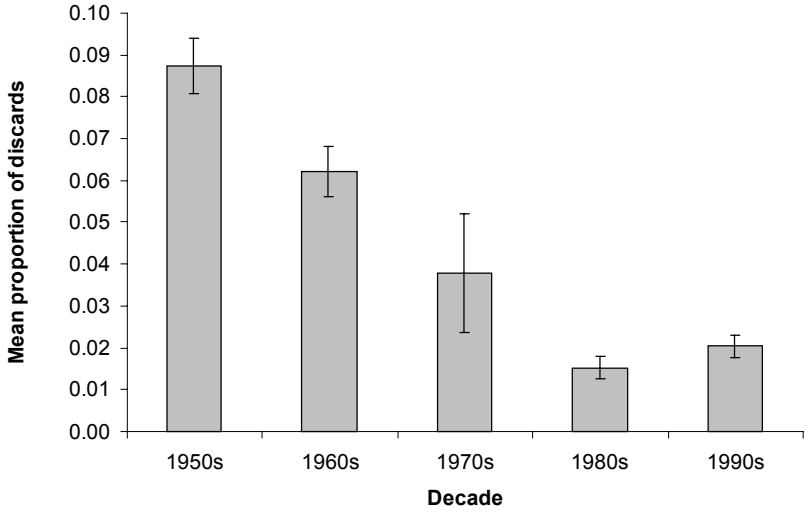

Figure 3. Mean discard rate (± SE) of Atlantic cod per decade (all countries) in ICES I, IIa and IIb.

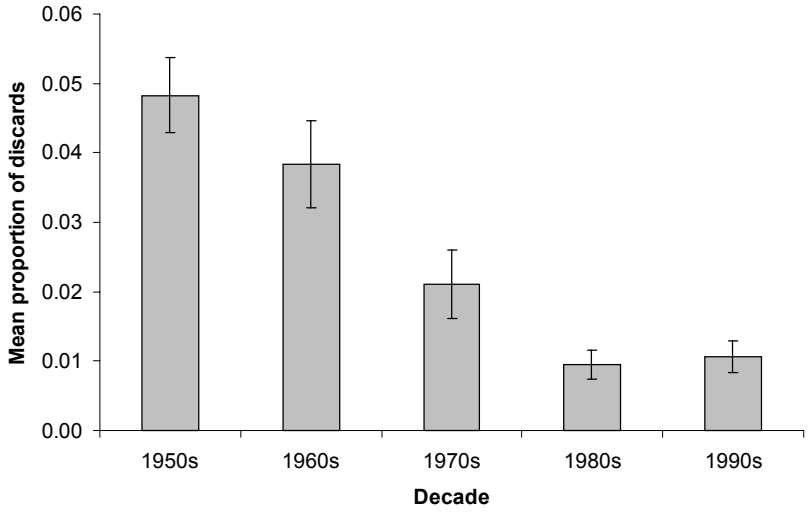

Figure 4. Mean discard rate (± SE) of cod by Norway in ICES I, IIa and IIb.

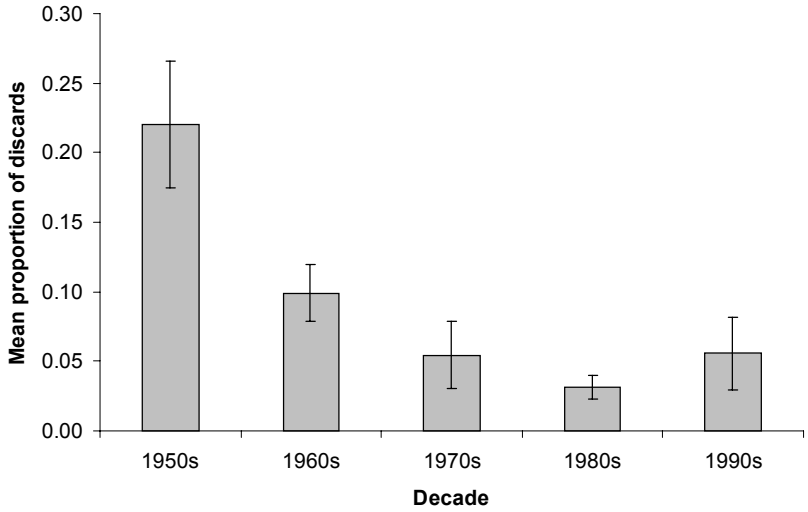

Figure 5. Mean discard rate (± SE) of cod by all countries excluding Norway in ICES I, IIa and IIb.

bottom trawl (Dingsør, this volume). The lack of information on discards for gear other than bottom trawl suggests that the cod discard rates reported here for Norway may underestimate the total discard rate for cod.

Secondly, additional evidence for underestimates of the unreported catches of cod come from two reports and state that large quantities of cod (average: 50,000 t·year^{-1} from 1990 to 1996) were being harvested in the international 'loophole' in the Barents Sea (Anon., 2000: 1990-1994; Norwegian Directorate of Fisheries [unpublished]: 1995-1996). This area is outside of the multi-national agreements on total allowable cod catches. The year in which this harvesting began is unknown, but assumed to predate 1990. Attempts have been made by Norway and Russia to stop or control these catches through negotiations with the offending countries. However, no evidence exists to indicate that the negotiations have been successful to date (G. Dingsør, Institute of Marine Research, Bergen, Norway, pers. comm.).

On the other hand, it is possible that Norway's unreported catches in recent years may in fact be close to the true value for two reasons. Since the late 1980s Norway has a 'discard ban', and more recently a policy of temporary closure of fishing areas has been implemented to conserve stocks (Isaksen, 1997). The area closure system, introduced in 1986, is a system of real-time closures of areas containing large quantities of small fish. Presently, an area is being closed when:

- more than 15% of the catches are below minimum catch size; or
- the by-catch exceeds 1000 individuals of juvenile haddock and cod per tonne; or
- the by-catch exceeds 300 individuals of Greenland halibut per tonne; or
- the by-catch exceeds 1000 individuals of redfish per metric ton shrimp catch.

The closing and opening of areas is based on extensive surveys by chartered commercial fishing vessels. Furthermore, since 1986 a change of fishing area is mandatory if a vessel encounters too many non-targeted species or juveniles (Isaksen, 1997). Thus, commercial skippers have the legal responsibility to move their vessel a minimum distance of 5 nautical miles when the mixture of 'illegal' to legal fish becomes to high (G. Dingsør, Institute of Marine Research, Bergen, Norway, pers. comm.). However, discarding may still occur as enforcement of these rules is problematic and therefore it would be expected that some discarding would still occur above the level reported.

Redfish

During the 1980s a fishery for northern shrimp (*Pandalus* spp.) developed in the Barents Sea (ICES I). ICES undertook a study that reported on additional catches of non-targeted species (Dingsør, this volume). Data presented here relate to redfish (*Sebastes* spp.) catches that were discarded from the shrimp fishery during an assessment period from 1983-1987.

The total reported landings for redfish from ICES I over the five-year time period was 18,145 tonnes, representing an average of 3,629 tonnes per year (range 2, 027-5, 411; Figure 6). Discards of redfish from the shrimp fishery amounted to 171,800 tonnes over the five year assessment period. This represents an average of 34, 360 tonnes per year or over 87 % of the total extraction of Barents Sea redfish. The discarded amount of redfish (171,800 tonnes) was nearly the same as the amount of northern shrimp targeted (192,923 tonnes over 5 years).

Subsequently, discard rates have decreased due to changes in the shrimp fishing gear, e.g., in 1989 the 'Nordmøre' sorting grid was introduced into the shrimp fishery to decrease by-catch of juvenile fish (especially cod and haddock). As a result of adopting these sorting grids fishers were allowed into formerly closed areas (Isakesen, 1997). In 1993 both Norway and Russia made the use of the grid compulsory in the shrimp fishery in their EEZs and around Svalbard (Isaksen, 1997).

Haddock

The haddock fishery in the North Sea mainly involves vessels of Belgian, Danish, English, French, Scottish, and Norwegian origin (Anon., 2001). Some haddock are also taken as by-catch in the industrial fishery for such species as herring, sandeels and Norway pout undertaken by Danish and Norwegian vessels (Anon., 2001). In recent years the haddock stock has been dominated by the strong 1999 year class (Anon., 2001).

The quantities of unreported catches of haddock (tonnes) from Kattegat and Skagerak (Area IIIa, Figure 1) and The North Sea (Area IV, Figure 1) are amongst the highest unreported catches documented for any of the species examined (Table 2). Furthermore, these unreported catches of haddock were consistently high (average annual unreported catch: approx. 129,000 tonnes, range: 28,500 – 599,000 tonnes (Figure

7, Table 2) across the entire 36-year time period for which data were available. Interestingly, these levels of unreported catches were consistent despite by-catch limitations (haddock and other species) imposed on the shrimp fishery in the early 1980s, and a haddock discard ban, introduced in the late 1980s (Dingsør, this volume).

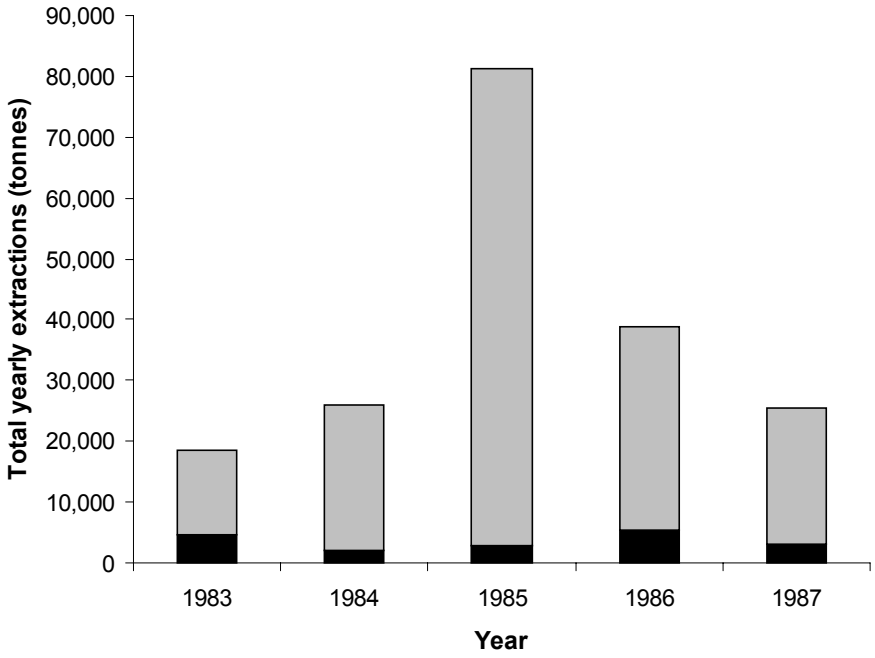

Figure 6. Total annual extractions of redfish (reported landings plus discards) in the Barents Sea (ICES I), based on the assessment period from 1983-1987. Black: official ICES reported landings. Grey: discards of redfish by the northern shrimp fishery.

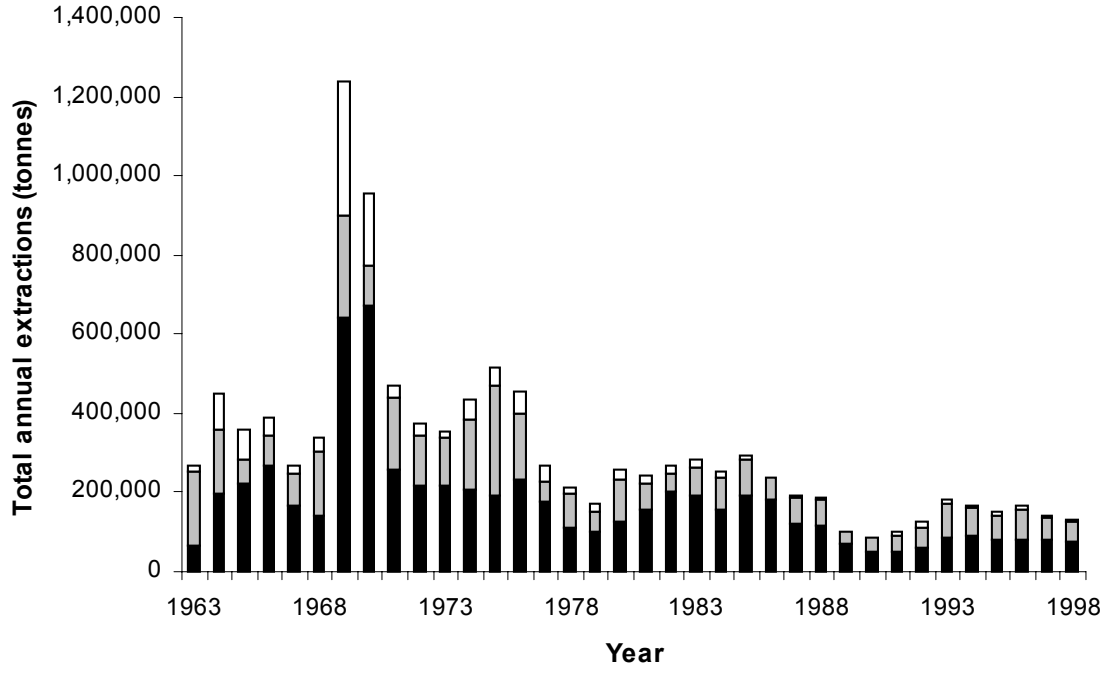

Figure 7. Total annual extractions of haddock taken by all countries in ICES IIIa and IV. Black: official landings from ICES STATLANT. Grey: Discards as estimated by Dingsør (this volume). White: unreported catches as estimated by Dingsør (this volume).

CONCLUSIONS

This assessment indicates that unreported and discarded catches can be of a substantial magnitude in some stocks. The discrepancies between the official ICES data (ICES STATLANT) and adjusted total catches illustrate that complete public accounting of extractions of a publicly owned resource should form the foundation of fishery management. Knowledge of total extractions could be important to the stability of the stocks even when total catch is low (Hilborn and Walters, 1992). While we acknowledge that in many cases these non-landed or non-reported catches are incorporated into stock assessments by the ICES Working Groups (e.g., Working Group on the Assessment of the North Sea, Skagerrat and Kattegat, Anon., 2001), it is surprising that none of these unreported catch estimates are accounted for in the official ICES database (STATLANT). Given that the general public is the ultimate resource owner, they should have the right to know what is extracted from the ocean and how much of this extraction is actually being landed, discarded or not reported. This would contribute markedly to transparency in publicly run institutions.

ACKNOWLEDGEMENTS

We would like to thank the Pew Charitable Trusts for the funding of the *Sea Around Us* project.

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SOME INFORMATION ON RUSSIAN CATCHES IN THE BARENTS SEA AND WHITE SEA: 1950-1995.

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ABSTRACT

Catch data for the Barents Sea and White Sea are given, containing reported and unreported data. Unreported catches mainly pertain to the 1950-1954 time period and were caught by the Murmansk trawling fleet. However, it is uncertain if some of the unreported catches reported relate to artisanal fisheries. Some information on catches of marine mammals are also given. Total landing for the trawl fishery in the Barents Sea are given for the time period 1961-1976, as well as for 1978, 1980 and 1985. It is possible to separate the catch taken from the White Sea and the Barents Sea, based on species distribution

RUSSIAN CATCHES

Information was gathered on Russian catches for some commercial fish species for the Barents Sea (Table 1) and White Sea areas (Table 2) for intermittent periods between 1950 and 1995. Information includes both catches that were reported to the International Council for the Exploration of the Sea (ICES) and available in the official ICES database (STATLANT), as well as unreported catches. Unreported catches may have been caught in ICES Fisheries Statistical Areas I, IIa or IIb since all these areas cover a portion of the Barents Sea. However any unreported Barents Sea catch, as well as all the White Sea catches were assigned to ICES I.

Table 1. Species and time periods reported for the Barents Sea.

Species	Common name	Time period
Anarhichas spp.	Catfish	1950-1958; 1961-1976
Boreogadus saida	Polar cod	1961-1976
Carchariniformes	Ground sharks	1950-1958
Clupea harengus	Atlantic herring	1950-1958; 1961-1976
Elasmobranchii	Sharks and rays	1961-1976
Eleginus navaga	Navaga	1961-1976
Gadus morhua	Atlantic cod	1950-1995
Macrouridae	Rat-tails	1961-1976
Mallotus villosus	Capelin	1951-1976
Melanogrammus aeglefinus	Haddock	1950-1958; 1961-1976
Micromesistius poutassou	Blue whiting	1961-1976
Osmerus eperlanus	European smelt	1961-1976
Pleuronectidae	Flatfish	1950-1958; 1961-1976
Pollachius pollachius	Pollack	1950-1958; 1961-1976
Reinhardtius hippoglossoides	Greenland halibut	1950-1958; 1966-1976
Sebastes spp.	Redfish	1950-1958; 1961-1976
N/A	Miscellaneous marine fishes	1950-1958; 1961-1976

Table 2. Species and time periods reported for the White Sea.

Species	Common name	Time period
Anarhichas spp.	Catfish	1971-1985
Clupea pallasii	Pacific herring	1971-1985
Eleginus navaga	Navaga	1950-1984
Mallotus villosus	Capelin	1960-1984
Pleuronectidae	Flatfish	1960-1984

Unreported catches were first compared to the reported totals from the ICES database for all three areas. Subsequently, only that portion of the Russian data remaining unexplained was allocated to ICES I. With the exception of redfish (*Sebastes* spp.: 1956-1958 & 1964) and haddock (*Melanogrammus aeglefinus*: 1968), unreported catches of all species now accounted for, were subtracted from the 'miscellaneous marine fishes' category in the *Sea Around Us* projec database (*www.fisheries.ubc.ca/projects/SAUP*).

Russian catches not previously reported by ICES mainly pertain to the 1950-1954 time period (Table 3). During this time period two Russian fleets operated in these waters, the Murmansk and the Arkhangelsk fleets. Landings are given for selected species caught by the Murmansk trawling fleet operating in the Barents Sea for the time period 1950-1958 (Table 4). Total landings

Table 3. Unreported catches for the time period 1950-1954.

Species	Common Name	Unreported catch (tonnes)
Anarhichas spp.	Catfish	26,450
Carchariniformes	Ground sharks	980
Eleginus navaga	Navaga	4,740
Mallotus villosus	Capelin	3,479
Melanogrammus aeglefinus	Haddock	22,650
N/A	Miscellaneous marine fishes	193,956
Pleuronectidae	Flatfishes	1,000
Pollachius pollachius	Pollack	2,260
Sebastes spp.	Redfish	86,320

Table 4. Landings for the Murmansk trawling fleet for the time period 1950-1958, sorted by species.

Species	Common name	Landings (tonnes)
Anarhichas spp.	Catfish	46,250
Carchariniformes	Ground sharks	2,240
Clupea harengus	Atlantic herring	21,180
Gadus morhua	Atlantic cod	2,147,820
Melanogrammus aeglefinus	Haddock	66,960
Pleuronectidae	Flatfishes	6,140
Pollachius pollachius	Pollack	2,400
Reinhardtius hippoglossoides	Greenland halibut	3,188
Sebastes spp.	Redfish	397,720

by the USSR from the Barents Sea is given for the time period 1961-1976 as well as for the individual years 1978, 1980 and 1985, and compared with the official ICES database entries for the corresponding years and area I (Table 5).

Table 5. Total landings for the USSR in the Barents Sea as assembled by the author.

Year	Landings (t)
1961	329,133
1962	495,770
1963	487,607
1964	279,191
1965	192,378
1966	252,912
1967	321,364
1968	615,388
1969	593,634
1970	531,672
1971	501,224
1972	474,279
1973	668,928
1974	832,573
1975	748,711
1976	885,456
1978	853,129
1980	584,448
1985	473,023

Since 1960 most catches from the White Sea were generally included in the total numbers reported by the former USSR to ICES. Catches that were not previously reported may come from large commercial fisheries or from small (artisanal) fisheries carried out by the local populace, such as the fishery for cod (*Gadus morhua*). However, whether or not the catches from the White Sea were reported, it is possible to separate some of them from the Barents Sea catches as in most cases different species are taken from each. For example, Navaga (*Boreogadus saida*), which is reported for the Barents Sea area (ICES I), is only caught in the White Sea, as is Pacific herring (*Clupea pallasii*). Most of the salmon (*Salmo salar*, and since the 1970s *Oncorhynchus gorbuscha*) are also taken from the White Sea and Murman (north-east coast of Kola peninsula).

Artisanal catches of cod (*Gadus morhua*) were estimated for Kandalaksha Bay (White Sea) for the time period 1950-1954 (Table 6). Mean catches of catfish (*Anarhichas* spp.) were estimated to be 15-20 tonnes per year in the same area during the 1950s and 1960s.

Table 6. Estimated catch of cod (*Gadus morhua*) by the artisanal fishery in Kandalaksha Bay in the White Sea.

Year	Estimated catch (t)
1950	10.30
1951	5.40
1952	2.75
1953	3.46
1954	3.45

Some catches of marine mammals were also reported. This information has been incorporated into the Marine Mammal Database (see Kaschner *et al.*, this volume). For example, the mean number of ring seals (*Phoca hispida*) caught during the 1960s was about 3,000 animals per year and the mean catch of Beluga whales (*Delphinapterus leucas*) from 1950-1985 was 233 individuals per year.

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FAROESE WATERS: ENVIRONMENT, BIOLOGY, FISHERIES AND MANAGEMENT

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ABSTRACT

The annual marine resources status report produced by the Faroese Fisheries Laboratory (available at *www.frs.fo* under the title 'Fiskastovnar og Umhvørvi 1998') contains a useful overview of the environment and fish stocks of Faroese waters. Unfortunately, the text is in Faroese, which makes it difficult to read by non-Faroese speaking people. This presents a summary of said report, including legends for those of its tables and figures not reproduced here. This account thus presents an overview of the marine environment, and fisheries and fisheries management measures, including allocated effort quotas and spatial management patterns.

INTRODUCTION

The report presented here is an extracted and translated summary of the Faroe Islands fisheries status report 'Fiskastovnar og Umhvørvi 1998' (Anon., 1998), which is only available in the Faroese language. In the present document the figures and tables from this status report will be the 'Status Report' or Anon. (1998), and consist of multi-level numbers (e.g., Figure 1.2.3), whereas Tables and Figures explicitly included in the present report are labeled with single-level numbers (e.g., Figure 1).

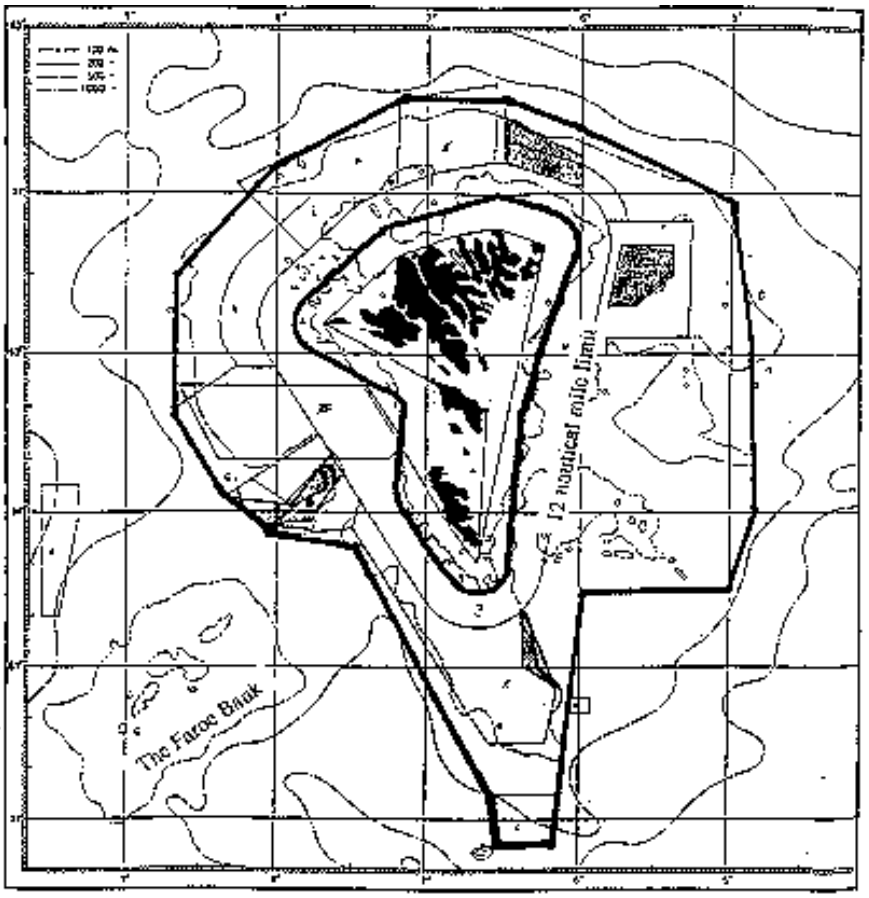

Figure 1. Fishing area regulations in ICES area Vb (Faroe Plateau). Allocation of fishing days applies to the area inside the outer thick line. Holders of effort quotas who fish outside this line can triple their numbers of days. Trawlers are generally not allowed to fish inside the 12 nautical mile limit and only longliners < 100 GRT and jiggers < 100 GRT are allowed to fish inside the innermost thick line. Several areas are closed for parts of the year, to protect spawning areas, exclude separate gears etc.

THE MARINE ENVIRONMENT

The waters around the Faroe Islands are dominated by the North Atlantic Current in the upper 500 m, which to the north of the islands meets the East Icelandic Current (Figure 2.2.2 in Anon., 1998). Clockwise current systems create retention areas on the Faroe Plateau and on the Faroe Bank. The deeper waters to the north and east consist of deep Norwegian Sea water and to the south and west of Atlantic water (Figure 2.2.3 in Anon., 1998). From the late 1980s the intensity of the North Atlantic current passing the Faroe area was found to be decreasing. The productivity of the Faroese waters was very low and recruitment and growth of many fish stocks was very poor during this time. However, in recent years productivity has increased again. Measurements of phytoplankton production show that the situation has gradually improved since 1991. This is illustrated in Figure 2.3.2 in Anon. (1998) which shows the reduction of the nitrate content from winter to late June from 1990-1997. In Figure 2.3.2 of the same report, the phytoplankton biomass per month for 1997 is shown as $\mu g \cdot l^{-1}$ of Chlorophyll *a*, illustrating a typical year sequence. The biomass of zooplankton in June 1991-1997 on the Faroe Plateau shallower than 200 m is also shown in Figure 2.3.7 (Anon., 1998) measured as $mg \cdot m^{-3}$ dry weight. Since 1992, the recruitment of important prey fish species, such as sandeel (*Ammodytes* spp.) and Norway pout (*Trisopterus esmarki*), has been good, and the growth of fish such as cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*) and saithe (*Pollachius virens*) has improved considerably. As well, the productivity of important seabirds has also improved.

TOPOGRAPHY

The topography of Faroese waters is shown in status report Figure 2.2.1 in Anon. (1998), and Table 1 gives the sizes of different areas.

THE FISHERIES AND ASSOCIATED MANAGEMENT MEASURES

For centuries the fishing grounds around the Faroe Islands have been open to international fisheries, involving several countries. Apart from a local fishery with small wooden boats, the Faroese offshore fishery started in the late 19th century. In order to compete with international fisheries, particularly British vessels, a large part of the Faroese fishing fleet specialized as a long-distance fleet and fishing in other areas. Thus, most of the Faroese fleet fished around Iceland, at Rockall, in the North Sea and in more distant waters like Grand Bank, Flemish Cap, Greenland, the Barents Sea and Spitzbergen (Svalbard).

Table 1. Surface areas of different regions within the Faroese 200 nm Exclusive Economic Zone. When a particular area includes the Faroe Islands, the land area of the Islands (1,400 km²) is included. To obtain sea areas only for those cases, the 1,400 km² must be subtracted.

Area	Size (km²)
Faroe Islands (land)	1,400
200 nm zone (includes land)	273,800
ICES Sub-division Vb1 (includes land)	174,600
ICES Sub-Division Vb2	20,750
Faroe Plateau < 200 m (includes land)	21,400
Faroe Plateau 200-500 m	14,900
Faroe Bank < 200 m	4,900
Faroe Bank 200-500 m	3,000
Bill Bailey < 200 m	600
Bill Bailey 200-500 m	2,500
Lousy Bank < 500 m	2,700
Faroe-Iceland Ridge	17,500

Up to 1959, all international vessels were allowed to fish around the Faroe Islands outside the 3 nm fisheries zone. During the 1960s, the fisheries zone was gradually expanded, and in 1977 an EEZ of 200 nm was introduced in the Faroe area. The demersal fishery by foreign countries has since decreased and Faroese vessels now take most of the catches. The fishery may be considered a multi-fleet and multi-species fishery, and is described in Appendix 2.

During the 1980s and 1990s, the Faroese authorities begun to regulate the fishery and investment in fishing vessels. Since 1987 a system of fishing licenses has been introduced, and the demersal fishery of the Faroe Islands has been regulated using technical measures including minimum mesh sizes and closed areas. Closed areas are used in order to protect juveniles and young fish. Fishing is temporarily prohibited (for 1-2 weeks) in areas where the number of small cod, haddock and saithe exceeds 30% of the total catch. After 1–2 weeks of closure the areas are again opened for fishing. A reduction of effort has also been attempted through banning of new licenses and buy back of licenses.

A new quota system, based on Individual Transferable Quotas (ITQ), was introduced in 1994. The fishing year started on September 1 and ended on August 31 the following year. The aim of

the quota system was, to restrict Total Allowable Catches (TACs) for the period 1994–1998, in order to increase the Spawning Stock Biomass (SSB) of Faroe Plateau cod and haddock to 52,000 t and 40,000 t, respectively. The TAC for saithe was set higher than recommended by scientists. It should be noted that cod, haddock and saithe are caught in a mixed fishery and any management measure should account for this. Species under the quota system were Faroe Plateau cod, haddock, saithe, redfish and Faroe Bank cod.

The catch quota management system introduced in the Faroese fisheries in 1994 was met with considerable criticism by the industry, and resulted in substantial discarding and mis-reporting of catches. Reorganization of enforcement and control did not solve the problems. As a result of the dissatisfaction with the catch quota management system, the Faroese Parliament discontinued the system from May 31 1996. In close co-operation with the fishing industry, the Faroese government has developed a new system based on 'fleet category individual transferable effort quotas', measured in days. The new system was put into place June 1, 1996 and the fishing year from September 1 to August 31, as introduced under the catch quota system, has been maintained.

The individual transferable effort quotas apply to:

- longliners less than 100 GRT;
- longliners greater than 100 GRT;
- jiggers;
- single trawlers less than 400 HP; and
- pair trawlers.

The single trawlers greater than 400 HP do not have effort limitations, but they are not allowed to fish within the 12 nautical mile limit. The areas closed to them, as well as to the pair trawlers, have increased in area and time. Their catch of cod and haddock is limited by maximum bycatch allocation. The single trawlers less than 400 HP are given special licenses to fish in certain areas inside 12 nautical miles with a bycatch allocation of 30% cod and 10% haddock. In addition, they must use sorting devices in their trawls.

One fishing day by longliners less than 100 GRT is considered equivalent to two fishing days for jiggers in the same gear category. Longliners less than 100 GRT could therefore double their allocation by converting to jigging. Table 2 shows the number of fishing days used by this fleet category for 1985–1995 and 1998-1999 and Table 3 shows the number of allocated days inside the outer thick line in Figure 1. Holders of individual transferable effort quotas who fish outside this line can fish for 3 days for each day allocated inside the line.

Table 2. Number of fishing days[a)] used by various fleet groups in ICES area Vb1 1985-99. For other fleets there are no effort limitations. Catches of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*) and redfish (*Sebastes* spp.)are regulated by the by-catch percentages given in section 2.1.1. In addition there are special fisheries regulated by licenses and gear restrictions.

Year	Longliner 0-110 GRT, jigger, trawlers < 400 HP	Longliner > 110 GRT	Pairtrawlers > 400 HP
1985	13,449	2,973	8,582
86	11,399	2,176	11,006
87	11,554	2,915	11,860
88	20,736	3,203	12,060
89	28,750	3,369	10,302
90	28,373	3,521	12,935
91	29,420	3,573	13,703
92	23,762	2,892	11,228
93	19,170	2,046	9,186
94	25,291	2,925	8,347
95	33,760	3,695	9,346
mean (85-95)	(22,333)	3,023	10,778
98	23,971	2,519	6,209
99	21,040	2,428	7,135
mean (98-99)	(22,506)	2,474	6,672

[a)] This is the real number of days fishing not affected by doubling or tripling of days by changing areas/gears.

The effort quotas are transferable within gear categories. The allocations of number of fishing days by fleet categories was arranged in such a manner that, together with other regulations of the fishery, they should result in average fishing mortalities of 0.45 $year^{-1}$ on each of the three stocks, corresponding to average annual catches of 33% of the exploitable stocks in numbers. Built into the system is also an assumption that the day system is self-regulatory, because the fishery will move between stocks according to the relative availability of each of them and no stock will be overexploited.

In addition to the number of days allocated, it is also stated in the legislation what percentage of total catches of cod, haddock, saithe and redfish, each fleet category on average are allowed to fish (Table 4).

Table 3. Number of allocated days for each fleet group since the new management scheme was adopted and number of licenses per fleet.

	Fleets	1996/97	1997/98	1998/99	1999/2000	No. of licenses
Group 1	Single trawlers > 400 HP	- Regulated by area and by-catch limitations -				13
Group 2	Pair trawlers > 400 HP	8,225	7,199	6,839	6,839	31
Group 3	Longlners > 110 GRT	3,040	2,660	2,527	2,527	19
Group 4	Longliners and jiggers 15-110 GRT, single trawlers < 400 HP	9,320	9,328	8,861	8,861	106
Group 5	Longliners and jiggers < 15 GRT	22,000	23,625	22,444	22,444	696

Table 4. Legally defined average percentage of total annual catch of cod (*Gadus morhua*), haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*) and redfish (*Sebastes* spp.) allocated to gear category for Faroese vessels.

Fleet category	Percentage catch			
	Cod	Haddock	Saithe	Redfish
Longliners < 110 GRT, Jiggers, Single trawl.<400HP	51.0	58.00	17.5	1.0
Longliners > 110GRT	23.0	28.00	0.0	0.0
Pairtrawlers	21.0	10.25	69.0	8.5
Single trawlers > 400 HP	4.0	1.75	13.0	90.5
Others	1.0	2.00	0.5	0.5

Technical measures such as area closures during the spawning periods to protect juveniles and young fish, and mesh size regulations as mentioned above are still in effect. Overviews of spawning area closures and areas closed to trawling, together with the periods when the areas are closed, are given in Figure 2 and 3, respectively. In addition to these trawl ban areas, no trawling is allowed within twelve nautical miles of the Faroese territorial baseline. However, during summer, 10-15 small trawlers (<500 Hp) are allowed to fish in specified areas within this limit, targeting mainly lemon sole and plaice.

The Faroe Bank (ICES area Vb2) is managed separately from the Faroe Plateau (ICES area Vb1). Areas on the Faroe Bank shallower than 200 m are permanently closed to all trawl gear, and the longline fishery is regulated by individual day quotas.

ACKNOWLEDGEMENTS

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Closed spawning areas.

Nr.	From	To
1	15-Feb	31-Mar
2	15-Feb	15-Apr
3	15-Feb	15-Apr
4	01-Feb	01-Apr
5	15-Jan	15-May
6	15-Feb	15-Apr
7	15-Feb	15-Apr
8	15-Jan	01-Apr

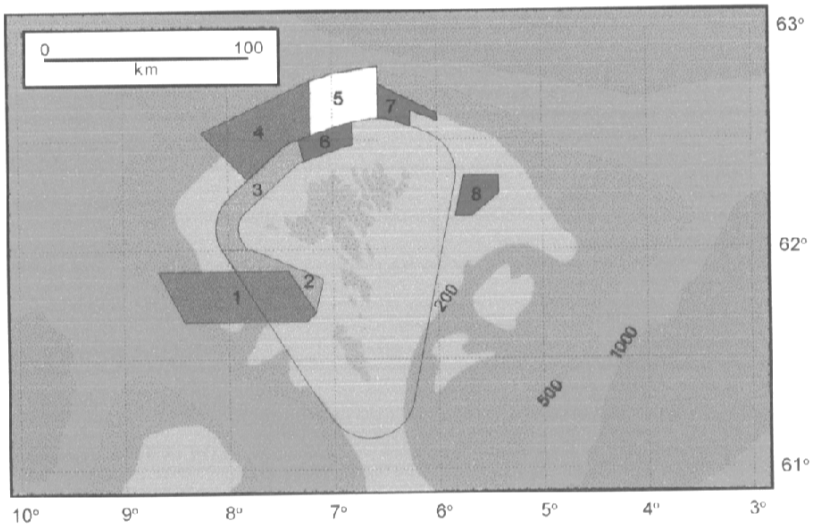

Figure 2. Spawning area closures (all gears) in ICES area Vb1 (Faroe Plateau) and the time periods of closure.

Areas closed for trawl fishery.

Nr.	From	To	> 500 hk
A	01-Jan	31-Dec	
a	01-Jun	31-Aug	
B	20-Jan	01-Mar	
C	01-Jan	31-Dec	
D	01-Jan	31 Dec	
E	01-Apr	31-Jan	
F	01-Jan	31-Dec	
G	01-Jan	31-Dec	
H	01-Jan	31-Dec	
I	01-Jan	31-Dec	500
J	01-Jan	31-Dec	500
K	01-Jan	31-Dec	
L	01-Jan	31 Dec	
M	01-Feb	01-Jun	
O	01-Jan	31-Dec	
P	01 Jan	31 Dec	
R	01-Jan	31-Dec	500
S	01-Jan	31 Dec	500

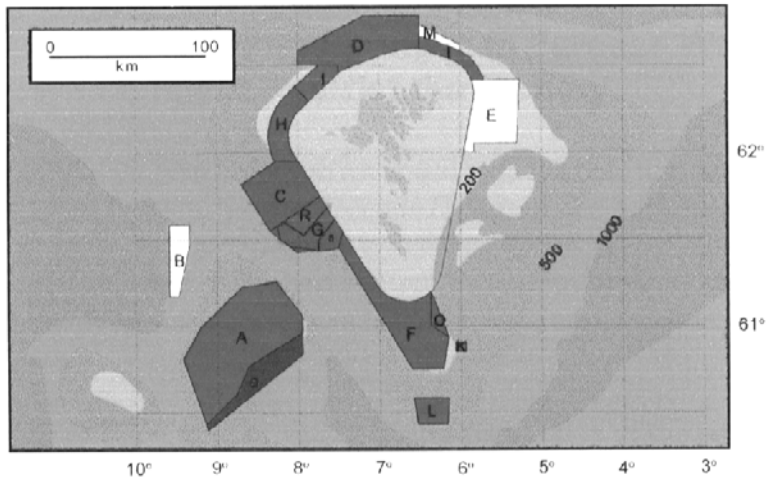

Figure 3. Areas in ICES Vb1 outside the 12 nm zone around the Faroe Islands that are closed for trawl fishery and the periods when they are closed.

APPENDIX 1: LEGENDS TO FIGURES AND TABLES IN 'FISKASTOVNAR OG UMHVØRVI 1998' (ANON., 1998)

Text in Faroese only (*www.frs.fo*)

2.2 The ocean surrounding the Faroe Islands

2.2.1 Bottom topography in the ocean surrounding the Faroe Islands.

Table 2.2.1. Standard values for temperature and salinity in the various watermasses in Faroese waters.

Water mass	Temp. (°C)	Salinity
Atlantic water	7-9	35.14-35.35
East Icelandic water	2-4	34.7-34.9
Norwegian Atlantic water	~5	~ 35.0
Scottish Atlantic water	9-11	35.25-35.45
Deep Norwegian Sea water	-1-0	34.9
Faroe Plateau water	6-10	35.0-35.25

2.2.2 Mean features of the upper-layer circulation in the eastern North Atlantic. NAS = North Atlantic Current, EÍS = East Icelandic Current; SSS = Scottish Slope Current; JMF = Jan Mayen Front; ÍF = Iceland Front; FS = Faroe Current; IS = Irminger Current; EGS = East Greenland Current.

2.2.3 At depths of approximately 500 m and deeper, very cold sea water is found to the east of the East Greenland - Scotland ridge as opposed to the area west of the ridge with much warmer sea water at all depths. Occasionally, cold water flows over the ridge into the Atlantic, and a steady flow through the Faroe Bank Channel is to the west (the white arrows).

2.2.4 Three cross-sections of the Faroe plateau (location indicated on the map). Each shows the average depth of the various water masses.

2.2.5 Average direction (arrows) and strength (length of arrow) of the current around the Faroe Plateau. Release points of drifters at black dots.

2.3 Plankton in Faroese Waters

2.3.1 Schematic representation of the first three trophic levels in the ocean. In the first level are the primary producers (phytoplankton), in the second level are the grazers (herbivorous zooplankton) and in the third are the larger zooplankton feeding on smaller zooplankton. In the figure, only fish larvae are shown in the third trophic level. Many other organisms, however, may be in that level as well. The organisms representing each trophic level are only selected examples of the many marine species that could be present in that level.

2.3.2 Phytoplankton biomass (µg chl. *a* l^{-1}) and nitrate concentrations (µM) on the central Faroe shelf (northeast of Nólsoy) during 1997.

2.3.3 Nitrate concentrations on the central Faroe shelf between 3 May 1995 and 4 June 1998. The samples were collected to the north of Skopun.

2.3.4 Reduction in nitrate concentrations on the Faroe shelf from winter concentrations to 26 June each year during the period 1990-1997.

2.3.5 Abundance of copepods and barnacle larvae on the central Faroe shelf during 1997. Copepod larvae are not included in the figure although they were found in significant numbers. No other zooplankton occurred in significant amounts.

2.3.6 Egg production of the copepod *Calanus finmarchicus* (eggs $female^{-1}$ day^{-1}) on the Faroe shelf during 17-25 April 1998.

2.3.7 Mean zooplankton biomass (mg dry weight m^{-3}) in the upper 50 meters of the water column on and off the Faroe shelf, respectively, in June 1990-1997.

2.3.8 Absolute and relative abundance of neritic and oceanic copepods on the Faroe shelf during June from 1989 to 1997.

2.3.9 Mean abundance of barnacle larvae (upper figure) and relative abundance of barnacle larvae and copepods (lower figure) on the Faroe shelf during May from 1989 to 1997.

3.1 Fish and Fisheries Biology

3.1.1 Elements that affect the size of the fish stock.

3.1.2 The graph depicts the decrease in number of an average year class of cod and Norway pout on the Faroe Plateau. This graph only takes into account the effects of natural mortality.

3.1.3 The graph depicts the decrease in numbers of cod for an average year on the Faroe Plateau for three different fishing mortality rates. Calculations are based on a natural mortality rate of 0.2 and a recruitment age of two years.

3.1.4 Relationship between natural mortality rates and percentage of total fish population on the Faroe Plateau.

3.1.5 Mean length and mean weight at age for cod on the Faroe Plateau.

3.1.6 The graph depicts the biomass with age for an average year class of cod under normal growth conditions at different fisheries mortality rates.

3.1.7 Projection of yield per recruit on the Faroe Plateau at different fishing mortality rates.

3.1.8 Age distribution of herring in landings from the North Sea in the years 1952, 1962 and 1972. Fishing mortality rates for these years are also indicated.

3.1.9 Projection of the number of cod on the Faroe Plateau over a ten year period assuming 1) a natural mortality rate of 0.2 for all ages; 2) a fishing mortality rate of 0.0 for ages 1-2, 0.3 for age 3, and 0.7 for age 4 and older; 3) an average fishing pattern over the last ten years; and 4) a recruitment of 16 million fish at age two. The graph shows that under current fishing patterns only a few age groups will be represented in the fishery.

Table 3.1.1 Overview over samples from landings at Faroe Islands in 1997. Numbers of samples measured and weighed are presented as numbers of fishes which are length measured or weighed respectively. Number of samples age measured are those which, in addition to being length measured, had their otoliths taken for aging. Species of fish listed: Cod (*Gadus morhua*), Faroe Plateau, cod, Faroe Bank, haddock (*Melanogrammus aeglefinus*), saithe (*Pollachius virens*), redfish (*Sebastes* spp.), tusk (*Brosme brosme*), ling (*Molva molva*), blue ling (*Molva dypterygia*), Greenland halibut (*Reinhardtius hippoglossoides*), whiting (*Merlangius merlangus*), blue whiting (*Micromesistius poutassou*), greater silver smelt (*Argentina silus*), angler fish (*Lophius* sp.), plaice (*Pleuronectes platessus*), Norway lobster (*Nephrops norvegicus*), queen scallop (*Chlamys islandica*).

3.2 Catches and Fishing Fleet

3.2.1 Landings by Faroese vessels of demersal fish from Faroese waters.

3.2.2 Landings of demersal fish from Faroese waters by gear type.

Y-axis: Landings (tonnes)
X-axis: Year
Black circles: Trawling and Gill-netting
Clear squares: Hook and line

Table 3.2.1 Number of fishing days by vessel type in Faroese waters, 1985-1996. Unfortunately, there are as yet no reliable numbers for 1997. It is anticipated, however, that levels will remain the same as the previous year. These are the vessels types used for stock assessments. For the purpose of this report, more vessel types are included than those defined in Faroese regulations. Gear types listed: Open boats, smaller vessels using hook and line, small trawlers, gill-netting vessels, jigging vessels, single trawlers < 1000 Hp, single trawlers > 1000 Hp, pair trawlers < 1000 Hp, pair trawlers > 1000 Hp, larger longline vessels.

3.2.3 Average landings of demersal fish per fishing day by three vessel types for the years 1985-1996. Listed from top to bottom: Single trawlers >1000 Hp, pair trawlers >1000 Hp, single trawlers < 1000 Hp.

3.2.4 Average landings of demersal fish per fishing day by three vessel types for the years 1985-1996. Listed from top to bottom: Larger longliners, small trawlers, smaller vessels using hook and line.

3.1.1. Elements affecting fish stocks

	Positive		Negative	
Recruitment	→	Stock size and Weight	→	Natural mortality
Growth	→		→	Fishing mortality

Table 3.1.2. Sample of short-term predictions for catches and stocks, in this case of haddock in the Faroes region. (See chart).

Fisheries policy	Fishing mortality (year^{-1})	Fishery catch (tonnes)	Spawning stock (tonnes)
No fishery	0.00	0	74,000
Fishing mortality < 30% of 1996 level	0.21	12,000	59,000
Fishing mortality equal to 1996 level	0.31	16,000	54,000
Fishing mortality > 30% of 1996 level	0.40	20,000	49,000

4.2 Cod (*Gadus morhua*) from the Faroe Plateau

Table 4.2.1 Faroese landings of cod taken from the Faroe Plateau 1985-1997, by gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important Faroe Plateau cod as a fishing species has been for each fleet during this period.

4.2.1 Main spawning grounds of cod on the Faroe Plateau.

4.2.2 Growth rate of Faroe Plateau cod as shown by mean length (cm) as a function of age (years). Data are from the yearly spring survey. Length at 50 % maturity is also shown.

4.2.3 Total landings of cod (in round weight) from the Faroe Plateau 1903-1997. For the years 1903-1964, the landings from the Faroe Bank are also included.

4.2.4 Cod landings per unit of effort expressed as kg/day for selected commercial fleets (pair trawlers > 1000 HP and longliners > 100 GRT) and the survey vessel *Magnus Heinason* expressed as kg/two fishing-hours.

4.2.5 Total landings of cod for 1997 shown as percentage of fish in each age group.

4.2.6 Average weight of Faroe Plateau cod 1960-1997. The graph represents the mean year class strength of the weight of four, five, six and seven year old cod.

4.2.7 Year class strength of cod 1959-1996 as two-year olds. The number for 1996 is based on the spring survey, in contrast to the others, which are based on virtual population analysis (VPA).

4.2.8 Spawning biomass of Faroe Plateau cod 1961-1997 in tonnes at the beginning of each year.

4.2.9 Fishing mortality of Faroe Plateau cod as a mean for 3-7 year old cod.

4.2.10 Yield-per-recruit as a function of fishing mortality of Faroe Plateau cod. Arrows indicate the fishing mortality giving the highest yield-per-recruit (Fmax) and the fishing mortality in 1997 (F97).

4.3 Cod from the Faroe Bank

Table 4.3.1 Faroese landings of cod taken from the Faroe Bank 1985-1997, by gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important Faroe Bank cod as a fishing species has been for each fleet during this period.

4.3.1 Growth rate of Faroe Bank cod as shown by mean length (cm) as a function of age (years). Data are from the yearly spring survey. Length at 50 % maturity is also shown.

4.3.2 Total landings of Faroe Bank cod (round weight) 1965-1997.

4.3.3 Landings of Faroe Bank cod per unit of effort expressed as kg/day for the larger longliners (>100 GRT) and smaller longliners (<100 GRT) 1988-1997.

4.3.4 Landings of Faroe Bank cod per unit of effort expressed as kg/hour from the spring survey 1983-1998, based on hauls from depths < 200 m.

4.4 Haddock (*Melanogrammus aeglefinus*)

Table 4.4.1 Faroese landings of haddock taken from the Faroe area 1985-1997, by gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important Faroe haddock as a fishing species has been for each fleet during this period.

4.4.1 Main spawning grounds of haddock on the Faroe Plateau.

4.4.2 Growth rate of Faroe haddock as shown by mean length (cm) as a function of age (years). Data are from the yearly spring surveys 1983-1997. As three years old, 60% have attained maturity.

Table 4.4.2 Short-term predictions for catches of Faroe haddock. Landings in 1998 are set at 14,000 tonnes, corresponding to a fishing mortality of 0.32 (equal to 1997). The spawning biomass at 1 January 1999 is estimated to be 42,000 tonnes.

Fisheries policy	Fishing mortality ($year^{-1}$)	Fishery catch (tonnes)	Spawning stock (tonnes)
No fishery	0.00	0	48,000
Fishing mortality < 20% of 1997 level	0.25	9,000	38,000
Fishing mortality equal to 1997 level	0.32	11,000	36,000
Fishing mortality > 20% of 1997 level	0.38	13,000	34,000

4.4.3 Total landings of haddock (in round weight) from the Faroe area 1903-1997.

4.4.4 Haddock landings per unit of effort expressed as kg/day for selected commercial fleets (pair trawlers > 1000 HP, longliners > 100 GRT and longliners < 100 GRT).

4.4.5 Total landings of haddock for 1997 shown as percentage of fish in each age group.

4.4.6 Average weight of Faroe haddock (age group 3-7) since 1976.

4.4.7 Yearly class-strength of haddock 1959-1996 as two-year olds. The numbers for 1996-97 are based on the spring survey in contrast to the others which are based on virtual population analysis (VPA).

4.4.8 Spawning biomass of Faroe haddock 1961-1997 in tonnes at the beginning of each year.

4.4.9 Fishing mortality of Faroe haddock as a mean for 3-7 year old haddock.

4.4.10 Yield-per-recruit as a function of fishing mortality of Faroe haddock. Arrows indicate the fishing mortality giving the highest yield-per-recruit (F_{max}) and the fishing mortality in 1997 (F97).

4.5 Saithe (*Pollachius virens*)

Table 4.5.1 Faroese landings of saithe taken from the Faroe area 1987-1997, by gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important Faroe saithe a fishing species has been for each fleet during this period.

Table 4.5.2 Short-range prediction of landings and spawning biomass of Faroe saithe. Landings in 1998 are set at 21,000 tonnes, corresponding to a fishing mortality of 0.44.

4.5.1 Main spawning grounds of saithe on the Faroe Plateau.

4.5.2 Growth rate of Faroe saithe as shown by mean length (cm) as a function of age (years). Data are from landings 1995-1997. As five year old 50% have attained maturity.

4.5.3 Total landings of saithe (in round weight) from the Faroe area in this century.

4.5.4 Saithe landings per unit of effort expressed as kg/day for selected commercial fleets (pair trawlers > 1000 HP, Single trawler >1000 HP and jiggers).

4.5.5 Total landings of saithe for 1997 shown as percentage of fish in each age group.

4.5.6 Average weight of Faroe saithe (age group 4-8) since 1960.

4.5.7 Yearly class-strength of saithe 1957-1996 as three-year old fish. The numbers for 1996-97 are preliminary estimates in contrast to the others which are based on virtual population analysis (VPA).

4.5.8 Spawning biomass of Faroe saithe 1960-1997 in tonnes at the beginning of each year.

4.5.9 Fishing mortality of Faroe saithe as a mean for 3-7 year old saithe.

4.5.10 Yield-per-recruit as a function of fishing mortality of Faroe saithe. Arrows indicate the fishing mortality giving the highest yield-per-recruit (F_{max}) and the fishing mortality in 1997 (F97).

4.6 Redfish (*Sebastes* spp.)

4.6.1a Distribution of the western stock complex of ocean perch (*Sebastes marinus)*.

4.6.2 Mean length at age for ocean perch and deep sea redfish. As redfish are difficult to age, especially at older ages (more than 25 years), the figure is tentative only.

4.6.1b Distribution of the western stock complex of deep sea redfish (*Sebastes mentella*).

4.6.3 Total landings of redfish from the western area (Faroes, Iceland, East Greenland, Rockall and Hatton Bank) during this century. Shown also are the landings from the Faroe area.

Table 4.6.1 Faroese landings of redfish taken from the Faroe Plateau 1985-1997, by gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important redfish as a fishing species has been for each fleet during this period.

4.6.4 Landings per unit of effort expressed as tonnes/day of redfish by the larger, wet-fish trawlers in the Faroes, 1985-1997.

4.6.5 Total landings of ocean perch from the western area (Faroes, Iceland, East Greenland, Rockall and Hatton Bank) since 1978. Also shown are the landings from the Faroe area.

4.6.6 Length distribution of ocean perch in Faroese landings from the Faroe area in 1995.

4.6.7 Total landings of deep sea redfish from the western area (Faroes, Iceland, East Greenland, Rockall and Hatton Bank) since 1978. Also shown are the landings from the Faroe area.

4.6.8 Length distribution of deep sea redfish in Faroese landings from the Faroe area in 1997.

4.7 Blue Ling (*Molva dypterygia*)

Table 4.7.1 Faroese landings of blue ling taken from the Faroe Plateau 1985-1997, by gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important blue ling as a fishing species has been for each fleet during this period.

4.7.1 The distribution of blue ling (*Molva dypterygia)* in the Northeast Atlantic.

4.7.2 Growth rate of blue ling based on investigations with '*R/V' Magnus Heinason* 1987-1993. Also indicated is the age when 50% have attained sexual maturity. From the graph it can be seen that the males mature approximately one year earlier than the females. Blue ling are difficult to age and the values represent a best estimate.

4.7.3 Total landings of blue ling from the Faroe area since 1963.

4.7.4 Landings per unit of effort expressed as tonnes/day of blue ling by the larger, wet-fish trawlers (> 1000 HP) in the Faroe area during the period March-May 1985-1997.

4.7.5 Length distribution of blue ling in Faroese landings from the Faroe area in 1997.

4.8 Ling (*Molva molva*)

Table 4.8.1 Faroese landings of ling taken from the Faroe Plateau 1985-1997, by gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important ling as a fishing species has been for each fleet during this period.

4.8.1 The distribution of ling (*Molva molva)* in the Northeast Atlantic.

4.8.2 Average growth rate of ling based on age readings taken of Faroese landings in January-June 1996 (five-year and older fish) and from Icelandic bottom trawl surveys (one to four-year old fish). As the growth rate might vary between the Faroes and Iceland, the results should be treated with caution.

4.8.3 Total landings of ling from the Faroe area since 1904.

4.8.4 Landings per unit of effort expressed as kg/day of ling by the larger, longline vessels in the Faroe area during the period 1985-1997.

4.8.5 Age distribution of ling in Faroese landings from the Faroe area in 1997.

4.9 Tusk (*Brosme brosme*)

Table 4.9.1 Faroese landings of tusk taken from the Faroe Plateau 1985-1997, by gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important tusk as a fishing species has been for each fleet during this period.

4.9.1 Distribution of tusk (*Brosme brosme)* in the Northeast Atlantic.

4.9.2 Average growth rate of tusk based on age readings taken of Faroese landings in January-June 1996 (seven-year and older fish) and from Icelandic bottom trawl surveys (one to six-year old fish). As the growth rate might vary between the Faroes and Iceland, the results should be treated with caution.

4.9.3 Total landings of tusk from the Faroe area since 1906.

4.9.4 Landings per unit of effort expressed as kg/day of ling by the larger, longline vessels in the Faroe area in the period 1985-1997.

4.9.5 Age distribution of tusk in Faroese landings from the Faroe area in 1997.

4.10 Greenland Halibut (*Reinhardtius hippoglossoides*)

Table 4.10.1 Faroese landings of Greenland halibut from the Faroese fishing area 1985-1997, as shown by the gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important Greenland halibut as a fishing species has been for each fleet during this period.

4.10.1 Total landings of Greenland halibut (round weight) in the Faroese fishing area 1971-1997 and total landings in Faroese, Icelandic, and East Greenland fishing areas combined.

Table 4.10.2 Short-range prediction of landings and spawning biomass of Greenland halibut. Landings in 1998 are set at 23,000 tonnes, corresponding to a 20 % reduction in fishing mortality from 1997 to 1998. This yields a spawning biomass of 61,000 tonnes as of 1 January 1999.

4.10.2 Landings per unit of effort expressed as kg/day of Greenland halibut for Faroese gill-netters, single trawlers > 1000 HP, and longliners > 100 GRT.

4.10.3 Length distribution of 1997 landings of Greenland halibut for single trawlers and gill-netters.

4.10.4 Spawning stock biomass of Greenland halibut in Faroese, Icelandic, and East Greenland fishing areas combined.

4.10.5 Year class strength of Greenland halibut 1970-1992 as number of five-year olds.

4.10.6 Fishing mortality of Greenland halibut 1975-1997, averaged for age classes 8-12 years.

4.10.7 Yield-per-recruit of Greenland halibut as a function of fishing mortality.

4.11. Angler Fish (*Lophius* spp.)

Table 4.11.1 Faroese landings of anglerfish from the Faroese fishing area 1985-1997, as shown by the gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important anglerfish as a fishing species has been for each fleet during this period.

4.11.1 Total landings of anglerfish (round weight) in the Faroese fishing area 1906-1997.

4.11.2 Landings per unit of effort expressed as kg/day of anglerfish for Faroese gill-netters, single trawlers < 400 HP, single trawlers 400-1000 HP, and single trawlers > 1000 HP.

4.11.3 Length distribution of anglerfish in the 1997 landings for gill-netters.

4.12 Lemon Sole (*Microstomus kitt*)

Table 4.12.1 Faroese landings of lemon sole from the Faroese fishing area 1985-1997, as shown by the gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important lemon sole as a fishing species has been for each fleet during this period.

4.12.1 Growth rate of lemon sole in Faroese waters.

4.12.2 Total landings of lemon sole (round weight) 1903-1997 on the Faroe Plateau and the Faroe Bank combined.

4.12.3 Landings per unit of effort expressed as kg/day of lemon sole in Faroese waters 1988-1997 for single trawlers < 400 HP and single trawlers 400-1000 HP.

4.13 Plaice (*Pleuronectes platessus*)

Table 4.13.1 Faroese landings of plaice from the Faroese fishing area 1985-1997, as shown by the gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important plaice as a fishing species has been for each fleet during this period.

4.13.1 Total landings of plaice in Faroese waters from 1903 to 1997.

4.13.2 Landings per unit of effort expressed as kg/day of plaice in Faroese waters 1988-1997 for single trawlers < 400 HP and single trawlers 400-1000 HP.

4.14 Halibut (*Hippoglossus hippoglossus*)

Table 4.14.1 Faroese landings of halibut from the Faroese fishing area 1985-1997, as shown by the gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important halibut as a fishing species has been for each fleet during this period.

4.14.1 Spawning area of halibut northwest of the Faroe Bank.

4.14.2 Growth rate of halibut in Faroese waters. Note that male and female growth rates are different from age seven.

4.14.3 Total landings of halibut (round weight) 1903-1997 on the Faroe Plateau and the Faroe Bank combined.

4.14.4 Landings per unit of effort expressed as kg/day of halibut 1988-1997 for single trawlers > 1000 HP, longliners < 100 GRT and longliners > 100 GRT.

4.15 Whiting (*Merlangius merlangus*)

Table 4.15.1 The Faroese landings of whiting from the Faroese fishing area 1985-1997, as shown by the gutted weight in tonnes (bottom row) and corresponding percentages taken by each commercial fleet. The column to the right shows in percentages how important whiting as a fishing species has been for each fleet during this period.

4.15.1 Growth rate of whiting in Faroese waters.

4.15.2 Total landings of whiting (round weight) 1905-1997 on the Faroe Plateau and the Faroe Bank combined.

4.15.3 Landings per unit of effort expressed as kg/day of whiting 1988-1997 for pair trawlers > 1000 HP and longliners < 100 GRT.

4.15.4 Length distribution of 1997 Faroese landings of whiting for pair trawlers > 1000 HP.

4.16 Norway Pout (*Trisopterus esmarki*)

4.16.1 Area with highest biomass of Norway pout in the Faroes area.

4.16.2 Average length by age of Norway pout in the period 1985-1994.

4.16.3 The Faroese catch (in 1,000 tonnes) at Faroes of Norway pout in the period 1980-1994.

4.16.4 Average age of Norway pout by percent of catch in the period 1985-1994.

4.16.5 Average length of Norway pout in percentages of catch in the period 1985-1994.

4.17 Greater Silversmelt (*Argentina silus*)

4.17.1 Area with highest biomass of greater silversmelt in the Faroes area.

4.17.2 Average length by age of male and female greater silversmelt in the period 1987 to 1988

4.17.3 The Faroese catch (in tonnes) of greater silversmelt in Faroese waters in the period 1987-1997.

4.17.4 Age distribution of greater silversmelt by percent of catch in 1997.

4.18 Blue Whiting (*Micromesisitus poutassou*)

4.18.1 Main distribution and migration of blue whiting between spawning (south) and feeding areas (north).

4.18.2 Average weight of blue whiting by age in the Northeast Atlantic.

4.18.3 Yearly international catch of blue whiting (in tonnes) as well as the Faroese catch from 1980 to 1997.

4.19 Herring (*Clupea harengus*)

4.19.1 Distribution and migration pattern of Norwegian Spring Spawning herring showing spawning and feeding areas since 1991.

4.19.2 Migration pattern of older Norwegian Spring Spawning herring in 1996. During March the main concentration were found west of the middle of Norway; in May they migrated to Faroese waters and in August they were found farther north off northern Norway.

4.19.3 Migration pattern of young Norwegian Spring Spawning herring in 1996. During March the main concentration were found west of the middle of Norway. In May-June they entered Faroese waters and later in August migrated farther north and then into Norwegian waters.

4.19.4 Migration pattern of Norwegian Spring Spawning herring in 1997. In April the herring moved from Norwegian into Faroese and international waters. In June they began to move northward until in August they were found in the northern reaches of the Norwegian waters.

4.19.5 Migration pattern of Atlanto Scandian herring during the period 1950-1962.

4.19.6 Migration pattern of Atlanto Scandian herring during the period 1963-1966.

4.19.7 Migration pattern of Atlanto Scandian herring during the period 1967-1968.

4.19.8 Average weight by age of Norwegian Spring Spawning herring in 1997.

4.19.9 Total international catch of Atlanto Scandian herring in millions of tonnes during the period 1950-1997.

4.19.10 Fishing mortality (age 5-14 years) of Atlanto Scandian herring during the period 1950-1997.

4.19.11 Spawning biomass by millions of tonnes of Atlanto Scandian herring during the period 1950-1997.

4.19.12 Recruitment of three-year old Atlanto Scandian herring (in 1,000 millions) during the period 1950-1997.

4.20 Mackerel (*Scomber scombrus*)

4.20.1 Migration pattern of mackerel which spawn in the area west of Ireland.

4.20.2 Growth in weight of mackerel by age.

4.20.3 The total international catch of mackerel (in tonnes) in the Northeast Atlantic.

4.20.4 The catch of mackerel (in tonnes) from Faroese waters.

4.20.5 Fishing mortality of mackerel (ages 4-8) for the period 1984-1996.

4.20.6 The total mackerel spawning biomass (in millions of tonnes) for the period 1984-1996 (all stocks combined).

4.20.7 Recruitment at age 0 for the western mackerel stock for the period 1984-1996.

4.21 Salmon (*Salmo salar*)

4.21.1 Distribution of salmon in the North Atlantic and the Faroese fishing area before and after 1984.

4.21.2 Average ratio (with 95% confidence limits) of salmon tagged at the Faroes and recaptured in countries of origin, corrected for fishing mortality in same.

4.21.3 Yearly catch of salmon (in tonnes) from the North Atlantic and the Faroese catch north of the islands for the period 1960-1997.

4.22 Norway Lobster (*Nephrops norvegicus*)

4.22.1 Distribution of Norway lobster in Faroese waters.

4.22.2 Length by age of male Norway lobster.

4.22.3 The Faroese catch of Norway lobster by year from the lobster trawlers.

4.22.4 Effort (thousand of trawl hours) by the lobster trawlers.

4.22.5 Landings per unit of effort expressed as kg/trawl hour by the lobster trawlers.

4.22.6 Seasonal landings in tonnes by the lobster pot fishers.

4.22.7 Effort in thousand of pot days by the lobster pot fishers.

4.22.8 Seasonal catch per unit of effort (g/pot days).

4.22.9 Length of male Norway lobster as measured by percent of catch during the season of 1997/1998.

4.23 Shrimp

4.23.1 Areas around the Faroes with most shrimp.

4.23.2 Length of shrimp as measured by percent of catch in May 1995.

4.23.3 Length of shrimp as measured by percent of catch taken from the Faroe Plateau in June 1996.

4.24 Queen Scallop (*Chlamys islandicus*)

4.24.1 Main areas of Queen scallop east and north of the Faroes.

4.24.2 Average size (height) in cm by age in the catches during the period 1990/91-1992/93 and 1994/95.

4.24.3 Average weight of muscles and milt/roe for the 6 cm group of Queen scallop during the year.

4.24.4 Faroese catch of Queen scallop during the period 1970-71 to 1997-98.

4.24.5 Effort expressed as thousands of dredge hours during the period 1970-71 to 1997-98.

4.24.6 Catch per unit of effort expressed as kg/dredge hour of Queen scallop during the period 1970-71 to 1997-98.

4.24.7 Age distribution expressed as a percent of the Queen scallop catch in the 1997-98 season.

APPENDIX 2 : FISHERIES AROUND THE FAROE ISLANDS

The fisheries in Faroese waters consist of single-species, pelagic fisheries and mixed-species, demersal fisheries (coastal and offshore). The demersal fisheries are mainly conducted by Faroese fishers, whereas the major part of the pelagic fisheries are conducted by foreign fishers licensed through bilateral and multilateral fisheries agreements.

PELAGIC FISHERIES

Three main species of pelagic fish are fished in Faroese waters: blue whiting, herring and mackerel. Several countries participate.

Pelagic species

Blue Whiting

The major spawning areas for blue whiting are along the shelf break to the west of the British Isles, from south of Ireland in the south, to the Wyville-Thomson Ridge in the north. The spawning period is from late February to mid-April.

Following spawning, the bulk of the spawning stock migrates north into the Norwegian Sea to feed. The migration route is, to a large extent, through Faroese waters on both sides of the Faroe Plateau, through the Faroe Bank Channel and the Faroe-Shetland Channel at a depth of approximately 300-400 m.

During summer and autumn, the stock is widely distributed in the Norwegian Sea on the southern and eastern side of the Atlantic Front. The migration south to the spawning areas commences in late November/early December through the Faroe-Shetland Channel.

Blue whiting eggs and larvae are pelagic and are carried to the north with the prevailing currents. The nursery areas are along the shelf break around the Faroe Plateau, west and north of Scotland, the Norwegian Deep and to the west of Norway.

Blue whiting are fished with pelagic trawls. In Faroese waters, the largest catches are taken by Russian factory trawlers, which process the catches for human consumption. Their fisheries take place almost every month of the year. The main area fished is around the southern tip of the Faroe Plateau.

The catches by Norwegian, EU and Faroese vessels, which are almost exclusively reduced to fishmeal and oil, are taken from late April through May around the southern tip of the Faroe Plateau.

Herring

Three herring stocks, Atlanto Scandian Spring-Spawning herring (also called Norwegian Spring-

Spawning herring); west of Scotland Autumn-Spawning herring; and local, Summer-Spawning herring are fished in Faroese waters. The Atlanto Scandian Spring-Spawning herring is by far the most important of these stocks.

Almost extinct in the early seventies, the spawning stock has rebuilt to the same level as it was in the late fifties and early sixties. The stock spawns on the banks off western Norway in March. Subsequently (in the most recent years), the spawning stock migrates to the west and south into the southern and central parts of the Norwegian Sea to feed. In late April, May and June, a significant part of the stock is distributed in the northern parts of Faroese waters. In late summer and during autumn, the stock migrates to the north and finally into a few northern, Norwegian fjords for over-wintering (hibernating) prior to the southward migration to the spawning areas.

In some years, the west of Scotland Autumn-Spawning stock has, during its feeding migration, reached the eastern parts of the Faroe Plateau. Catches of several thousand tonnes have been fished on the eastern and southern banks.

In offshore Faroese waters, herring is almost exclusively fished by purse seine and the concentrations are found by sonar. The fishing vessels follow the shoals for long distances.

The local, Summer-Spawning stock of herring is very small compared to the two other herring stocks and is almost exclusively distributed inshore. The fishery occurs in the fjords and sounds with the use of gill-nets.

Mackerel

In order to feed, the western stock component of mackerel migrates to the north from the main spawning areas south of Ireland during May and June into the southern and central parts of the Norwegian Sea. The return migration takes place in the winter.

During the feeding period, a significant part of the stock is also distributed and fished in Faroese waters. Mackerel are difficult to detect by echo sounding systems unless in large concentrations. The main migration pattern, therefore, is almost exclusively deduced from the fisheries. Historically, the annual distribution of the fisheries has varied to a very large extent. In later years, the fisheries for mackerel spread into new areas in the Norwegian Sea. A complete picture of the distribution pattern for mackerel, therefore, has yet to be drawn. Mackerel are fished by purse seine and pelagic trawls.

Pelagic Fishing Fleet

The Faroese pelagic fisheries are almost exclusively conducted by purse seine vessels and larger purse seine vessels also equipped for pelagic trawling. Pelagic fishery by Russian vessels is conducted by large factory trawlers. Other countries use purse seine and factory trawlers.

COASTAL FISHERIES

Open boats and smaller vessels using hook and line can be categorized as coastal fisheries. Using longline and to some extent automatic, jigging engines, they operate mainly on a day-to-day basis, targeting cod, haddock and, to a lesser degree, saithe. The large number of open boats participating in the fisheries are often operated by non-professional fishers. In the fishing year 1996/1997, a total of 1,414 licenses were issued to these two groups, including 1,098 licenses to vessels fishing only part of the year. These fisheries are mainly conducted in the most central part of the Faroe Plateau.

Demersal species

Cod

There are two, self-contained stocks of cod in Faroese waters: one located on the Faroe Plateau and the other on the Faroe Bank.

The Faroe Plateau stock, by far the largest of these two, spawns from late February to early May in two distinct spawning areas to the north and west of the Islands. The pelagic eggs and larvae are to a large extent contained in the clockwise water circulation on the Plateau.

In June/July, at a length of 4-5 cm, the juveniles descend from the upper-water layers to the bottom, and migrate to the nursery areas, which are mainly found in the littoral zone and in shallow waters inshore. After spawning, the spawning stock is dispersed over the entire Plateau mainly at depths down to approximately 350 m.

The Faroe Bank cod stock spawns from March to May with the main spawning in the first-half of April in the shallow areas of the Bank. The eggs and larvae are contained in the clockwise water circulation on the Bank. The juveniles descend to the bottom of the Bank proper in July. No distinct nursery areas have been found on the Bank. It is anticipated that the juveniles are widely distributed on the Bank, finding shelter in areas difficult to access by fishing gear.

Haddock

Haddock are distributed throughout Faroese waters, from inshore waters to a depth of approximately 600 m. Apart from the Faroe Plateau and the Faroe Bank, they are also distributed on Bill Bailey's Bank and Lousy Bank.

The spawning takes place from March to May over a wide area on the Faroe Plateau. The location of the main spawning is normally between 50 and 200 m, and may geographically vary from one year to the next. Four main spawning areas, however, have been identified. During the summer, juveniles descend after the pelagic phase and are subsequently found widely distributed on the Plateau at depths between 50 and 200 m.

Saithe

Saithe are widely distributed around the Faroes, from the shallow, inshore waters to depths of 350 m. They are found both dispersed on the bottom, and in shoals on the bottom and in mid-water. For all practical purposes, the saithe in Faroese waters are regarded as belonging to a single stock. Tagging of live saithe, however, has demonstrated migrations between the Faroes, Iceland, Norway, west of Scotland and the North Sea.

The main spawning areas are found at 150-250 m depths east and north of the Islands. Spawning takes place from January to April, with the main spawning in the second-half of February. The pelagic eggs and larvae drift with the clockwise current around the islands until May/June, when the juveniles, at lengths of 2.5-3.5 cm, migrate inshore. During the first two years of life the nursery areas are in very shallow waters in the littoral zone.

During the subsequent two-year period, young saithe are also distributed in shallow depths near shore, but at increasing depths with increasing age. Saithe enter the adult stock at the age of three or four years. Although saithe are fished throughout the year, the highest catch-rates are obtained in the spawning areas at spawning time. During the summer, when the young fish recruit to the fishery, high catch-rates can also be obtained.

Tusk

Tusk are widely distributed in the Northeast Atlantic, but the precise stock structure is not known. In the Faroes, tusk are normally fished at depths between 200 and 500 m, but may be distributed over the entire depth range 50-1,500 m. Spawning in Faroese waters takes place from April to June at depths of about 200 m. No specific spawning area has been identified. The eggs and larvae are pelagic and the juveniles descend to the bottom at a length of about 6 cm. Nothing is known of the whereabouts of these young fish until they reach a length of about 20 cm.

Ling

Ling are also widely distributed in the Northeast Atlantic. It is not known whether this distribution is composed of one or more discrete stocks. In the Faroes, ling are generally fished at depths of 100- 400 m. They are found, however, in more shallow and deeper waters. Spawning mainly takes place at depths of 60-200 m in May/June.

Blue Ling

Blue ling is also widely distributed in the Northeast Atlantic, yet very little is known about the stock structure. There are, however, indications that blue ling concentrations found in Faroese waters are related to concentrations found farther south. Spawning in Faroese waters takes place in April/May at depths of 500-2,000 m (mainly at 1,000 m) in the Atlantic waters south of the western banks. The catch-rates in the fishery for blue ling indicate that migration toward the spawning area commences in February.

Redfish

Two species of redfish are fished in Faroese waters, *Sebastes marinus* and *Sebastes mentella*. No distinction is made between the two species at landing. Figures given in the official catch statistics are, therefore, the combined catch of both species. The concentrations of *S. marinus* found around the Faroes, Iceland and East-Greenland are considered to belong to the same stock. The same applies to the *Sebastes mentella*, but in addition, this stock also is distributed in the Irminger Sea.

Sebastes marinus is commonly distributed in Faroese waters at depths of 200-400 m. The main spawning of *S. marinus* takes place at depths of 300-550 m in the southwest of Iceland from April to June. They mate in the feeding areas around the Faroes, Iceland and along East Greenland in late autumn and winter. In early spring, the females migrate to the spawning area. The nursery areas are in shallow waters along East Greenland, northwest and northeast of Iceland.

In Faroese waters, *S. mentella* is fished throughout the region at bottom depths of 300 to 650 m. They mate in the feeding areas in late autumn and winter. The main spawning takes place at 550 m or more southwest of Iceland from April to August. The nursery areas are in the shallow waters off East Greenland.

Demersal Fishing Fleets

Although they are conducted by a variety of different vessels, the demersal fisheries can be grouped into fleets of vessels operating in a similar manner.

Open boats

This is a huge group of smaller vessels often used by non-professional fishers (see ‘coastal fisheries’ above)

Smaller vessels using hook and line

This category includes all the smaller vessels operating mainly on a day-to-day basis. The area fished is mainly near shore, using longline and to some extent automatic jigging engines. The target species are cod and haddock. See ‘coastal fisheries’ above.

Longliners > 100 GRT

This group refers to vessels with automatic baiting systems. The main species fished are cod, haddock, ling and tusk. The target species at any one time are dependent on season and availability. In general, they fish mainly for cod and haddock from autumn to spring and for ling and tusk during the summer. During summer they also make a few trips to Icelandic waters.

Single trawlers < 500 HP

This refers to smaller fishing vessels with engine powers up to 500 Hp. The main areas fished are on the banks outside the areas closed for trawling. They mainly target cod and haddock. Some of the vessels are licensed during the summer to fish within the twelve nautical mile territorial fishing limit, targeting lemon sole and plaice.

Single trawlers 500-1000 HP

These vessels fish mainly for cod and haddock. They fish primarily in the deeper parts of the Faroe Plateau and the Banks.

Single trawlers >1000 HP

This category includes the deep-water trawlers. These trawlers target several deep-water fish species in Faroese waters, especially redfish, blue ling, saithe, Greenland halibut, grenadier and black scabbard fish.

Pair trawlers <1000 HP

These vessels fish mainly for saithe, however, they also have a significant by-catch of cod and haddock. The main areas fished are the deeper parts of the Faroe Plateau and the Banks.

Pair trawlers >1000 HP

This category targets mainly saithe, but their by-catch of cod and haddock is important to their profit margin. In addition, during summer some of these vessels have a special fishery in deep water for greater silver smelt. The areas fished by these vessels are the deeper parts of the Faroe Plateau and the Banks.

Gill netting vessels

This category refers to vessels fishing mainly Greenland halibut and monkfish. They operate in deep waters off the Faroe Plateau, Faroe Bank, Bill Bailey's Bank, Lousy Bank and the Faroe-Iceland Ridge. This fishery is only regulated by the number of licensed vessels.

Jiggers

This is a mixed group of smaller and larger vessels using automatic jigging equipment. The target species are saithe and cod. Depending on availability, weather, and the season, these vessels operate throughout the entire Faroese region.

FAROESE FISHERIES: DISCARDS AND NON-MANDATED CATCHES

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ABSTRACT

The issue of discards and unreported catches is briefly discussed with regards to the Faroe Islands fisheries. No quantitative estimates of discarding have been undertaken at the present. However, some preliminary data based on on-board observer programs are available for some gear types, and is included here. Definitions of gear breakdown used in the management of Faroe Islands fisheries is also included.

INTRODUCTION

In the fisheries in Faroese waters, discarding of all fish is officially banned. However, this is not strictly enforced in many cases. With no quota regulations currently in use, there should be little temptations of discarding for the purpose of maximizing catch value. However, discarding might take place for other reasons. Faroese fisheries' legislation defines two categories of undersized fish. First, fish with a total length less than the minimum legal landings size are in principle not allowed to be on board and not allowed to be marketed. This can lead to discarding of undersized fish. Second, for each of the most important fish species, there is a length below which fish are categorized as 'young fish'. In cases where the proportion (by numbers) of 'young fish' in the catches exceeds certain limits in any fishing area, this area has to be closed temporarily for fishing. These closures generally last for only a short period of time, i.e., 1-2 weeks. Unverified reports indicate occasional discarding of young fish in order to avoid closure of an area with high catch rates.

Thus, three types of discarding can be identified:

- Discarding undersized commercial fish;
- Discarding damaged fish of commercial sizes; and
- Discarding non-commercial species.

The amount of discarded fish will mainly depend on the availability of such fishes. Availability, in turn, varies between years, seasons, areas and the selectivity of the gears. In this paper, these factors will be related to the different vessel groups in the Faroese fishing fleet.

Most of the non-mandated (i.e., not requiring reporting) catches in Faroese waters are used for private consumption, ranging from recreational fishing to the commercial vessels where the crew usually are allowed to take a small part of the catch for personal use. It is very difficult to assess the extent of this practice.

A special Faroese phenomenon is the hanging of fish to dry in the wind – an old tradition in the Faroes for preserving fish, appropriately called 'hung fish'. The fish is allowed to hang in the open to dry and is consumed at various degree of dryness. A special quality is obtained when the fish is allowed to hang and dry on a vessel at sea. By custom, fishing vessel crews are allowed to hang and dry all undersized fish for their own consumption and to give them away to family and friends. In years with good recruitment of young fish this can amount to a significant number of fish which are caught, hung and landed but not accounted for in the fisheries statistics. There are only limited data on the size and age distribution of these unrecorded catches. They are not included in the stock assessments but regarded as a part of natural mortality. Some attempts to estimate this amount have been made, but with limited success. These estimates are based on the assumption that each person in the Faroe Islands eats fish with a certain frequency, therefore it is theoretically possible to come up with 'guesstimates' on these amounts. One problem is that the age distribution of these fish is not known, and furthermore, fish which are accounted for in the fisheries statistics may also be used for the same products (dry fish).

In 1997, the Faroese Fisheries Laboratory initiated an observer program aimed at a quantitative description of the amounts of discards/non-mandatory catch in the traditional demersal fisheries within the Faroese fishing zone. For various reasons, the coverage of the fleet has so far not been adequate. Preliminary results from this program together with other information will be used to illustrate possible discarding practices and non-mandatory catches in the different Faroese fisheries.

RESULTS BY BOAT TYPE

Open boats

A large number of boats are within this group, most of them less than 2-3 GRT. Some of them take part in commercial fisheries, but most of them are used for recreational fisheries. They fish mainly for cod (*Gadus morhua*) and haddock (*Melanogrammus aeglefinus*). Discarding is not believed to be a big problem but non-mandatory catches are likely to be common in some instances. The total catch, however, is small.

Longliners less than 110 GRT

In total, 800 licenses are within this group, i.e., 5-15 GRT: 696 licenses, 15-40 GRT: 57 and 40-110 GRT: 47. Some of them are also using jigging machines at times. Most of them target cod and haddock. With respect to discarding/non-mandatory catch, they behave almost as the larger longliners (see below), although they very seldom fish in deep waters.

Longliners larger than 110 GRT

This group consists of 19 vessels. Very little is known about possible discarding and non-mandated catches. However, data exist from two trips with observers in 1997 and 1998. The results are given below, by trip.

Trip 1. 19. November - 3. December 1997

Three areas to the Northwest and West of the Faroes, all within the 200-m depth contour, were fished during this trip. All areas are recognized as good fishing areas for cod and haddock.

Effort: The long line was shot twice a day in a horseshoe pattern. Each set contained approximately 22,500 hooks. The setting was timed to the lunar cycle, avoiding sets at neap tides.

Catch: The catch of 127 tonnes (Table 1) consisted almost entirely of cod and haddock, which, apart from a few kg of fish that had been crushed in the conveyer belt systems, were landed. Bycatches of dab (*Limanda limanda)*, starry ray (*Raja radiata)* and small redfish (*Sebastes viviparus)* were discarded. The number of young fish was quite high during this trip and quite a number of fish were hung. For a number of reasons the crew are sensitive to exposure of this custom, and the observer therefore refrained from taking any accurate census of the number hung. The observer, however, estimated the total number of fish hung to be in the order of 4,000 fish, with an assumed average weight of 0.5 kg. This estimate is included in Table 1.

Table 1. The total catch, discarded and landed catch on the first long line trip. All weights in kg. 'Hung' refers to catches air-dried by crew and landed for personal use without being recorded in official landings records.

Species	Cod	Haddock	Starry ray	Dab	Small redfish	Others	Total
Catch	65,362	61,955	216	176	9	23	127,741
Discards	62	55	216	176	9	23	541
Hung	2,000	-	-	-	-	-	2,000
Landings	63,300	61,900	0	0	0	0	125,200

Trip 2. 23. February - 3. March 1999

While the first trip took place in the autumn the second trip took place in the spring on pre-spawning fish, in two areas to the West of the Faroes in slightly deeper water compared to the first trip.

Effort: During this trip the entire line (approximately 42,000 hooks) was set in one setting per day in a criss-cross pattern, as compared to the two settings in a horseshoe pattern on the previous trip. The setting was timed to the most favourable tidal currents.

Catch: The total catch (62 tonnes) was lower, but more diverse compared to the first trip (Table 2.), and the catch rates were also less. The most significant reduction was in the catches of cod. However, cod and haddock were of significantly larger size compared to the first trip. There were significant bycatches

Table 2. Catch in kg by species during the long line trip in February-March 1999.

Species	Cod	Haddock	Saithe	Ling	Tusk	Angler fish	Halibut	Starry Ray	Dab	Total
Catch	14,950	39,300	350	1,350	3,000	200	300	1,275	1,215	61,940
Discard	0	0	0	0	0	0	0	1,275	1,215	2,490
Landing	14,950	39,300	350	1,350	3,000	200	300	-	-	59,450

of ling (*Molva molva*) and tusk (*Brosme brosme*) in addition to minor bycatches of saithe (*Pollachius virens*), anglerfish (*Lophius piscatorius*) and halibut (*Hippoglossus hippoglossus*), which were landed. As on the first trip, the bycatch of dab and starry ray were discarded. These 2.5 tonnes (both species combined) represented 4% of the total catch, and was considerably high compared to the first trip. The crew took no fish during this trip to dry for private consumption.

Single trawlers less than 500 HP

During summer time these trawlers (about 5 vessels in this group) are allowed to fish inside the 12 nm zone, which is generally closed to all trawlers. These small trawlers target flatfish. In order to reduce the bycatch of other fish they are obliged to use sorting grids in the trawls. As a consequence, their catches consist primarily of the target species and discarding is believed to be minimal. As for other groups, small amounts of non-mandatory catches are expected. In other times of the year this group behaves like the single trawler 500-999 Hp.

Single trawlers 500-999 HP

There are only about 4 vessels in this group. Target species are cod and haddock. The minimum legal mesh size of 145 mm stretched mesh should disallow large bycatches of undersized cod and haddock, and the same applies to catches of other smaller fish species.

Single trawlers above 1000 HP

This group contains 13 vessels, which mainly target redfish (*Sebastes* spp.), Greenland halibut (*Reinhardtius hippoglossoides*), blue ling (*Molva dypterygia*) and other deepwater species. In this fishery the minimum legal mesh size is 135 mm stretched mesh (in the blue ling fishery 120 mm) and they are known to discard considerable amounts of non-commercial species. However, at the present time it is not possible to quantify the discard. During part of the year they also target saithe, cod and haddock (mesh size 145 mm) with bycatch similar to the smaller single trawlers.

Pair trawlers less than 1000 HP and above 1000 HP

These two groups have 32 vessels. Mostly they target saithe with bycatch of cod and haddock. However, in years with high availability of cod and/or haddock they prefer to target these due to the higher market prices. The minimum legal mesh size of 145 mm stretched mesh should disallow large bycatch of undersized cod and haddock, and the same applies to catches of other smaller fish species. But no data exist at this stage.

Jiggers

These vessels can change between longline and jigging. When they use jigging machines they target cod and saithe with small bycatch of redfish, ling and others. Most of the catch is composed of large commercial species and discarding is believed to be minimal.

Gill netting vessels

Traditional fishery with gill nets for cod, saithe etc. has been banned for the last 20 years due to the risk of losing nets ('ghost fishing') and poor quality of the fish. However, since the beginning of the 1990s some vessels have been given special licenses to fish anglerfish (4 licenses) and Greenland halibut (6 licenses) with gill nets. Due to the large mesh sizes, bycatch of small fish species and undersized fish is almost non-existent. Catches of starry rays and other smaller skates are discarded. If the nets are allowed to fish for a longer period than usual, e.g., due to bad weather, the quality of the catch is so poor that large parts will be discarded.

The Fisheries Laboratory has on several occasions placed observers on board these vessels and some preliminary results are given here.

Greenland halibut fishery

During a 5 day trip in July 1998, total catch was about 50 tonnes, of which 25% were discarded. Discarded species were: Starry ray (23%), Greenland halibut (1%), cod/redfish/blue ling (1%). This appears to be a typical picture. If, as is thought to happen occasionally, the nets are allowed to fish for too long (e.g., due to poor weather), the discarding rate can rise up to 40% due to poor quality of the target species.

Monkfish fishery

The mesh sizes are larger than in the Greenland halibut fishery and the bycatch of non-commercial species/sizes appears negligible. As with the Greenland halibut fishery, if nets are allowed to fish for too long, problems with poor quality of the fish exist. However, not to the same degree, since monkfish seem to survive for a longer time in the nets.

Industrial trawlers

A mixed industrial bottom trawl fishery (for fishmeal and oil production) was initiated in 1982 with annual catches of 5,000-30,000 tonnes (reported to ICES). The majority of the catch is comprised of Norway pout (*Trisopterus esmarki*), but also some blue whiting (*Micromesistius poutassou*) and Argentine (*Argentina* spp.). The regulations stipulate a maximum bycatch of undersized 'food fish' (e.g., cod, haddock, saithe, ling etc.) of 2%. Two extremely large year-classes of haddock, i.e., the 1993 and 1994 year classes, created large bycatch problems for the mixed industrial fisheries starting from 1994. In 1994 large numbers of small haddock were found throughout the Faroe Plateau, which made it impossible to conduct the industrial fishery within the bycatch legislation. The mixed industrial bottom trawl fishery was consequently closed, and has since been banned within Faroese waters.

Pelagic vessels

Most catches are used for fishmeal and oil production and discarding is not a big problem. Catches of large herring and mackerel are mostly used for consumption and discarding is almost zero.

CONCLUSION

As the data presented here indicates, up to now discards and unreported catches have received little attention in the Faroe Islands. This short-fall requires attention.

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GERMAN FISHERIES: INSTITUTIONAL STRUCTURE FOR REPORTING OF CATCHES AND FLEET STATISTICS (1991-1999)

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ABSTRACT

The availability and accessibility to German fisheries data is complicated by the historic changes in reporting responsibilities between federal agencies, and by changes in fleet category definitions. Here we summarize the institutional structure for fisheries related data reporting established in Germany, and report on the structure of the German fishing fleet database. Initially, from 1924-1980 all fisheries statistics were compiled and reported by the Bundesfischereiforschungsanstalt (BFA, Federal Research Institute for Fisheries). From 1980 to 1990, this task was carried out by the Statistische Bundesamt (Federal Statistical Office). Since the German re-unification in 1990, the Bundesministerium für Landwirtschaft, Ernährung und Forsten (BML, Federal Ministry for Agriculture, Food and Forestry) holds the responsibility for the reporting of fisheries statistics. The BML produces the 'Annual Report on German Fisheries', which includes information on all catches (including invertebrates), general fleet statistics and economics. The report also includes information on German landings abroad and foreign landings in Germany. This report and associated data appear to form the basis of what is officially reported to the International Council for the Exploration of the Sea (ICES). In preparation of the annual report, the BML receives data and information from several federal (Bund-) and provincial (Land-) agencies which are outlined here. This includes information from the German fishing fleet database, developed since the early 1990s, and being administered by the Bundesanstalt für Landwirtschaft und Ernährung (BLE, Federal Institute for Agriculture and Nutrition). Its purpose is primarily to assist in the management and control of German and EU fisheries policies. From 1991-1996 vessels were categorized in fleet segments as defined by a 'Multi-Annual Fleet Adjustment Program' (MAP III). In 1997 fleet categories were re-defined under MAP IV (1997-2001). Unfortunately the two different fleet categories are not always consistent, as some vessels were re-assigned to other segments based on their gear types. Thus, both time periods are not directly comparable. Fishing effort within the database is presented as sea-days, and effort information has only been included in the BLE database in a standardized and comprehensive manner since 1995.

SUMMARY OF INSTITUTIONS

Bundesfischereiforschungsanstalt (BFA, Federal Research Institute for Fisheries)

The BFA continues to produce an annual report which mainly documents the status of ongoing research. Furthermore, since the early 1990s, the BFA maintains a database which includes the most reliable data on catches, catch per unit effort (hours/days fished) and fleet category (Peter Cornus, Catch Statistics Expert, BFA, pers. comm.). However, this database deals only with vertebrates (for invertebrates see Landesfischereiämter below), and reports only on catches from vessels with log-book duties (vessels > 12m length with fishing trip length exceeding 24 h). Thus all the data are based on log-book information. The content of this database forms the basis of the work conducted by ICES working groups, including stock assessments, TAC recommendations, estimates on misreported catches etc. It is this database that forms the foundation of the national dataset (1995-1998) contributed to the *Sea Around Us* project (*www.fisheries.ubc.ca/projects/SAUP*).

Bundesanstalt für Landwirtschaft und Ernährung (BLE, Federal Research Institute for Agriculture and Nutrition)

The BLE maintains a database on fleet statistics, including effort data (in kilowatt days). This information appears to be forwarded to the BML for their annual report. The German fishing fleet database has been developed since 1991/92 within the BLE. It is used as a tool to manage and control the on-going implementation of EU fisheries and fishing fleet policies. An older database version exists dating back to 1989. However, this older database is less comprehensive, and was not considered here due to the differences in data structure and very low levels of confidence in its contents.

The majority of fleet capacity information provided in the final dataset (for datasets described in this report see *www.fisheries.ubc.ca/projects/SAUP*) was taken from the BLE database. Some exceptions exist (indicated in the dataset by 'ca.', for *circa*, or *approximately*). Fishing effort within the database is presented as sea-days, and is defined as: 'date of return – date of arrival + 1', thus including the departure day as a full day at sea.

From 1991-1996 vessels were categorized in fleet segments as defined by a 'Multi-Annual Fleet Adjustment Program' (MAP III). In 1997 fleet categories were re-defined under MAP IV (1997-2001). Unfortunately the two different fleet categories are not always consistent, as some vessels were re-assigned to other segments based on their gear types. Thus, both time periods are not directly comparable. Both types of fleet categories have been provided for 1996 to illustrate the transition (see Table 1).

Table 1. Changes in fleet categories between MAP III (1991-1996) and MAP IV (1997-2000) for the German fleet.

MAP III	Map IV
4C5	C11 and C12
4C6	G19
4C7	G22
4CZ	Z25
Vessels in other categories were re-assigned based on gear type:	
4C1	C19 vessels < 12 m length, plus some vessels from G16/17
4C2	G21 + C19 vessels > 19 m length
4C3	vessels from G16/17, minus some vessels that are now part of 4C1, plus some vessels from C19

Effort information has been included only in the BLE database in a standardized and comprehensive manner since 1995. Information prior to that (1991-1994) has to be regarded with a low level of confidence, as data acquisition and entry had not been sufficiently standardized at this stage. This was especially apparent in the numbers provided for fleet segments C11, C12 and C19 in 1991. To complete and verify the data from the early 1990s, the information was compared with that available in the MAGP report (Multi-annual Guide Program) to the European Commission about the capacity of the German fishing fleet in 1996. When the exact fleet size was not provided, vessel numbers were extrapolated from data available in the database. Unfortunately, there remain some discrepancies between effort data reported in this report and in the database. These inconsistencies between the two sources are noted in footnotes in the spreadsheets available on the *Sea Around Us* project web page (*www.fisheries.ubc.ca/projects/SAUP*). However, fleet capacity data were consistent between the two sources and therefore the overall result should reflect the actual fleet capacity and integrated effort fairly accurately, at least post 1995 (see also Tyedmers, this volume).

Statistische Bundesamt (Federal Statistical Office):

The statistical office retains the responsibility for the statistical analyses within the BML annual report.

Landesfischereiämter (Provincial Fisheries Offices)

Each of the coastal provinces compiles information about provincial invertebrate catches. These catches are quite high, as they make up about 30% of the present total value of German catches. This information is forwarded to the BML for the annual report.

The data responsibilities and reporting structure outlined above is illustrated in Figure 1.

DEFINITIONS OF DIFFERENT FISHERIES CATEGORIES

Große Hochseefischerei (GHS)

This translates into 'Great High Seas Fisheries' and consist of large trawlers distinguishable into pelagic trawlers targeting Herring (*Clupea harengus*), horse mackerel (*Trachurus* spp.), mackerel (*Scomber scombrus*) and redfish (*Sebastes* spp.), and demersal trawlers targeting groundfish. This fleet corresponds more or less to EU fleet segments 4C6, 4C7 (vessels > 400 GRT), and undertake long trips from home ports, fishing in northern and western Atlantic waters.

Große Heringsfischerei/Loggerfischerei (GH)

This fleet segment, called 'Great Herring/Lugger Fishery' contributed about 10% of overall annual German catches in 1950 (Bartz, 1964), but ceased to exist in the 1980s.

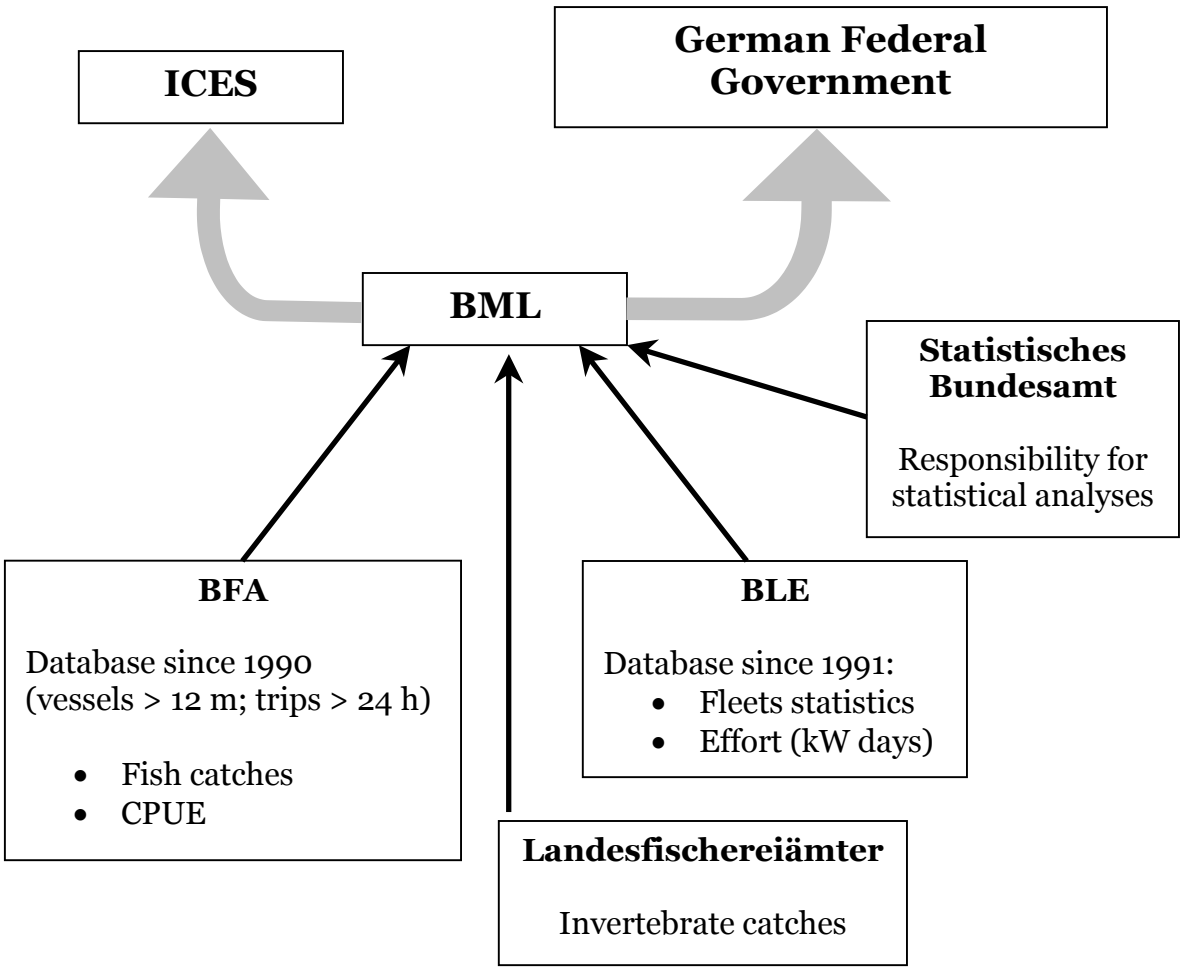

Figure 1. Institutional structure for the data collection and reporting of German fisheries statistics. BFA: Federal Research Institute for Fisheries, BLE: Federal Research Institute for Agriculture and Nutrition, ICES: International Council for the Exploration of the Sea, Landesfischereiämter: Provincial Fisheries Offices, Statistisches Bundesamt: Federal Statistical Office.

Kleine Hochseefischerei (KH)

This segment consists of 'Small High Seas Fisheries, Cutter Deep Sea Fisheries', and corresponds in part to EU fleet segments 4C3 and 4C4. These vessels fish in the North Sea and Baltic Sea, and are generally combined with the KF (Coastal Fishery, see below). Landings of KH and KF combined make up about 20-25% of overall annual catches (KH ~ 3% and KF ~ 18%). KH is a demersal fisheries for cod and flatfishes, but contribute also to a mixed fishery; landing tuna and herring for reduction to fish oil and fish meal (industrial fisheries).

Küstenfischerei (KF)

This refers to the 'Coastal Fisheries', which generally fish within the 20-m bathymetry line and undertakes trips less than 24 h long. Gears used include beam trawl, set nets and weirs, and which target mainly shrimp and mussels. The KF contributes approximately 18% of the total catch, and corresponds to EU fleet segments 4C1, 4C2, 4C5, 4CZ and most of 4C3, 4C4.

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PRELIMINARY REPORT OF COASTAL FISHERIES AROUND THE COASTS OF THE BRITISH ISLES 1950-1999

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ABSTRACT

The following report and the associated spreadsheets constitute a summary of the data that have been gathered for the *Sea Around Us* project between November and December 1999. Guidance from personnel and access to data at the Fisheries laboratories in both Aberdeen and Lowestoft are available. People from the sports fishing sector have been extremely enthusiastic. The Shark tagging association, British Conger Club and the National Federation of Sea Anglers have provided access to their archives of match fishing from the 1920s onwards. Angling organizations feel that, relative to commercial fishers they presently have a weak voice in the politics of marine resource management and conservation. The European Federation of Sea Anglers is presently submitting a proposal for a study to examine the economic importance of sports fishing. Information presented here include time series data on UK lobster (*Homarus gammarus*) and Scottish salmon catches, conger angling data, as well as findings from a coastal fisheries survey.

INTRODUCTION

The data presented here on the coastal fisheries around the British Isles represent a very small proportion of what is available. Most initial effort has been aimed at making contact with possible sources of information. Many fisheries scientists approached for assistance were initially fairly skeptical but when assured that we required little more than access to data and that we were painting with a fairly broad brush, most have been willing to help.

FISHERIES DATA

There are a wealth of good quality data available from both Aberdeen and Lowestoft Laboratories. The main problems with it are that it has never been transferred from paper and much of it is recorded in a form that may not be understandable without explanation. In addition, the finest resolution that may be available for much of the data are at the 'statistical square' level (30 km^2). The main concerns of those people approached are that much of the information remains confidential and that the data do not provide a good reflection of abundance. For example, changes in market demand and fishing technology may affect catch as much as any population variations. The fisheries scientists at Aberdeen and Lowestoft do not wish to be associated with conclusions drawn from 'their data' that may, in their eyes, be unsupportable. Although there is some desire to see archived data put into a useable format they are worried about becoming involved in a project that might require them to commit resources. Highlighted problems with official data include the under-reporting of catches by around 30% (S. Greenstreet, pers. comm.) and the huge variation in discards between species and years.

ANGLING DATA

The advantages of angling data are that they will have been less affected by economics, and sports fishing methods have remained virtually unchanged for the last century or so. Angling data may give good indications of long term changes in local abundance. However, most angling archives will only contain records of fish of over a particular size. It is possible that there may be data available from some clubs of competition fishing catches where anglers recorded everything caught during a set time. Also, it is possible that there are some individuals that have recorded all of the fish that they have caught over the past 10 to 50 years.

DATA AND DATA SOURCES

UK Lobster catches

These data were taken from a workshop report (Bannister, 1998). There are a lot more data available on this species that will give some indication of effort (Nick Bailey, pers. comm.). Generally the lobster (*Homarus gammarus*) season in the UK runs from March to October. Full-time fishers will set 250-1,200 creels or pots

while a significant number of part-time fishers will lay 20-100 pots. The minimum landing size in the UK is 85 mm and average daily catch rates vary from 10-15 lobsters per 100 pots in poor fisheries to 40-80 pots in better fisheries.
UK catches have varied between 750 and 1,550 tonnes since 1945 (Figure 1). There was a fairly steady decline in landings from 1960 onwards. Year class strength of lobsters is thought to be strongly affected by sea surface temperature variations and the peak in landings in 1984 has recently been attributed to the 1982 El Niño Southern Oscillation (ENSO) event (Sheehy *et al.,* 2000). Effort directed towards lobsters is likely to be affected by both the recreational nature of lobster fishing for some part-timers and the need to stake a claim to an area by leaving pots in place even when catches don't merit the effort.

Conger Angling Data

These data were kindly provided by the British Conger Club (BCC) and consist of catches made by members of the association that are of a size large enough to merit recording. Members may catch many smaller conger eels *(Conger conger*) but those less than 25 lbs. (11.34 Kg) in weight are not recorded.

The mean weights of conger eels landed and recorded by the BCC over the past 10 years has declined from a peak of 28.6 Kg in 1991 to a minimum of 23.6 Kg in 1998 (Figure 2). In addition, the number of eels caught by members that are of a size to merit recording has declined from a maximum of 322 in 1994 to 113 in 1999 (Figure 2). These data are somewhat limited in their geographic extent - conger eel fishing is particularly popular around the south coast of England.

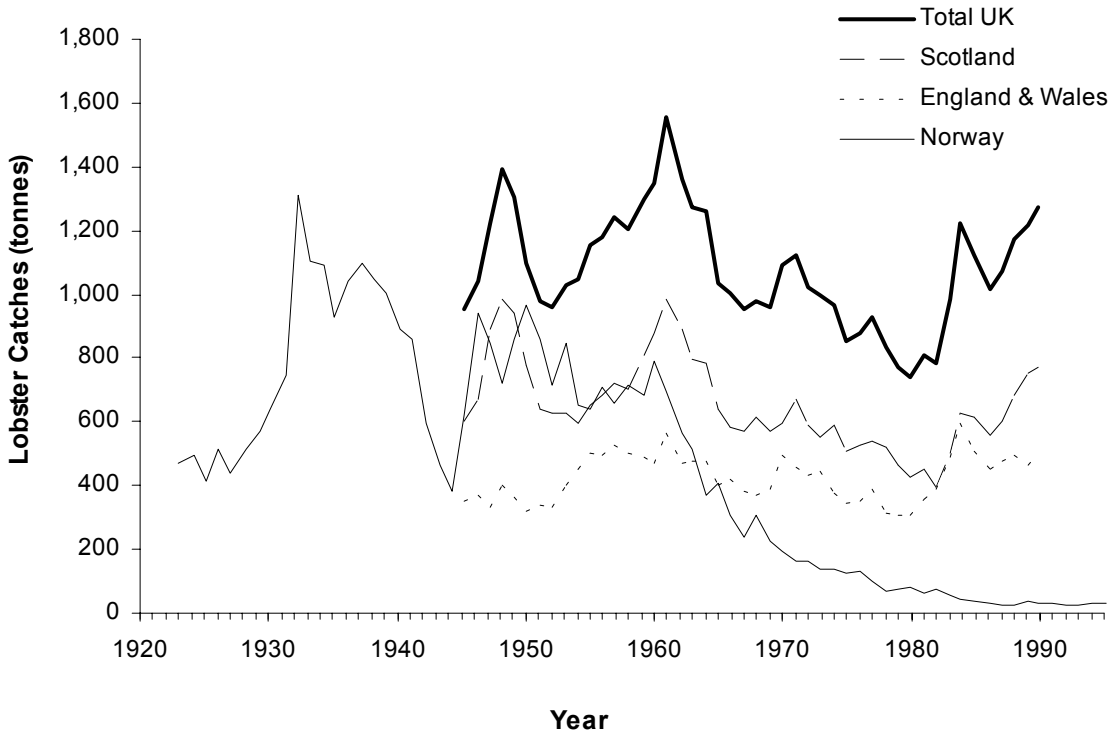

Figure 1. Summary diagram of lobster landings around the coast of the UK and Norway from 1923 onwards.

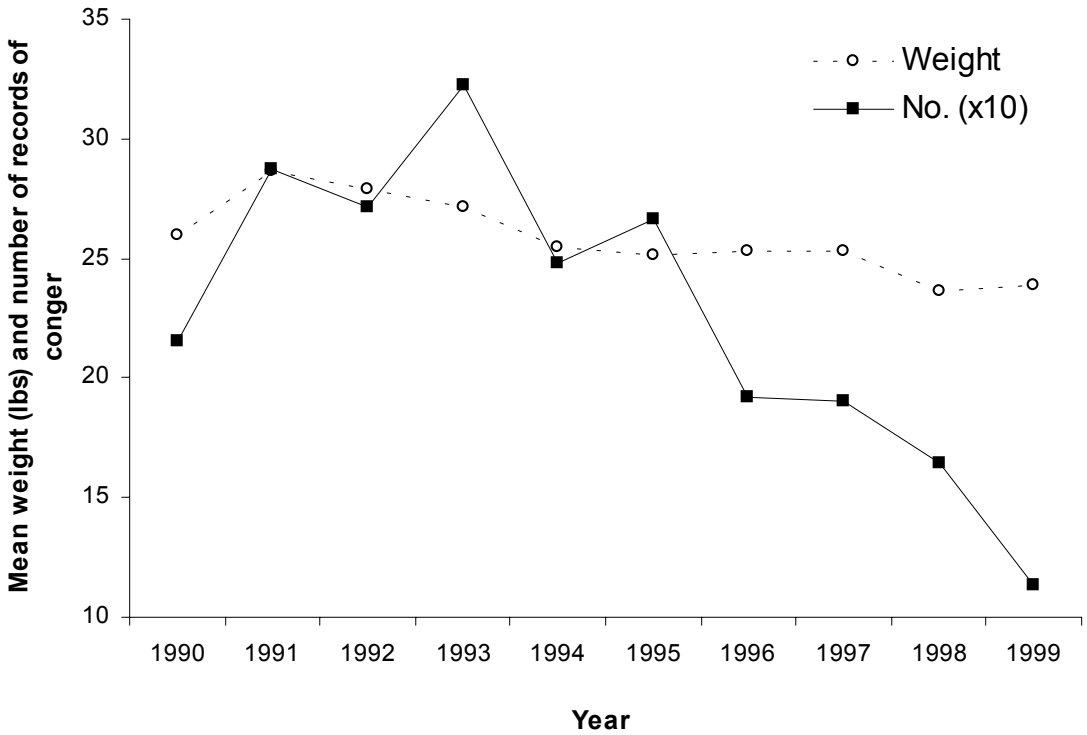

Figure 2. Number of records and mean weights of conger eels *(Conger conger)* of over 25 lbs. (11.34 Kg) landed by members of the BCC between 1990 and 1998. (Note that vertical scale does no start at origin.)

Coastal survey 1981

The data presented here are extracted from one of a series of three reports on the coastal fisheries of England and Wales (Pawson and Benford, 1983; Pawson and Rogers, 1989; Gray, 1995). The 1983 report contains details of catch and effort of coastal fisheries on a port by port basis, although a few pages are missing from the copy obtained.

The 1995 report contains details of effort only. There are some problems presented by the qualitative nature of some of the reports of numbers of boats involved in particular fisheries, e.g., "in this port there are many part-time boats with pots for lobster or nets for cod, which operate only when weather permits". There are at least 36 different methods of fishing recorded in the 1981 report and both Pawson and Rogers (1989) and Gray (1995) suggest that the versatility of inshore fishers is a response to seasonal fluctuations of individual resources, longer term variations in abundance and marketing and management controls. In addition, it is likely that many part-time coastal fishers, for whom fishing is not their primary source of income (e.g., retired full-time fishers, unemployed heavy industry workers, crofters), are less driven by the need to make a profit.

Hopefully, these reports will provide a good reference point. Preliminary analyses of the 1981 data suggest that there are no obvious relationships between effort (defined as number of boats x length x 0.5 for part time or 1.0 for full time) and reported catch. This may be a function of the inaccuracy of the data for either catch or effort, or of the wide variety of methods and species taken by inshore fishers.

Together the three reports should give a good indication of how fishing techniques amongst coastal fishers have changed over the last 10 years. From the 1981 report it is clear that trawling (39%) dominated effort at this time (Figure 3). This is probably a reflection of the fact that only larger boats are capable of trawling efficiently and larger boats are much more likely to work full-time. Although the estimated efforts for potting and angling are lower than for trawling. the numbers of boats fishing for crabs and lobsters (1,767) or taking out angling parties (2,239) was higher then trawling (1,514). Many of the boats involved in these non-trawl fisheries work part-time or seasonally and are incapable of working in inclement conditions.

Pelagic species were the largest group landed by coastal fishers in 1981 (Figure 4). This could be expected given the dominance of trawling effort in comparison to other species. Although Pawson and Benford (1983) made no clear indication one

way or the other, it is doubtful that catches by sports anglers are included to any significant degree in the landing figures. When it is considered that just under 6 tonnes of conger alone are recorded as landed at competition weight (> 11 Kg) from a restricted area of the coast each year, and that angling effort is second only to trawling, it would appear that a significant portion of fishing effort is effectively ignored. Since fishers preferentially fish for benthic and demersal species it is likely that the estimations of landings for these groups are under reported.

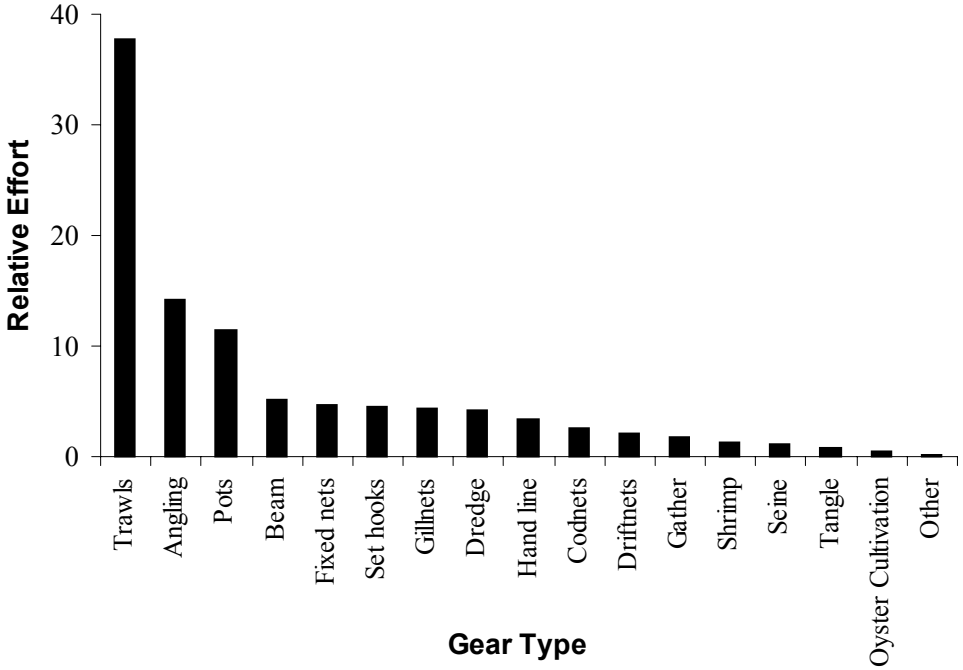

Figure 3. Estimated fishing effort with different types of gear by English and Welsh coastal fishers in 1981. Figures are proportions of the total effort.

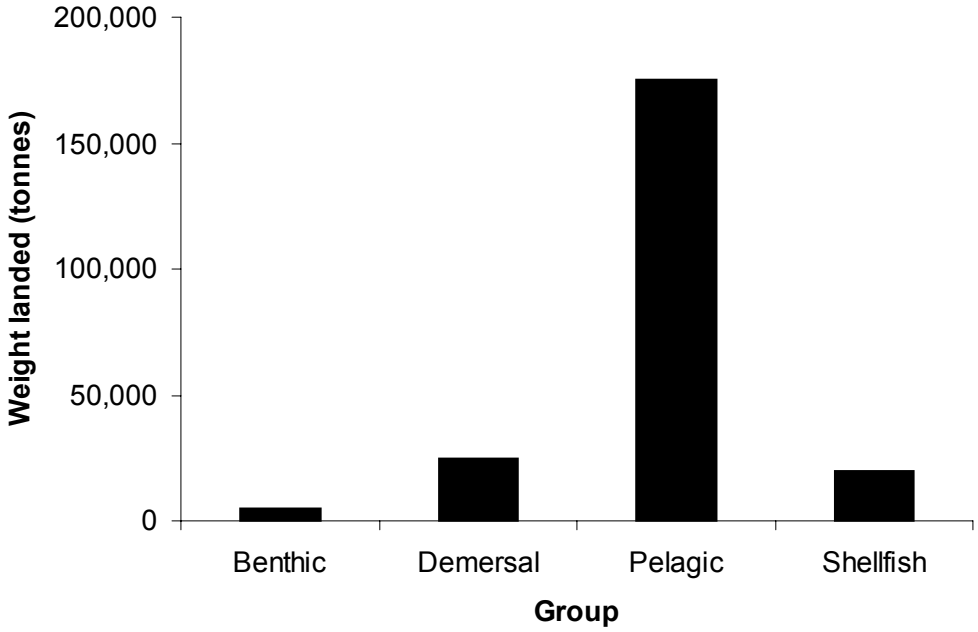

Figure 4. Weights of fish and shellfish (in tonnes) landed around the coasts of England and Wales by coastal fishers in 1981. Benthic (Flatfish and skate). Demersal (Cod etc). Pelagic (Herring etc).

Scottish salmon and sea trout landings

Salmon and sea trout landings since 1952 are summarized every year in Fisheries Research Services statistical bulletins. These break catches down by area, gear type and into the categories of sea trout, grilse, spring and winter salmon. The three salmon categories show differing susceptibilities to different fishing methods. For example, mature, late running salmon tend to have a reduced appetite and are therefore less likely to be taken by rod and line fisheries (Shelton and Heath, 1999). In addition, there is much in the way of useful qualitative and quantitative data contained in Williamson (1991). The weight data presented (Figure 5) were extrapolated from the detailed data for 1989 catches that have been obtained so far.

Williamson (1991) points out that landings in Scotland can be split into four parts: 1952-61 when the catch averages just over 300,000 fish; 1962-75 when it reached around 400,000; 1976-86 just over 250,000 and the years since 1987 when catch numbers have always been less than 200,000 fish. The fact that the catch has been lower in the past 14 years than it was in the first ten may be attributed in large part to the influence of interception fisheries. The catch figures from these fisheries (English NE coast, W Greenland and N and W Ireland drift-net fisheries, Faeroes long-line fishery) were as great from 1976 to 1986 as they were in the 1950s. There has been a significant reduction in the numbers of net-caught salmon taken in Scotland; this has been the result of reduced effort by net fishers using fixed engines when catches are too low to merit upkeep of their nets. At the same time, various organizations and individuals have purchased fishing rights in many estuaries and rivers with a view to enhancing game (rod and line) fishing.

Although sea trout will be affected by many of the same factors that influence salmon fisheries, and a general reduction in total landings can be seen, substantial changes in landings do not occur simultaneously for both species. Sea trout landings peaked at 356 tonnes in 1967 and then declined until 1982 when landings reached 237 tonnes (Figure 6). This second peak that interrupts the general decline is attributable to the reductions in net fishing effort that took place in the 1980s (Anon., 1994). For both species rod and line landings appear to show less variation than net methods.

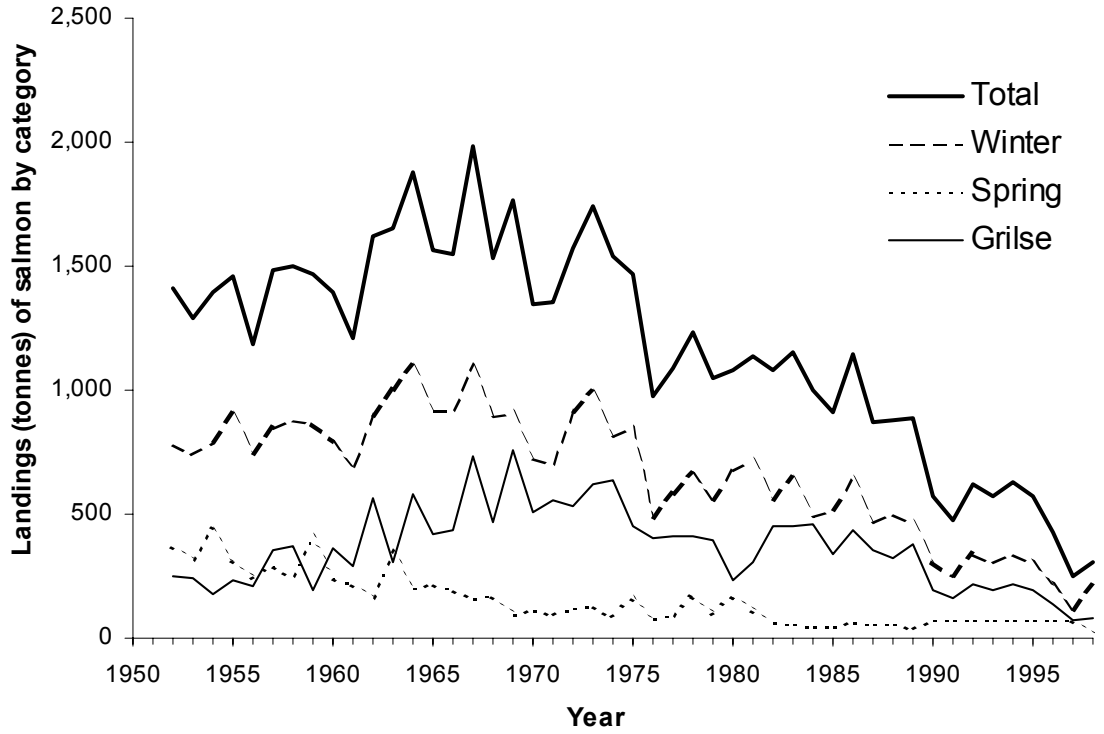

Figure 5. Total landings (tonnes) of salmon around the coast of Scotland since 1952 by category. Spring Salmon:- January to April; Winter Salmon- May to December .

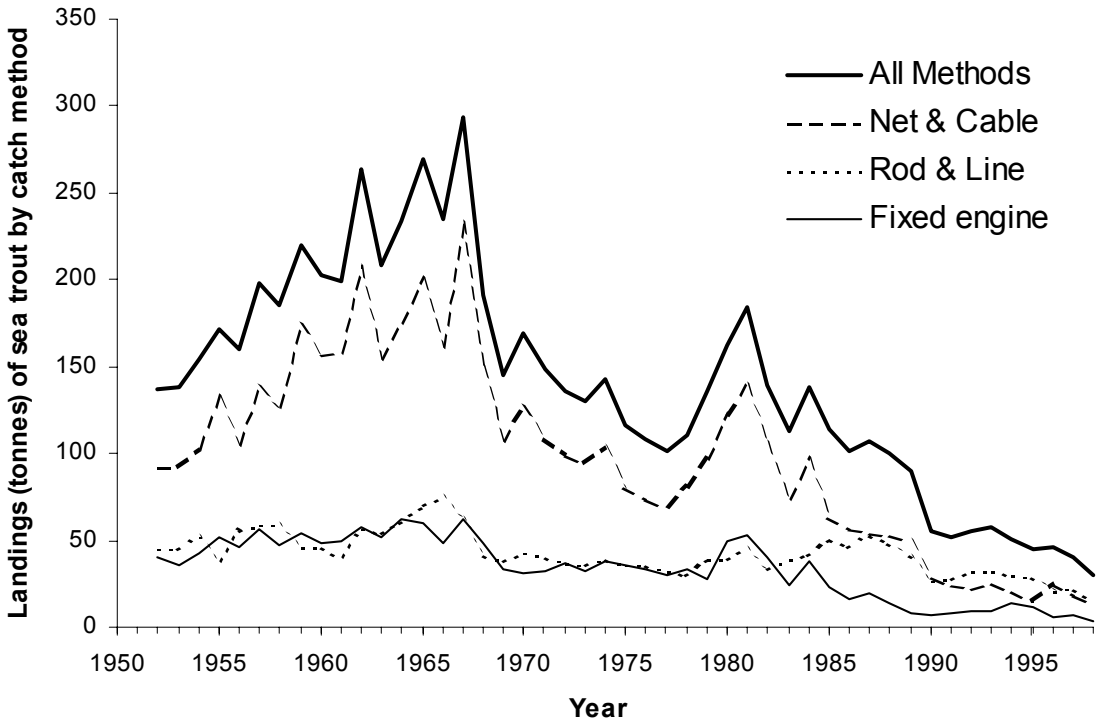

Figure 6. Total landings (tonnes) of sea trout around the coast of Scotland by catch method.

DATA AVAILABLE

In summary, we found the following data sets to be available:

- Pre-1990 Conger data. Archived on paper;
- NFSA match data on a range of fish species. The data are available as paper archives;
- Inshore fin-fish, Lobster, scallop and crab data (Lowestoft and Aberdeen);
- Coastal survey 1981: Landings data from this report are available on a month by month basis, the report also contains some details of fishing legislation and seasons;
- Coastal surveys 1985 and 1989 available from Lowestoft;
- Salmon and sea trout catch data at higher geographic resolution, effort data;
- English and Welsh fisheries data for salmon and trout, also for eels/elvers.

However, considerable resources may have to be devoted for consistent catch time series to be extracted from these data.

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AN OVERVIEW OF THE NETHERLANDS OPEN SEA AND COASTAL FISHERIES: STATE OF THE ART

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ABSTRACT
This paper describes the commercial fisheries fleet of the Netherlands, including the coastal fisheries and the cutter and trawler fleets. A discussion is presented on the theoretical approach to economic analysis, property rights and the ecological analysis of fisheries. Dutch institutional arrangements, both nationally and within the larger framework of the European Union's Common Fishery Policy, are also discussed. The implementation of ITQs in the plaice (*Pleuronectes platessus*) and sole (*Solea solea*) fisheries, along with the role of *Bieshuvel* Groups as a co-management tool are also presented. Finally, three interviews with Dutch fisherman are provided, which present their views on both national and European Union management issues.

DATA GATHERING BACKGROUND
The transaction costs involved in obtaining information and data on fisheries in the Netherlands are high, and the time and money required to collect the necessary information is considerable. As a consequence, the data are not readily available. It involves building trust with fishers and people operating within the relevant institutions. It also involves time in identifying the right sources of information.

The last section in this report (Analysis) provides data on catch taken by both the large scale and coastal fisheries. Data on sport fisheries are difficult to obtain. I contacted the Director of the Anglers Society (Mr. Oppeneer) who recommended that I contact the Chairman of the Anglers Society (Mr. Doman). I spoke with Mr. Doman. He told me that over the years there have been shifts in the type of fish species caught by members of the Anglers Society. He thinks this is partly due to changes in water temperature. However, he said the Anglers Society only keeps a record of the catches made during fishing contests. The data are kept in large files at his place. However, resources were not available to collate and process these data.

Estimate to illustrate importance of fisheries
In order to make an estimate illustrating the importance of fisheries, more data are necessary. It is likely that many of the fisheries activities of the Netherlands are operating under foreign flags. If it is true that all landings are made in the Netherlands, these data also need to be considered.

The fisheries sector has been approached directly. However, due to many fishers spending considerable time out at sea, it was not always possible to reach them. The Board of Commodities (*Productschap Vis*) was also contacted and kindly provided data (see Analysis Section).

Estimate of ecological and economic costs/benefits of two fisheries
An estimate of the ecological and economic costs/benefits of fisheries, such as the large scale and coastal fisheries, requires data on the ecological impact of each fishery. The Fisheries Year Book 2000 (*Visserij Jaarboek* available at *www.abrh.nl*), for example, does provide information on the horsepower deployed by each vessel comprising the Dutch commercial fleet.

INTRODUCTION

The North Sea
The North Sea waters wash the northern and western shores of the Netherlands. It is a shelf sea of the Atlantic Ocean, with a well-mixed southern adjoining basin of depths up to 36 meters and a northern basin with depths up to 90 meters. Only at the Norwegian Trench, does it reach greater depths of 761 meters. The Skagerrak and Kattegat connect the North Sea with the Baltic, whereas the Straits of Dover connect it with the English Channel. The complex depth structure and tidal regime that characterizes the North Sea, has led to the evolution of diverse benthic communities and fish species (Boddeke and Hagel, 1991).

The North Sea is exploited by a number of fishing fleets that operate various types of fishing gear under the Common Fisheries Policy (CFP) of the European Union. The beam trawl fleet, however, contributes more than two-thirds of the international landings. This is in contrast to the otter trawl, Danish seine and gill nets, which account for one third of the international landings.

The Netherlands commercial fisheries sector

Based on data in the *Visserij Jaarboek*, the Netherlands commercial fishing fleet comprises 494 cutters, 13 freezer trawlers and 148 dredgers. The average size and horsepower (HP) of Dutch vessels are 120 Gross Registered Tonnes (GRT) and 1,100 HP, respectively. Fishing in the Netherlands accounts for 0.3% of total (regionally-oriented) employment. The fisheries sector is comprised of both sea and coastal fisheries. In comparison, the role of the small scale and/or sport fisheries is rather limited. The total value of fishery products including landings, trade, added value and processing is presented in Table 1, and landings by the Dutch fisheries from 1960 to 1969 are presented in Table 2. Landings, and corresponding revenue, by species, of the large and small scale Dutch fisheries between 1970 and 1976 are documented in Tables 3 and 4, respectively. Landings (1976-1982) and revenue (1976-1998) for large and small scale fisheries (including mussel and oyster culture), by major fleet types, are summarized in Tables 5 and 6, respectively.

Table 1. Values of fish landings, trade and processing. Source: Ministry of Agriculture, Nature Conservation & Fisheries (Ministerie van Landbouw, Natuurbeheer en Visserij)

Economic activity	Total value in NLG[a)]
Fish landed by fishing vessels	1.0 billion
Imports	1.2 billion
Exports	2.3 billion
Added value of trade and processing	0.95 billion

[a)] NGL = Netherland Guilders = US$ 0.41, 26. Sept. 2001.

Table 2. Landings (tonnes) by Dutch Fisheries. Source: Productschap Vis.

Landings	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Fresh herring landed	51,117	55.329	34,006	53,782	56,161	38,453	28,677	16,517	10,901	12,321
Processed	4,025	5,160	280	8,789	5,618	577	2,229	168	240	880
Withdrawn from market	1,242	1,024	419	1,668	1,559	1,999	1,311	271	141	147
Mackerel landed	25,173	24,480	18,973	11,978	17,531	17,868	12,881	13,293	7,421	7,289
Processed	320	203	259	56	873	3,169	825	1,716	650	815
Withdrawn from market	450	441	541	397	696	774	352	602	246	212
Haddock landed[a)]	1,110	693	1,134	1,644	3,706	24,003	16,671	8,307	6,606	11,059
Processed	30	55	19	91	973	7,445	1,548	605	444	2,427
Withdrawn from market	15	4	16	26	73	669	551	225	117	74
Pollack landed	-	-	-	-	207	7,300	6,834	11,052	13,862	13,511
Processed	-	-	-	-	0	813	625	1,770	3,545	573
Withdrawn from market	-	-	-	-	0	46	40	37	75	68
Cod landed[b)]	-	-	-	-	569	16,550	18,533	21,535	25,330	15,951
Processed	-	-	-	-	87	577	414	926	607	35
Withdrawn from market	-	-	-	-	1	111	107	126	115	44
Whiting landed[c)]	5,110	7,056	6,520	6,843	4,617	8,019	8,516	8,674	11,255	11,944
Processed	492	1,197	298	1,707	196	1,365	383	809	1,561	2,933
Withdrawn from market	3	3	13	21	6	80	104	123	77	57
Plaice landed	6,633	6,505	8,072	9,123	17,737	20,859	24,040	26,627	29,925	35,036
Processed	52	117	190	652	952	115	280	2,778	4,582	1,833
Withdrawn from market	1	0	4	1	5	6	11	16	15	9
Shrimps landed	4,296	5,595	5,290	8,955	9,478	8,232	7,583	7,599	6,710	7,511
Processed	7	108	14	910	592	186	197	193	151	762

[a)] Until 14/12/1964, haddock <30 cm were only landed.
[b)] Cod were registered from 14/12/1964 onwards.
[c)] Until 14/12/1964, whiting < 30 cm were only landed.

Table 3. Landings (tonnes) by large scale and coastal Dutch fisheries. Source: CBS, LEI-DLO.

Landings	1970	1971	1972	1973	1974	1975	1976
Herring: salted	22.3	18.6	22.0	26.1	20.4	21.8	17.4
Deep frozen	3.3	4.7	9.1	18.0	16.0	24.8	25.6
Fresh	5.4	5.7	7.2	8.6	4.4	3.0	0.2
Total	31.0	29.0	38.3	52.7	40.8	49.6	43.2
Mackerel salted	0.9	1.2	2.0	0.9	2.0	1.6	0.9
Deep frozen	0.7	1.2	2.0	3.3	4.3	10.5	13.3
Fresh	3.1	3.6	4.0	4.5	1.7	1.9	1.1
Total mackerel	4.7	6.0	8.0	8.7	8.0	14.0	15.3
Other fish: fresh	33.6	32.8	31.9	18.1	19.7	14.4	8.8
Deep frozen	0.7	0.7	1.7	4.1	4.3	5.7	3.8
Total fish	34.6	33.5	33.6	22.2	24.0	20.1	12.6
Grand total	70.3	68.5	79.9	83.6	72.8	83.7	71.1

Table 4: Revenue (million NLG)[a)] generated by large scale and coastal Dutch fisheries (*Source: CBS, LEI-DLO).*

Revenue	1970	1971	1972	1973	1974	1975	1976
Herring: salted	29.5	27.9	28.6	34.9	33.1	32.1	29.6
Deep frozen	4.8	6.6	10.7	22.0	22.3	37.1	43.6
Fresh	3.5	3.5	4.4	6.6	2.9	2.4	0.2
Total herring	37.8	38.0	43.7	63.5	58.3	71.6	73.4
Mackerel salted	0.6	0.9	1.6	0.7	1.8	1.4	0.8
Deep frozen	0.5	0.6	1.2	2.2	2.5	5.0	6.9
Fresh	1.6	1.6	2.0	2.2	0.8	0.6	0.2
Total mackerel	2.7	3.1	5.0	5.1	5.1	7.0	7.9
Other fish: fresh	26.4	28.5	33.5	25.3	28.3	16.8	10.9
Deep frozen	0.3	0.4	0.7	1.7	2.2	3.5	2.5
Total fish	26.7	28.9	34.2	27.0	30.5	20.3	13.4
Grand total	67.2	70.0	82.7	95.6	93.9	98.9	94.7

[a)] NGL = Netherland Guilders = US$ 0.41, 26. Sept. 2001.

Table 5. Landings (tonnes) by large scale and coastal Dutch fisheries (includes landings in foreign ports) Source: Netherlands Ministry of Agriculture, Nature Conservation and Fisheries, Productschap Vis, LEI-DLO.

Landings	1976	1977	1978	1979	1980	1981	1982
Cutter fleet	114	114	126	133	149	162	167
Large scale fisheries	71	69	82	104	126	175	202
Total large scale fisheries	185	183	208	237	275	337	369
Mussel culture	64	95	103	84	67	95	112
Oyster culture	1	1	1	1	1	1	1
Other	1	1	1	1	1	1	1
Grand total	250	279	313	323	344	434	483

Table 6. Revenue (million NLG)[a)] generated by large scale and coastal Dutch fisheries (includes landings in foreign ports and since 1996 landings made by WIRON vessels) Source: Netherlands Ministry of Agriculture, Nature Conservation and Fisheries, Productschap Vis, LEI-DLO.

Revenue	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
Cutter Fleet	321	327	368	421	438	521	541	635	693	794	762	744	649
Large scale fisheries	97	97	86	86	98	143	168	181	203	215	171	161	139
Total large scale fisheries	418	424	454	507	536	664	709	816	896	1,009	933	905	788
Mussel culture[b)]	29	25	37	50	53	39	37	40	29	49	68	69	77
Oyster culture	16	15	16	15	11	10	12	12	13	13	17	14	17
Other	1	0	0	0	1	1	1	1	1	1	1	1	1
Grand Total	464	464	507	572	601	714	759	869	939	1,072	1,019	989	883

[a)] NGL = Netherland Guilders = US$ 0.41, 26. Sept. 2001.
[b)] Data on mussel culture do not include the revenue generated by the Mussel Foundation.

Table 6 (continued)

Revenue	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Cutter fleet	661	692	744	652	661	625	629	607	571	607
Large scale fisheries	152	149	162	168	185	147	166	189	214	249
Total large scale fisheries	813	841	906	820	801	772	796	796	785	856
Mussel culture[b)]	70	105	85	91	92	105	126	106	118	98
Oyster culture	17	11	6	8	8	7	7	6	4	6
Cockle fisheries	44	31	13	52	43	32	25	17	9	50
Other	1	1	1	1	1	1	1	1	1	1
Grand total	963	983	1,017	973	941	917	955	926	917	1,011

[b)] Data on mussel culture do not include the revenue generated by the Mussel Foundation.

The cutter fleet

The cutter fleet operates in distant waters, like the North Sea and Atlantic Ocean. It is a modern fleet consisting mainly of large vessels, with 78% being beam trawlers. Since 1972, the number of cutters has fallen by over 80% from 72 to 13 vessels. In contrast, the fleet's engine capacity has doubled. The landing of flatfish such as plaice (*Pleuronectes platessus*) and sole (*Solea solea*), is the most profitable activity of Dutch fishers. This is a fishery which is characterized by large bycatch. In 1991, the flatfish landings accounted for NGL 550 mill. (NGL = Netherland Guilders = Dutch Florint = US$ 0.41, 26-September, 2001), a 31% increase compared to 1987. The volume landed in 1991 of pelagic fish, like horse mackerel (*Trachurus trachurus*), mackerel (*Scomber scombrus*) and herring (*Clupea harengus*), amounted to NGL 163 mill., an increase of 22% compared to 1987. In 1991 the value of landings of roundfish like cod (*Gadus morhua*) was NGL 91 mill., a 46% decrease compared to 1987.

The trawler fleet

The North Sea beam trawl fleet started to develop in the mid-1960s and has expanded up to the 1990s (ICES, 1999). It comprises a lucrative and prosperous commercial fisheries sector, targeting mainly flat fish species such as plaice and sole. Plaice and sole are taken by beam trawl fleets in a mixed fisheries in the southern part of the North Sea (ICES, 1999). The fleet plays a dominant commercial role, although it only comprises a small part of the Dutch economy (the beam trawl fisheries sector grosses approximately 70% of the total national landings). Beam trawl vessels vary in size and HP, ranging from less than 300 HP to a maximum of 2,000 HP. These vessels are owned by fishers who pay their crew by share contract. The Dutch beam trawl fleet comprises family businesses, where fishers and crew are mostly family or close friends from the Dutch fishing community known as *Urk*.

The larger beam trawl vessels with an engine capacity greater than 300 HP have fishing trips that usually last at least one week. Following the introduction of the 'Plaice Box' in 1989 (Rijnsdorp, 1999), the distribution pattern of beam trawl vessels >300 HP has changed. Since 1989, the 'Plaice Box' has been closed to beam trawlers >300 HP during the second and third quarter of the fishing year. In 1994, the 'Plaice Box' was also closed during the fourth quarter. Since 1995, it has been closed for the whole year. Today, the 'Plaice Box' is characterized by high concentrations of small plaice fished by beam trawlers <300 HP (see interview with fisher B; ICES, 1999). However, the 'Plaice Box' remains open to Norwegian vessels, who operate in the North Sea waters under bilateral agreements with the EU.

The coastal fisheries

The coastal fisheries are mainly concerned with cockle fisheries, seed mussel fisheries, oyster cultures and shrimp fisheries in the East and West Schelde, the Grevelingen, the Voordelta and the Wadden Sea. Both the fisheries and the birds depend on the shellfish stocks of the Wadden Sea and the East Shelde. Today, many fishers feel they compete with large numbers of cormorants for fishery resources.

METHODOLOGY

Statement of the problem

The North Sea is characterized by a dissipation of economic rent and over-exploitation of the resource because of excess fishing effort, non-selective fishing gear and un-cooperative behavior. Currently, fishing effort and investments into vessel modernization exceed optimum resource levels with the result that fish stocks, like cod, sole and plaice, are overexploited. The fishing industry is characterized by economic activities that are not viable in the long term. As a consequence, the recommendations made by the *International Council for the Exploration of the Seas* (ICES) include the adoption of the precautionary principle in order to ensure a high probability that the spawning stock is above the threshold where recruitment is impaired. Moreover, it integrates the realization that changes in fisheries systems are only slowly reversible, very difficult to control, not well understood, and affected by the environment and by human values (ICES, 1999).

Components of institutional analysis

"Institutions are the humanly devised constraints that structure human interaction. They are made up of formal constraints (rules, laws, constitutions), informal constraints (norms of behaviour, conventions, and self-imposed codes of conduct), and their enforcement characteristics. Together they define the incentive structure of societies and specifically economies." (North, 1990).

"In institutional economics, the property rights of an actor are embodied both in formal rules and in social norms and customs, and their economic relevance depends on how well the rights are recognised and enforced by other members of society." (Alston *et al.*, 1996).

The objective of an institutional analysis may include:

- identifying the determinants of institutions;
- explaining the evolution of institutions over time;
- evaluating their economic efficiency;
- assessing their distributional implications.

The economic functions of institutions include:

- reduction in transaction costs;
- allocation of risks;
- supply of information;
- supply of public goods.

Examples of these include:

- property rights, such as individual transferable quotas (ITQs);
- contractual arrangements (public-private; private-private);
- markets;
- codes of conduct;
- behavioral norms.

Components of economic analysis

In an attempt to illustrate the economic costs and benefits of the North Sea fisheries activities performed by the Dutch, it is important to include principle transaction costs and liability entitlements. The North Sea fisheries are characterized by transaction costs that are positive. Therefore, ownership of property rights is of concern because the size of the transaction costs depends on the way fishing rights have been assigned. Transaction costs include the "*the costs of measuring the valuable attributes of what is being exchanged and the costs of protecting rights and policing and enforcing agreements*"

(North, 1990). Hence, the basic unit of transaction costs analysis is the 'contract' or a single transaction between two parties in an economic relationship, like the state and the fisher (Dixit, 1996). The contract is a reciprocal promise to exchange valued properties between two or several parties. This has the notion of a voluntary exchange, but need not be one. In the extreme case of domination, the ruler (principal) extracts revenue from his subjects (agents) in exchange for the promise to limit or refrain from punishment.

Moreover, *"the enforcement of property rights involves excluding others from the use of scarce resources. Exclusive ownership calls for costly measurement and delineation of assets and enforcement of ownership rights."* (Alston *et al.*, 1996).

Major transaction costs include:
- Information cost on price and quality of commodities, on potential buyers and sellers and on their behavior and circumstances;
- Bargaining costs;
- Contracting costs;
- Monitoring cost of contract abidance;
- Enforcement costs and costs of obtaining redress in the event of damage;
- Protection costs of property rights against third party encroachment (Alston *et al.*, 1996).

Additional information required for an economic analysis include:
- Investment costs, such as ITQs, vessel, sea-days license, fishing gear, on-vessel fish sorting equipment, GPS, computers, telephone;
- Operational costs, such as fuel, lubricating oil to operate/maintain fishing gear, ice, fish boxes;
- Vessel maintenance costs, such as antifouling, motor maintenance and cleaning equipment/products;
- Crew;
- Auction tax and payment of grading;
- Taxes on income and profit;
- PO Membership fee (and possibly a *Biesheuvel* group fee);
- Membership fee of Fishers's Association;
- Possible sanctions incurred (lawyers, fines);
- Insurance (health, vessel, third party);
- Auction fee.

Property rights

"The rights of individuals to the use of resources (i.e., property rights) in any society are to be construed as supported by the forces of etiquette, social custom, ostracism, and formal legally enacted laws supported by the states' power of violence of punishment." (Alchian, 1977).

Property rights include:
- Right to legitimate use and to physically transform an asset;
- Right to earn income from an asset and contract over the terms with other individuals;
- Right to transfer permanently to another party ownership rights over an asset - that is, to alienate or sell an asset (Alston *et al.*, 1996).

Conditions of economically functional property rights:
- Specification and delineation of the asset;
- Measurement of the valued attribute(s) of the asset;
- Protection from expropriation of the valued attribute(s) of the asset.

Components of ecological analysis

From a human, intergenerational perspective, the ecological costs and benefits of fishing activities performed by the Dutch in the North Sea include market and non-market values. The former involves using market prices as a monetary valuation technique to assess the commercial value the Dutch pay for a given marine resource, such as fresh fish. The latter, however, is more complex and requires a differentiated approach. For example, it can include indirect costs and benefits such as the role of marine organisms in risk reduction and human health. Risk reduction includes the role of the marine environment in climate stability and their role in maintaining human health through the provision of iodine-rich foods, fresh water and oxygen. Moreover, it includes *hedonic* costs and benefits, like the effect of beautiful views and the pleasure of being in natural surroundings.

The ecological analysis requires an ecosystems approach. This is difficult considering the gaps in information available and knowledge surrounding the complexity of the ecosystems dynamics constituting marine environment. An attempt is therefore made towards a pooled analysis using both types of (market and non-market) data.

Ecological considerations include:

- Regulatory functions include: acting as a climate/energy regulator ; acting as a sink for CO_2, NO_x (NO_2 and NO_3 or nitrous oxides) and SO_x (SO_3 and SO_4 or sulfur oxides); roles in hydrological, meteorological and oceanographic cycles and being a source of water;
- Habitat functions, including refuge, nursery (plaice, sole, shrimps); biodiversity; and evolutionary processes
- Productive functions include: oxygen production; sources of energy for life; and medicine
- Recreational activities, such as sport fisheries, sailing and eco-tourism.

INSTITUTIONAL ARRANGEMENTS

In an attempt to gain insight into the transaction costs of politics, the institutional arrangements within the Dutch commercial fisheries are described. Moreover, interviews with fishers allows the reader to gain insight into the experiences of those operating within the boundaries set by existing institutional arrangements, such as the Common Fisheries Policy (CFP) and Individual Transferable Quotas (ITQs).

The Common Fisheries Policy

The Common Fisheries Policy (CFP) is the European Union's instrument for the management of fisheries and aquaculture. It was created to manage a common resource and to meet the obligation set in various treaties, particularly the 'Treaty of Rome' (hereafter referred to as 'Treaty'). The founding objectives of the CFP are described in Article 3 of the Treaty, notably *"for the purpose set out in Article 2, the activities of the Community shall include … (d) the adoption of a common policy in the sphere of agriculture …"*; and Article 38 of the Treaty, whose first paragraph states *"… the common market shall extend to agriculture and trade in agriculture products. 'Agricultural products' refers to products of the soil, of stock-farming and of fisheries and products of first-stage processing directly related to these products"*. The general objective of the establishment of the CFP is to provide a legal framework for the *"… rational and responsible exploitation of the living marine resources on a sustainable basis, in appropriate economic and social conditions for the sector taking account of its implications for the marine ecosystem and of the needs of both producers and consumers."*

The CFP has 4 main components:

1. The conservation and enforcement policy (1983) – Regulation 170/83 establishing a Community system for the conservation and management of fisheries resources which was replaced in 1992 by Regulation 3760/92 establishing a Community system for fisheries and aquaculture;
2. The structural policy (1970) - Regulation 2141/70 laying down a common structural policy for the fishing industry;
3. The marketing policy (1970) - Regulation 2142/70 on the common organization of the market in fisheries products;
4. The external fisheries policy (post 1977).

National institutional arrangements

The general objective of the Netherlands Ministry of Agriculture, Nature Conservation and Fisheries (LNV, *Ministerie Landbouw, Natuur en Visserij*, hereafter referred to as the Ministry) within the CFP framework, was published in its 1993 Policy Document on Sea and Coastal Fisheries. This policy states that the Netherlands sets out to promote responsible fishing effort and a balanced durable exploitation of fish stocks until the year 2003 (Davidse, 1996; Salz and DeWilde, 1996). The Fisheries Management Board (*Directie Visserijen van het Ministerie van Landbouw, Natuurbeheer en Visserij* (LNV)) of the Ministry has the delegated task to manage matters concerning the production, marketing, price-setting and processing of fisheries products within the CFP framework. The Fisheries Management Board plays a pivotal role in representing the Netherlands in decision-making processes at the Community level and in bringing into force EU regulations at the national level. Together with the Ministry's Legal Planning Office (*Juridische Bedrijfsorganisatorische Zaken (JBOZ) van het Ministerie LNV*), the Ministry's Fisheries Management Board translates European policies into national fisheries policies. In this legislative process, the Government and Parliament together determine the constitutionality of proposed laws under consideration. The Supreme Court ensures a uniform application of Dutch law, although it cannot suspend a law as being contrary to the constitution. National laws, which are contrary to European agreements can be abrogated by Dutch courts.

Specific tasks concerning the management of quotas, fish trade and fish processing in the Netherlands, are tackled by the Commodity Board of Fish and Fish Products (*Productschap Vis*). This is an economic sector of the corporate *Publiekrechtelijke Bedrijfsorganisatie* (PBO). Tasks concerning the enforcement of EU and national control measures are given to the Ministry's *Algemene Inspectiedienst* (AID), the Dutch general inspectorate. The AID identifies and reports un-cooperative behavior observed out at sea and/or on fishing vessels. Fishers caught performing illegal behavior are prosecuted by one of the Netherlands' sixty-two cantonal courts. The administration of justice is entrusted to appointed judges. Cantonal courts, however, only have jurisdiction over minor fisheries suits. If the case and appeal of a cantonal court decision is of greater importance, it is handled by one of nineteen district courts. Appeals to decisions of district courts are handled by one of five courts of appeal.

Individual Transferable Quotas (ITQ)

In 1977, the Ministry introduced an individual transferable quota (ITQ) system for plaice and sole. This was done in the hope that through the allocation of exclusive fishing rights to the fishers, the prospect of earning resource rent would motivate precautionary and responsible fishing behavior at sea (Davidse, 1996). However, the one-off transfer of fishing rights to the fishers did not achieve the efficiency, social stability or responsible fishing behavior the state had hoped for. External inter-related factors, such as a 200% rise in the price of fuel in 1973, an expanding beam trawl fleet, unlimited vessel HP and weak control enforcement measures did not guarantee success of this ITQ scheme (Davidse, 1996). The State undermined the assumption that it did not matter whether fishers used *"a Citroën deux chevaux or a Mercedes"* to catch their individual quotas. Ecological, environmental, technical and equity problems ensued (Hinssen and van der Schans, 1994). Data on plaice indicated that the catch per unit effort (CPUE) and fishing mortality more than doubled from 0.25 to 0.55 in the period ranging from 1960 to 1989 (Boddeke and Hagel, 1991). In fact, the specialization on flat fish meant that Dutch beam trawl fishers got a disproportionately large share of North Sea demersal landings. The landings of plaice, for example, increased from 38% in 1971-1974 to 63.6% in 1981-1983 of the total North Sea landings (Boddeke and Hagel, 1991).

The allocation of individual quotas were based on historical catches and/or vessel engine power, and were awarded in an arbitrary fashion by the Ministry to Dutch fishers, for free (see interview with fisher B; Hinssen and van der Schans, 1994). For example, fishers with vessels active in the North Sea during the period prior to January 1974, received individual quotas based on the largest quantity of plaice and sole landed in the period 1972-1974, whereas, vessels below 1,250 HP commissioned after 1974, received quotas based on the average performance of vessels in the same HP-group (Davidse, 1996). Hence, fishers who had always landed large catches were given large individual quotas. Moreover, banks were only willing to give loans to those fishers who had high quotas.

Government policies and premiums also stimulated overcapitalization of the beam trawl fleet. Economic pressures to avoid quota limitations combined with weak control enforcement measures, led to a growing tension between ITQ restrictions and increased fishing effort (Davidse, 1996). Side-effects of this system were the illegal activities which proliferated within the fisheries sector. These activities led to the establishment of 'gray' and 'black' fish markets. Many more catches were landed than was allowed under the Community quota system. Although Dutch ports such as Ijmuiden were controlled, ports in the North East of the Netherlands like Lauwersoog, were not sufficiently monitored. Fisheries biologists believe this may still be the case. Numerous illegal landings of catches outside the official ports resulted in very high incomes. This gave fishers, especially those from the fishing community of *Urk*, a bad reputation. This reputation is still very prevalent amongst the Dutch today, although it is not fully justified.

As a consequence, the fisheries biologists of the RIVO-DLO assumed catches went unreported, which in turn affected the reliability of the logbook data. The trust was gone and the accuracy of the assessments on North Sea flat fish stock dynamics were put into question. Fisheries biologists made estimates of the predicted and potential catch which other interested parties, such as fisheries economists of the Dutch Agriculture Economics Institute (LEI-DLO) and fishers considered to be too high (Smit *et al.*, 1992). Fishing effort continued to increase and the TACs allocated to the Netherlands by the North East Atlantic Commission (NEAFC), were soon exhausted.

The rise in fishing effort, unreliable data, and government threats to impose general stops on fishing, created anxiety at the fishers' level which resulted in a further race for fish (The Skagerrak incident described by fisher C is a genuine example of how a combination of overcapacity, quota overfishing and poor communication led to top-down policy-making, resulting in the loss of the fishing rights of Dutch fishers in the Skagerrak grounds, and increased conflicts and competition between fishers.). The Government, however, soon realized that in order to ensure a balanced and durable exploitation of fish stocks, engine capacity (measured in HP/Kw) reduction was needed. Hence, a licensing system was introduced in 1985 followed by a further reduction of HP in 1987. In 1987 another attempt was made to limit fishing effort by introducing a limit of 12 meters in the beam trawl width of vessels. As well, a limit on the number of days spent at sea and a voluntary decommissioning scheme were implemented (Hinssen and van der Schans, 1994; Davidse, 1996).

Today, the ITQs are distributed as a type of document by the Ministry. A Government revision of the individual quota system in 1977 based quota allocation on the average catch of the past six years according to HP-group and made individual quotas officially transferable by imposing certain restrictions on their transfer. Fishers can only buy an ITQ from another ITQ holder if they are in possession of a fishing license. Transfers of ITQs must be approved by the Ministry and fishers are not allowed to sell parts of ITQs separately. That is, the ITQ must be transferred from fisher to fisher as a whole. Only Producer Organizations (POs) can buy ITQs and sell parts of it to individual fishers (Davidse, 1996). These ITQ transfer regulations imposed by the Ministry on fishers has made fishing a very expensive business activity for the individual fisher acting alone. As a collective (*Biesheuvel* Group) operating within the framework of private *Biesheuvel* groups, fishers can afford to transfer ITQs amongst themselves. The *Biesheuvel* Steering Committee introduced a co-management system in 1992 allowing fishers to rent and/or barter quotas within the *Biesheuvel* groups which operate under private law. Consequently, the ITQ system has made the beam trawl fisheries sector and *Biesheuvel* associations very exclusive. In order to become part of private *Biesheuvel* associations a fisher must already have an ITQ, a fishing license and a vessel. The introduction of regulatory measures by the Ministry to manage ITQs, has reinforced the exclusion of outsiders from this industry. In contrast, fishers who have been in possession of such a document since 31st December of the previous year, are automatically given an ITQ by the Government (Davidse, 1995). These costs of fishing rights have triggered concentration: today fishing is either a family business or a business partnership.

Although today the prices of quotas are very variable, they are strong, and as long as the quotas do retain their present value, the fishers presently holding them will remain content. In 1995, the rental of a quota of sole cost a fisher about five NGL per kilogram. It is not certain what will happen once prices of quotas are increased further, and the quotas themselves are decreased. This will probably make the Dutch beam trawl industry more exclusive. From an intergenerational perspective, if the transfer of ITQs is facilitated from father to son, as is presently the case with Dutch milk quotas, it could cause discontent amongst those sons who left the industry (Hinssen and van der Schans, 1994).

Problems in trying to keep an equilibrium between fishing effort and quota limitations remain. It is only by using a combination of control measures enforced by the AID and fishers groups that the Ministry has succeeded in maintaining order up to now. The decommissioning of Dutch vessels also contributed to a decrease in Dutch fishing effort although the Netherlands failed to satisfy the targets set in the European Multi-Annual Guidance Programs (MAGP V). Recent policy developments at the European level, notably the Structural Funds 1999, indicate that the European Commission and national Governments seek to decommission the European fleet through joint ventures with third countries under bi- and/or multi-lateral agreements.

The Subsidiarity Principle

The increase in mutual consultation and the co-ordination of fisheries activities at the ICES and European level has placed a significant burden on national administrations to effectively ensure surveillance and control resource-user compliance to Community and national management regulations. These administrations have the task to regulate conflicts between different interest groups, whilst simultaneously safeguarding ecological health and continued productivity of the resource and its environment. According to the Subsidiarity Principle of the EU, it remains within the competence of member states to draw attention to the responsibilities of

fishers as resource managers of the ecosystem they exploit (Laurec and Armstrong, 1997). Although TACs are established at the European level and allocated to member states, the task of distributing quotas and associated fishing rights must be dealt with at the national level. The national quotas can either be allocated to individual fishers directly by the state or distributed to private associations like POs. Through enforcing the Subsidiarity Principle, the Commission hopes to ensure that management decisions are made at the lowest possible level. However, this does not entail decentralization. It is strictly top-down: what is decided at the national level cannot be introduced at the European level. Interestingly, the Netherlands argues that although it does not satisfy the MAGP targets, its co-management structure has ensured that fishing activities performed by fishing vessels flying the Dutch flag remain within the established TACs. However, it remains to be seen what will happen once the quota will start to decrease.

Co-management: Producer Organizations and *Biesheuvel* Associations

In 1992, the Netherlands introduced a co-management system through the introduction of *Biesheuvel* groups. These private fishers' associations formed by the Steering Committee *Biesheuvel* , enforce control at the fishers' level by means of mandatory auctioning (Hinssen and van der Schans, 1994; Laurec and Armstrong, 1997). This co-management system seeks to promote resource-user participation in fisheries management through the creation of incentives for individual fishers to voluntarily organize themselves, via producers organizations (PO), into regional groups of corporate personality. The PO is exempt from the EU anti-trust regulation (Article 85/86 of the Treaty of Rome; Hinssen and van der Schans, 1994) and has the delegated responsibility to manage the uptake of national quotas by controlling member vessel activities as they see fit. In this way, the PO gives industry maximum flexibility to manage its quotas while the Government mainly operates at the strategic level.

The interviewed fishers are enthusiastic about the *Biesheuvel* associations. Within these groups, fishers can communicate with each other and rent and/or barter individual quotas and sea-days. The private associations provide the fishers with a legal structure that allows them to avoid being sanctioned (Hinssen and van der Schans, 1994). In failing to comply to the private obligations, members are faced with a private penalty system. The costs of overfishing and failing to operate within the established quotas, have been internalized through private law at the individual level. At the group level, these fishers associations have public obligations whilst at the individual level, members are subject to private obligations.

The fishing rights of the private *Biesheuvel* associations consist of the sum of the ITQs of the members, supervised by an independent chair working within a management framework approved by the acting secretariat, the Commodity Board of Fish and Fish Products. As a group, fishers remain subject to public law to prevent the overfishing of joint quotas. In 1994, the Dutch Fisher's Union estimated that at least 96% of the total Dutch cutter fleet was actively participating within the structure established through the Steering Committee *Biesheuvel*.

Fishers feel that the private *Biesheuvel* associations provide an efficient means to enforce control on activities within the fisheries sector. For example, Article 2.2a of the national Regulation No J 7391 imposes stringent control measures on catch reporting. The present mandatory auctioning has provided a more time- and cost-effective alternative to the European logbook system established in 1988, that required the completion and submission of logbook entries within half an hour of landing at ports in the Netherlands.

INTERVIEWS WITH DUTCH FISHERS

In this section, the interviews of three Dutch fishers have been translated and transcribed. As stated in the introduction, the term fisher represents a fishing enterprise that is either owned individually or in partnership. The owner may actively use the fishing vessel, or be a person who owns the vessel but does not actively fish, or the owner may represent either a corporate co-operative or company that owns one or more vessels. The aim lying behind these interviews is to illustrate the attitude and response of fishers to legislative measures imposed onto them by the EU and Dutch authorities, in an attempt to limit or direct fish capture activities. The reactions of fishers to these regulations largely determines the success of any regulation in practice. Co-operation within the fisheries industry and with members of outside authorities dealing with fisheries, is essential if fisheries policies are to be effective in managing a fisheries in a sustainable manner. Communication is essential for

successful resource-use management. The *milieu* of these fishers can also be seen as a *fisheries market* so as to distinguish it from the fish market.

Fisher A

Fisher A is from *Urk*, a Dutch fishers village, but has reflagged his two beam trawl vessels of 900 HP (a family business) and now fishes for flatfish under the British flag. There are many reasons why the Netherlands could find it less costly to 'import' fisheries services rather than attempting to produce them under her own flag. Importing these services can enhance the net benefits from the fisheries enjoyed by the Netherlands by decreasing the catch per unit effort of domestic fishing activity. Reflagging means less Dutch vessels to survey, monitor and control. These burdensome costs are therefore reduced allowing for greater investment and flexibility in domestic fisheries management by Dutch authorities. The flag state, such as the UK, acquires the responsibility for compliance by all vessels flying its flag with the coastal State's access regime, based on the concept of *pacta sunt conservanda* (Moore, 1983). Also, less vessels fishing under the Dutch flag can imply larger quota for those vessels carrying the Dutch flag, although the resource is processed and marketed in the Netherlands by Dutch fish operators. The landings he makes in Lauwersoog are treated by the Dutch authorities as import.

Although fisher A fishes under the British flag, he is still a member of the PO (Oost-Nederland U.A.) responsible for *Urk* fisheries activities. The net profits of his catch are accrued by processing and marketing operators in *Urk*. Hardly any real profits obtained from skipper A's landings go to the UK. Skipper A's contacts remain predominantly in the Netherlands. His only obligation to the UK is to respect British fishing regulations and fulfill the obligatory number of landings (8 per year) established by the Ministry of Agriculture, Fisheries and Food (MAFF) in the UK, although this does not necessarily imply the actual landing of fish!

Via the Netherlands, his landings are exported to Italy, Spain and Austria, where fish prices are higher. It is surprising that the Spanish market demand should be so high; and it raises the question as to where Spanish vessels land their catches. However, like the Italians, Spanish consumers will pay for good quality fish. Fisher A is in the possession of quotas for plaice, cod, sole, flounder and a determined quantity of bycatch, but he does not specify this any further. He therefore does not throw all his bycatch back into the North Sea. His quota is based on a three-year track record of all his catches, of which he receives a third of the average. Placing an upper limit on his catch in the form of a quota is not very attractive to fisher A. This quota is established by the MAFF and allocated to him via a British PO in the UK. If he has fished his quota for cod, he and his crew (all his crew come from the Dutch town of *Urk*) change fishing grounds and switch to catching plaice, while trying to limit the amount of cod bycatch. However, he is not happy with today's quota system. He does not return most of the flatfish he catches to the sea as their fins, skin, bladders and other body parts are damaged by the nets and pressure changes as they are hauled to the surface. Not only does the non-selective fishing gear detrimentally affect bycatch, but it is also responsible for the poor quality of fish sold to fish markets. Furthermore, many plaice and sole bury themselves into the sand in an attempt to avoid being caught in the nets of the beam trawl. Although tickler chains of beam trawls are effective at herding plaice and sole into nets, damage to benthic communities is considerable.

Fisher A has a 'water and bucket' system on his ship to keep bycatch alive, in order to return them to the North Sea in as 'healthy' a state as possible, if and when necessary. Hence, fish that are undersized and therefore too small to land legally, but not small enough to avoid getting trapped in the fishing nets, are returned to the sea alive (what the actual chance of survival is remains unknown). He emphasized the fact that many fishers from *Urk* use this 'water and bucket' system as they are very environmentally conscious. Fishers are aware of the increasing economic importance of Dutch consumers perceiving fishers as behaving in an environmentally conscious manner. Greenpeace Netherlands is currently providing a Dutch fishing vessel with the necessary funds to operate environmentally-friendly fishing gear (Van den Broek, pers. comm.). Another Dutch vessel is also undertaking similar steps.

When asked why he had chosen to reflag, fisher A said it had been the inflexibility of the Dutch legal and control/inspection system (Algemene Inspectie Dienst (AID), the Netherlands surveillance, monitoring and fisheries control enforcement inspectorate) that had forced him to decommission and to start again in the UK. In the early 1980s, the Netherlands had adopted a system in which the maximum a landing could consist of was approximately 75 boxes of fish, the

same system adopted in Harlingen. However, the 'box' unit system is not standardized. Fisher A found the system flawed and inflexible because it did not take into account the high ecological and environmental variability characteristic of the North Sea ecosystem. There could be weeks in which fishers caught very little, and weeks in which they caught a lot fish. These seasonal periods when the catches are abundant should be more stringently controlled, as it is probably a period in which damage should be limited. Excess fish caught had to be 'done away with' and was therefore often landed illegally and sold on the 'black' or 'gray' fish market.

Control of illegal activities within the fisheries sector is difficult. Unsustainable behavior at sea will only become unattractive if it is economically unprofitable. An article published 20 April 1977 In the Dutch intellectual newspaper *Vrij Nederland* looked at the accountants working for *Urk* fishers. The advice given at the time to the fishers was to ignore reports of the Government's Agricultural Economic Research Institute (LEI-DLO) on economic developments in the flatfish fisheries. The accountants thought that the techniques used by LEI-DLO economists were too theoretical and did not necessarily reflect reality. The LEI-DLO economists realized a need to investigate this further in late 1977 and temporarily their credibility was put to question by the *Urk* fishers. Today, however, the picture is quite different: fishers take the analyses and advice given by the LEI-DLO seriously. At the same time, the institutional stucture of the Dutch Government research authorities, like the LEI-DLO and the Netherlands Fisheries Research Institute (RIVO-DLO) has changed. These institutions are output-oriented and operate on the basis of contractual arrangements. As a consequence, the transaction costs have increased and transparency has been reduced significantly, as it has become very difficult for third parties to obtain access to data and information on fisheries. This has severe consequences for public accountability of marine resource use, which is a public resource.

The fishers found themselves in a difficult situation, having to compensate for those weeks in which the catch was less successful by selling fish illegally on the black market. In this way, the *Urk*ers build themselves a bad reputation during the 1980s. However, this was also very much the result of the inflexibility of the Dutch fisheries regulations, forcing many *Urk*ers to land fish illegally when the fishing seasons were good. The general public, policy makers and enforcers did not see this as the result of bad policy making, but rather as a characteristic typical of the people from *Urk*. Although the European Economic Community adopted a Common Fisheries Policy in 1983, control systems were inadequate and underdeveloped. It was therefore easy for fishers to fish in excess of their quotas as inspections and control measures were very poorly enforced. Weak control enforcement by AID officers in the early days of the CFP allowed un-cooperative behavior to occur at the fishers level.

Economic pressures, an oil crises, quota limitations and an expanding fleet, were all contributing forces in the development of gray and black fish markets, illegal landings and uncommunicative behavior of fishers. Today, the co-management model has gained wide popularity amongst fishers and politicians. The Dutch co-management system was set into force by the *Biesheuvel* Steering Committee in 1992. Dutch fishers can rent and/or barter quotas within *Biesheuvel* groups operating under private contractual arrangements. The events from 1983 to 1986 stigmatized the people from *Urk*, giving them a reputation of being law breakers from which they have not yet recovered.

Fisher A felt that it was not feasible to enforce established rules as to how a fisheries should be run because the catch is too variable and does not respect national or EU regulations. According to him, a more flexible policy making system is needed that takes into account the chaotic nature and high variability of the North Sea environment. The average fisher from *Urk* does not like to throw fish back into the sea once it has been caught and pulled on deck. Most fish do not survive the experience, especially flatfish, as the trawl damages their fins, internal organs and skin. When the fish are thrown back into the water, they are usually dead or will die soon afterwards. This fish has therefore gone to waste, something the *Urk*er does not like to see happen. But due to the inflexibility of the quota system established by the EU and set into force at the national level, the *Urk*ers find they have little choice but to throw back bycatch.

Today, the legal system in the Netherlands is very biased regarding matters involving the people from *Urk*. It is immediately assumed by Dutch lawyers and judges that fishers from *Urk* will do anything to overfish their quota and/or try to land fish illegally. This was, for example, what fisher A experienced and what has led him to reflag. He was fined two hundred thousand guilders for having landed too many fish, as he refused to throw dead fish back into the North Sea in order to legally stay within his quota.

According to fisher A, bad policy making, biased opinions, and inadequately trained officers of the AID (*"who cannot distinguish plaice from sole!"*) are making life for Dutch fishers fishing under the Dutch flag very difficult. The fine imposed on fisher A, combined with a series of bad catches and repairs to his ship, which caused him to remain in harbor for half a year, forced him to decommission his vessel. However, the decommissioning money which he received from the Dutch Government, was not enough for him to start again in the Netherlands. Hence, he lost his quotas. Furthermore, fisher A considers Dutch quotas to be too expensive; that is, approximately 75 NGL per kilogram of plaice; 65 NGL per kilogram of sole; and 15 NGL per kilogram of cod. British quotas are cheaper, although fisher A did not wish to specify by how much.

Furthermore, inspection measures are more appealing in the U.K than in the Netherlands. It is not clear whether or not this statement implies control enforcement measures in the UK to be more 'relaxed', and therefore possibly dissatisfactory from point of view of resource sustainability. The UK has a limited license system which controls fishing effort. Fishers fishing under the British flag are required to report for inspection to local Fisheries Inspectors. Fishers must also report before departure when intending to land at British ports, or when crossing ICES areas, or landing at non-UK ports. Compared to control enforcement in the Netherlands, it appears inspectors in the UK rely heavily on law-abiding behavior of fishers. Fisher A also did not like the Dutch system of sea-days. Hence, reflagging to fish under a British flag became a very appealing option for fisher A. Today, the only true obligation he has towards Britain is to land at least eight times a year in Lowestoft, U.K. However, this does not necessarily mean he actually lands any fish in the U.K.

The British quotas are established on the basis of a three-year record and are a third of the price paid in the Netherlands. Quotas are allotted on a yearly basis according to the fishing effort of the vessel. The quota system allows the Ministry of Agriculture Food and Fisheries (MAFF) and the POs to establish the fishing effort of each vessel fishing under the British flag. The technical drawback of this system, however, is that it forces fishers to lie still in harbors until the quotas have been established. It is possible that with the introduction of an Individual Transferable Quota (ITQ) system, as the British Government plans to do in the near future, this technical drawback will no longer exist. The introduction of an ITQ system will mean that prices of the British quotas will rise. In this way, the British Government hopes quotas will be sold at more profitable prices. Today, however, the British quotas are still distributed via POs, which a fisher must have been a member for at least three years before he is given access to British quotas. If a fisher is caught overfishing his quota; if he has been fined several times; or if he has broken British fisheries rules and regulations, MAFF will repossess all the fish caught by the fisher and his fishing license is taken away. Hence, although the British are considering the idea of introducing an ITQ system, the quotas are not yet fully in the possession of the fishers.

However, Fisher A did not think Britain was ready for an ITQ system (Due to lack of international experience, the introduction of an ITQ system will require massive educational effort. Other requirements include greater government control; a new bureaucracy; greater information costs; changes in fishers' lifestyles; and, increased at sea monitoring and control enforcement. A race for fish is likely to result if control is not sufficiently stringent, with the result that under-reporting will prevail). His impression of the British fisheries sector is that it is in total disarray and that it lacks any form of organization or specialization. The British fishers are depressed and their level of education is lower than that of Dutch fishers. Furthermore, fisher A said British fishers did not keep up maintenance levels and vessels were not kept clean. In fact, Dutch fishers consider British vessels to be very dirty and kept in a very bad state. He also said he did not think British fishers had evolved a similar level of organization typical of Dutch fisheries sectors today. In fact, the high level of organization of *Urk* fishers has allowed them to exert a lot of influence within the British flat fish sector too. Because of such different standards between Britain and the Netherlands, he thought the internationalization of resource user participation could itself pose a problem. Not every member state fishing in the North Sea has yet evolved the same social organization at the fishers level.

Fisher A was in favor of an ITQ system, although such a system will result in quotas becoming more expensive. He thought multinational companies, such as 'Findus', would be amongst the few possessing sufficient capital to buy more ITQs than the average fisher. Such organizations will therefore be at a considerable advantage. He also recognized the fact that such a system will force the smaller fishers out of the commercial fisheries sector, just like the smaller farmers were

forced out of the farming industry in the Netherlands. Hence, it will reduce diversity at the fisher's level and make it very difficult for young fishers to start fishing.

Today, only wealthy beam trawl owners can afford lawyers and experts so as to benefit most from EU and national aids. This puts them at a competitive advantage to small trawl owners, as the experts provide information on what advantages (in terms of subsidies) can be had from EU and/or national aid systems. Fisher A found that it is a system that stimulates capitalism and where money makes money. He knows of cases where wealthier beam trawl owners could obtain more sea-days as well as extra quotas to make up for the overcapacity of their vessels. Their vessels are often registered as lying within the 2,000 HP limit, although he believes these vessels to be capable of a much greater HP. They can do so because these fishers can afford to hire the best lawyers and experts on matters regarding EU and national policies.

When fisher A was asked what he thought of the Spanish and Portuguese fishers fishing in the North Sea, he replied by saying that he did not find their behavior very responsible and that on this basis they should not be allowed access to the North Sea. He found that some of the fishing techniques they use are not appropriate for the long-term viability of the fish populations. They catch juveniles by using a mesh size that is illegal and they make other member states fishing in the North Sea, especially the U.K., very angry. He considers their behavior to be disrespectful of the North Sea environment.

When asked whether or not fishers allowed their logbooks to be seen by other fishers, fisher A said this did not happen. Fishers are individualists, who are always suspicious of fellow fishers. Every fisher is out for themself, which can be quite uncooperative. He did not think that a system of property rights where each fisher was assigned a specific territory could ever work. However, he did find that the introduction of the steering group *Biesheuvel* had calmed the waters considerably, establishing a means for fishers to co-operate. It had lessened the number of fines distributed by the AID to fishers overfishing their quotas as fishers could now barter and/or rent fish.

Fisher A did not find that the stocks in the North Sea were declining and did not believe there was such a problem as overfishing. Due to the establishment of the 'Plaice Box' (Rijnsdorp, 1999), he had been forced to seek new fishing grounds although he often did fish around the borders of this protected area. He was not a great supporter of the plaice box as he said there was no evidence as to whether or not the setting up of protected areas was of any benefit for the plaice stocks. He found that if certain regulations had not proven to be effective within a given period, that they should then be made redundant. According to him, the plaice box should also be open to beam trawlers greater than 300 HP. He believed fisheries biologists to be incorrect in saying that the plaice box was of benefit to plaice. He did not have much faith in fisheries biologists as they had made many incorrect assessments of the state of the fish stocks in the North Sea. So far, fisheries biologists had been proven to be wrong in many of the conclusions and assumptions they had made regarding the dynamics of North Sea stocks. He therefore believed that the plaice box was another mistake based on incorrect assumptions, miscalculations and lack of knowledge on matters concerning the North Sea ecosystem.

Fisheries biologists cannot expect to reach a complete understanding of the North Sea ecosystem. Recruitment patterns and dynamics are still a complete mystery to the fisheries biologists. Hence, fisher A believed that overfishing was also the result of miscalculations by fisheries biologists and therefore does not exist. He found that nearer to the Dutch coast it was good for fishing on sole, whereas nearer to the Danish coast, plaice was more abundant. He therefore moved from one fishing ground to another according to fish stock abundance. Furthermore, fisher A was also very much in favor of eutrophication as it increases the abundance of flat fish, especially plaice. When asked whether he believed a system based on eutrophication could be sustainable in the long term, he said his experience was to always find the most abundant fishing grounds to be rich in sewage, phosphates and nitrates. According to fisher A, agricultural waste provided food for the benthic communities, which form the basis of the food chain of flat fish, such as plaice and sole. He praised eutrophication and would like to see more of it in the North Sea.

When asked if he thought he could influence the fish market by holding fish back, he said that was impossible as the quality of fish is short-lived. Fresh fish is approximately five days old when it is landed. If it is kept one day longer, it will not fetch a decent price on the fish market. Furthermore, *Urk*ers do not believe in wasting fish. However, he did emphasize the fact that the East European countries are influencing the European market. These fish are sold on the black

market and therefore bring down the prices of the fish caught by Dutch fishers that are sold in Dutch fish auction halls. There is no policy to control illegal importing of fish from Eastern European countries, as the Dutch Government and AID only concentrate on vessels fishing and landing under the Dutch flag. He was not aware of any EU control system that kept such illegal imports in check (This is a very important observation and indicates the need for adequate control enforcement at the international level). However, as a consequence of such competition, which is out of the control of Dutch fishers, fisher A said Dutch fishers were furious and frustrated, and they would like to see Dutch control measures to be enforced at the international scale. Fisher A feels he has no power to do anything about the present situation, which is affecting the quality of fish entering the EU market. For example, he said that the quality of the fish provided by the Eastern European countries is poor; at least 20% of it is rotten.

However, the multinational companies that do buy this fish for a very low price mix it with fresh fish as well as preservatives, which lowers both the quality and the price of the product (clearly an issue for consumer awareness programs). The fish bought and processed by multinationals is not really fresh. However, the customer is not informed of these facts and no control is put into force to prevent these events from happening. It is detrimentally affecting the Dutch commercial fisheries sector. Fisher A felt that after seventeen years of experience in this sector, he found that the economic situation of the Dutch commercial North Sea fisheries sector had become less attractive to him. It is unlikely, he believed, that the fish prices would increase as the consumers of fish want the prices to remain low, regardless of quality. Unless consumers are informed of what is actually happening, the present situation will not change. Only in Italy, where he exports his fish, do consumers buy fish at a very high price. Hence, the fish he lands in the Netherlands as import, is immediately exported to the South of Europe, where consumers will pay more for quality. He said he did not find the Northern European fish market profitable and did not find demand for North Sea fish in the Netherlands was stimulating.

He would like to see some form of property rights in the market system, which would give fishers a voice in matters concerning the processing and trade of fish. He thought that in this way fishers could protect their industry from illegal imports of fish from countries without environmental legislation. He said that either environmental legislation on matters regarding the commercial fisheries sector would have to be enforced and standardized at the international level, or a system protective of those countries that do abide to environmental legislation should be given a competitive advantage to those countries that do not enforce such legislation. Today he said that Dutch fishers fishing under the Dutch flag were at a disadvantage as the AID is very strict; fines are very high; Dutch rules and regulations are inflexible; and other member states and non-member states do not have such authorities working against them, giving them a competitive advantage at the fish market level. According to fisher A, Dutch inspectors should be employed at the international level.

Fisher B

Fisher B started in 1969, when gas and oil was discovered in the North Sea. He saw Member States being assigned their three nautical mile (nm) territorial zones and their 12 nm zones, which were heavily praised by both the Danes and Germans. In fact, the Federal Republic of Germany was the first country to enforce stronger control measures on matters concerning fishing activities in their coastal zones. Denmark, the Netherlands and the Federal Republic of Germany were all very happy about the establishment of a 12 nm territorial sea as it gave these countries the power to protect their coastal areas, and hence power over the nursery areas of commercially exploited stocks, such as plaice and sole. In 1989, entry was allowed to beam trawlers, such as today's Euro-cutters, of 300 HP.

Fisher B has fished for plaice for about 45 years of his life, although at times when plaice stocks were low, he also targeted species such as sole. Hence, he experienced the establishment of the 'Plaice Box', which lies at latitude 57 degrees north off the Dutch coast. Fisher B insisted that he respects the 'Plaice Box' and never fishes inside the protected area. The second year this protected area was set up, he noticed that the plaice he was catching around the borders of 'Plaice Box' had flesh the color of salmon! He would fish plenty of small red plaice which were incredibly tasty and he concluded that these plaice specimens were feeding solely on shrimp (no communication on this between fisher B and scientists ever took place). Because the fishing effort within the 'Plaice Box' had suddenly declined in a radical fashion, the plaice stock had grown to its saturation level; that is, the size of the plaice stock had out-competed all other populations within the 'Plaice Box', leaving the plaice with little else

to feed on than shrimp present within the box. The benthic communities in the 'Plaice Box' were no longer being churned up by the beam trawlers and therefore the population dynamics within the protected area had changed (Fisher B is aware of how fishing activities have altered the population dynamics of demersal communities, making them dependent on the nutrient turnover that arises through the trawlers. On average one square metre of the southern North Sea is overturned by beam trawlers at least once every year. Some areas can be touched more than seven times (Niels Daan, RIVO-DLO, *pers. comm.*). Every year, as he returned to fish at the borders of the 'Plaice Box', he noticed the plaice were becoming smaller and smaller. It was obvious that the plaice were not migrating out of the box, as the juveniles that did try to leave the box were immediately fished by the beam trawlers at the borders of the protected area. The juveniles were not strong enough to avoid being caught by the beam trawlers, and hence, recruitment was declining within the box. Those plaice specimens that did leave the box never returned to spawn, whilst the weak plaice specimens did not leave the 'Plaice Box'. Never again has fisher B seen large, healthy looking plaice specimens return to the 'Plaice Box' to spawn. In his opinion, the 'Plaice Box' is a failure. He blames it on the fisheries biologists. Danish fishers, for example, used to catch at least 300 boxes of plaice in 7 to 8 fishing days. Today they have to fish 8 days in order to obtain 100 boxes (35 kg) of plaice. Plaice stocks have declined along the Danish, Norwegian and Dutch coasts.

The 'Plaice Box' has both its advantages and disadvantages. The advantages are for those fishers who own beam trawlers of 300 HP (Euro-cutters) which are allowed to fish there. But there is no control over the number of Euro-cutters that are allowed into the 'Plaice Box', so that today the number of Euro-cutters entering the area is increasing. Hence, the effect is the same as if large beam trawlers had been allowed to fish in the protected area. High numbers of Euro-cutters are just as destructive to the environment of the North Sea as beam trawlers greater than 300 HP. Fisher B said that there was a trend amongst Dutch fishers to sell their larger vessels with a HP greater than 300 HP and to invest in a Euro-cutter, which will give them access to both the 12 nm territorial zone and the 'Plaice Box'. Fisher B has indicated a major flaw in policy making at the European level. The number of Euro-cutters entering the 'Plaice Box' needs stringent surveillance. Euro-cutters should not be exempted from logbook obligations.

Fisher B does not believe the North Sea is being overfished because fishing is a seasonal activity, something which he reckons the fisheries biologists refuse to understand. In the 1950s, for example, he used to fish herring in the summer months and plaice in the winter. There has always been plenty of fish in the North Sea. Unfortunately, fisheries rules and regulations do not see fish dynamics as being seasonally determined.

Decommissioning began in 1973, when herring stocks had declined radically. In 1977, he was given a quota by the Dutch Government, but because he had always fished for quality unlike his fellow fishers who fished for quantity, the quota allocated to him was very small. Those who had fished heavily, but who had fished irrespective of the size and quality of the fish, received a large quota. Hence, as control and safety measures were slowly put into force by the Dutch authorities during the 1970s, fisher B needed money for repairs on his beam trawler in order to keep within the Dutch safety measures. He therefore needed to borrow money from the bank. However, banks were only willing to give loans to vessel owners who had large quotas, which they saw as a guaranteed investment. As a result of his small quota, fisher B had trouble obtaining a loan and was forced to invest fifty thousand NGL, borrowed from family and friends, in order to cover his costs. This, however, was still not enough to meet the required safety standards established by the Dutch authorities and hence, his vessel came to lie still in the harbor of Lauwersoog. As a consequence of this, he had to sell his vessel for a price amounting to five million NGL. This was not a problem because fishers buy vessels for the quota, regardless of the state of the vessel. In 1977, the Dutch Government had individualized quotas, thereby making them transferable. In order to remain in the fishing industry, fisher B and his brother decided to invest in a second beam trawler of 600 HP. The quota allocated to this second vessel was the average of the past six years of fishing activities performed by other beam trawlers in the same 600 HP group. The quota he therefore received was much greater than the one allocated to his first vessel.

Today, fisher B sees fishing as being very different to what it used to be when he first started. That is, in order to survive, he now finds himself having to think on a European scale. He only chose to respect those national regulations which were advantageous to him, and does not really take much notice of the European regulations until they come of practical use to him (Fisher B does

not respect fisheries regulations because they do not reflect the problems of his profession). Hence, after he suffered several fines in the Netherlands during the 1980s, which amounted to at least 150,000 NGL, he decided to reflag and fish under the Belgian flag. This decision gave him an unlimited quota for plaice and an unlimited number of sea-days. He now also has less to do with inspection officers as efforts to control fishing regulations are more relaxed in Belgium than in the Netherlands. Furthermore, the Dutch authorities do not inspect vessels that do not fish under the Dutch flag. His present quota and beam trawler of 2,000 HP, which he fishes for plaice of 12 cm in length, are worth at least seven million NGL. He knows he would have no problem selling his vessel and quotas if he ever decides to bring his fishing activities to an end. But he has invested in this new vessel primarily for his sons, in the hope that one day they will take over his business. Today the process of handing his quota and vessel over to his sons is still quite difficult because the quota is very expensive. Fisher B, however, hopes that the process will eventually be facilitated when the government decides to put into force the same system as is presently in use in the Dutch agricultural sector. This would then allow the sons of fishers to inherit the vessels and quotas of their fathers, if the sons are still in the fisheries industry.

Fisher B is a member of the PO of *Urk*, which provides him with information on national fisheries regulations, as well as news on EU regulations. Within the POs and the steering committee *Biesheuvel* , he can rent and/or barter other fish species and obtain advice on legal and/or financial matters concerning his fishing activities.

When asked how he felt about the Spanish and Portuguese fisheries operating in the North Sea, he said that they should never have been allowed access to these Community waters, as their fishing activities do not respect EU regulations. The mesh sizes they use are too small and therefore they catch many juvenile fish, which will ultimately affect the state of the stock. According to him, fishers should be allowed access on a basis of historical rights in the North Sea. As far as he was concerned, the Spanish and Portuguese fishers do not have such rights. Furthermore, the expansion of the commercial fisheries sector should be brought to a halt at the European level and thus, decommissioning should be enforced at the European level. The Netherlands has no more fishing licenses to hand out. Mesh sizes should be standardized and enforced at the European/international level, as should control measures concerning other fisheries activities be enforced at an international level. It is pointless to have strict control in one member state if other member states do not have similar control standards. Also, it should be made obligatory for fishers to land in specific ports, as this would facilitate the enforcement of control. Furthermore, the regulations adopted at the national and international level should reflect the nature of the ecosystem in question; that is, the North Sea is a highly variable ecosystem and fishers, over the years, have learnt to adapt themselves to it accordingly. However, the regulations put into force today are not flexible enough to take this variability and seasonal nature of the resources, such as fish, into account. As a means of making up for the inflexibility of current EU and national regulations, Dutch fishers formed groups such as POs and private *Biesheuvel* associations.

Fisher B did not feel many attempts were being made by the Dutch authorities to improve the socio-economic situation of Dutch fishers. He emphasized that there is a lack of communication between the various authorities involved with fisheries activities, fisheries biologists and the fishers. He felt that none of the authorities determining the activities of fishers in the Netherlands, or in the EU, had made any real effort to communicate with fishers. In his opinion, the only fisheries biologists who had ever made a true attempt to understand the problems of fishers was R. Boddeke. He regretted that there are not more of such fisheries biologists today. According to him, statistics and data analyses are not sufficient to form an idea of what is happening in the North Sea. It is important that fisheries biologists become more involved with the fishers and that they make a greater effort to communicate with the fishers. Fisher B also criticized the complicated language fisheries biologists used, which he did not understand and therefore did not find interesting. He believed that if fishing effort was to be reduced and brought under control, communication between fishers and others experts and authorities involved in the commercial fisheries sector had to be improved. Effort had to be made to help fishers understand why certain regulations were being put into force as opposed to others, which fishers felt to be more stringent.

Fisher B does not think the ITQ system is a good idea, although he would like to see an alternative system to the present quota system put into force. He does not object to a system where the national quotas are allocated to the individual fishers via the POs. Quotas should be assigned per country

and not according to vessel. The quotas should not be allowed to be transferable amongst individuals as it would empower the rich and make the weak weaker (Fisher B prefers ITQs to be state controlled). He felt that the Steering Committee *Biesheuvel* had brought some peace amongst Dutch fishers by providing a means of communication. Fishers can now rent and/or barter quotas and fish, providing an alternative to sanctions distributed by the AID. Today fewer fishers are fined for overfishing their quotas. However, he felt very strongly that historic fishing rights should be enforced.

Fisher C

Fisher C fishes with his trawler using otterboards, employing a Danish system which consists of two nets rigged especially for catching Norwegian lobster (*Nephrops norvegicus*). He used to fish in the Skagerrak, but in recent years the Dutch do not get a quota in this area. This was the result of fishers who were fishing in other parts of the North Sea, who discovered that Dutch quotas for Skagerrak were not being used completely. Hence, they started to charge part of their catch to the Skagerrak with the consequence that this quota was suddenly being used up very rapidly. As a result of this, the fishers who did fish in the Skagerrak were suddenly forced to stop fishing, as they were told by the *Algemene Inspectiedienst* (AID) that they had used up their quota. Although this was unjust, the whole event led the Dutch Minister to trade in the Dutch fishing quotas for the Skagerrak for something else. The Dutch fishers who had always fished in this area subsequently lost their traditional fishing grounds. This happened to fisher C, who was subsequently forced to look for new fishing grounds. They found these grounds in the 'Silver Pit', a deep water area south of the Dogger Bank, which is rich in Norwegian lobster. However, all this could have been avoided. In the court cases which characterized this whole happening, fisheries biologists were called in as witnesses who, on the basis of occurrence of a specific parasite in the flat fish, could establish whether or not they had been fished in the Skagerrak. However, these findings did not prevent the Dutch fishers from losing their traditional fishing grounds. He felt the Dutch Government had acted unjustly towards Dutch fishers.

There is no quota for *Nephrops. norvegicus*. Fisher C also had a small quota for cod, whiting, sole and plaice; that is, approximately 1,100 kg for sole and 1,600 kg for plaice. The market for langustines is mainly in Italy, although there is some demand for it in Denmark. The Dutch are not familiar with this species and therefore do not buy it on the market in the Netherlands. One of the problems concerning the fishing of langustines is that mesh sizes of 70 mm are required. For cod and similar species, the minimum mesh size allowed is 100 mm. Although it is allowed to fish with a mesh size of 70 mm, this is only possible if a certain percentage of the catch consists of fish. This is subject to inspection procedures at sea and it is almost impossible to adhere to the langustines to fish ratio for each individual haul, as a fisher can only see what he has caught once the catch has been pulled on board.

Fisher C receives a document annually, issued by the Ministry of Agriculture, Nature Management and Fisheries (LNV), indicating his assigned quota. The document is in Dutch, but even British inspection vessels have the details of Dutch fishing vessels' licenses in their computers. The quota varies from year to year, depending on the Total Allowable Catch (TAC) assigned to the Netherlands by the EU. For 1995, fisher C had a quota of 1,060 kg sole; 9,620 kg whiting; 32,390 kg cod; and 1,610 kg plaice.

Before the introduction of the steering committee *Biesheuvel* , the commercial fisheries sector had problems dealing with bycatch. Despite quota limitations, many fishers agree with fisher C in that they refuse to throw bycatch back into the sea. As a consequence, fisher C has also suffered numerous fines given to him by prosecutors in the Frisian capital Leeuwarden, fisher C has experienced several court cases and was given fines amounting to two hundred thousand NGL. He had gone through the entire Dutch judicial system, and even made a request to the Dutch Queen to be granted a reprieve, but this did not help.

According to fisher C, it is vital that the commercial fisheries sector is made more labor-intensive. It is important that more is invested in keeping smaller vessels at sea, thereby keeping diversity within fleets. Presently, more is invested in larger vessels, forcing small vessel owners to sell their quotas and vessels, and to either leave the fisheries sector or work on some-one else's vessel. Hence, the rich get richer and more powerful, whilst the poor are forced out of the industry and the fish gets cheaper. He also knew of large trawl owners from *Urk*, who hired crew from Harlingen. The crew had to pay board and lodging when on a fishing trip. The amount the crew owed the trawl owner, was deducted from what the crew earned as a salary from one

week's catch. Hence, if the crew experienced a bad catch, they lost money. He knew of a lot of fishers from Harlingen, who were not very fond of these *Urk* trawl owners.

The installation of freezing and sorting systems on board of vessels would also be of benefit. Currently, once fish is landed, it needs to be sorted and weighed and afterwards it is sold at an auction and immediately frozen. These activities of sorting fish according to species and size, and the weighing of the fish, are organized by the POs. Fishers have to pay for these services. Hence, if this could be done on board ship, the fisher would not have to worry about the freshness of the fish or have to pay staff on land to sort the fish according to size. It would be both cost- and time effective. Another problem he had experienced and had been fined for concerned the average content of a fish box. He thought that this most probably only applied to Harlingen, and maybe not to other places such as Ijmuiden. That is, all fish boxes are weighed and the contents are expressed in kilograms. However, it is very easy to be slightly over the permitted weight of contents per box. Hence, if this system was standardized, maybe unnecessary fines could possibly be avoided.

Fisher C was very much in favor of multi-purpose boats, such as the research vessel used by the Dutch Fisheries Research Institute (RIVO-DLO) in Ijmuiden. It would reflect the multi-species and multi-gear nature of the North Sea commercial fisheries sector, and thereby provide fishers with the necessary flexibility to complete their job. He also said that the new engines of 2,000 HP employed today, have relatively more power than the old ones. This means that a new engine of 2,000 HP can have a much greater power than an old engine of 2,500 HP. Fisher C therefore suggested that the consumption of fuel would possibly be a better measure of effort than the HP of the engine. He also thought that the decommissioning of vessels had not reduced the amount of effort in the North Sea, because those vessels which were decommissioned had not been participating in fishing activities, whilst the new ships entering the sector had a much greater fishing capacity than could be expressed in the HP of the engine. Even if the HP of the engine had been reduced, the total fishing capacity of the fleet did not necessarily decrease. On the contrary, fisher C believed it had increased considerably. In the 1980s, a subsidy was introduced in the Netherlands to stimulate investment in the fishing industry. This amounted to 18% of the total amount invested in the fishing industry. Although not intended, it also applied to the construction of new fishing vessels. Added to this subsidy was a second of 25-35%, which was given to further stimulate construction. All this led to an overcapacity of the Dutch vessels, which proved to be disastrous to the North Sea ecosystem.

Larger beam trawlers have more capital and can therefore take more advantage of the national and EU aid system, as they can afford subsidies experts and lawyers, who can ensure that the vessel owner gets the best deal. Fisher C knew of large vessel owners who, in this way, had obtained more quotas and more sea-days. The amount of sea-days are allocated to a fisher in relation to the size of his previous quota and the HP potential of his vessel. This is usually done on a monthly basis. Some vessels with large quotas may have excess sea-days. These can be transferred to other vessels, along with a part of the quota, if the vessel in question is unable to complete its assigned sea-days. As a consequence, small vessels are often negatively affected by this system, as they cannot go out fishing during adverse climatic conditions, such as storms.

Mesh size and shape was another point of concern. Fisher C believed that diamond shaped meshes were far better than square meshes because they remain open all the time and therefore do not close under strain like square meshes do, allowing more smaller fish to escape.

When asked whether or not he believed overfishing was a problem of the North Sea, he said it was a serious one indeed. He firmly agreed with the establishment of the 'Plaice Box', as it had saved plaice stocks from collapse. The *Urkers* would have liked to scrape the whole of the North Sea empty, but thanks to the good intentions of the fisheries biologists, this had not happened. Control was needed. He had fished in the waters of New Zealand and said that they had a good ITQ system, and that the EU should learn from the experiences of the New Zealanders. He did not fully support the system of ITQs, as he felt that it would make the rich richer and empower multinational companies. A better solution had to be found that avoided sole ownership of what is primarily a commons. He had also fished for many years with the Danes, and had seen how badly the Danish fishers owning small vessels had been affected by decommissioning schemes. The beaches in Denmark had been a graveyard for decommissioned vessels, and it had been a very depressing sight.

DISCUSSION

State ownership versus group and private ownership

The advantages of state ownership include no need to specify, measure and enforce individual property rights over the valued attributes of fishery resources. However, the disadvantages are that the State (principal) needs to monitor fishers to whom the ITQs have been delegated. As a consequence, the State is required to specify, measure and enforce such rights through effective monitoring, surveillance and control enforcement (MSC). The State is also required to obtain all relevant information to specify these rights in line with the objectives/preferences of the fishers and society at large. That is, the Netherlands has to ensure that it does not exceed its national quotas. The AID has the delegated responsibility to inspect vessels at sea and in ports. Moreover, AID inspection also takes place at the auctions as it is mandatory for fishers to sell their landings via the auction system.

Information is also valuable. As the State authorities are increasingly operating on an output basis, it is difficult for third parties to access and obtain information on fisheries. Often the fee to obtain access to information is considerable. For example, the LEI-DLO is willing to supply information on landings and market prices at a total cost of NLG 8,000 to 10,000, with the added condition that the LEI-DLO agrees to the use to which it is put.

Information on the modernization of vessels is not accessible to third party. This information is stored in the VIRIS database of the Ministry to which only the RIVO-DLO has access.

From the point of view of the state, the advantages of group ownership include no need to specify, measure and enforce individual property rights over the valued attributes of fishery resources; no need to obtain information on the objectives/preferences of fishers; and limited or no need to monitor fishers. The disadvantages, however, include the need to specify, assign and enforce exclusive rights of the group; objectives may not meet societal values; and there is a need to resolve the collective action problem in the use of common property resources. Similarly, private ownership has its advantages in that it allows an efficient use of privately-held information and there is not a collective action problem. However, the disadvantages are that there is a need to specify, measure and enforce individual property rights over the varied valued attributes of fishery resources.

There are eight *Biesheuvel* Groups (group ownership) in the Netherlands, viz: Delta/Zuid; Nederlandse Vissersbond I; Nederlandse Vissersbond II; Nederlandse Vissersbond III; Nieuwe Diep; van de PO-Oost; Texel; van de PO-Wieringen. I phoned the various groups to ask for information about operational, organizational and administrative costs involved. I was not able to obtain information. The people contacted said they did not have the time to speak with me. In general, the following picture emerged:

The *Biesheuvel* group provide the conditions for fishers to rent and/or barter (transfer) individual quotas under private law. From the state perspective the costs of transfer and overfishing are internalized at the lowest possible level. It falls in line with the subsidiarity principle. Dutch fishers feel that the political value of the *Biesheuvel* groups is considerable. They feel that the improved co-ordination of micro-decisions in the collective interest has created opportunities for co-operation and interactive co-governance among chain partners to seek alternatives to command-and-control systems, like incurring a sanction. It remains difficult to assess whether the 'sharing' of rent amongst the fishers operating within the *Biesheuvel* groups may have provided incentives for the sharing of information surrounding the natural resource.

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PART III: SOUTH-EASTERN NORTH ATLANTIC

THE FRENCH FISHERIES IN THE NORTH-EAST ATLANTIC (ICES AREAS VII AND VIII), 1996-1998

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ABSTRACT
We present a brief summary of how French fisheries data are compiled, and compare landings data from the French national fishing institute (IFREMER) with ICES data. We noted discrepancies between the two sources that result from fish being caught in one area but landed and reported for another area. After ICES landing statistics by species were allocated to the various French fleets, we used discard rate estimates from three studies to estimate discards and reconstruct the catch of each species by fleet and area. We estimated that, on average, 18.1% of the catch in area VII and 21.0% in area VIII was discarded. Trawlers caught the majority of the total catch and had the highest discard rate of any fleet.

FISHERIES STATISTICS AND THE STRUCTURE OF DATA ACQUISITION

Species landings and fishing effort statistics are recorded separately in France. Landings information comes from either the auction or non-auction network, depending on the type of marketing chosen by the fisher.

The auction network (RIC)

The auction ('inter criée') network concerns the landings sold within the auction system under the supervision of the local authority ('halle à marée'). Tonnage per species, market prices, and discard prices ('prix de retraits') are collected by the National Inter-professional Office of Fisheries and Aquaculture Products (OFIMER; FIOM before 1997), which reports the data to the Regional Centre of Statistical Treatment (Centre Régional des Traitements Statistiques, CRTS) of the region (Boulogne, Saint Malo or La Rochelle). This information is centralized at the Administrative Centre for Maritime Affairs (Centre Administratif des Affaires Maritimes, CAAM) and is used for the creation of ZA files, in which catch and effort are given by port and by period.

The non-auction ('hors criée') network

The Scientific and Technical Institute of Marine Fisheries (Institut Scientifique et Technique des Pêches Maritimes, ISTPM) created an inspectors network in 1966 in order to improve the compilation of information by distributing fishing forms to fishers. The system initially included only two species at the La Rochelle port, but was eventually extended to all French ports and to almost all commercially exploited species. Today, these reporting forms are collected by local committees and forwarded to the French Research Institute for the Exploitation of the Sea (IFREMER) who propose to CAAM the required corrections for information taken from the non-auction network. In spite of its role of scientific adviser, IFREMER is not involved in validating this information.

Little information collected from both the auction and non-auction networks are used in the creation of the national statistical database on French production. Only the non-auction statistics of the Bay of Biscay are taken into account by CAAM (A. Forest, IFREMER, pers. comm.).

Other sources of information

Logbooks
All ships measuring more than 12 meters have to fill out European Union logbooks which include information on fishing hours, fishing zone, gears used and catch per species. The information is collected by marine affairs officers and analyzed at CAAM. The landings from vessels less than 12 m would only be recorded by the non-auction network.

The 'États A'
The marine administration has also designated staff to verify the coherence between declared catches and real catches. Their opinions are called 'États A'. Once validated by CAAM, the fishery statistics are edited by OFIMER each year. Many organizations published these data by ports or by region ('quartiers'), with variable number of species and varying degrees of precision. The Marine Fisheries Direction (Direction des Pêches Maritimes)

presents exhaustive statistics for both species and ports from 1860 to 1988. Aggregated information of the most important species, by marine region, is presented by the Central Committee for Marine Fisheries (from 1970 to 1992), FIOM (from 1993 to 1996), and OFIMER (from 1997 until the present).

Summary of the information

The matching of production data and fishing activity information from the logbooks is undertaken at CAAM. This results in the creation of ZA files, in which catch and effort are given by port and by period. These data become the official French fisheries statistics that are reported to international organizations (FAO and ICES). The ZA files are forwarded to the IFREMER office in Brest, where they are corrected with information coming from fishing forms. Unfortunately, the electronic files are not available for public consultation as basic fishing data are used in the European Union bargaining process. An attempt was made to build a time series of effort using historical data on boat descriptions and effort. See Appendix 1 for a brief description of the fishing activity and effort of various fleets between 1961-1975.

COMPARISON OF IFREMER AND ICES LANDINGS DATA

Landings data for the period of 1996-1998 were obtained from IFREMER. The database included 224 species and was divided by year, port, region, and vessel origin. It included foreign vessels (i.e., Spanish, Portuguese etc.) unloading in French ports. However, we assumed landings in French ports by other countries to be minimal. Only the Atlantic ports were considered.

The average annual estimate by IFREMER of total landings in area VII, 194,388 tonnes, was much lower than the ICES estimate of 529,038 tonnes. Conversely, in area VIII the IFREMER total landings estimate of 161,628 tonnes was somewhat higher than the ICES estimate of 137,213 tonnes. Discrepancies between the two data sources in each fishing area occurred for several taxonomic groups (Figure 1). In area VII, ICES landing estimates were higher for all groups, especially algae, groundfish, molluscs, and elasmobranchs (skates, rays, dogfish and other sharks) (Figure 1a). Echinoderm landings have been omitted from Figure 1 as they were low and similar between data sources in both areas. The yearly trends in landings from 1996 to 1998 are inconsistent between data sources for some taxonomic groups. For example, ICES data show a steady decrease in algae landings, whereas IFREMER landings show a sharp increase in 1997 followed by a decrease in 1998. (Although, the original ICES data also showed a substantial increase in 1997 to over 600,000 tonnes. We determined that the algal group comprising the majority of this weight, *Macrocystis*, was likely overestimated after looking in detail at algal species landings. We therefore used a lower estimate in our analysis (Figure 1) that was at least comparable to other sources.) Similarly, ICES data show an increase in landings of molluscs and pelagic fish, whereas IFREMER data show a slight decrease. In area VIII, the landing estimates are more similar between data sources for all taxonomic groups, with the exception of groundfish (Figure 1b).

It is interesting to note that IFREMER estimates for groundfish landings were less than ICES estimates in area VII by nearly the same amount as they were greater than ICES estimates in area VIII. In other words, the groundfish landings from areas VII and VIII combined were very similar between data sources (Figure 1c). Thus, there appears to be uncertainty about the location of fishing grounds. Assuming that the methods of extrapolation from sampled landings to total landing estimates were similar in both areas and between organizations, there are two possibilities as to how this might arise: (i) either groundfish catches from area VIII were recorded for area VII by ICES, or (ii) catches from area VII were recorded for area VIII by IFREMER.

Looking at individual groundfish species, we note that landings of Atlantic cod (*Gadus morhua*), megrim (*Lepidorhombus whiffiagonis*), anglerfish (*Lophius piscatorius*), whiting (*Merlangius merlangus*), and hake (*Merluccius merluccius*) were proportioned differently between fishing areas even though the total landings from these areas were similar (Figure 2). In each case, IFREMER landing estimates were less than ICES estimates in area VII but greater than ICES estimates in area VIII. By themselves, the differences in landings of these five species between data sources and fishing areas accounted for over half the differences in all groundfish landings shown in Figure 1. Other species showed similar patterns, such as long-fin tuna (*Thunnus alalunga*) and Norway lobster (*Nephrops norvegicus*). Comparing this trend with the location of fishing grounds in areas VII and VIII for these species (Abbes, 1991) (Table 1), we see that the principal fishing grounds for some species such as *Gadus morhua* were concentrated in area VII, whereas they were concentrated in area VIII for other species such as *Thunnus alalunga*. For these

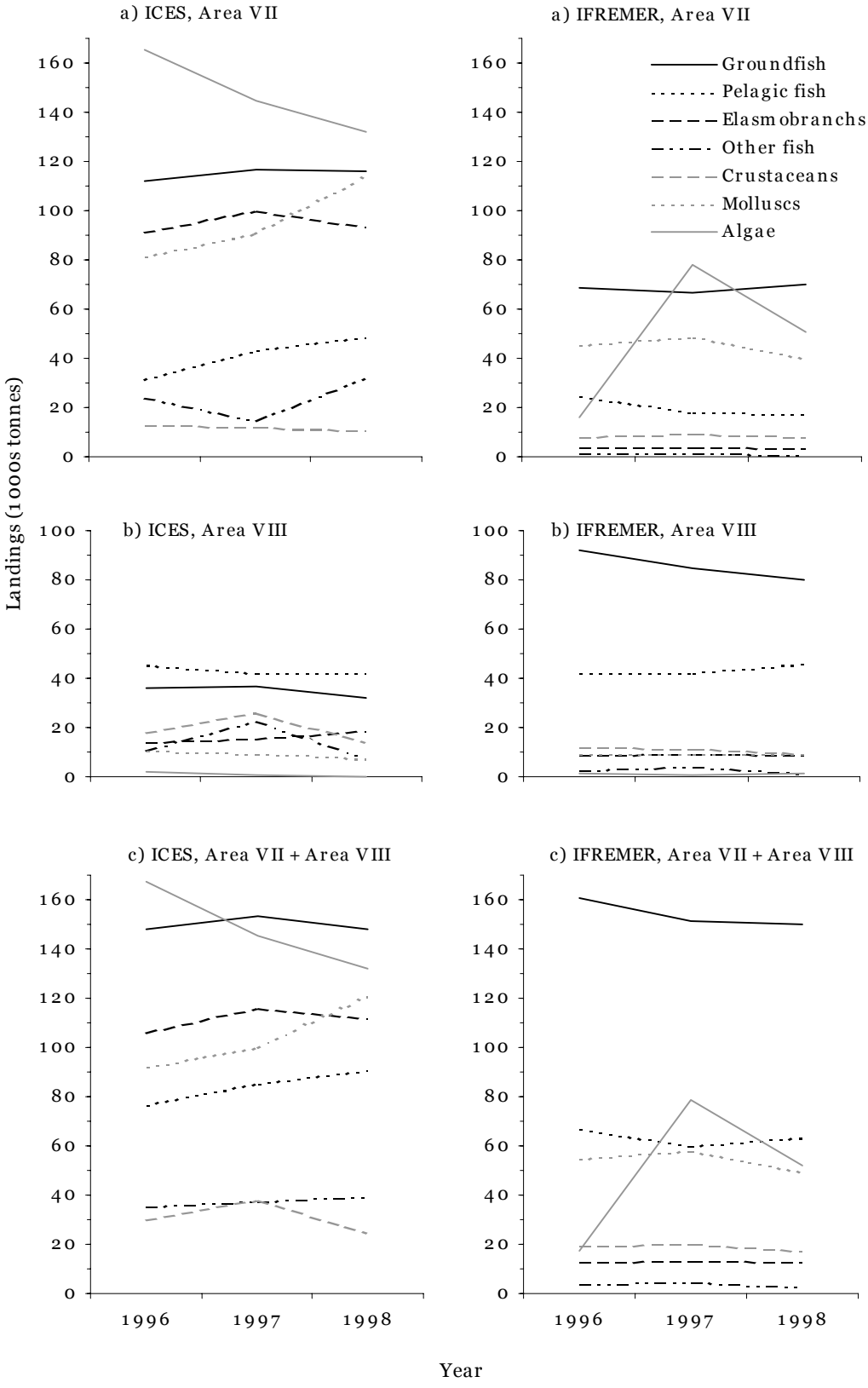

Figure 1. French landings in ICES areas VII (a), area VIII (b) and both areas combined (c) from 1996 to 1998, according to ICES (left column) and IFREMER (right column). Data are divided into major functional groups. Note: ICES landings statistic for *Macrocystis* (an alga) in area VII in 1997 is 520,960 tonnes. However, this figure is suspect, and we considered a landing of 52,096 tonnes to be more realistic and subsequently used this in our analysis.

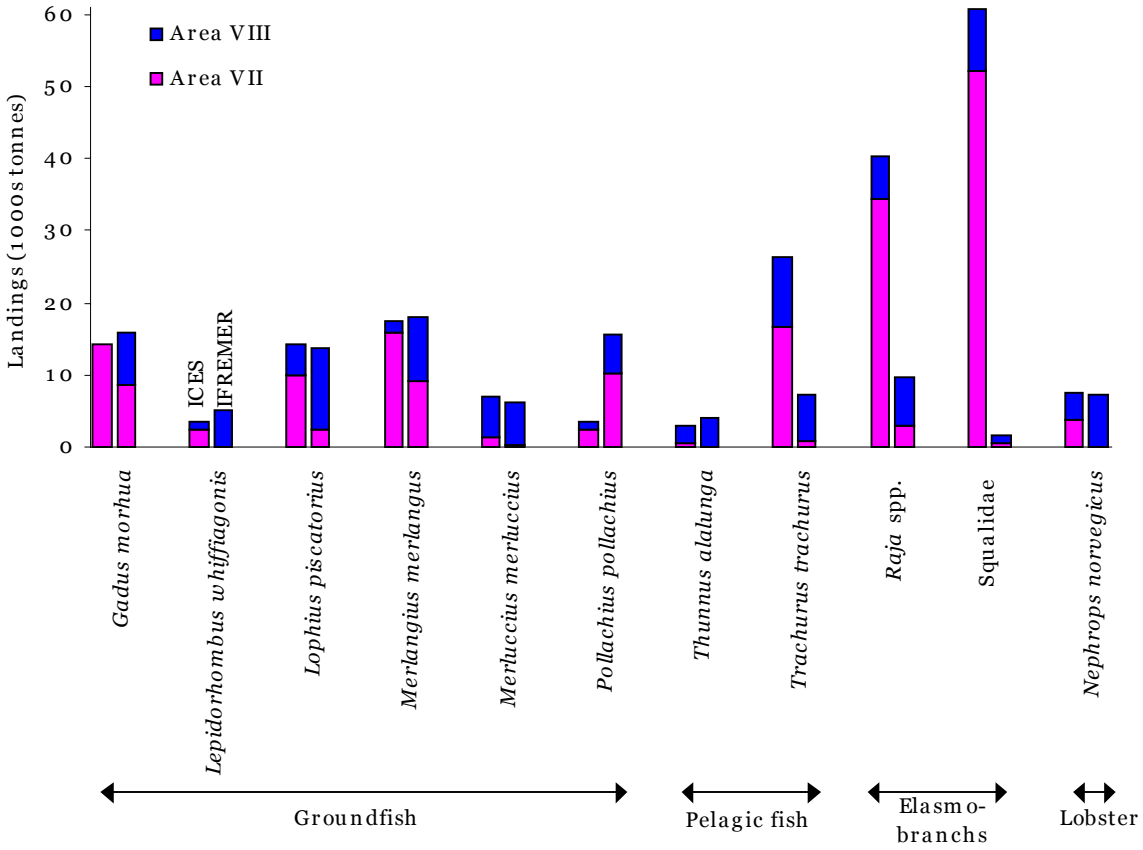

Figure 2. Selected species with either large differences in landings between ICES and IFREMER estimates (pollack [*Pollachius pollachius*], Atlantic horse mackerel [*Trachurus trachurus*], rays [*Raja* spp.], dogfish [Squalidae]) or similar landings that are proportioned differently between areas VII and VIII (cod [*Gadus morhua*], megrim [*Lepidorhombus whiffiagonis*], anglerfish [*Lophius piscatorius*], whiting [*Merlangius merlangus*], hake [*Merluccius merluccius*], long-fin tuna [*Thunnus alalunga*], Norwegian lobster [*Nephrops norvegicus*]). Data are yearly averages of French landings from 1996-1998.

species that ICES listed as 'relatively more caught in area VII' and IFREMER listed as 'relatively more caught in area VIII', it appears as if most principal fishing grounds were in area VII. Thus, possibility (ii) seems more likely, that is, ICES had more often attempted to record the catch by where it was caught, while data from IFREMER were more often collected by port of landing regardless of where they came from. ICES recorded far greater landings than IFREMER of other species in area VII, without the negative compensation in area VIII. The sum of landings from areas VII and VIII were much greater in the ICES data for Atlantic horse mackerel (*Trachurus trachurus*), rays (*Raja* spp.) and dogfish (Figure 2). Pollack (*Pollachius pollachius*) is one of the few species for which the opposite was true (Figure 2). Therefore, of the two sources, ICES data may be a more complete estimate of the total biomass landed by the French fisheries in areas VII and VIII.

Reconstruction of actual catch and discards for French fisheries

We used ICES landings data to estimate the total weight caught and discarded by French fisheries from 1996 to 1998. The species list for ICES landings was shorter than the IFREMER list because minor species landings were grouped into larger, or 'general' categories (e. g. 'Miscellaneous marine molluscs', 'Sparidae', etc.). First, we allocated the catch of each species among various fleets by estimating what proportion of the catch was taken by each of the following French fleets: coastal demersal trawls, offshore demersal trawls, pelagic trawls, purse seines, pole and lines, long lines, gill nets, and 'other coastal gears' that include cephalopod pots, hand lines, and crustacean traps. These proportional fleet allocations for individual species and taxonomic groups in areas VII and VIII are listed in Appendix 2. Next, we applied fleet-specific discard rates to the landings of each species or 'general' group in order to estimate the total weight caught and discarded in each fleet.

Table 1. Fishing grounds by species (Abbes, 1991)[a].

Species	**Fishing zones**																								
	------IV------			---VI---		----------VII----------											----------VIII----------					---IX---		X	XII
	a	b	c	a	b	a	b	c	d	e	f	g	h	I	j	k	a	b	c	d	e	a	b		
Gadus morhua	P	S	P	P		**S**	**S**		**P**	**S**	**P**	**P**	**S**		**S**										
Thunnus alalunga															**P**	**P**	**P**	**P**	**P**	**P**	**P**	P	P	P	P
Merluccius merluccius	S			P		**S**	**S**			**S**		**P**	**P**	**S**			**P**	**P**							
Merlangius merlangus	P	P	P	S	S	**S**			**P**	**S**		**P**	**S**	**S**			**P**	**P**							
Lophius piscatorius	S			P			**S**	**S**		**P**		**P**	**P**		**S**	**S**	**P**	**S**		**S**					
Nephrops norvegicus						**P**	**P**	**P**		**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**	**P**							
Sardina pilchardus																	P	P							
Pollachius virens	P			P		S	S	S		S	S	S	S	S		S									
Melanogrammus aeglefinus	P	S		P			S	S		S	S	S	S	S											
Molva molva	P			P						P	S	P	P		S		S								
Lophius budegassa	S			P			S	S		P		P	P		S	S	P	S		S					
Solea vulgaris								P	P	S	S	S	S				P	P							
Skates						S			S	P		P	P	S			P	S							
Maja squinado										P															
Sepia officinalis									C-F	C-F			F				C-F	F							
Pectens maximus									P	P							P								
Lamaria spp.										P															
Venerupis rhoboides										P															
Glycymeris glycymeris										P							P								
Spisula spp.										P							P								

[a] P = Principal fishing area, S = Secondary fishing area, C = Coastal fishery, F = Offshore fishery.

The fleet-specific discard rates (the percent of the total catch that was discarded) came from three studies that focused on various gear types in one or both ICES areas. Pérez *et al.* (1996) calculated discard rates of all species in catch samples from Spanish demersal trawlers and longliners in area VII, and demersal trawlers, longliners, purse seiners, and gillnets in area VIII. Morizur *et al.* (1996a) calculated discard rates from various pelagic trawls, mostly in area VIII, and some in area VII as well. Morizur *et al.* (1996b) gave the number of individuals caught and discarded per length class for French coastal demersal trawls, offshore demersal trawls, and gillnets in area VII. The mean body weight of individuals (W_i) of each length-class (L_i) was calculated, after Beyer (1987), as:

$$W_i = \frac{1}{L_{i+1} - L_i} * \frac{a}{b+1} * \left(L_{i+1}^{\,b+1} - L_i^{\,b+1}\right) \quad ...1)$$

where W_i is weight, L_i is total length, and a and b are parameters of a length-weight relationship of the form $W=aL^b$. For species that were caught in very small numbers and for which we had no length distribution, we assumed weight corresponding to juvenile individuals for the large species and average length for the others (see Appendix 3).

When a discard rate for a given species and fleet in one area was not available, we assumed it to be the same as that from the other area. In cases where a discard rate for a certain species and fleet was not available for either area, we estimated it from that of a species in the same genus, if possible. Otherwise, we calculated the weighted average of discard rates of similar species caught in that fleet and applied it to the species with the missing discard rate. Similarly, discard rates were applied to the 'general' species groups as the weighted average of the known discard rates of species in that group. If more than one study reported a discard rate for a certain species from the same fleet in the same area, then the estimate which we considered most reliable, based on the extent of sampling, was selected instead of the others.

Only species or 'general' groups that were regularly landed (target species) would be properly represented in the estimation of total catch based on landings and discard rates. The actual catch of species that were rarely or never landed (non-target species) could be mis-represented if it were reconstructed from its own landings, so it was therefore linked to the catch of a target species. A species with over 100 tonnes landed annually in either area VII or area VIII was assumed to be a target species in that area. Likewise, any species or 'general' groups with annual landings under 100 tonnes were not considered a target species, but a by-catch of a fishery targeting another species. Species were separated into target and non-target species in order to properly estimate catch.

For target species, we reconstructed their actual catch (before discards) by fleet and area based on their landings in that area, the allocation of the catch among different fleets, and discard rates, as:

$$C_{sfa} = \frac{L_{sa} * \%allocation_f}{1 - \%discard_{sfa}} \quad ...2)$$

where C_{sfa} is catch and L_{sa} is landings for the target species s by fleet f in area a. To calculate the estimated discards by species, fleet, and area, we multiplied the total catch by the % discard rate. In order to verify our calculations, actual landings were compared to our estimated landings (catch minus discards). For all target species in each area, the sum of estimated landings of all fleets was equal to the ICES landings data.

The small landings of non-target species may have yielded unrealistic extrapolations of estimated catch if it had been reconstructed from landings. Instead, the estimated catch of non-target species in each fleet and area was linked to the estimated catch of a main target species in that fleet and area. The catch ratio (before discards) between these non-target species and the main target species was taken from two sampling studies of the catch of different fleets. In other words, the ratio of non-target species a catch to target species b catch taken by an entire French fleet in one area should be the same ratio as non-target species a catch to target species b catch in a sampling study for the same fleet and area. Thus, catch of non-target species C_{nfa} was estimated as:

$$C_{nfa}\,estimated = C_{sfa}\,estimated * \frac{C_{nfa}\,sampled}{C_{sfa}\,sampled} \quad ...3)$$

where n is a non-target species and s is the main target species for that fleet and area. From the sampling study by Pérez *et al.* (1996), we used the following target species to link our estimated catch of non-target species: hake (*Merluccius merluccius*), for coastal demersal trawls, offshore demersal trawls, and longlines in both areas VII and VIII; anglerfish (*Lophius piscatorius*), for gillnets in area VIII (and applied to area VII also); and sardine (*Sardina pilchardus*), for purse seines in area VIII (and applied to area VII also). From Morizur *et al.*

(1996a), we used these target species: European seabass (*Dicentrarchus labrax*), for pelagic trawls in area VII, and European anchovy (*Engraulis encrasicolus*), for pelagic trawls in area VIII. We also applied this catch-linking method to discarded species that do not occur on the ICES list because they are seldom landed, but are known to be caught in areas VII and VIII. We did not link the catch of non-target species to target species in the 'pole and line' or 'other coastal gears' fleets because no catch ratio information was available for these fleets. However, as we consider these gear types to be more species-specific, the number of non-target species caught by these fleets is probably very low.

We calculated the estimated discards of non-target species by fleet and area by applying discard rates to their estimated catch. We then compared the sum of estimated landings (catch minus discards) of all fleets to the ICES landings data for that species in that area. As the estimated catch of a non-target species was linked rather than reconstructed from its own landings, we do not expect the estimated landings to be exactly the same as the ICES data. However, estimated landings were not unreasonable for any species when compared to the ICES data.

ESTIMATED CATCH AND DISCARDS BY FLEET, AREA, AND SPECIES

Under our proportional fleet allocation (Appendix 2) and discard rate regimes, our reconstruction predicts a total annual catch (1996-1998) for all French fleets combined of 646,685 tonnes in area VII and 176,842 tonnes in area VIII. We estimate that total discards were 117,001 tonnes (18.1%) in area VII and 37,190 tonnes (21.0%) in area VIII. The resulting estimated landings (529,684 tonnes in area VII and 139,652 tonnes in area VIII) differed by less than 1% from the ICES landings data. It is unlikely that our linking method of reconstructing catches of non-target species led to considerable overestimations of the total catch, as non-target species only made up 1.3% of the total estimated catch in area VII and 5.0% in area VIII.

The landings of algae, groundfish, molluscs, and elasmobranchs were all considerably larger in area VII than in area VIII (Figure 3), but the discard rates were generally similar between areas (Table 2). Small pelagic fish, however, had nearly identical landings between areas but had a greater discard rate in area VII (55.2%) than in area VIII (33.1%). Overall, crustaceans also had higher discard rates in area VII (34.3%) than in area VIII (14.9%). However, this difference seems less when we compare discard rates of lobsters, crabs, shrimps, and other crustaceans separately, due to the large variation among species (Table 2). Conversely, when we compare mollusc groups separately, greater differences in the discard rates of cephalopods between areas VII and VIII are revealed (Table 2). Echinoderms and 'miscellaneous' invertebrates (cnidarians, etc.) are not shown in Figure 3, as their catches were quite low.

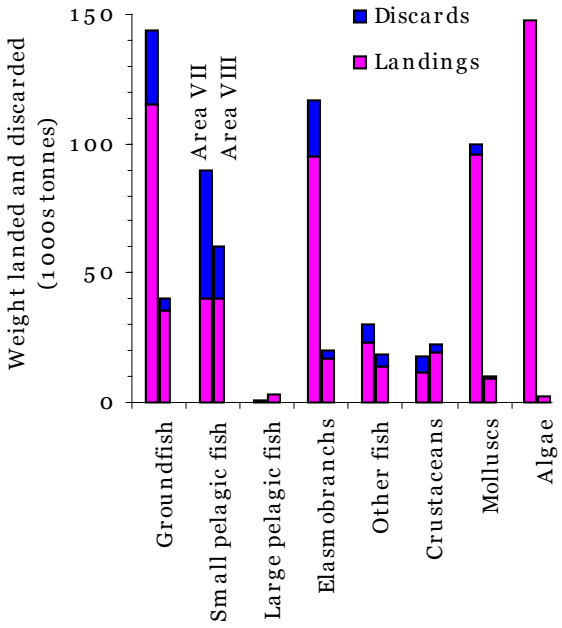

Figure 3. Estimated weight of landings and discards of different functional groups by the French fisheries in ICES areas VII and VIII. Estimates are yearly averages from 1996-1998.

The most highly discarded species in terms of weight in both areas VII and VIII was Atlantic horse mackerel (Figure 4). They were particularly high in area VII because 60% of the catch was taken by demersal trawlers in area VII (Appendix 2) that had high discard rates. Excluding algae, this species also had the greatest landings in area VII and the second greatest landings in area VIII, after European anchovy. The second most highly discarded species in both areas was mackerel (*Scomber scombrus*, Figure 4). Other species with high levels of discards included sardines in area VIII, whiting, haddock, and blue whiting in area VII, and crab (*Cancer pagurus*) and pouting (*Trisopterus luscus*) in both areas. Algae are not shown in Figure 4; the green alga *Chondrus crispus* had the highest landings of any species in area VII (93,833 tonnes), with no discards. Species which were only listed by ICES under family names or under 'general' groups are

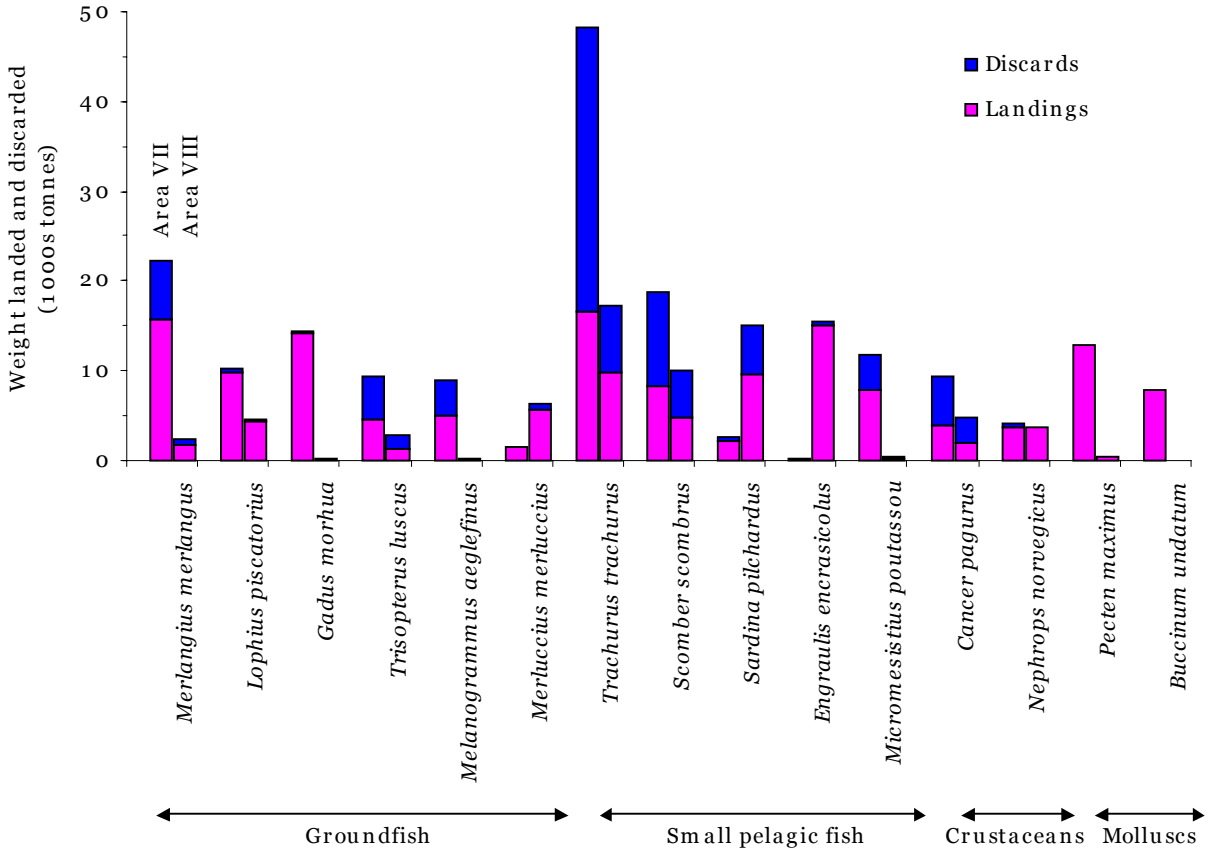

Figure 4. Estimated weight of landings and discards of several highly commercial species by the French fisheries in ICES areas VII and VIII. Estimates are yearly averages from 1996-1998.

also not included in this figure. For example, rays (*Raja* spp.) and dogfish had high levels of landings and discards in both areas, but they were not identified to species or were not listed by species. Similarly, Sparidae (seabreams) and Sepiidae (cuttlefish) had high landings in both areas, and Triglidae (searobins) had high discards in both areas.

When the total catch is separated by fleets, again we observe differences in estimated landings and discards between areas and between different fleets (Figure 5). As expected from our proportional fleet allocation, the three trawling fleets had much larger catches than those of purse seines, pole and lines, longlines, or gillnets, especially in area VII (Table 3). Catches from the 'other coastal gears' fleet were also high in area VII, with algae forming 68% of the landings, and crustaceans and molluscs making up most of the rest.

The trawling fleets also had the highest discard rates (Table 3; Figure 5). By itself, Atlantic horse mackerel accounted for a large proportion of the discards by demersal trawlers (29.3% of all coastal demersal trawl discards in area VII, and 27.1% in area VIII; 36.6% of all offshore demersal trawl discards in area VII, and 37.4% in area VIII).

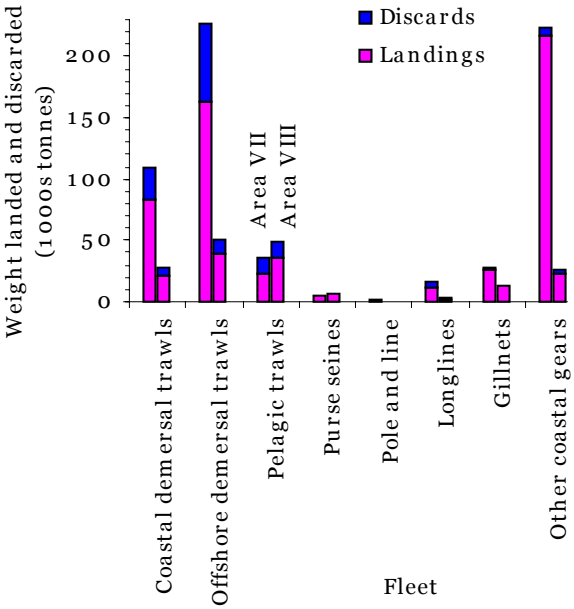

Figure 5. Estimated weight of total landings and discards by different French fleets in ICES areas VII and VIII. Landings are averages of species data from 1996-1998 allocated among different fleets. Percent discard rates from Pérez *et al.* (1996) and Morizur *et al.* (1996 a, b) were applied to the species landings data. Estimated total catch by fleet is the sum of landings and discards.

The catches of the coastal and offshore demersal trawling fleets were dominated by elasmobranchs and groundfish (Figure 6). The offshore demersal trawling fleet caught more groundfish and had higher discard rates (24.8% in area VII and 19.5% in area VIII) than the coastal demersal trawling fleet (19.5% in area VII and 16.8% in area VIII). Elasmobranchs (sharks, skates and rays), on the other hand, had similar landings by coastal and offshore demersal trawlers, but the discard rate was higher for coastal (20.7% in area VII and 20.2% in area VIII) than for offshore demersal trawls (11.4% in area VII and 10.3% in area VIII). Small pelagic fish formed a substantial proportion of the total discards from offshore demersal trawls.

Obviously, small pelagic fish were the main catch and discards of pelagic trawls (Figure 6), and were much less in pelagic trawls (33.3% in area VII and 26.8% in area VIII) than they were in coastal demersal trawls (83.1% in area VII and 84.0% in area VIII) or offshore demersal trawls (72.0% in area VII and 76.9% in area VIII). Mackerel made up 33.0% of all pelagic trawl discards in area VII, while sardines made up 41.7 % of pelagic trawl discards in area VIII. Most of the groundfish, elasmobranchs, and 'other' fish caught by pelagic trawls in area VII were discarded (72.7%, with balck seabream [*Spondyliosoma cantharus*] forming most of the total discard), while only 20.0% were discarded in area VIII.

Overall discard rates were also high for longlines (Table 3) due to the large discard of elasmobranchs (50.0% in area VII and 40.0% in area VIII). Conversely, overall discard rates were much lower for purse seines, pole and lines, gill nets, and 'other coastal gears' (Table 3; Figure 5). The discard rate for gillnets and 'other coastal gears' is even lower if we exclude crabs, of which smaller body sizes were discarded. Crabs accounted for 30.9% of all gillnet discards in area VII and 23.0% in area VIII, as well as 88.7% of all 'other coastal gears' discards in area VII and 93.9% in area VIII.

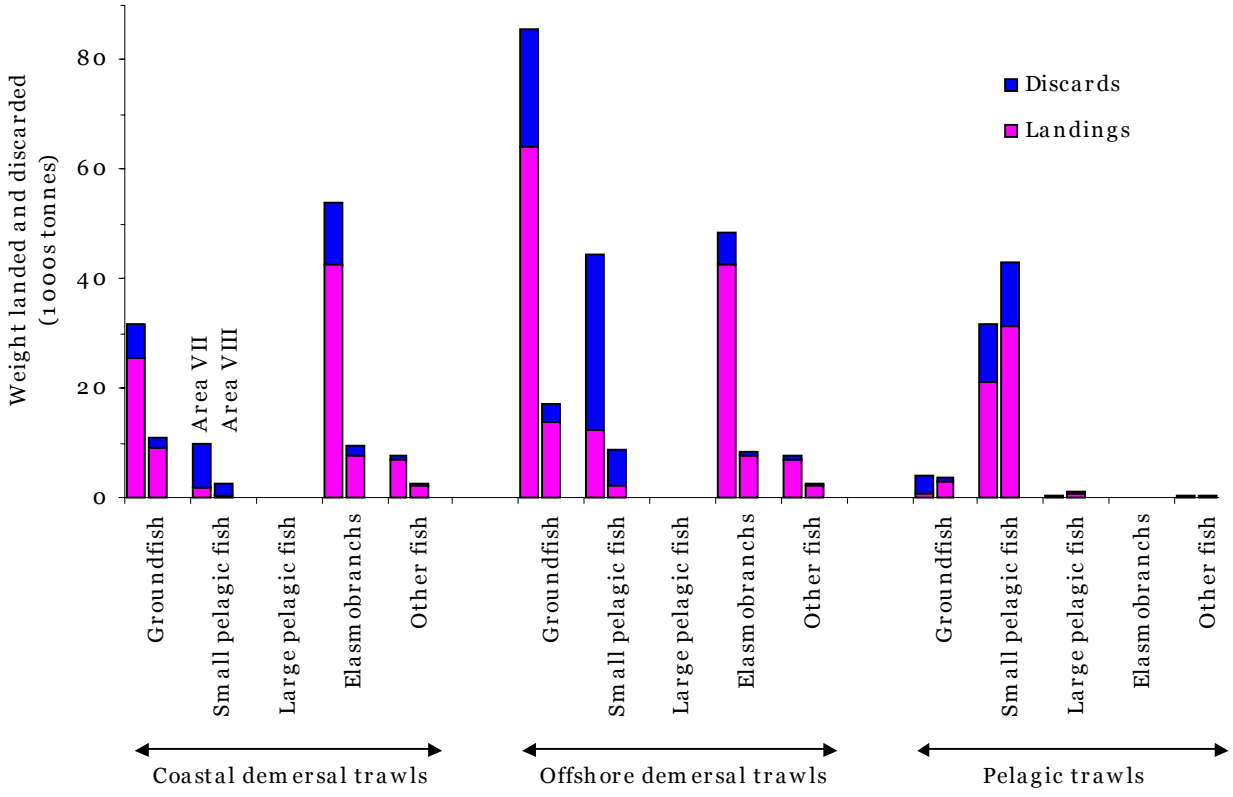

Figure 6. Estimated weight of landings and discards of different fish groups by the French trawling fleets in ICES areas VII and VIII. Estimates are yearly averages from 1996-1998.

Table 2. Reconstructed annual catch and overall discard rate of various species groups caught in the French fisheries (all fleets combined) between 1996-1998 in ICES areas VII and VIII.

Species group	Estimated catch (t)		% of catch discarded	
	Area VII	Area VIII	Area VII	Area VIII
Fish	380,948	141,675	28.0	23.0
Groundfish/demersals	143,444	40,552	19.9	12.1
Small pelagics	89,882	59,926	55.2	33.1
Large pelagics	712	3,104	0.8	8.1
Sharks/skates/rays	116,406	19,753	18.4	15.6
Anadromous (mostly eels)	68	6,325	1.3	1.3
Other or 'general' fish	30,436	12,015	22.9	37.5
Crustaceans	17,924	22,648	34.3	14.9
Lobsters	4,715	4,341	10.1	5.7
Crabs	12,689	5,621	44.5	50.2
Shrimp	73	435	0.3	0.1
Other or 'general' crustaceans	447	12,251	4.5	2.4
Molluscs	100,123	9,775	4.1	7.0
Bivalves	20,698	819	0.0	0.4
Cephalopods	14,951	5,835	18.9	9.4
Other or 'general' molluscs	64,475	3,120	2.0	4.1
Echinoderms	82	188	100.0	96.5
Algae	147,505	2,247	0.0	0.0
Cnidarians and other animals	103	310	100.0	100.0

Table 3. Reconstructed annual catch and overall discard rate of different French fleets (all species combined) between 1996-1998 in ICES areas VII and VIII.

Fleet	Estimated catch (t)		% of catch discarded	
	Area VII	Area VIII	Area VII	Area VIII
Coastal demersal trawls	109,818	27,600	24.4	24.6
Offshore demersal trawls	225,986	50,794	28.1	24.2
Pelagic trawls	36,335	48,177	37.7	26.3
Purse seines	5,194	7,176	8.8	12.9
Pole and line	1,720	775	0.0	0.0
Longlines	16,013	2,456	33.5	27.3
Gillnets	28,458	13,807	6.1	8.6
Other coastal gears	223,161	26,057	2.5	10.1

POSSIBLE SOURCES OF ERROR IN THE RECONSTRUCTION OF TOTAL CATCH

The estimated weight of discards and catch that we reconstructed from species landings depend directly on the proportional allocation of the catch to each fleet, and on the percent discard rate of each species within each fleet. Alternate fleet allocation regimes would change our estimated catch and discards. Allocating too much of the catch to fleets with higher discard rates would result in overestimating discard estimates. Further, the discard rates that we assumed from the catch sample studies may not be representative of the entire French fleets as a result of different fishing grounds, fishing tactics, or seasonal fishing variations. If the discard rate for a given species, fleet and area from the sampling studies is higher than the actual rate of the fleet that landed that species in that area, then the total discard weight would likely be overestimated. Finally, we have not attempted to correct for unreported catches, only for discarded catch. The total catch and landings are therefore likely somewhat higher than what we have estimated.

ACKNOWLEDGEMENTS

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APPENDIX 1

EARLIER FISHING ACTIVITY - FLEET DESCRIPTION

The description of French fleets are based on the records of the merchant navy and edited each year in annual reports of the Direction of Maritimes Fisheries, from the end of last century to 1979. From 1950 to 1958 they present the number of ships, propulsion type, region, tonnage classes, and tonnage and total power per type of propulsion. From 1959 to 1979, they present the number of ships, gear type, region, and tonnage and total power per gear type. For 1986-1987, they present tonnage, number and power (HP) of ships, region, and length class. The IFREMER inspectors network also collects information about fishing activity (gear type, zone and fishing time) by using logbooks. All the data were integrated together, but because of imprecision in each source, it is not possible to link the fleets with the fishing areas.

The second data set comes from the appendices from the Marine Fisheries Institute (Guillou and Njock, 1978), which resulted in a file integrating the numbers of ship per region and weight class for ships of Atlantic ports fishing in the North-east Atlantic, and a second file listing the fishing effort of ships related to Atlantic ports (trawlers per ICES zone in days and HP, other ships in month*ships).

FISHING EFFORT

Effort data were available by region, vessels and hours and is broken down by tonnage class and gear type for the period 1961-1975. The first suggested unit to measure standard fishing effort of all the ships was horse power (HP). This unit, chosen by Europe to regulate the development of the fleets requires, however, according to the data available, a key of conversion for power by gear and class of tonnage. The day*HP does not really consider effort of ships not using trawlers (gill net effort, for example, is quantified more rigorously by the mileage of nets employed). Fishers change gear often, according to fish availability in the sea within a fishing season. Due to its mixed gear nature, effort for the fleet was characterized by number of ships by tonnage class for each portion of the month using one specific gear (Guillou and Njock, 1978). The effort developed by these fleets is thus quantified in months (number of month during which the boats used the gear each year), or in boats (crew members of the virtual fleet).

In absence of conversion data, we used published results to allocate effort in the Northeast Atlantic from 1961-1975. Trawlers effort (in day*HP) were

already attributed to ICES fishing zones, while other ships effort (in month*boat) have been attributed to a zone, based on the bibliography available according to the following criteria. For most ships, the allocation of effort by zone was obtained from Guillou and Njock (1978). Effort of ships of less than 25 GRT have been attributed to the zone based on the species targeted or the gear type. As tuna 'germon' is fished during its migration from zone IX to zone VII, tuna boat effort was equally apportioned to the two zones. Because of the migratory and gregarious nature of tuna, the fishing activity includes long searching periods and considerable mobility. Thus the proportion of captures and effort may vary considerably among years and fishing zones.

The trawlers total effort vary among Atlantic ports and ICES zones (Figure 1.1) with areas VII and VIII having the largest effort compared to areas IV and VI. Effort increased continuously from 1962 to 1975. During this period, trawlers were probably the most important fleet in French fisheries. However, some other gear type, such as dredges, gillnets, tremaille, longlines and various types of traps were also used in French fishery. These gears effort seem to have remained constant during the study period (Figure 1.2).

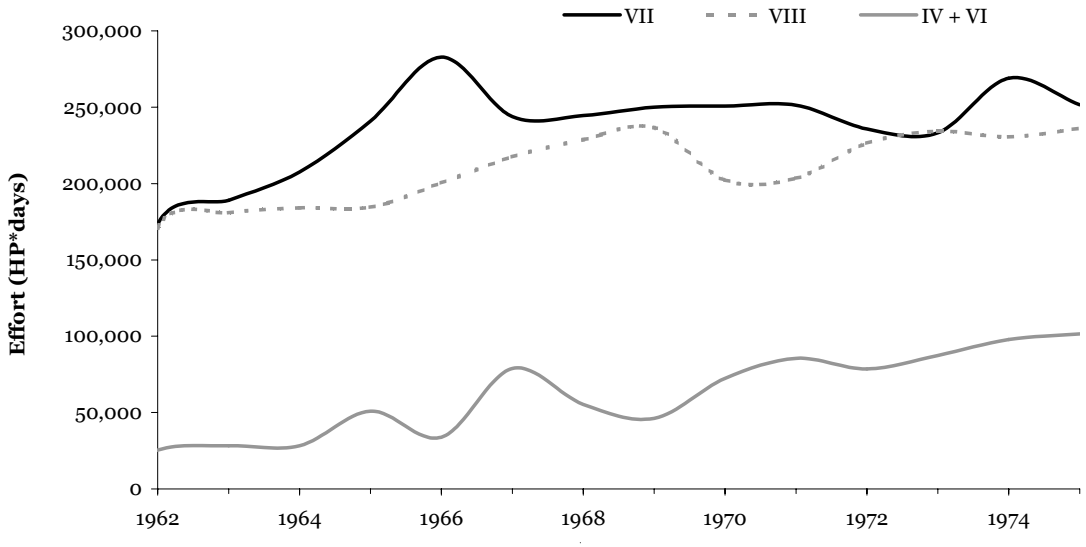

Figure 1.1. Total fishing effort of French trawlers in ICES areas IV, VI, VII and VIII from 1962 – 1975.

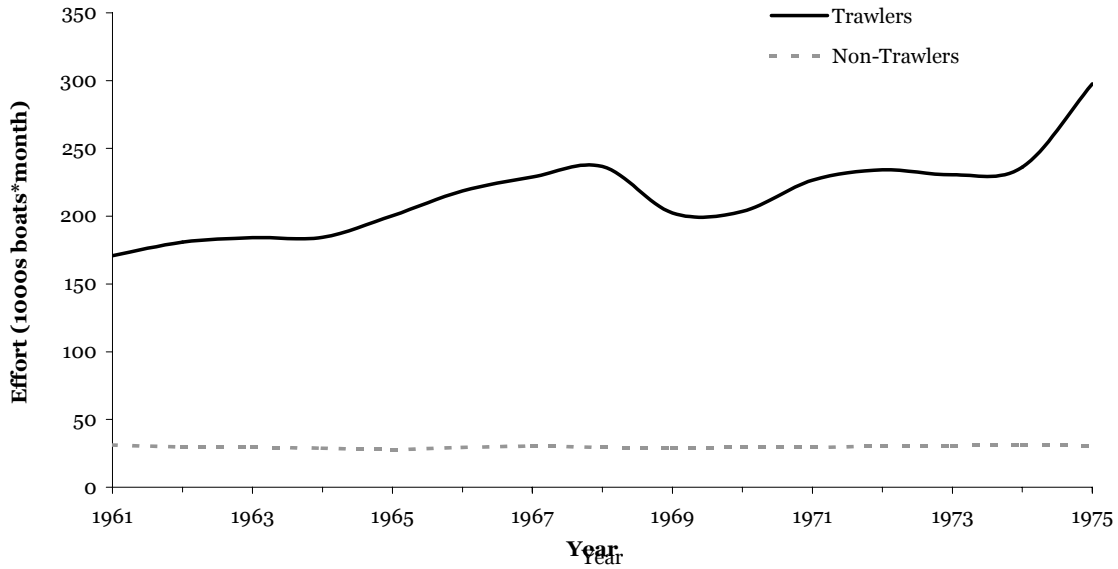

Figure 1.2. Fishing effort in ICES area VIII for trawlers and non-trawler fleets, from 1961 - 1975.

APPENDIX 2

The proportional fleet allocations of the total catch of individual species and larger taxonomic groups are listed in Table 2.1, for area VII, and Table 2.2, for area VIII.

Table 2.1. Fleet allocation for French catches in ICES area VII (all figures in %).

Species / taxonomic group	Coastal demersal trawls	Offshore demersal trawls	Long-line	Gill-net	Pole and line	Other coastal	Purse seine	Pelagic trawls
Fish								
Groundfish/demersals								
Merluccius merluccius	10	45	35	10	-	-	-	-
Spondyliosoma cantharus	20	15	5		-	-	-	60
Dicentrarchus labrax	5	10	10	15	-	-	-	60
Solea solea/vulgaris	60	30	-	10	-	-	-	-
Pollachius pollachius	15	65	5	15	-	-	-	-
Merlangius merlangus	10	90	-	-	-	-	-	-
Gadus morhua and other cods	10	69	1	10	10	-	-	-
Lepidorhombus whiffiagonis	-	100	-	-	-	-	-	-
Lophius piscatorius	10	60	30	-	-	-	-	-
Melanogrammus aeglefinus		100	-	-	-	-	-	-
Trisopterus luscus	10	90	-	-	-	-	-	-
Other groundfish	35	35	4	25	-	1	-	-
Small pelagics								
Engraulis encrasicolus	-	-	-	-	-	-	10	90
Sardina pilchardus	-	-	-	-	-	-	90	10
Trachurus trachurus	10	50	-	-	-	-	-	40
Micromesistius poutassou	-	-	-	-	-	-	-	100
Scomber scombrus	-	50	-	-	-	-	-	50
Other small pelagics	-	-	-	10	-	-	45	45
Large pelagics								
Xiphias gladius	-	-	100	-	-	-	-	-
Tunas and other large pelagics	-	-	-	34	33	-	-	33
Other mackerels, tunas, bonitos	-	-	-	10	10	-	40	40
Sharks, skates, and rays	45	45	5	5	-	-	-	-
Anadromous fishes (mostly eels)	-	-	-	-	-	100	-	-
Other Perciformes	30	30	-	20	-	20	-	-
Miscellaneous marine fishes	20	20	-	-	-	20	20	20
Crustaceans								
Lobsters	-	50	-	-	-	50	-	-
Crabs	-	-	-	10	-	90	-	-
Shrimp	20	-	-	-	-	80	-	-
Other crustaceans	-	50	-	-	-	50	-	-
Molluscs								
Bivalves	5	-	-	-	-	95	-	-
Cephalopods	40	50	-	-	-	10	-	-
Other molluscs	5	-	-	-	-	95	-	-
Echinoderms	-	-	-	-	-	100	-	-
Algae	-	-	-	-	-	100	-	-

Table 2.2. Fleet allocation for French catches in ICES area VIII (all figures in %).

Species / taxonomic group	Coastal demersal trawls	Offshore demersal trawls	Long-line	Gillnet	Pole and line	Other coastal	Purse seine	Pelagic trawls
Fish								
Groundfish/demersals								-
Merluccius merluccius	30	25	5	10	-	-	-	30
Spondyliosoma cantharus	30	20	-	-	-	-	-	50
Dicentrarchus labrax	5	5	10	20	10	-	-	50
Solea solea/vulgaris	30	-	-	70	-	-	-	-
Pollachius pollachius	10	40	-	40	10	-	-	-
Merlangius merlangus	10	60	-	-	-	-	-	30
Gadus morhua and other cods	10	85	-	5	-	-	-	-
Lepidorhombus whiffiagonis	-	100	-	-	-	-	-	-
Lophius piscatorius	10	80	-	10	-	-	-	-
Melanogrammus aeglefinus	-	100	-	-	-	-	-	-
Trisopterus luscus	20	80	-	-	-	-	-	-
Other groundfish	35	35	4	25	-	1	-	-
Small pelagics								
Engraulis encrasicolus	-	-	-	-	-	-	10	90
Sardina pilchardus	-	-	-	-	-	-	40	60
Trachurus trachurus	4	10	-	-	-	-	-	86
Micromesistius poutassou	-	50	-	-	-	-	-	50
Scomber scombrus	-	20	-	-	5	-	5	70
Other small pelagics	-	-	-	10	-	-	45	45
Large pelagics								
Xiphias gladius	-	-	10	60	-	-	-	30
Tunas and other large pelagics	-	-	-	60	10	-	-	30
Other mackerels, tunas, bonitos	-	-	-	10	10	-	40	40
Sharks, skates, and rays	45	45	5	5	-	-	-	-
Anadromous fishes (mostly eels)	-	-	-	-	-	100	-	-
Other Perciformes spp.	30	30	-	20	-	20	-	-
Miscellaneous marine fishes	20	20	-	-	-	20	20	20
Crustaceans								
Lobsters	-	50	-	-	-	50	-	-
Crabs	-	-	-	10	-	90	-	-
Shrimp	-	-	-	-	-	100	-	-
Other crustaceans	-	50	-	-	-	50	-	-
Molluscs								
Bivalves	2	-	-	-	-	98	-	-
Cephalopods	30	70	-	-	-	-	-	-
Other molluscs	2	-	-	-	-	98	-	-
Echinoderms	-	-	-	-	-	100	-	-
Algae	-	-	-	-	-	100	-	-

APPENDIX 3

Table 3.1. Outline of the method used to calculate weights of discards for species for which the generic length-weight relationships described in the text were not employed.

Table 3.1. Method used to assign weight to discards of species for which the generic length-weight relationships described in the text were not employed.

					Length-weight parameters used			
Species	**Max length (cm)**	**Mean length (cm)**	**Max weight (kg)**	**Mean weight (kg)**	**a**	**b**	**Source**	**Note**
Palinurus elephas	-	-	-	-	0.00056	3	Data for *Scyllarus latus*, Mediterranean locust lobster (Anon., 1998)	2% (in numbers) was discarded, we assumed they were small specimens which led to negligible weight
Spider crab	-	-	-	-	0.79464	3.2754	Based on Tanner crabs in Alaska (Clark *et al.*, 1999)	Based on length structure of discards
Conger conger	300	-	110	-	0.0006	3.22	Fishbase[a)]	Assumed that fish discarded were small, 1 kg on average
Labrus bergylta	60	16.5 -47.5	4.35	-	0.0119	3.115	Fishbase[a)]	Assumed discarded fish are on average 10 cm long (13.59 g)
Loligo vulgaris	-	-	-	0.5				Mean weight based on the lower range of Azores catches (Martins, 1982)
Microchirius variegatus	-	-	-	-	0.0089	3.079	(Morizur *et al.*, 1996b)	Based on length structure of discards
Squalus acanthias	160	90	9.1	-	0.01	3	Fishbase[a)]	Based on length structure of discards
Spondyliosoma cantharus	60	-	-	-	0.01	3.14	Fishbase[a)]	Based on length structure of discards
Cancer pagurus	-	-	-	-	7.9E-05	3.27		Based on length structure of discards

[a)] see *www.fishbase.org*

SPANISH FISHERIES IN ICES AREA VIII, 1950-1999

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ABSTRACT

The following report discusses the main data discrepancies between the catch datasets from ICES and Spanish national statistics, and explores the reasons behind these differences. Furthermore, a summary of major fisheries off the north coast of Spain (ICES area VIII) is provided, together with catch summaries.

DISCREPANCIES BETWEEN ICES AND SPANISH NATIONAL STATISTICS

A major obstacle in analyzing the Spanish fisheries in ICES area VIII is the availability and accuracy of statistical information. Both ICES and Spanish Fisheries Yearbooks (SFY) offer data for 1950-1999, with ICES data being provided by Spain through official statistics. Examining the landings data from each source reveals that both sources have biases in their reported statistics and differed from each other (Figure 1). The Spanish landings reported by the SFY were, on average, 3.8 times higher than those reported by ICES before 1978, with the greatest differences occurring in the late 1960s. Two problems make it difficult to determine exactly what the data from each source portray.

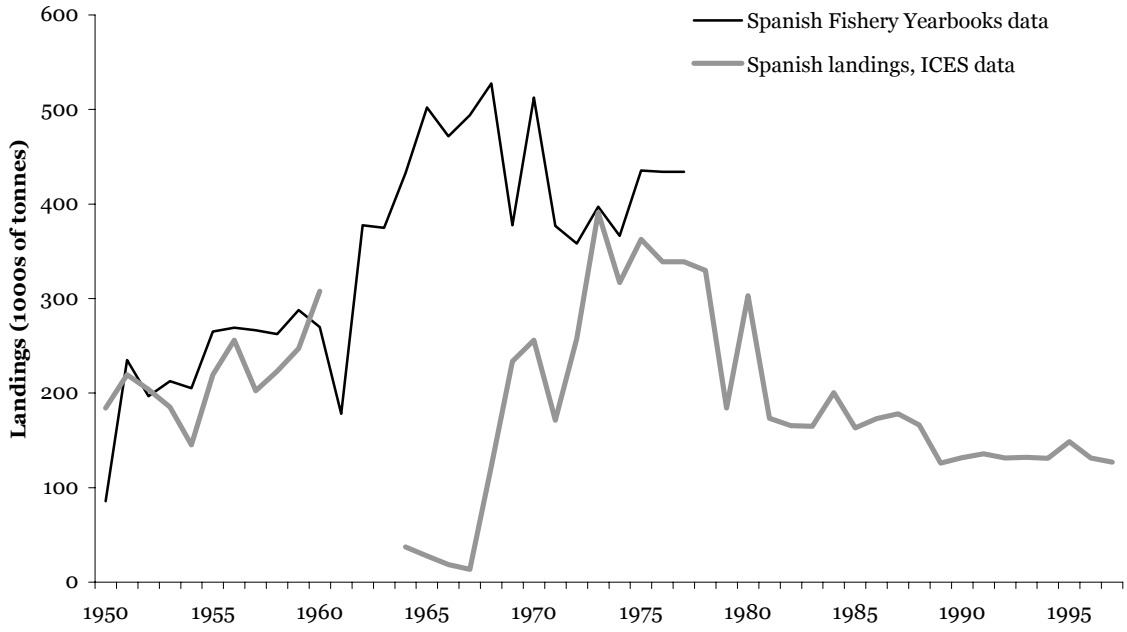

Figure 1. Comparison between Spanish Fisheries Yearbook data and ICES data for Spanish landings in ICES area VIII during the period 1950 to 1997.

The first problem is that the catching zones reported by the two sources are geographically different (Figure 2). The SFY structured the study area in two different areas: Cantabrian and Northwest areas, which are not congruent with the ICES divisions. Further, ICES divided its Northwestern region into two parts: North of 42º N belonged to area VIIIc, and south of this latitude belonged to area IXa. The practical consequences of this discrepancy were evident: when Spain sent catch data from area VIII, Spanish bodies summed the data of these areas without taking into account that nearly half of the Northwestern region did not belong to area VIII. This may have heavily affected the validity of the ICES data for Spain until 1989.

The second problem is as important as the previous one: even more often than ICES, the SFY only referred to where catches were landed, making it almost impossible to determine where they were fished. For example, there was an obvious difference between sources in recorded landings of Atlantic cod (*Gadus morhua*), as well as other commercial species such as hake (*Meluccius merluccius*) and blue whiting

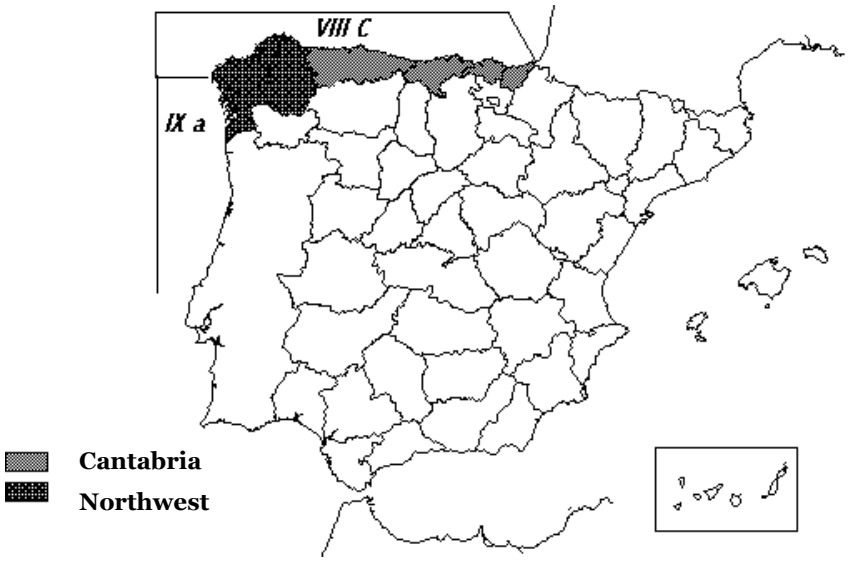

Figure 2. Comparison of the ICES divisions (areas VIIIc, IXa) with the Spanish statistical regions (Cantabrian and Northwest).

(*Micromesistius poutassou*) (Figure 3). In each of these cases, especially for Atlantic cod, the SFY landings statistics were much higher than ICES statistics. This was probably because part or all of the SFY landings in area VIII were caught elsewhere, whereas ICES made some attempt to record where the fish were caught and not just where they were landed. Hake caught by trawlers in ICES areas VII and VI are landed and registered in area VIII (Figure 3). Catches from other fisheries, after filtering or estimating those from area IXa, were likely from area VIII. The fish obviously caught in other areas have been removed from the SFY data set.

In 1960, the ICES landings in area VIII of most species were equal to the sum of the SFY landings in the Cantabrian Sea and Northwestern ports, except for common sole (*Solea solea*), northern bluefin tuna (*Thunnus thynnus*), albacore tuna (*Thunnus alalunga*), and Atlantic horse mackerel (*Trachurus trachurus*) (Table 1). In the case of albacore and northern bluefin tuna, most of the catches were from area VIII (although not just VIIIc). Since the 1960s, however, these species were increasingly fished in waters of the Azores Archipelago (see Morato *et al.*, this volume). In 1973, there were greater differences between the ICES area VIII and SFY reported landings (Table 2). The differences in the tuna data (Tables 1 and 2) most likely relates to the way in which ICES accounts for landings of all tunas in the north of Spain. Whereas albacore had the highest landings in area VIII among different tunas, they were likely recorded as northern bluefin tuna by ICES in 1960.

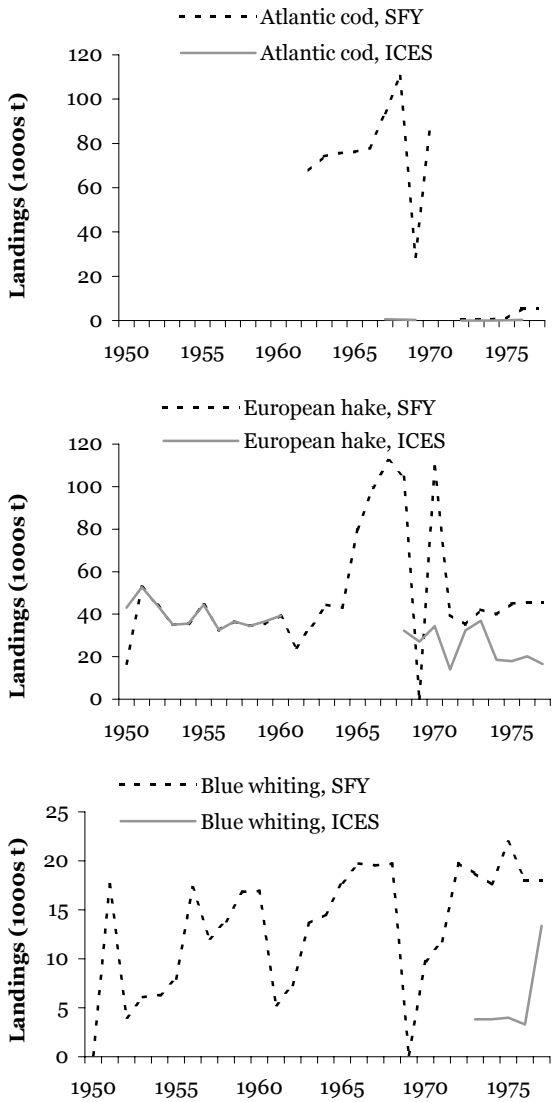

Figure 3. Comparison between Spanish Fisheries Yearbook data and ICES data for Spanish landings of Atlantic cod, hake, and blue whiting, in ICES area VIII during 1950 to 1977.

Table 1. ICES data of Spanish landings in ICES area VIII and Spanish data of landings in Cantabrian (C) and Northwest (N) Zones. Statistics for the year 1960, in tonnes. The species for which the catch in both sources do not match are in bold.

Species name	Common name	ICES	Spanish statistics		
		Zone VIII	C+N	C	N
Anguilla anguilla	**European eel**	33	32.9	18.8	14.1
Belone belone belone	Garpike	804	804.4	9.3	795.1
Conger conger	European conger	3,231	3,231.1	511.9	2,719.2
Lepidorhombus whiffiagonis	Megrim	6,839	6,838.9	1,337.4	5,501.5
Lophius piscatorius	Anglerfish	4,440	4,439.8	1,155.4	3,284.4
Merluccius merluccius	European hake	39,357	39,356.6	19,723.6	19,633.0
Pollachius pollachius [a)]	Pollack	558	557.8	36.3	521.5
Psetta maxima	Turbot	87	88.6	2.3	86.3
Sardina pilchardus	European pilchard	38,244	38,243.9	1,797.0	36,446.9
Scomber scombrus	Atlantic mackerel	5,270	5,270.4	4,339.1	931.3
Solea solea	**Common sole**	**408**	**84.2**	42.1	42.1
Spondyliosoma cantharus	Black seabream	4,171	4,171.6	96.7	4,074.9
Sprattus sprattus	European sprat	20	20.1	0.1	20.0
Thunnus thynnus thynnus	**Northern bluefin tuna**	**31,204**	**298.0**	292.8	5.2
Thunnus alalunga	**Albacore**	**0**	**5,412.1**	-	-
Trachurus trachurus	**Atlantic horse mackerel**	**30,047**	**8,304.5**	5,888.7	2,415.8

[a)] In Spanish Statistics, this fish appears as '*Gadus pollachius*'.

The discrepancies between the two sources of statistics are even more evident when we look closer at hake catches in European waters in 1973 (Table 2) and 1976 (Table 3), which were greater in the ICES than in the SFY data set. The two estimates were closer from 1977 onwards (Table 3). We are not certain of where the fish were caught due to lack of information from SFY. However, most of the Spanish trawlers or longliners working in areas VI and VII came from the Northwest zone, while most of the Cantabrian trawlers worked on the French continental shelf. These trawlers were targeting hake and associated species (blue whiting, anglerfish [*Lophius piscatorius*], megrim [*Lebidorhombus whiffiagonis*]), which are almost exclusively deep sea species. Some problems of species identification would have arisen in, for example, different species of tuna and sea bream. However, this by itself would not explain the large differences between sources, especially when we look at the total catch instead of at individual species that may have been misidentified.

ICES data were missing in the 1960s for several important commercial species such as Atlantic horse mackerel, Atlantic mackerel (*Scomber scombrus*), hake and European pilchard (*Sardina pilchardus*). For other important species such as albacore, blue whiting, and European anchovy (*Engraulis encrasicolus*), records only began in the late 1960s or 1970s. The missing ICES data for these important species could explain why the ICES total landings are considerably lower in the 1960s than SFY data (Figure 1). A major part of this discrepancy between data sources in the early 1960s appears to be for pelagic fish (Figure 4a), as well as for the species in Figure 3. Very little of this discrepancy, if any, can be accounted for by categorizing fish as 'unidentified', 'various', or 'unsorted' instead of as their proper species label (Figure 4b). The 'unidentified' category of the SFY data was even larger than the ICES one, accounting for 10% of the total landings between 1950-1977.

Table 2. ICES data of Spanish landings in ICES area VIII and Spanish data of landings in Cantabrian (C) and Northwest (N) Zones. Statistics for the year 1973, in tonnes. The species for which the catch in both sources do not match are in bold.

Common name	Spanish statistics			ICES					
	C+N	C	N	VIII	IX	VII	VI	VIII +IX	Total ICES
European conger	2,595.5	632.3	1,963.2	943	461	921	686	1,404	3,049
European anchovy	23,195.9	23,189.1	6.8	23,196	2,332	-	-	25,528	25,528
Dusky grouper	199.6	72.9	126.7	199	169	-	-	368	368
Atlantic cod	419.8	214.2	205.6	30	-	301	208	30	4,125
Megrim	**10,296.9**	1,847.6	8,449.3	**876**	-	8,747	727	**876**	11,949
Angler	**12,501.3**	3,036.1	9,465.2	**775**	503	11,202	428	**1,278**	12,995
Haddock	1,666.6	-	1,666.6	42	-	890	497	42	4,041
Whiting	-	-	-	65	-	1,121	1,540	65	3,011
European hake	**42,191.9**	19,384.1	22,807.8	**15,597**	20,812	19,838	6,455	**36,409**	62,926
Blue whiting	18,738.3	6,087.2	1,2651.1	3,816	99	8,821	5,751	3,915	18,837
Striped red mullet	247.4	227.4	20.0	-	-	-	-	0	489
Saithe	-	-	-	220	-	444	1,980	220	5,064
European pilchard	44,768.0	8,569.9	36,198.1	44,768	18,523	-	-	63,291	63,291
Atlantic mackerel	25,676.2	11,780.0	13,896.2	25,677	2,334	-	-	28,011	28,011
Common sole	376.6	45.1	331.5	116	1,535	209	-	1,651	1,891
Black seabream	7,404.3	1,056.1	6,348.2	-	-	-	-	-	-
Albacore	**15,001.5**	10,500.2	4,501.3	**19,322**	1	-	-	**19,323**	19,323
Northern bluefin tuna	**2,192.2**	1,935.9	256.3	**3,395**	651	-	-	**4,046**	4,046
Atlantic horse mackerel	111,843.2	44,674.0	67,169.2	90,368	1,518	15,624	5,851	91,886	113,361
Pouting	7,732.9	3,554.7	4,178.2	3,865	160	3,187	680	4,025	7,892
Swordfish	5,245.4	0	5,245.4	5,245	1,020	-	-	6,265	6,265

Table 3. Comparison of Spanish hake (*Merluccius merluccius*) landings (tonnes) in European waters in 1976 and 1977 from ICES and Spanish sources.

ICES area	ICES stats		Spanish statistical region		Spanish sources	
	1976	1977			1976	1977
VI	4,120	1,579	-			
VII	20,820	5,299	-			
VIII	20,202	16,630	Cantabria	Hake	5,472	3,734
				Small hake	18,139	14,950
				total	23,611	18,684
IX	13,710	17,501	Northwest	Hake	4,884	4,259
				Small hake	17,119	18,066
				total	22,003	22,325
Total	**58,852**	**41,009**			**45,614**	**41,009**

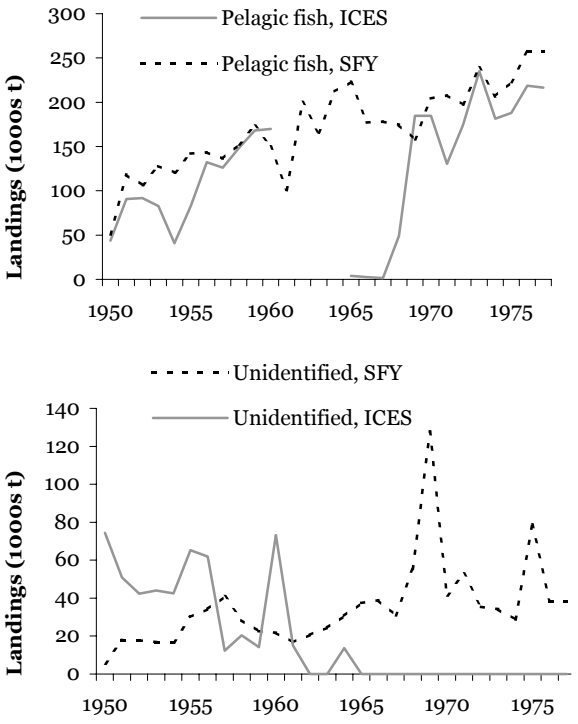

Figure 4. Comparison between Spanish Fisheries Yearbook data and ICES data for Spanish landings of pelagic fish (upper panel), including commercially important species such as Atlantic horse mackerel, Atlantic mackerel, European pilchard, Albacore, bluefin tuna, and European anchovy; and unidentified catch (lower panel), in ICES area VIII during 1950 to 1977.

A SHORT DESCRIPTION OF THE SPANISH FLEETS IN ICES AREA VIII

The number of boats employed in the trawling, purse seine, and surface Spanish fleets remained fairly constant from 1978 to 1986 (Figure 5). The total landings reported by ICES fluctuated, decreasing in the first few years of that period before they stabilized and remained fairly constant after 1981.

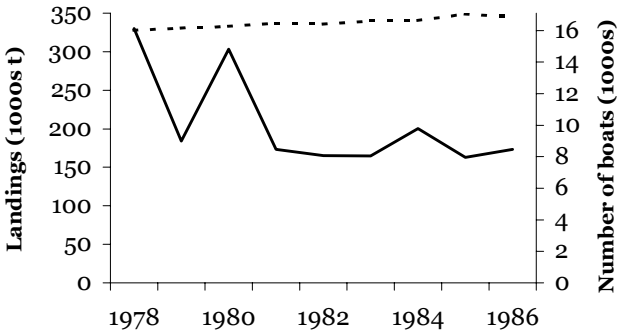

Figure 5. Landings (ICES data, solid line) and number of boats in the Spanish fishery from 1978-1986 (trawlers, purse seines and surface fisheries, dotted line).

The Spanish fisheries in area VIII are characterized by the diversity and the heterogeneity of processes, techniques, objectives, and organizational structures. However, the fisheries can be divided into three broad types:

Coastal fleet

In the Basque Country, as in the rest of area VIII, the coastal fleet typically employs small motor vessels of up to 30 GRT, even though it is possible to find vessels of higher tonnage (Table 4). Other characteristics of the fishing methods utilized are also presented in Table 4; note however, that vessels may switch gears very rapidly. The range of fishing methods is wide because depending on the season, and also the market, fishers can employ longlines, pole and lines, hand lines, bottom nets and traps interchangeably.

As mentioned, the thoroughness of landings recorded for a given species may vary depending on the port and its traditions, as well as on the area within the Cantabrian Sea. The fishing grounds of the Basque coast, Cantabria, and Asturias are shown in Figures 6, 7, and 8, respectively. These three regions plus the coast of the province of Lugo compose the Cantabrian coast, or the Spanish coastline of ICES area VIIIc. Obtaining information for all the ports and fishing districts of area VIII is difficult, as official statistics ceased in 1986 and the literature published by local bodies is very scarce. Nevertheless, data for the Basque coast is complete enough to give a clear picture of the different fisheries carried out in the grounds close to shore. Table 5 shows the different species caught by the Basque coastal fleet, listed by fishing methods, between July 1991 and June 1992.

Although the Atlantic mackerel fishery, using primarily hand lines, is the largest among the coastal fisheries in terms of weight (Table 5), the hake fishery, using pole and lines, bottom nets, and longlines, is the greatest in terms of economic value (Table 6). The other species are substantially less important than these two in both catch weight and value. Excluding the hake and mackerel fisheries, bottom net catch weights and values were the greatest, followed by longlines. The bottom net fishery is the most valuable overall despite having lower total fleet GRT and HP than the longline and pole and line fisheries (Tables 4 and 6). The trap fishery, catching only crustaceans, is the smallest among the coastal fisheries in number of vessels, catch weight, and value.

Table 4. Number of vessels and their technical characteristics employed in the coastal fleet, by gear type, 1991-1992.

		Vessel average				*Entire fleet*		
Method	**Vessels**	**Length (m)**	**GRT**	**HP**	**Crew**	**GRT**	**HP**	**Crew**
Longlines/hand lines	115	12.5	20.4	140	3.3	2,340	16,082	387
Bottom nets	71	10.3	10.9	91	2.9	772	6,457	203
Pole and lines	31	15.5	30.0	215	5.1	931	6,675	157
Traps	14	8.3	7.4	66	2.1	103	921	28
Total	**231**	**-**	**-**	**-**	**-**	**4,146**	**30,135**	**775**

Table 5. Landings (tonnes) by species and gear type in the Basque coastal fleet. Data from July 1991 – June 1992.

Common name	**Scientific name**	**Bottom net**	**Longline**	**Pole and line**	**Hand line**	**Trap**	**Total**
European hake	*Merluccius merluccius*	174	127	165	-	-	466
Sea bream	*Pagellus cantabricus*	-	2	-	-	-	2
Conger eel	*Conger conger*	1	56	-	-	-	57
White hake	*Urophycis tenuis*	-	77	-	-	-	77
European seabass	*Dicentrarchus labrax*	4	21	-	-	-	25
Striped red mullet	*Mullus surmuletus*	45	-	-	-	-	45
Angler	*Lophius piscatorius*	35	1	-	-	-	36
Red sea scorpion	*Scorpaena lutea*	13	1	-	-	-	14
Atlantic mackerel	*Scomber scombrus*	262	12	46	3,679	-	3,999
Sharpnose sevengill shark	*Heptranchias perlo*	-	107	-	-	-	107
Chub/Spanish mackerel	*Scomber japonicus*	1	-	-	-	-	1
Atlantic horse mackerel	*Trachurus trachurus*	97	12	107	2	-	218
Pouting	*Gadus luscus*	59	3	-	-	-	62
Crustaceans		3	-	-	-	74	77
Other		132	40	8	-	-	180
Total		**826**	**459**	**326**	**3,681**	**74**	**5,366**

Table 6. Value of the landings of the Basque coastal fleet, in millions of current (2001) pesetas[a)] (1991-1992).

Common name	**Scientific name**	**Bottom net**	**Longline**	**Pole and line**	**Hand line**	**Trap**	**Total**
European hake	*Merluccius merluccius*	150	132	173	-	-	455
Sea bream	*Pagellus cantabricus*	0	4	0	-	-	4
Conger eel	*Conger conger*	0	18	0	-	-	18
White hake	*Urophycis tenuis*	0	34	0	0	0	34
European seabass	*Dicentrarchus labrax*	6	36	0	-	-	42
Striped red mullet	*Mullus surmuletus*	54	0	0	-	-	54
Angler	*Lophius piscatorius*	22	1	0	-	-	23
Red sea scorpion	*Scorpaena lutea*	27	1	0	-	-	28
Atlantic mackerel	*Scomber scombrus*	30	1	5	140	-	176
Sharpnose sevengill shark	*Heptranchias perlo*	0	20	0	-	-	20
Chub/Spanish mackerel	*Scomber japonicus*	0	0	0	-	-	0
Atlantic horse mackerel	*Trachurus trachurus*	21	3	16	0	0	40
Pouting	*Gadus luscus*	8	0	0	-	-	8
Crustaceans		4	0	0	-	30	34
Others		53	16	3	-	-	72
Total		**375**	**266**	**197**	**140**	**30**	**1,008**

[a)] 100 pesetas = US$ 0.55 (27-September, 2001).

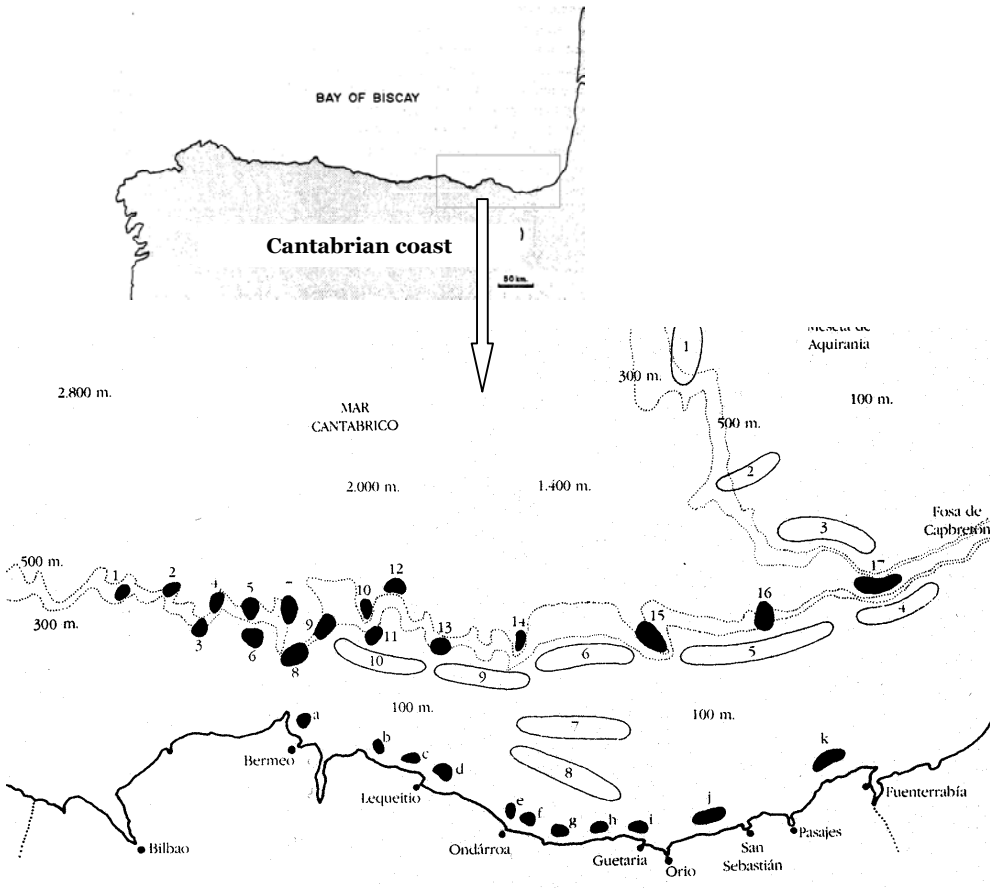

Figure 6. Fishing grounds along the coast of Basque Country (see insert for general location). Dark-colored grounds a-k: coastal grounds for hand lines, lines, drift nets and other fixed bottom nets for a great variety of fishes. Dark-colored grounds 1-17: hand lines and longlines on the border of the continental shelf for seabream, hake and related species. Light-colored grounds 1-10: small grounds for trawling.

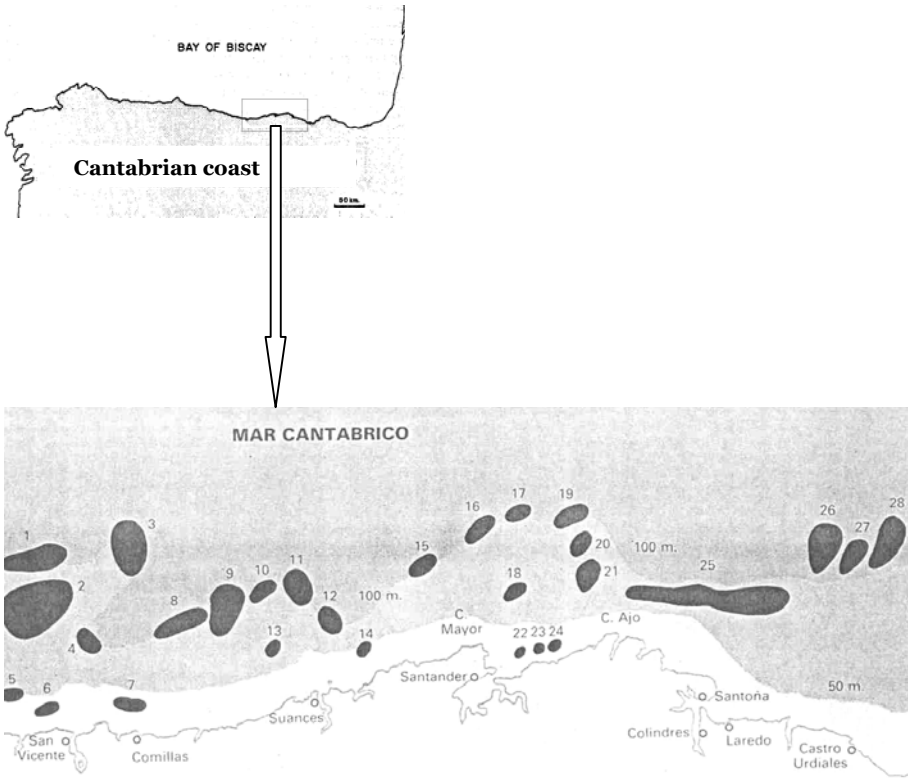

Figure 7. Fishing grounds along the Cantabrian coast (see insert for general location). Grounds 1-28: coastal grounds for hand lines, lines, drift nets and other fixed bottom nets for a great variety of fishes, as well as hand lines and longlines on the border of the continental shelf for seabream, hake and related species.

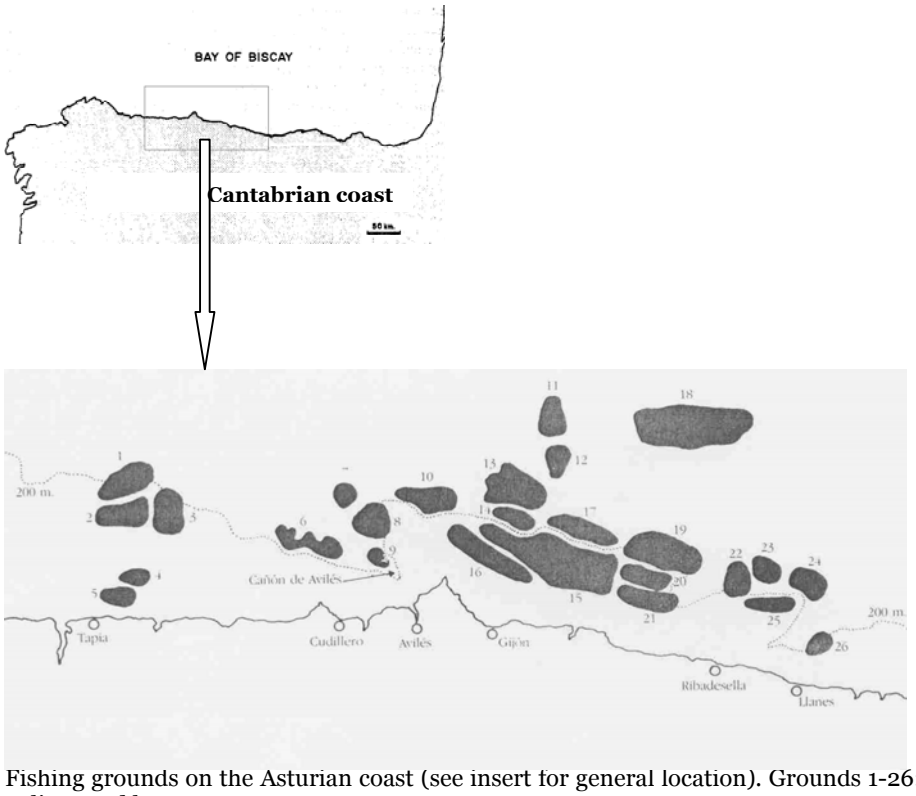

Figure 8. Fishing grounds on the Asturian coast (see insert for general location). Grounds 1-26: coastal grounds for lines, longlines and bottom nets.

Surface fleet (Pelagic fleet)

Fisheries for anchovy, tuna, albacore, mackerel, pilchard and horse mackerel are the most important in the center and east of area VIII, although albacores are also important in the western corner of the area in ports of the province of Lugo in Galicia. Albacore and anchovy landings constitute the main source of earnings for the fishers of this fleet. The processes and vessels used are remarkably different from the coastal fleet. Vessels of 100 GRT or larger are equipped to fish with purse seines and different line systems for tuna and albacore (Tables 7 and 8). In absence of these main target species, fishers rely more on other species, especially mackerel, horse mackerel, and in some ports northern bluefin tuna, and species distribution of landings are determined by fishing seasons (Table 9).

Table 7. Number of vessels and their technical characteristics employed by the Basque pelagic fleet, 1991-1992.

	Vessels	**GRT**	**HP**	**Crew**
Entire fleet	189	19,949	93,299	2,673
Per boat	-	105.55	493.65	14.14

Table 8. Number of vessels and their technical characteristics employed by both the Basque coastal and pelagic fleets, by gear type, in 1999.

		Per vessel		*Entire fleet*	
Gear type	**Vessels**	HP	GRT	HP	GRT
Purse seines (anchovy, horse mackerel)	70	439.4	89.62	30,757	6,273.21
Live bait system (albacore, tuna)	55	595.3	125.51	32,742	6,902.92
'Cacea' (lines while sailing) (albacore)	8	227.3	31.82	1,818	254.59
Pole and lines (hake and demersals)	19	217.5	35.83	4,132	680.70
Longlines (demersals)	42	146.5	24.80	6,153	1,041.74
Traps	5	39.0	3.48	195	17.39
Other methods (mainly bottom nets)	138	126.2	18.01	17,415	2,485.35
Total	**337**	**-**	**-**	**93,212**	**17,655.90**

Table 9. Fishing schedule for each target species of the surface fleet in ICES area VIII, in the Basque Country.

Species	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Pilchard	-------	-------	-------	-------								
Anchovy		---	-------	-------	-------	-------						
Albacore							-------	-------	-------	-------		
Bluefin					--	-------	-------	-------	----			
Mackerel	-------	-------	-------									
Horse mack.			-------	-------	-------	-------	-------	-------				

Trawl fleet

Landings and vessels of the trawling fleet in area VIII have decreased substantially since the mid-1970s (Figure 9), for two reasons. The first is overfishing; while the second involves the institutional changes that adversely affected the Spanish deep sea fishing fleet. The new 'Law of the Sea' dramatically changed the ways the Spanish fleet fished in European grounds. After long and intensive discussions, the European Community accepted the Spanish presence in its waters but established a strict system of licences and quotas that was maintained after Spain entered the European Union (EU) in 1986. Figure 10 shows the most important trawling grounds visited by Spanish trawlers in ICES areas VIII and VII.

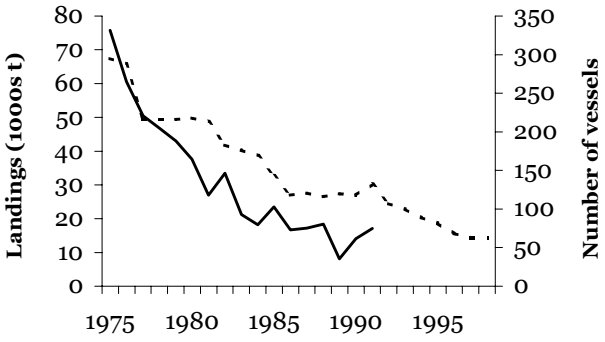

Figure 9. Landings (solid line) and number of vessels employed in trawl fisheries (dotted line) in the Basque Country (mainly in area VIII) during 1975 to 1998.

The Spanish trawling fleet in area VIII has historically targeted hake, one of the most valuable fishes on the Spanish market. Along with hake, other species such as megrim, angler, soles, whiting, and ling (*Molva molva*) were commonly caught, though in lower numbers. At times they are all categorized together as 'hake and related species'. Only in the last few decades, since hake landings and populations began to decline while prices rose, have some of these other species increased in importance. Unfortunately, it is only possible to get statistics of the Spanish trawling fleet from ICES or NAFO, not from SFY. Therefore, it is commonly admitted that most of the landings data sent from Spanish official bodies to international institutions are underestimated. Similarly, it is difficult to get discard or by-catch data.

DISCARDS

Discard rates were estimated from available 1994 data for area VIII (Pérez *et al.*, 1996). These data, from random sampling of fishing vessels, are given as the percent of catches that are discarded by species, ICES area, and gear type. These estimates were assumed to be valid only for the 1990s, presuming the level of discards would not be the same for earlier decades. Total discard rates of all catches in area VIII for the four different gear types analyzed were: gillnets, 14.7%; longlines, 13.1%; purse seines, 13.5%; and trawls, 44.9%.

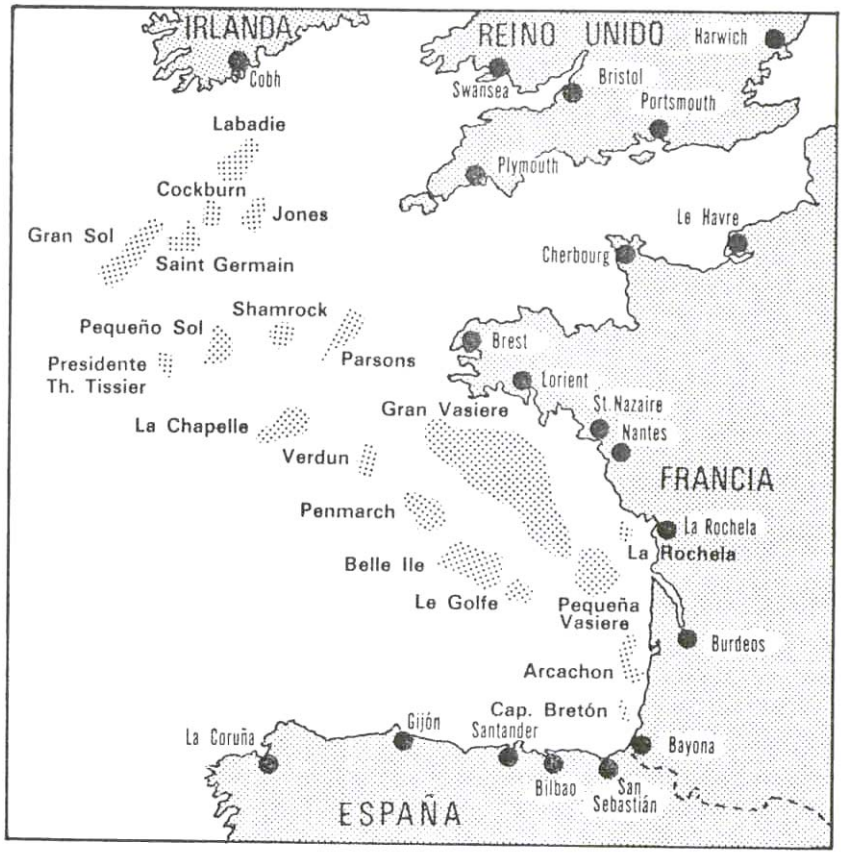

Figure 10. Trawling grounds in ICES areas VIII and VII used by Spanish vessels.

ACKNOWLEDGEMENTS

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PORTUGUESE FISHERIES IN PORTUGAL FOR THE PERIOD 1950-1999. COMPARISON WITH ICES DATA

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ABSTRACT

The Portuguese fishery in Portugal waters landed its greatest catches in the mid 1960s, and landings have remained lower but steady since then. Purse seines, targeting sardines (*Sardina pilchardus*), had the highest catches of all fisheries from 1950-1999. Fish and cephalopod trawls, crustacean trawls, and multi-gear vessels form the remaining fleets. During the 1990s, both the catch and value of most target species decreased slightly (except for octopus), due to decreasing fleet sizes in all fisheries. Official Portuguese catch statistics are compatible with ICES landing figures since the late 1980s. Prior to this period, Portuguese catch statistics are approximately 18% lower. We assume Portuguese discard rates are low. The Portuguese fishery is dominated by purse seines, which generally have low discard rates. This contrasts with Spanish fishery, which has a greater trawling fleet and is thus more likely to produce higher discard rates. Surprisingly, the biomass of shark discards in Portuguese fishery is probably quite high, as they form a substantial proportion of the trawling fisheries catches, and are nearly always discarded.

DESCRIPTION OF THE PORTUGAL FISHERIES

Fishing is a traditional, culturally important activity in Portugal, and is dominated by small, local fishing vessels. Over the past decade the number of vessels has decreased, but this has been compensated by an increase in power per vessel. In 1996, 98% of the fishing fleet was motorized - a 2% increase since 1986. Fishing vessels operate out of 32 ports in Portugal, distributed along the coast. The largest port is Aveiro, where 975 vessels are registered (Anon., 1998). Portuguese fisheries management is based on the European Union system, which includes TACs and quotas for some species, fishing area or gear restrictions, minimum size requirements for captures, standard mesh sizes, and maximum percentages of incidental catches.

According to the 1991 population census, 20,114 people are employed in the fisheries sector; this represents less than 1% of the total employable population above age 12 (Anon., 1998). Of these workers, 97% are male, often having a low level of education, with 9% being illiterate, and 68% having only primary school education (Anon., 1998). Younger workers, however, tend to have a higher education level.

The most important Portuguese fisheries, in terms of landings and value, are listed in Table 1. Unless indicated otherwise, the information presented in this report is based on Anon. (1994, 1997, 2000a, b, 2001) and Parente (2000). In 1996, the total landing for the Portuguese fleet was 164,103 tonnes, of which 58% were caught by purse seines, 13% by trawls and 29% by multigear fleets. The purse seine fishery targets mainly sardines (*Sardina pilchardus*), but also captures Atlantic horse mackerel (*Trachurus trachurus*), chub mackerel (*Scomber japonicus*) and Atlantic mackerel (*Scomber scombrus*) in smaller quantities. Sardine is the most important species in terms of total landings in Portugal, and are much higher than those of Atlantic horse mackerel, with the second highest landings (Figure 1). During the period 1986 – 1996 sardine accounted for an average of 40% of total landings of all species in tonnage, but only 11% of the total value of all landings. Over the past decade the quantity of sardines landed has decreased by 16%, and this was associated with the decrease in the number of vessels and the corresponding 23% decrease in total capture by the purse seine fishery. However, attempts to bring the sardine price in line with that from other European countries since Portugal joined the EU has resulted in an increase in value.

There are two distinct trawl fisheries in Portugal. One targets fish and cephalopods, and the other crustaceans. Over the past decade the total fish landings by trawlers have decreased by 40%. This decrease may have been due to a reduction in the number of trawlers, or due to reduced catches. The main species caught by the trawl fishery targeting fish are Atlantic horse mackerel (35% of landings in 1996), Blue whiting (*Micromesistius poutassou*; 15%), octopus (10%) and European hake (*Merluccius merluccius*; 3%). Landings and value of both Atlantic horse mackerel and European hake have decreased by about 50%

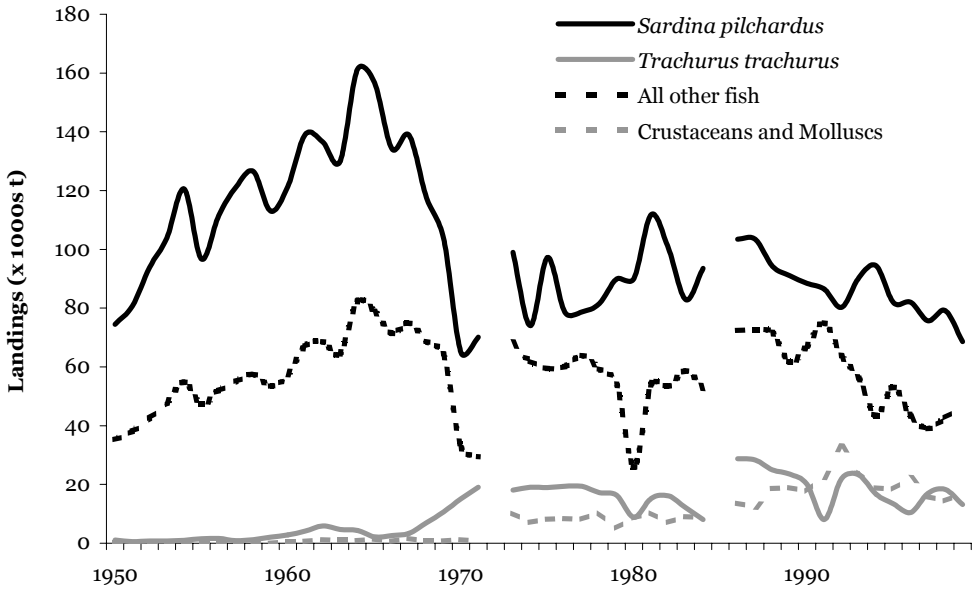

Figure 1. Landings by species or group of the Portuguese fisheries in ICES Area IXa, 1950-1999.

between 1986 and 1996. Conversely, octopus has shown a marked increase, both in terms of landings and value. Over the past decade there has been a 186% increase in landings and 100% price increase, thereby nearly quadrupling its value (Monteiro and Monteiro, 1997).

Although the trawl fleet that targets crustaceans is small, with only 30 registered vessels (reduced from 36 in 1995), it is a lucrative fishery. The main species captured are red shrimp (*Aristeus antennatus*) and deepwater rose shrimp (*Parapenaeus longirostris*). Crustaceans are considerably more expensive than other fisheries products. Therefore, although the quantity landed represents less than 1% of total landings, they account for almost 4% of the total value of landings (Cadima *et al.*, 1995).

The multigear fleet is made up of boats that are licensed to use several different gear types throughout the year. These boats operate in both coastal waters (smaller boats less than 9 m in length) and further offshore. The main gears used are gillnets, trammel-nets and longlines. The most important species in terms of weight caught by the artisanal fishery is octopus. This species is caught by pots and traps and represents 11% of all captures. European hake only represents 5% of the weight landed, but is the most important in terms of value (11%). Nevertheless, the gillnet fishery is considerably less important than the trawl fishery; in 1999 it only represented 4% of all hake caught. It is, however, more selective than trawls and only catches a small size range of fish. The number of vessels in this fishery has also decreased over the past decade.

Table 1. Major Portuguese fisheries.

Target Species	Scientific name	Gear type
European pilchard / Sardine	*Sardina pilchardus*	Purse seine
Atlantic horse mackerel	*Trachurus trachurus*	Bottom trawl
Atlantic horse mackerel	*Trachurus trachurus*	Purse seine
European hake	*Merluccius merluccius*	Gillnet
European hake	*Merluccius merluccius*	Bottom trawl
Crustaceans	-	Bottom trawl
Octopus	*Octopus vulgaris*	Pots and traps
Octopus	*Octopus vulgaris*	Bottom trawl

CATCHES IN ICES AREA IXA BY PORTUGUESE FLEETS

Figure 2 shows the total Portuguese landings by fleet from 1950 to 1999 (data for 1972 and 1985 are lacking). Purse seines account for the greatest total landings of any gear type. Their landings decreased considerably in the late 1960s, and have increased somewhat during the 1970s and 1980s. Artisanal gears appeared in the data set in the mid 1970s. Records continue until 1984, after which they were recorded under multigear fleets. Trawler landings are relatively low and reached a maximum during the early 1970s.

COMPARISON WITH ICES DATA

Before the 1990s, the total landing estimates from official Portuguese data were on average 18.7% below the ICES landings estimates for the same area, with the greatest difference in the early 1970s (Figure 3). The ICES data do not show the substantial decrease in total landings in the late 1960s like the Portuguese data do. After 1990, the two data sources were more similar.

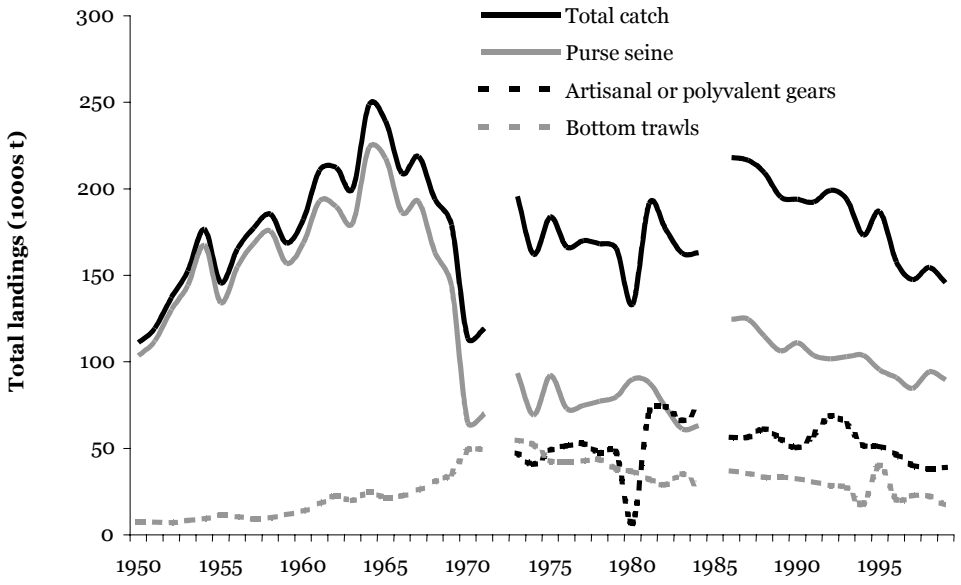

Figure 2. Total landings by fleet of the Portuguese fisheries in ICES Area IXa, 1950-1999.

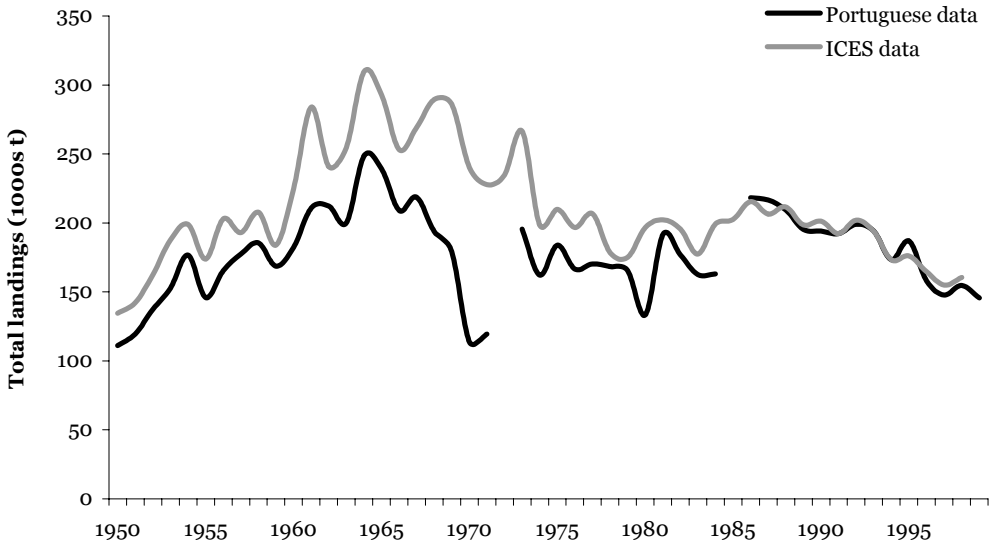

Figure 3. Comparison of total landings of Portuguese fleets between official Portuguese data and ICES data in Area IXa, 1950-1999.

DISCARDS

Except for the last few years, no discard data are available. However, these recent estimates seem suspect (there are some negative values) and are not species specific. Moreover, for some of the small scale fisheries, we do not even know what species are caught, let alone the quantities of each. Work is in progress to fill these gaps. However, we assume that discards in Portugal are relatively low, because the fisheries are mixed, targeting various species, and most fish are valuable, so will be landed.

For example, the semi-pelagic longline fishery in southern Portugal operates in deeper waters, targeting larger individuals of hake that are of high commercial value and never discarded (Erzini *et al.*, 1998). Conversely, discard levels of hake from Portuguese trawlers are likely higher, if they are similar to discard rates in Spanish trawlers: in 1994, when 42% of Spain's hake landings in Areas VIIIc and IXa were landed by trawlers, the hake discard rate was 7% of the total trawler landings by weight (Anon., 1999). In 1997, when trawlers landed 60% of Spanish hake landings, the hake discard rate from trawlers was estimated at 27% (Anon., 1999). The proportion of Portuguese hake landings by trawlers in the same area and the same years, however, was lower than those of Spain (26% of hake landings in 1994 and 38% in 1997; Anon., 1999). Thus, although the discard rates of hake by Portuguese trawlers are likely similar to the hake discard rates of Spanish trawlers, we might expect the hake discard rate of the entire Portuguese fishery to be lower than that of Spain, as a smaller proportion of hake are landed by trawlers.

In a study off the Southern Portuguese coast from May 1996 – June 1997, shark discards constituted 15.5% of the total catch by weight of all species caught in crustacean trawls or fish trawls (Costa and Borges, 1998). The most frequently discarded species was *Scyliorhinus canicula* (Scyliorhinidae) (5.1% of total catch by weight), which is occasionally included in commercial captures, as a limited market exists for it (Costa and Borges, 1998). All other shark species caught are always discarded due to their low commercial value, so that their proportion of capture equals their proportion discarded. These included *Galeus melastomus* (Scyliorhinidae, 3.6% of the total catch by weight of all species), *Hexanchus griseus* (Hexanchidae, 3.3%), *Etmopterus spinax* (Squalidae, 2.4%), *Etmopterus pusillus* (Squalidae, 0.8%) and *Dalatias licha* (Squalidae, 0.3%) (Costa and Borges, 1998).

Sharks were caught from late winter through late summer during the study (Costa and Borges, 1998). No sharks were caught by purse seines or trammel nets during the study. The longline fishery, fishing further off the coast of Southern Portugal, catches large *G. melastomus* individuals, and these are of some commercial value (Erzini *et al.*, 1998). As shark discards represent a considerable proportion of the total catch in weight, they are potentially valuable commercial species and could be important as a by-catch if a market were developed for them (Costa and Borges, 1998).

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THE FISHERIES OFF THE ATLANTIC COAST OF MOROCCO 1950-1997

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ABSTRACT

The reported landings for the whole coastline off Morocco have been assembled from FAO statistics, Moroccan and Spanish Ministries records, and FAO working group reports. The resulting estimate of reported landings is close to the published statistics from FAO for the years 1975-1997. For the period 1950-1974, the landings obtained are considered to be under-estimates as the reporting structure was not fully in place. Because the Spanish fisheries have been historically important on the coast of Morocco, a more complete description of their catch statistics have been included. In addition, discard rates and unreported landings have been estimated based on several studies in the region.

INTRODUCTION

This report attempts a reconstruction of the total extractions from the Atlantic coast of Morocco from 1950 to 1998 using estimates of the catch of small-scale fisheries, by-catch, as well as unreported catch sold through the black market or directly consumed. It also briefly describes the history of fishing in this region, as well as the evolution of the fleet size and fishing techniques used during this period.

The Atlantic coast of Morocco is nearly 3,000 km long, extending from Tangier (36° N) to Lagouira (20° N) on Cape Blanc (Figure 1). In 1975, Morocco incorporated the former Spanish Sahara (27° N to 20° N)[a)]. Considering the whole coast as an ecosystem, catch estimates are summarized for the whole region (Tangier-Cape Blanc) starting in 1950.

The width of the continental shelf varies from 18-126 km. Numerous upwellings cells, mainly between Safi (32° N) and Cape Blanc (20° N) are responsible for high primary production. The stocks of sardines (*Sardina pilchardus*) and octopus (*Octopus vulgaris*) are considered among the richest in the world.

HISTORY OF FISHERIES

In Morocco, fishing is a relatively new activity that was introduced by French, Spanish and Portuguese fishers. Although small dories (6 m in length) were operating in coastal villages before 1914, the development of the small-scale fishery started in 1930 (MPM, 1990). This development was the direct result of a forced labor law established by the French, from which fishers were exempt (Ayache, 1956).

Small-scale fishing is a seasonal activity located mainly in isolated coastal areas close to small villages and ports. The fishers use dories to catch fish, mollusks and crustaceans. This category also includes hand collection of algae and mussels and onshore fishing using lines. Most fishers live primarily from agriculture and livestock, and fishing activities represent a supplementary source of income. They fish mainly during spring and summer when the height of waves does not exceed 2 m.

The coastal fishery started around 1927 and was initiated by Spanish and Portuguese fishers. The 16 to 24 m wooden boats were made locally and had no catch preservation system onboard. They fished close to their port mainly on a day trip basis with local crews, targeting pelagic species using purse seines, and demersal species using long liners and bottom trawls.

The Moroccan industrial fleet started in 1972 and grew rapidly between 1973 and 1998. This fleet consists mainly of bottom trawlers targeting cephalopods and demersal species. The crews in charge of the fishing activity are mostly from foreign countries. The duration of fishing trips varies from 25 days to 3 months.

The Moroccan coast was used by foreign fishing interests as early as the 16th century. Starting in the 1960s, modern trawlers started fishing the Saharan coast more intensively. The size of the foreign fleet decreased as Morocco recognized the importance of fishing to its economy and extended its EEZ to 200 miles, as well as making large investments in the fishery sector.

[a)] The first author wants to stress that this occurred through legal action with the approval of the International Court of Justice in The Hague.

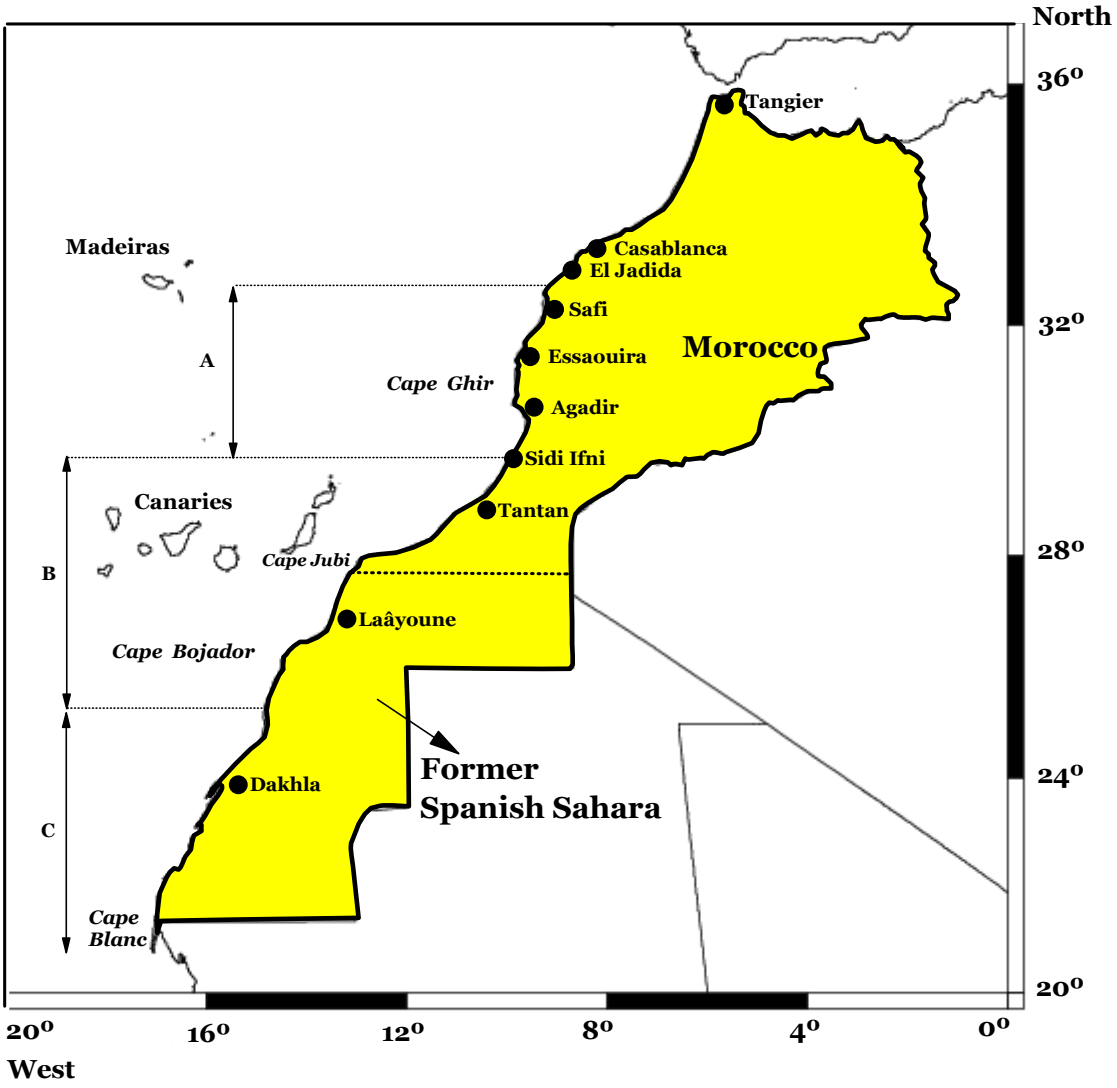

Figure 1. The Atlantic Moroccan coast showing the principal fishing ports, and the border with the former Spanish Sahara.

The Moroccan small-scale fleet

In the early days, the wooden dories measured 8 to 10 m in length and had a crew of 12. They were not mechanically powered and were not adapted to go through the surf in beaches from where they were launched. They were called 'korb' derived from the Arabic word meaning 'vessel'. Most of the catch was given locally to the French in exchange for food and clothes. Some of these vessels used purse seines to catch sardines in order to supply canning factories, e.g., in Agadir prior to 1960. This type of dory disappeared in the early sixties and was replaced by smaller ones of 5 to 6 m in length, carrying 2 to 3 fishers. In 1970, most dories were equipped with outboard motors of 6 to 25 horsepower.

The number of dories active in the small-scale fleet is difficult to assess and the actual estimates are not reliable. However, according to best estimates the total number of dories in Atlantic Morocco was approximately 3,600 in 1981-1982; 4,130 in 1983; 4,930 in 1984; 5,370 in 1985; 5,380 in 1988; and 8,000 in 1994 (MPM, 1990; MPM, 1994; Figure 2). The number of dories in the Atlantic coast account for approximately 75% of the total Moroccan dory fleet (Mediterranean and Atlantic; MPM, 1990). The spectacular increase of the number of dories was related to the new small-scale fishing activity in the Sahara which started in 1988 and targeted *Octopus vulgaris*. This fishery uses plastic pots weighted with cement, anchored on the bottom and hauled every 2 to 3 days (Baddyr, 1993). Fishing occurs at depths varying from a few meters to 120 m, and ranges from 100 m to 30 km from shore. Along

with the increase in number of dories, the number of pots also soared, reaching around 3,000 per boat (based on fishers interviews).

Squid (*Loligo vulgaris*) are fished using jigs, lead stem 5 cm in length with a ring of sharp needles at their lower end. Each dory carries two fishers using one jig line per hand or four jigs per boat. Fishing for squid occurs during daylight 300 to 400 m from shore, at depths of 10 to 20 m.

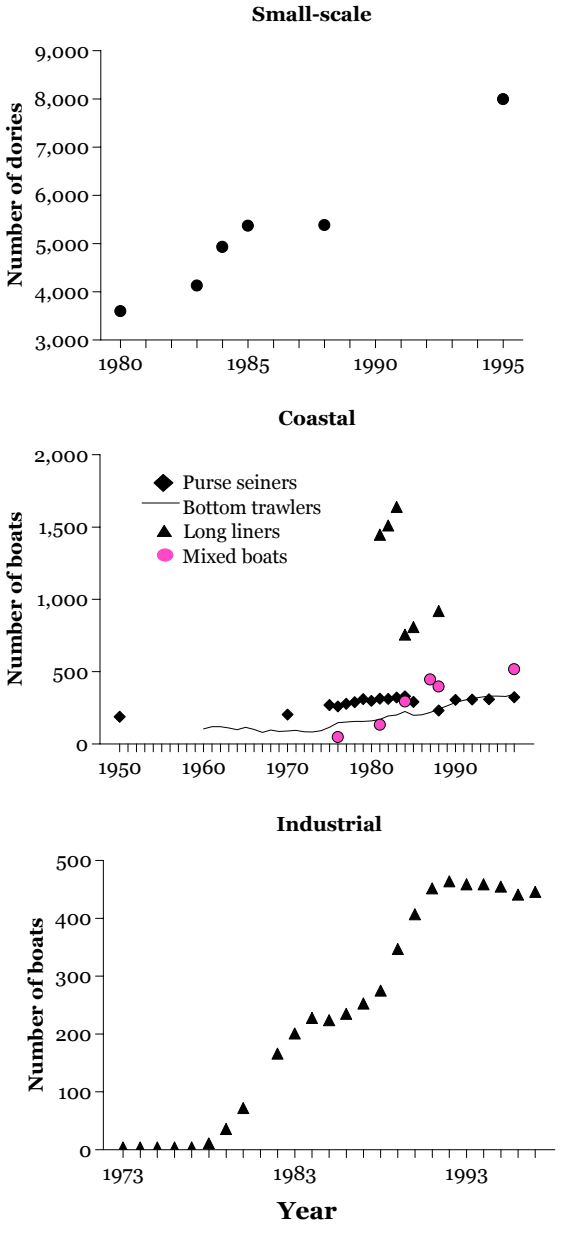

Figure 2. Development of Moroccan small-scale, coastal and industrial fleets.

Gill nets and trammel nets are used to catch fishes and crustaceans. The trammel net is 4m deep and has a stretched mesh size of 150 to 200 mm for the two outer trammel nets and 40 to 60 mm for the inner gill net. The mesh size of the gill net varies from 40 to 150 mm. These nets are anchored on the bottom at depths varying from 4 to 120 m and at distances ranging from 4 m to nearly 25 km offshore. The nets close to shore are hauled daily and the ones relatively far every three days. They also use hook and long lines to catch fish as well as traps to catch lobsters. Generally, sardines are used as bait.

Mussels are collected manually during low tide. Mussels are sun dried and sold locally or in nearby markets. Some mussel-related human deaths have been reported, and were due to accumulated toxins in their flesh caused by red algae blooms (Baddyr, 1992). Algae are also collected by hand during low tide. They are dried and sold to factories to extract agar-agar, and alginates used in the food industry as thickening agents.

The Moroccan coastal fleet

The Moroccan coastal fleet is composed of four types of boats: purse seiners, bottom trawlers, longliners and mixed gear boats.

Purse seiners

Purse seiners target mainly small pelagic species such as sardines, mackerels, anchovies and jacks. The boats leave port with a crew of 15 to 25 fishers on board late in the afternoon or at night. On the fishing grounds, fish stocks are detected using visual clues (birds, bubbles on the water surface) and echo-sounders. They use a seine net called 'cerco' that has a length of 250 to 400 m, a purse depth of 40 to 50 m, and a mesh size of 10 to 12 mm. Trips do not exceed 12 hours (Assabir, 1985).

In 1927, there were 26 purse seiners, and fishing was concentrated in the north of the country between Tangier and El Jadida (33° N, Figure 1). The fishing ports at that time were Larache, Mohammedia, Casablanca, and El Jadida (MPM, 1990). After the Second World War, a new and more important fishery was developed between 32°N and 30°N from the ports of Safi, Essaouira, and Agadir. The number of fishing boats in this area was over 180 (Belvèze, 1983) with an average of 34 GRT in Safi and 27 GRT in Agadir (bimodal distribution: 15 to 20 GRT; and 30 to 35 GRT).

The average power was 180 HP (Belvèze, 1971). In the 1980s, the stocks of pelagic species became more abundant in the southern part of the country. The biggest catches were landed in the ports of Tantan and Laâyoune.

The number of boats increased slowly, varying from 269 in 1975 to 323 in 1997 (Figure 2). The stagnation in the increase of boats during the last ten years is a consequence of the 1994 management policy halting the licensing for the construction of new boats. The age of the present fleet is about 40 years.

Bottom trawlers

Bottom trawlers, equipped with diesel engines of 120 to 450 HP (MPM, 1990), carry a crew of 10 to 15. They operate on a daily basis, leaving port at approximately 2 AM and return in the afternoon around 4 PM. Some trawlers might stay at sea up to one week when they fish in relatively distant fishing grounds. Fish are sorted by species onboard, and kept on ice. The trawl used on sandy or muddy ocean floor is called the 'atomic type', and has a mesh size of 25 mm at the cod-end. During each day trip, the boat undertakes two shots of 3 to 5 hours duration, depending on the availability of fish.

The number of coastal bottom trawlers tripled from 104 to 314 between 1960 to 1992 (Figure 2). However, their number was relatively low between 1960-1975, fluctuating between 104 to 116 vessels. The increase was then continuous from 1976 (148 boats) to 1994 (331 boats). The construction of trawlers has been halted since 1994. Approximately 80% of the Moroccan bottom trawlers work in the Atlantic (MPM, 1990).

Longliners

Longliners are smaller boats 8-10 m long with an average engine power of 50 HP and a capacity of 5 GRT. Their activity most likely started in the early 1930s. Each boat carries a crew of 13 to 14 and uses sardines as bait to catch demersal species. The long lines are hauled approximately every three days.

The number of longliners in Morocco increased from 1448 in 1981 to 1638 in 1983. Their number then dropped by half in 1984 to 756 units because of an increase in the mixed boats using long lines during this period. From 1984 to 1988, their number increased again from 756 to 920 (Figure 2). Nearly 96% of the total longliners operate in the Atlantic (MPM, 1990).

Mixed boats

These boats are permitted to use two fishing techniques depending on the availability of pelagic or demersal fish in their fishing zone. This permission was justified by the tremendous fluctuation in abundance of stocks near shore with seasons and years, jeopardizing the economic existence of boats using a single fishing technique only.

The number of mixed boats using purse seines and bottom trawl, or purse seines and long lines increased from 48 in 1976 to 517 in 1998 (Figure 2). The boats using bottom trawl and long lines did not exist before 1983, and their number increased from 36 in 1984 to 56 in 1988 (MPM, 1990).

The Moroccan Industrial fleet

The Moroccan industrial fleet started in 1973 with four boats based in Las Palmas (Canary Islands). The year 1975 marked the most significant development of the industrial fishing fleet, when Morocco incorporated the former Spanish Sahara. For the first time, the fishery sector was given particular attention in the 1973-1977 economic plan by the creation of the marine investment code. The marine investment code gave attractive loans (70% at low interest rate), 30% equipment bonuses, and established the 70 miles limit for the fishing exclusive economic zone (EEZ). In 1981, fisheries were recognized as a key sector of the Moroccan economy. A ministry of fisheries was created, the EEZ was extended to 200 miles, and large investments were made to build new fishing ports in the Sahara zone. From 1973 to 1986, the industrial fleet landed its catch in foreign ports, mainly in Las Palmas, and to a lesser extent in Portugal, Abidjan, and Dakar. In 1987, nearly two thirds of the fleet was based in Morocco in the ports of Agadir and Tantan. In 1992, all the boats landed in national ports.

The increase in the number of industrial boats over the years was considerable. They increased from 4 in 1973 to 166 in 1986, 452 in 1991, and 454 in 1998 (Figure 2). Stages of development followed beginning in 1973-1980 when 108 units (on average 12 per year) were bought using the loan advantages offered by the government. During the 1981-1984 period, 160 units were bought through association of Moroccan and

foreign investments, encouraged by the government. Between 1985-1988, the national financial institutions were more demanding in terms of loan acquisitions, which led to only 71 boat acquisitions. During the period 1989-1992, a total of 219 boats were bought through joint venture projects involving multinational fishing companies with investors from Morocco and other countries. Finally, during the period 1993-1998, the investment on this type of fishery was frozen by the government to avoid overexploitation of fish stocks. However, the replacement of old or damaged boats was permitted. In total 12 vessels were bought in this period.

Bottom trawlers fishing for cephalopods and demersal species represent, on average, 87% of the total of the industrial fleet, and operate in the Sahara zone. The duration of each fishing trip is 1 - 2 ½ months. The vessels are equipped with freezer holds, engines varying between 750 to 2,000 HP, and tonnage from 200 to 900 GRT. Bottom trawlers targeting shrimps as well as demersal species operate with a trip length of 50 days. They are smaller with engines of 550-850 HP and 140-250 GRT. In 1988 they represented 8% of the total of the industrial fleet. Trawlers equipped with a catch refrigeration system only, operate for short fishing trips of one or two weeks. They represented, on average, nearly 7% of the total fleet. Their tonnage ranges from 60 to 200 GRT.

The vessels fishing pelagic species use pelagic trawl as well as purse seines. They are equipped with freezers. Their tonnage varies from 600 to 1,300 GRT, and their engine power from 1,200 to 2,400 HP. They fish in the Sahara zone for up to two months at a time. The pelagic trawling net has a length of 110 m and a stretched mesh size of 40 mm. The length of the purse varies from 500 to 1,500 m. There were six pelagic freezer trawlers operating between 1982-1997, but were no longer operational by 1998 due to poor maintenance.

Foreign fleets

European vessels fished in the Moroccan Atlantic Ocean prior to 1918, mainly from Spain, Portugal, France, Italy, and Norway (Belvèze *et al.*, 1982). As Spain has a special historic link with the coast of Morocco, especially the Sahara, we describe their fisheries off this coast separately (see Guénette *et al.*, this volume).

In the 1960s, the existing foreign fleet size increased, and new ones came from Japan, South Korea, and Eastern Europe (USSR, Poland, Romania, and former East Germany), substantially increasing fishing pressures along the Saharan coast.

In 1988, Morocco signed the first four-year accord with the European Community (EC, now European Union, EU), in which 800 boats totaling 99,287 GRT were permitted to fish in the area. The Spanish fleet represented nearly 90% of the European boats. In 1992, a second accord for three years was signed in which 688 boats corresponding to 82,920 GRT were allowed to operate in the area. In 1995 a third accord for four years was signed in which 590, corresponding to a tonnage of 64,712 GRT were allowed to fish in the area. During this accord, the European fishing effort was reduced annually by 5 to 10% depending on the type of fishery. In November 1999, the fishing activity of the European feet was halted for an unknown period.

Spanish artisanal boats used 18 to 20 cylindrical traps to catch fish and crustaceans. In the Atlantic, the boats were allowed to fish from Tangier to El Jadida, and from El Jadida to Cape Ghir. Spanish cephalopod trawlers used bottom trawls similar to the one described for Moroccan vessels. The target species of these boats were cephalopods, mainly *Octopus vulgaris*. Hake (*Merluccius merluccius*) and shrimp trawlers also used the same type of trawl. In the Atlantic, cephalopod trawlers as well as boats that fish for hake were allowed to fish from Cape Bojador to Cape Blanc. The boats that fished for shrimps were allowed to fish from Tangier to El Jadida and from El Jadida to Cape Ghir. The European boats using purse seines targeted small pelagic species (sardines, anchovy), as well as tunas. The boats that targeted small pelagic species were allowed to fish in the Atlantic from Cape Ghir to Cape Blanc. The boats that fished for tunas were allowed to operate from Tangier to Cape Blanc. Spanish and Portuguese vessels using trammel nets, gill nets, and longlines targeted crustaceans and fish. These boats were also allowed to fish along the whole Moroccan Atlantic coast.

Japanese and South Koreans bottom trawlers started targeting cephalopods in the Sahara zone when abundant stocks were discovered in the area in the early 1960s (Voss, 1973). In 1969, the Japanese fleet left the area and moved further south to Mauritanian waters. In the early 1990s, Japanese longliners were permitted to fish tunas in the Moroccan Atlantic. This region is the obligatory passage for tunas towards their spawning grounds located in the Mediterranean Sea, and towards their feeding grounds in the

Gulf of Guinea. The secondary targets were sharks and other fishes. The scientific observers reported that the Japanese fishers kept the fins of the sharks onboard and discarded the rest. These boats were allowed to fish along the whole Atlantic coast of Morocco.

Countries from Eastern Europe fished mainly on small pelagic species. They used purse seines and semi-pelagic trawls. Factory boats were present in the fishing area processing the catch into canned fish and fishmeal products. They were allowed to fish from Cape Ghir to Cape Bojador and from Cape Bojador to Cape Blanc.

METHODODLOGY

Recorded landings

Moroccan small-scale fishery

Besides the seaweeds and mussels already accounted for in the FAO statistics, small-scale fleet landings are largely unknown. They were estimated by assuming a constant landing per dory. Thus, for the years 1981-1988 and 1995, the global catch of year i (C_i) was estimated as:

$$C_i = a * n_i \qquad ...1$$

where a is the average landing per dory in the small-scale fishery observed in Tifnit in 1986 equal to 1 tonne/dory/year (Baddyr, 1989), and n_i = number of dories in the Atlantic in year i (MPM, 1990; Anon., 1995). These estimates were based on the assumption that the average landing per dory per year was similar in all the fishing locations along the Atlantic coast, and that this average was constant throughout the years. The number of dories being unknown for the period 1950-1980, the total landings was assumed to amount to 1% of the sum of the coastal and industrial landings based on the percentage calculated from later in the 1980s.

$$C_i = 0.01 * T_i \qquad ...2$$

where T_i = total landings of coastal and industrial Moroccan fleet for year i. For the period 1989-1993 and 1996-1998, the total landings was assumed to amount to 3.5% of the sum of the coastal and industrial landings based on the percentages calculated for 1994-1995. Unfortunately, the catch composition observed in Tifnit in 1986 could not be extended to other sites in the Atlantic, since according to fishers, the catch composition varies greatly among years, and regions of the coast.

The Moroccan coastal and industrial fleets

The recorded landings of the Moroccan coastal fleet were taken from the FAO electronic database for years 1950-1962, 1964-1965 and 1967-1988; Collignon (1964, 1967) for years 1963 and 1966; and the Ministry of Fisheries (MPM, 1994, 1995, 1998) for the period 1989-1998.

In absence of collected data, the minimum Moroccan industrial catch for years 1973 to 1978 was estimated by multiplying the number of Moroccan trawlers by the annual average landing per boat derived from the Spanish trawlers using FAO data. Both Moroccan and Spanish cephalopod trawlers are similar and operate in the same fishing zone using the same fishing technique. Moreover, Moroccan boats are operated by experienced officers from foreign fleets. The 1979 catch statistics were taken from Shimura (1979, in Idelhadji, 1984). From 1980 to 1998, data from the Ministry of Fisheries was used. The catch composition of the different species was reconstructed throughout the years by using a combination of information found in the FAO statistics, the Ministry of Fisheries, Belvèze *et al.* (1982), Dochi and Lahlou (1983), Haddad (1994), and Kabadou (1996).

The foreign fleets

The recorded landings of the foreign fleet were based on the FAO electronic data set for the period 1972-1997 and on the printed Statistical Bulletin for the years 1964-1971 (FAO, 1976, 1979). Most industrial foreign fleets only started in the 1960s, except for Spain and Portugal. Data for the period 1950-1963 were difficult to obtain as fish were landed in foreign ports and reported without reference to the origin of the catch. We obtained partial landings for Spain (see Guénette *et al.*, this volume) but our estimation of the landings are likely underestimates for this period. This information was modified using catch data found in various working group reports (Anon., 1978a, b, c, 1982, 1986, 1990a, b; Lamboeuf *et al.*, 1984; Lamboeuf, 1997a, b, c).

Unreported landings

In 1984, the unreported landings of the coastal fisheries was estimated at 23% of the total reported landings in the ports of Tangier, Casablanca and Agadir (El Hannach *et al.*, 1986). El Mamoun (1999a, b), in a study using direct observations and a fishers' survey, described illegal trading of fishery products. The ports

studied in the Atlantic (Tangier, Casablanca and Agadir) are important ports through which a large proportion of the coastal fleet landings transit. Except for Tangier, landings arriving from boats or transiting through ports are reported in a larger proportion (30-60%) than those being transported by trucks (land transportation: 12%) (see Appendix 1). Under-reporting seemed to be more important for cephalopods and crustaceans.

The difference between the results obtained in 1984 and 1999 are large (Table 1) and most likely correspond to a change in social and economic incentives in Morocco. Prior to the 1990s fish were not consumed much by the local population, thus opportunities to sell the fish locally and directly were scarce. In the 1990s, the demand for fish increased sharply at the same time as the human population increased (24,285,960 in 1990 to 29,596,788 in 1999) and facilities to transport fish in refrigerated trucks increased.

The percentage of unreported catch has not been studied for the industrial fleet. However, it is likely that the unreported catch was very large during the 1970s when most vessels were landing in the Canaries and other foreign ports. In absence of data, the unreported catch of the industrial fleet demersal and pelagic species is assumed to be 47%, the same as in the coastal fishery of the 1990s (Table 1).

A 1993 study of the marketing of fish in Morocco estimated that the landings processed through illegal channels amounted to 60% of total landings (Durand, 1995). Although the Moroccan ports were under surveillance for one week only, interviews showed that buyers at different levels were obtaining 60% of their merchandise through illegal channels. The authors described several processes by which part of the landings are hidden to avoid taxes. For example, the crew share of fish (fakira) supposedly amounting to no more than one tonne for species landed in large quantities, is in reality more than 10 tonnes, unreported and sold directly. Mackerels and anchovies were mentioned as valuable species frequently sold this way by the fishers.

We assumed conservatively that the unreported landings of the Moroccan coastal fishery amounted to 23% or 47% depending on the fleet and the decade of the total landings (Table 1). However, we also applied the value of 60% for the Moroccan catches for comparison purposes. We do not have any information about the amount of unreported landings for the foreign fleet. However, we can assume that foreign fleets also have incentives not to declare all their catches. Thus, we utilized minimum and maximum rates of 23 and 47% (Table 1).

Table 1. Percentage of unreported landings and discard rate by decade.

Fleet	Fishery	1970s	1980s	1990s
		Unreported landings [a]		
Coastal	all	23 (assumed)	23 (El Hannach et al. 1986)	47 (El Mamoun, 1999) or 60 (Durand, 1995)[d]
Industrial	all	?	47 (assumed)	47 or 60 (Durand, 1995)[d]
		Discards [b]		
Coastal	pelagic	?	4 (assumed)	4 (El Mamoun, 1999)
	demersal	?	?	12 (El Mamoun, 1999)
Industrial	demersal trawlers	66% (Balguerías, 1997) [c]	46 (Balguerías, 1997) [c]	30 (Haddad, 1994)

[a] Expressed as the percentage of the total landing
[b] Expressed as the percentage of the total catch
[c] Cephalopod trawlers
[d] Used only for Morocco

Discarded catch

Based on observations of the small-scale fishery of Tifnit, discards were considered non-existent, since local fishers sold or consumed the total catch (Baddyr, 1989).

The discard estimates for the coastal fleet were based on research in the port of Agadir, Tangier and Casablanca in the Atlantic (El Mamoun, 1999a, b). The pelagic fisheries were found to discard 4% of the catch of sardines (Table 1). Discarded sardines were those eliminated from net cleaning operations, and those thrown overboard at sea due to their poor condition or their low price in the market on a given day. Sardines represented 94% of discarded pelagic fishes (Oueld Taleb, 1988). Coastal bottom trawlers were found to discard 12% of their catches (El Mamoun, 1999a, b). Discards included undersized and badly damaged commercial species, as well as non-commercial species dominated by boarfishes (*Macrorhamphorus scolopax* and *M. gracilis*), small-spotted catshark (*Scyliorhinus canicula*), rays, silver scabbardfish (*Lepidopus caudatus*), crabs, conger eel *(Conger conger)* and rockfishes. Since bottom trawlers landed more than 90% of the catch of demersal species, discard rates were not distinguished among demersal fishing gears.

The amount of discards of industrial pelagic boats is considered insignificant (Haddad, 1994). Based on reports of Moroccan scientific observers working onboard foreign trawlers for the years 1989-1993, Haddad (1994) reported similar discard rates for various foreign fisheries observed: hake trawlers 16-45% and longline 30%, cephalopod trawlers 30% and Spanish shrimp trawlers 20-30%. We retained a discarding rate of 30% for the industrial bottom trawlers in the 1990s.

Studies of discards for the Spanish cephalopod commercial trawl fishery documented larger rates of discards (Balgueíras *et al.*, 1993; Balguerías, 1997). The 1976-1977 (103 hauls) study mentioned discards of 66% of the total catch, while the 1989-90 (22 hauls) study reported a rate of 46% (Balguerías, 1997). The species composition of the discards was dominated by invertebrates other than cephalopods (16-28%), seabreams (4-9%), Elasmobranchs (5%), Triglidae (searobins, 10%) and various other demersal species (Haddad, 1994). For comparison, Mauritanian cephalopod trawlers fishing in Mauritania and in Senegal were found to discard 72% and 60-75% of their catch, while the Senegalese mixed fleet (targeting finfish and shrimps in shallow waters) had a discard rate of 67% (Balguerías, 1997). As an indication of shrimps fisheries, the Senegalese shrimp trawlers operating in Senegal and Guinea are thought to have discarded 38.5% of their catch in the mid-1980s.

Moroccan and foreign trawlers only differ in that foreign trawlers are not allowed within 12 miles of the coast. In absence of more precise data, it was assumed that the amount of non-commercial species discarded at sea is the same for both foreign and Moroccan trawlers. However, extrapolating the species composition would be difficult as it is likely to change depending on area fished, methods used, depth, population abundance and market conditions. We assumed that the discard rate given by Haddad (1994) may be underestimated compared with the Spanish studies. We have no data of discards for tuna and other large pelagics which should not have a large impact on the total estimated catch.

RESULTS AND DISCUSSION

Moroccan fleets

The recorded landings of the Moroccan fisheries in the Atlantic increased by a factor of 2 from 1950 (139.7 thousand tonnes) to 1974 (264.3 thousand tonnes) and a factor of five from 1950 to 1998 (708.7 thousand tonnes, Figure 3). The maximum catch of 843.5 thousand tonnes was recorded in 1995. This substantial increase was related to an increase in the fishing effort of all fleet (small-scale, coastal, and industrial) and to the inclusion of the former Spanish Sahara in 1975, almost doubling the coast length. The coastal fleet dominated the recorded landings of the Moroccan fishing fleet. It represented, on average, 96.5% of the annual total recorded landing for the period 1950-1972, and more than 75% for 1973-1998 (Figure 3).

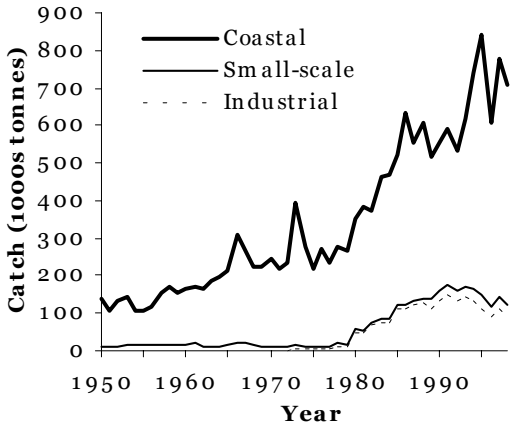

Figure 3. Recorded landings of Moroccan fishing fleets (cumulative graph).

Our estimate of landings for the small-scale fleet was approximately 25 thousand tonnes in 1993 (Figure 4). Durand (1995) reported an estimate of 30 thousand tonnes for this sector and the whole coast of Morocco, including the Mediterranean, and considered this number to be grossly underestimated. Thus, our reconstruction of the landings are probably very conservative for the whole period. During the period 1985-1998, demersal species were dominant in the landings, their catch increasing from 5.4 thousand tonnes in 1985 to 23.7 thousand tonnes in 1998. The spectacular increase at the end of 1989 was due to the development of the 'pot' trap technique to catch octopus in the southern part of Morocco (Dakhla). The landings of octopus increased from 3,000 tonnes in 1993 to 15,000 tonnes in 1998. In 1996, dories landed 22.3% of the total catch of octopus in the Atlantic. Their catch is so substantial and unregulated that the owners of the industrial fleet started to complain of unfair competition. Marine plants, collected by hand along the coast, dominated the catch in small-scale fisheries for the period 1950-1974, with their tonnage ranging from 10 to 18 thousand tonnes (Figure 4). The red Seaweeds (*Celidium* and *Graciliaris,* 90%) dominated the marine plants. The remaining is represented by *Laminaria*. Plants extracts were used as thickener agents in the food industry.

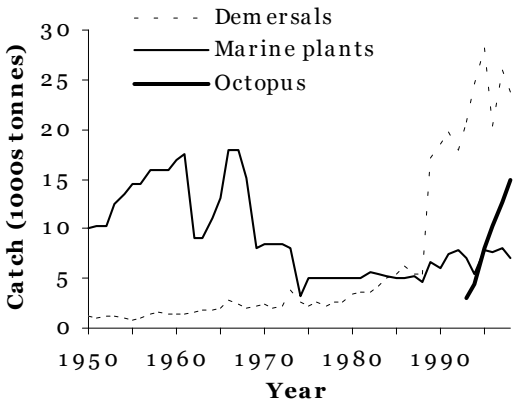

Figure 4. Composition of the recorded landings of the Moroccan small-scale fishery. The landings of octopus are already included in the demersals landings, estimated from the number of boats. Marine plants were taken from the FAO database. Sea mussels are not shown due to very small tonnage.

Small pelagic species have always dominated the total catch of the coastal fleet (Figure 5). Their catch increased from 110.8 thousand tonnes in 1950 to 485.5 thousand tonnes in 1998. The maximum catch of 618.1 thousand tonnes was recorded in 1995. The sardine (*Sardina pilchardus*) represented more than 85% of the annual landings from 1950 to 1998 (Figure 5).

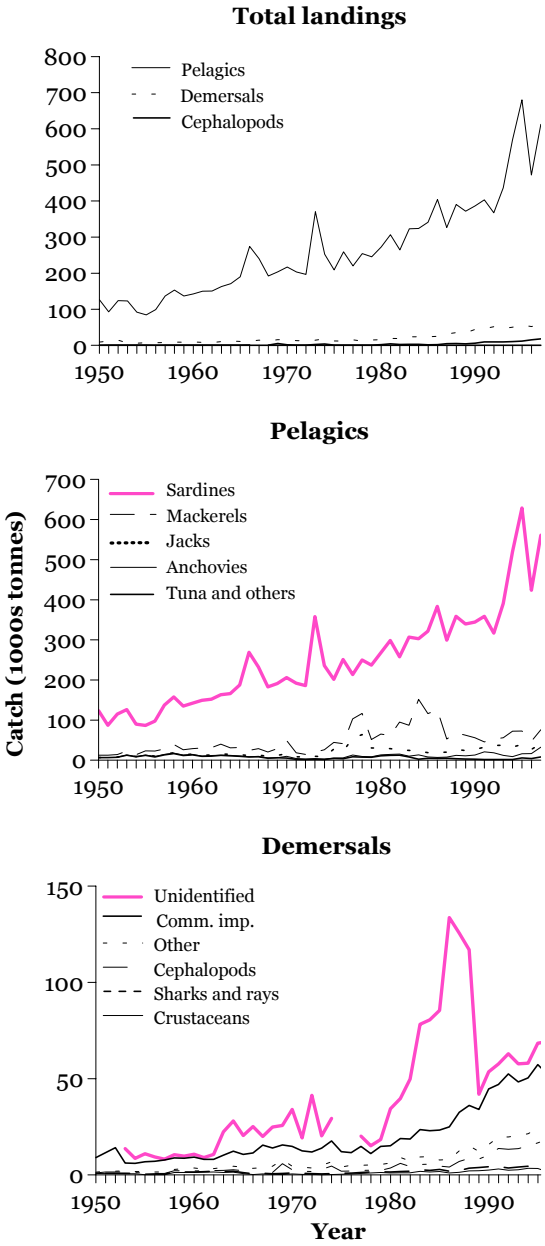

Figure 5. Composition of the recorded landings of the Moroccan coastal fishery. Crustaceans are mainly composed of European Rose shrimp. Commercially important demersals (Comm. imp.) include species from the following families: Trichiuridae, Sparidae, Merluccidae, Pleuronectiformes, Scianenidae, Haemulidae and Gadidae.

Mackerels are the second most important species in the small pelagic landings reaching a maximum in 1984 and 1986 of 127.3 and 101.7 thousand tones, respectively. Chub mackerel (*Scomber japonicus*) represented nearly 90% of the catch of mackerels (Belvèze *et al.*, 1982) while Atlantic mackerel (*Scomber scombrus*) is not important in the catch as the most southern limit of its geographical distribution is located near Agadir (30° N) and its abundance is low. Jacks (mainly the Atlantic horse mackerel *Trachurus*

trachurus) and anchovies (*Engraulis encrasicholus*) are landed in small quantities.

During the period 1950-1967, the catch of tuna species ranged from 4.1 to 13.5 thousands tonnes, and their annual average catch was 7.9 thousand tonnes. During the period 1968-1998, catches decreased substantially, ranging from 0.3 to 12.4 thousand tonnes, an average of 4.3 thousand tonnes per year.

The landings of demersal species is dominated by a mixture of unidentified species (Figure 5). Their landings varied from 1,700 tonnes in 1950 to 62,100 tonnes in 1998. The maximum was observed in 1986 with 120,000 tonnes (Figure 5). The catch of cephalopods, including octopus (*Octopus vulgaris*), squid (*Loligo vulgaris*), and cuttlefish (*Sepia officinalis*) increased from 200 tonnes in 1950 to 23,900 tonnes in 1998. The catch of sparids also increased from 5,400 tonnes in 1950 to 8,600 tonnes in 1998, with a maximum catch of 11,400 tonnes in 1992. Again, the opening of the Saharan coast to fishers of this fleet explains the increase in landings. The catch of hake (*Merluccius merluccius*) increased from 1.7 thousand tonnes in 1950 to 4.3 thousand tonnes in 1997. The maximum catch of 6.2 thousand tonnes was recorded in 1990.

With the exception of 1987, the catch of the Moroccan industrial fleet (composed to 94% of bottom trawlers) is dominated by demersal species (Figure 6), pelagic trawlers being present only from 1980-1998. Sardines (*Sardina pilchardus*) dominated the catch composition of small pelagic species (Figure 6) with landings increasing from 5,742 tonnes in 1980 to 29,034 tonnes in 1997. The maximum catch of 61,600 tonnes was recorded in 1987. The catch composition of demersals showed that cephalopods are the main targeted species (Figure 6) and during the period between 1973 to 1998, they represented a annual average of 68% of the total catch of demersal species. Their catch varied from 21,000 tonnes in 1973 to 63,000 tonnes in 1998. The overall annual catch of cephalopods is composed to 57 % of octopus, 15.7% of cuttlefish, and 9.4% of squid (Figure 6). The catch of sparids (seabreams) decreased from 13,124 tonne in 1984 to 3,240 tonnes in 1998, suggesting that these species may be overfished. The catch of flatfish species was relatively steady from 1980 to 1998 with an average catch of 3,800 tonnes per year. The catch of crustaceans started in 1986 with 812 tonnes and increased to 8,812 tonnes in 1998.

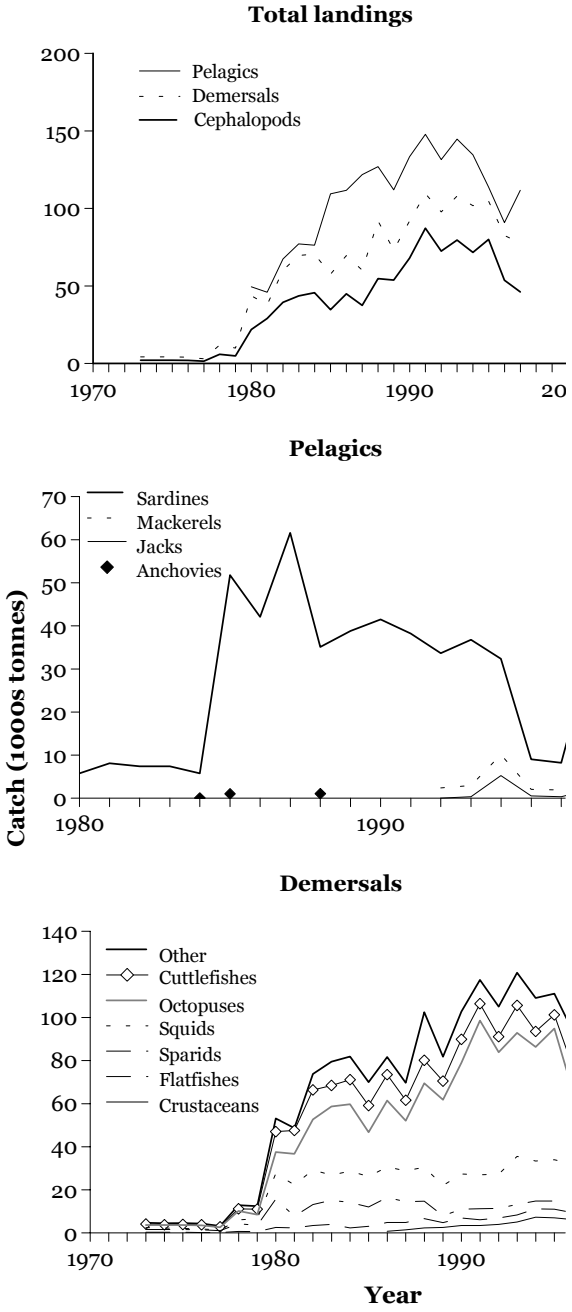

Figure 6. Recorded landings of the Moroccan industrial fishery. Composition of the total landings and of the pelagic and demersal species. Crustaceans consist mainly of Norway lobsters, shrimps and prawns.

Foreign fleet

Spain and Eastern European countries are the most important fishing countries on the coast of Morocco (Figure 7). During the period 1972-1990 the East European average landings (998.4 thousand tonnes) were more than two times larger than those of Morocco (402.2 thousand tonnes). For the same period, average Spanish

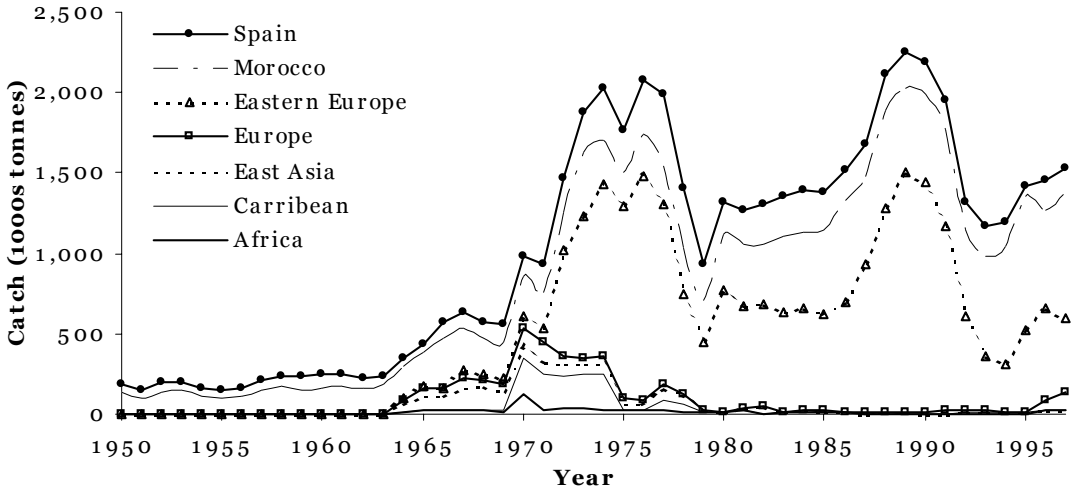

Figure 7. Recorded landings of foreign countries compared with Morocco.

landings amounted to 255 thousand tonnes, that is 86% of the Moroccan landings. These proportions decreased as access became increasingly restricted. Pelagic species, more precisely sardines, were the principal target species (Figure 8) and constituted 85% (62-92%) of the Eastern European landings. Spanish landings were dominated by demersal species, including cephalopods and crustaceans (see Guénette *et al.*, this volume). Note that a large part of the catch was reported as unidentified fish.

Landings reported by Japan were composed to 80% of cephalopods and demersal fish, with average catches between 1964-1979 of 46.5 and 12.5 thousand tonnes a year for cephalopods and fish, respectively. African countries, except Mauritania (i.e., São Tome, South Africa, Lybia and Ghana) have been fishing periodically in Moroccan waters, taking about 18 thousand tonnes a year between 1964-1979. However most of their catches remained unidentified. Mauritania's landings peaked at 30 thousand tonnes in 1972-1973, declining to 5,000 tonnes in the last two decades. European countries (excluding Spain) caught about 50 thousand tonnes of fish in the 1970s. Exceptional landings of about 40,000 t of round sardinella (*Sardinella aurita*) and 25,000 t of jacks (e.g., *Trachurus* spp.) in 1970-1971, and 41 and 87 thousand tomes of round sardinella in 1996 and 1997, respectively, inflated the catch of small pelagics for these countries.

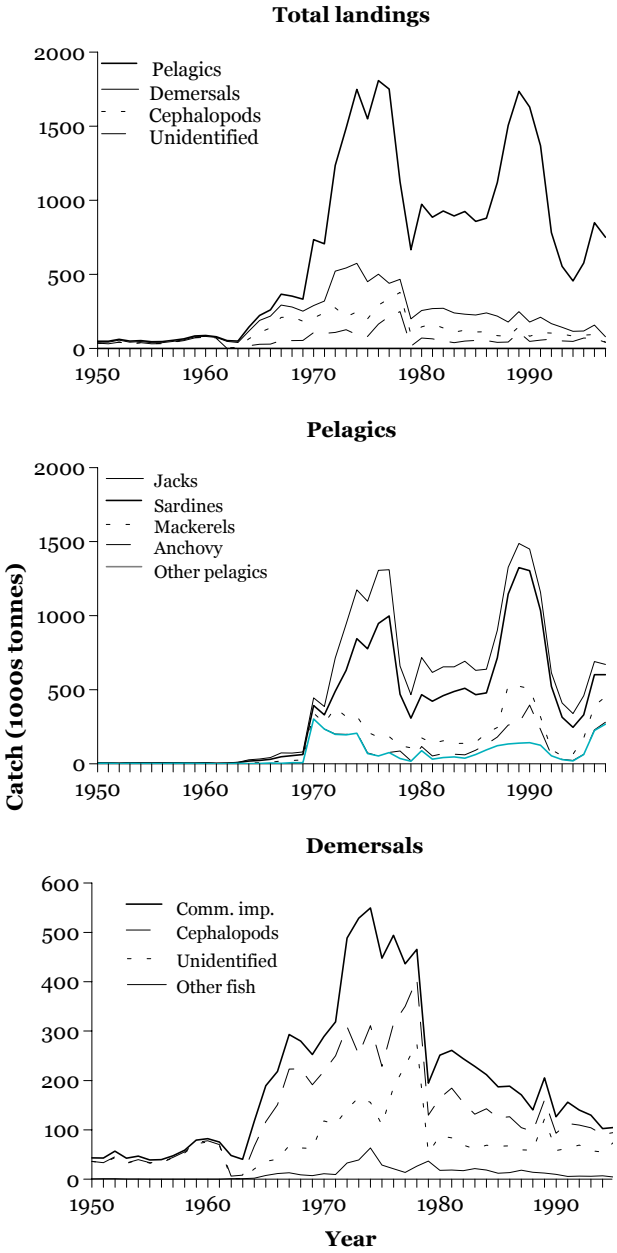

Figure 8. Composition of foreign landings. The demersal category in the total landings panel includes crustaceans, cephalopods, other invertebrates, shark and rays and demersal fish.

Comparing Reconstructed and FAO statistics

As FAO electronic data were not available before 1972 for the foreign fleet, statistics found in the various working group reports and those obtained from the official Spanish statistics (see Guénette *et al.*, this volume) were very important in reconstructing the catch before 1972. For the period 1950-1964, the new data added about 63 thousand tonnes or 45% of the reported landings. However, it is likely that our reconstruction for this earlier period is an underestimate.

For the period 1964 - 1997, the average difference between the reconstructed landings and FAO statistics is about 100,000 tonnes per year, or 9% of the reported landings (Figure 9). The difference for the foreign fleets is mainly due to the addition of catch data for hake (*Merluccius merluccius*), sardines (*Sardina pilchardus*), cephalopods, and seabreams from the various working groups. For Moroccan landings, the main difference is the addition of the artisanal landings which is still probably underestimated.

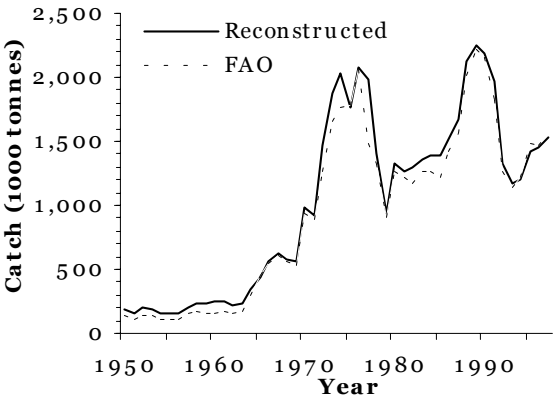

Figure 9. Comparison of FAO and reconstructed recorded landings.

Unreported landings and discards

For simplicity we computed average tonnage of discards and unreported landings and average total catch over each decade throughout this section.

For the Moroccan coastal pelagic fishery, where discards are estimated to be a small percentage of total catch (4%), unreported landings are the major source of discrepancy between the reported landings and total catch. This is especially so in the 1990's when unreported landings were estimated to be 47% to 60% of total landings (Table 1). Using these percentages, the average total catch for this decade was estimated to range from 858,028 tonnes to 1,136,160 tonnes (Figure 10), compared to reported landings of 436,564 tonnes for this period. Estimated total average catch for the 1980s, where a percentage of 23% was applied for unreported landings (no discard rate was available), total average catch was estimated as 384,551 tonnes compared to an average reported landing of 296,104 tonnes for that decade (Figure 10).

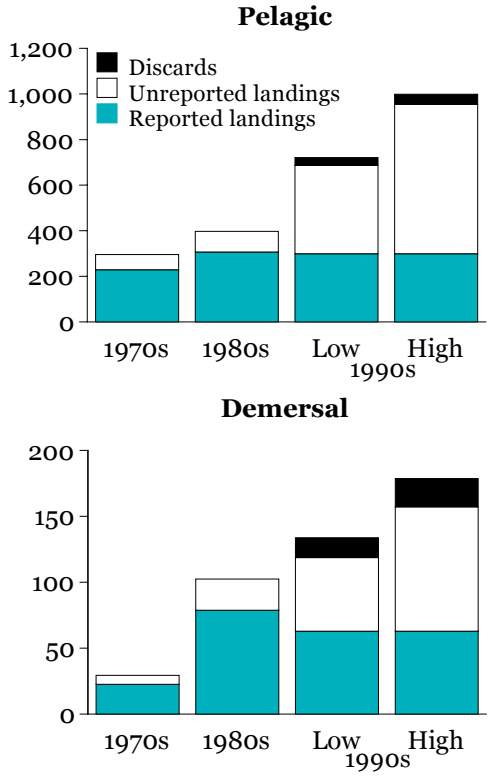

Figure 10. Decadal average reported landings, unreported landings and discards of the Moroccan coastal fishery. Missing discards correspond to missing estimates.

The two percentages (47% and 60%) of unreported landings were also applied to the Moroccan coastal demersal fishery, yielding estimates of unreported landings of 45,150 and 76,370 tonnes for the 1990s. (Figure 10). Discards, estimated at 12%, added another 12,266 to 17,357 tonnes for this decade. Thus, average total catches ranged from 108,329 tonnes to 144,640 tonnes (depending on percentage used for unreported landings) compared to the reported landings of 50,913 tonnes.

Similarly, unreported landings for the Moroccan industrial fishery in the 1990s, were estimated at 25,978 and 43,941 tonnes for the pelagic fishery (no discard percentage estimated) and 85,815 and 145,156 tonnes for the demersal industrial fishery (Figure 11). Discards for the latter would amount to 134,045 to 177,610 tonnes. Demersal discards and unreported landings totaled 316,632 tonnes to 419,537 tonnes compared to reported landings of 96,770 tonnes. Pelagic total catches would amount to 55,272 tonnes to 73,235 tonnes, compared to reported landings of 29,294 tonnes. If the proportion of unreported landings mentioned in Durand (1995) is a realistic estimation and widespread, the impacts on stock assessments and fisheries management could be considerable.

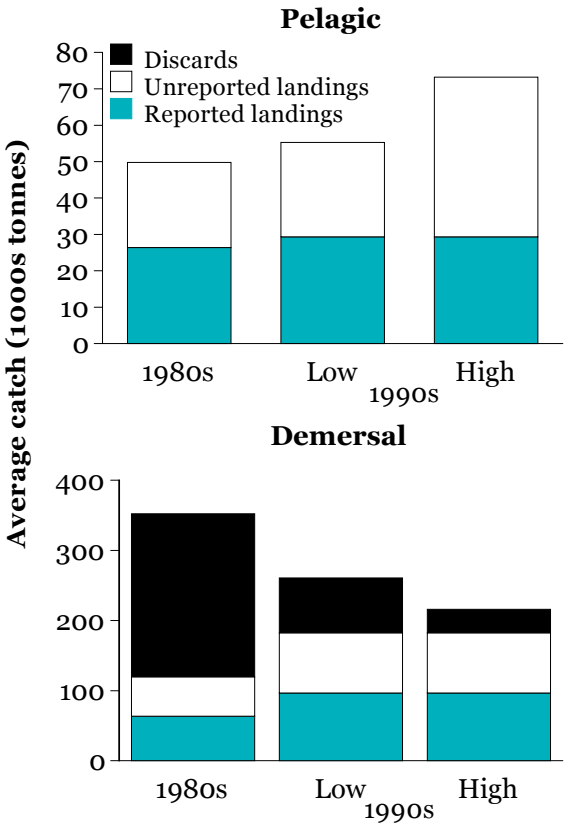

Figure 11. Decadal average of reported landings, unreported landings and discards of the Moroccan industrial fishery.

Discards and unreported landings for the foreign fishery (Figure 12) were calculated assuming similar rates as for Moroccan coastal and industrial fleets (23 to 47%). Unreported landings for the demersal fishery would vary between 71 and 211 thousand tonnes in the 1980s, and between 44 and 130 thousand tonnes in the 1990s. Similarly, unreported landings for the pelagic fishery vary between 252 and 789 thousand tonnes in the 1980s, and 205 and 608 thousand tonnes in the 1990s (no discard estimates available). Discards contributed an estimated minimum of 132,613 t in the 1908s and 81,677 t based on a discard proportion of 30% (Table 1).

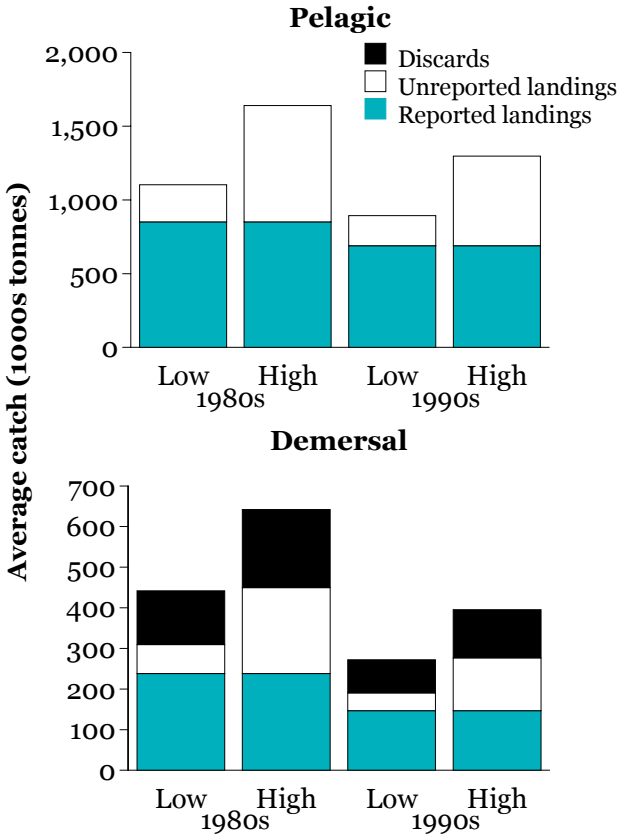

Figure 12. Decadal average of discards and reported and unreported landings for the foreign industrial fishery.

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APPENDIX 1. DISCARDS AND UNREPORTED LANDINGS AS REPORTED BY EL MAMOUN (1999a, b)

Percentage of discards and unreported landings for the coastal fleet according to El Mamoun (1999a, b). The percentage of discards relate to the total catch, while the unreported landings are expressed as the percentage of total landings (after discarding takes place).

	Total landings in 1997 (tonnes)	**Trawlers and longliners**		**Sardine boats**	**All sources**	**Average**
		seaway	**transit only**	**seaway**	**land transportation**	
Casablanca	26,465	-	-	-	-	-
discards	-	10	-	6	-	8.0
non-reported	-	67	67	55	88	69.3
Agadir	63,283	-	-	-	-	-
discards	-	12.46	-	3	-	15.5
non-reported	-	47	37	40	-	41.3
Tangier	5,984	-	-	-	-	-
discards	-	8	-	-	-	8.0
non-reported	-	17	-	-	3	10.0
weighted average discards		***11.5***	-	***3.9***	-	-
weighted average non-reported		-	-	-	-	***47.1***

SPANISH FISHING ACTIVITIES ALONG THE SAHARAN AND MOROCCAN COASTS

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ABSTRACT

Because of the geographical proximity between Spain and Morocco, and the poor resources around the Canary Islands, the fishers from the southern region of the Spanish mainland (especially Andalusia) and from the Canary Islands have been fishing along the African coast very early in history. Boats operating from the Canaries exploited resources on the Saharan coast (former Spanish province in Africa situated between approximately 21°N and 28°N and since 1976 under Moroccan administration), while those from Andalusia used to fish along the Atlantic Moroccan coast (between approximately 28°N and 36°N). Considering its historical importance, we briefly describe each of the fisheries, the landing data and their sources.

INTRODUCTION

Spanish catches along the Saharan and Moroccan coasts (Figure 1) were taken from several sources:

1. Official Spanish statistics for all boats landing in the Canaries between 1933-1972, as collected by the Spanish fisheries authority. This dataset is contained in a series of statistical bulletins published annually by landing region (e.g. Canary region, Andalusia region, etc.) and by species or group of species. The publication was discontinued after 1972. Most landings in the Canary region can be separated by their fishing origin (i.e., Canary Islands, Saharan coast) applying some basic criteria. However, those made in the Andalusia region are almost impossible to differentiate according to their fishing origin (Spanish coast, Moroccan coast, Portuguese coast).
2. Statistics for the fleets fishing for cephalopods (trawlers), for hake (*Merluccius merluccius*, *Merluccius senegalensis*) and shrimp (trawlers, gillnetters, longliners), for sardine (*Sardina pilchardus*; purse seiners), and for other demersal species (artisanal fleet using handlines and pots) for years 1976-1998, are collected by the Instituto Español de Oceanografía (IEO). This dataset consists of actual landing data recorded by a network of IEO technicians located at the landing ports in the Canaries and Andalusia. They record information on landings by species or group of species of every single Spanish vessel by trip, and also collect details such as fishing effort, gears used and fishing grounds visited. The statistical network was first established in the Canarian ports in 1975 and in the major fishing ports of Andalusia in 1980. Thus, data series start in 1976 and 1981 for each of the regions respectively.
3. FAO electronic data for the years 1972-1997. This data is compiled by the FAO from the STATLANT forms officially submitted by fishing nations and is available via the Internet.
4. Various working group reports provided information on sardines (Anon., 1978b, 1990; Lamboeuf, 1997b), hakes (Anon., 1978c; Lamboeuf, 1997c), cephalopods (Anon., 1978a, 1982; Lamboeuf, 1997a) and seabreams (Anon., 1986). The Spanish data within the working groups reports contain the same information as obtained from source 2 that have been submitted by IEO scientists to the working groups.

Data from different sources often overlapped and were sometimes conflicting. Thus, the data were examined by species and area. We used different sources of data to reconstruct temporal series depending on their reliability.

The Spanish fishery on the Atlantic Moroccan coast (28°N-36°N) is dominated by demersal fish (mainly hake) and crustaceans (mainly shrimp). There is also a limited fishery for small pelagics, mainly anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*), mackerel (*Scomber japonicus*) and horse mackerel (*Trachurus trachurus*) in the northern part of this coast (the 'North Zone') which extends from approximately 32°N to 36°N. As indicated in item 1 above, the reconstruction of long time series of landings from these fisheries is unreliable, mainly because of the mobility of vessels between fishing grounds and the similarity of the species that can be found in them, thus making it virtually impossible to discern the geographical origin of the catches. The only reliable statistical series on the Spanish catches made in this region starts in 1981 as stated in item 2 above . However, newly available information on landings in ports other than in the

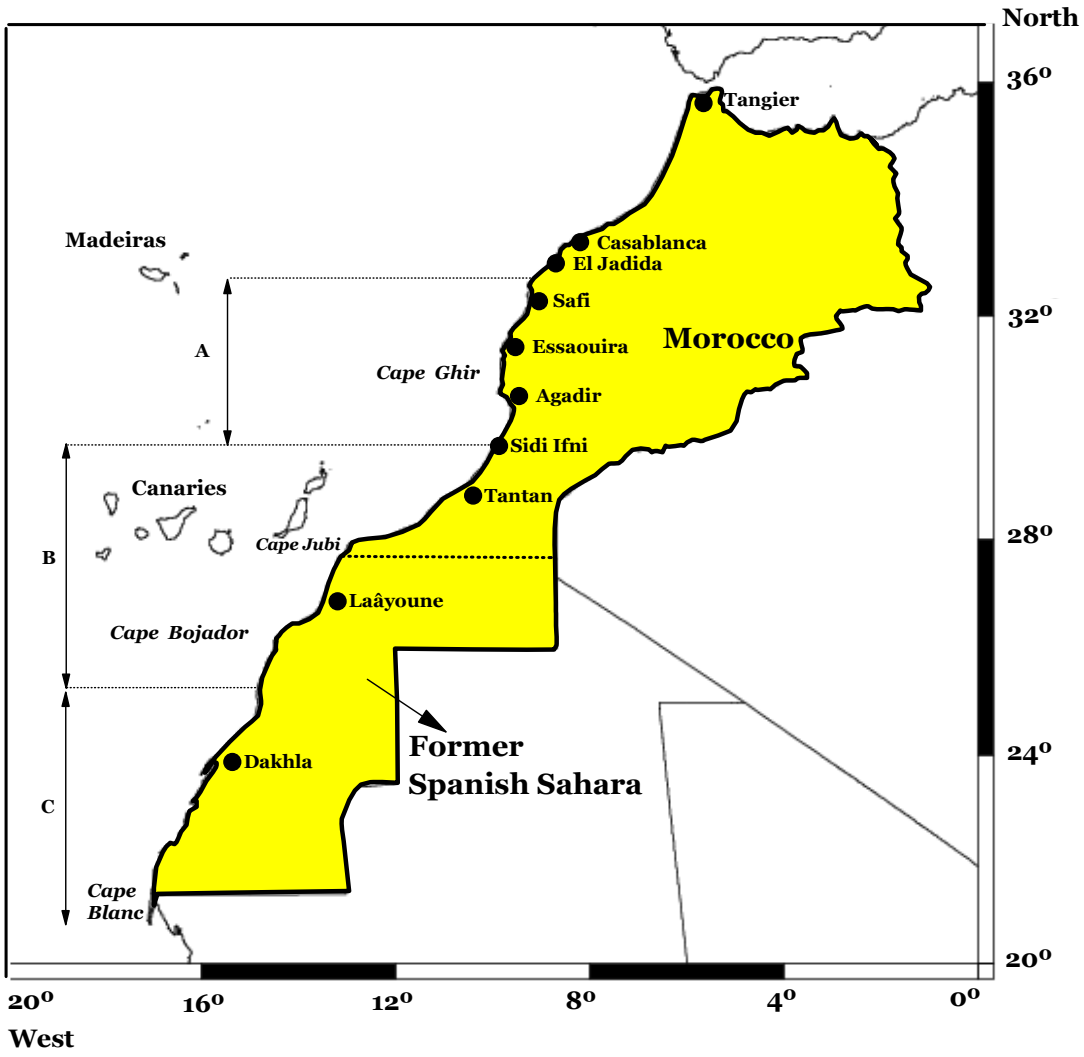

Figure 1. The Atlantic Moroccan coast showing the principal fishing ports, and the border with the former Spanish Sahara.

Andalusia region will be included in the dataset in the near future. In practical terms this means that figures on landings from some fishing gears (e.g., longliners fishing for hake) may be underestimated.

Major target species in the Saharan coast are sardines, demersal fish (mainly seabream) and cephalopods (octopus, cuttlefish and squid, Figure 2) for which the landings statistics are available since 1933. The first period, 1933 to 1972, was reconstructed using the Spanish official statistics described in source 1 above. There is a gap in data between 1935 and 1939 due to the Spanish Civil War. The second period in the series extends from 1975 onwards and was prepared using data gathered by the network of IEO technicians based at the landing ports (source 2 above). There is an intermediate period covering years 1973 and 1974 when the Spanish official statistics had already been terminated and the IEO network was not yet established. Therefore it was only possible to estimate landings of target species using alternative sources (e.g., professional associations). During this period, records of discarded species are absent. The rapid increase in catch in the 1960s in this region is due to the development of the specialized fisheries for sardine and cephalopods, which were landed in Canarian ports, as well as improved statistics gathering.

Currently, the fishing industry in these two regions can be divided into four main types of target species: the sardine (*Sardina pilchardus*), cephalopods (*Octopus vulgaris*, *Sepia hierredda*, *Loligo vulgaris*), hake (*Merluccius merluccius*, *Merluccius senegalensis*) and shrimps (*Parapenaeus longirostris*), and seabreams (family Sparidae) and other demersal fish.

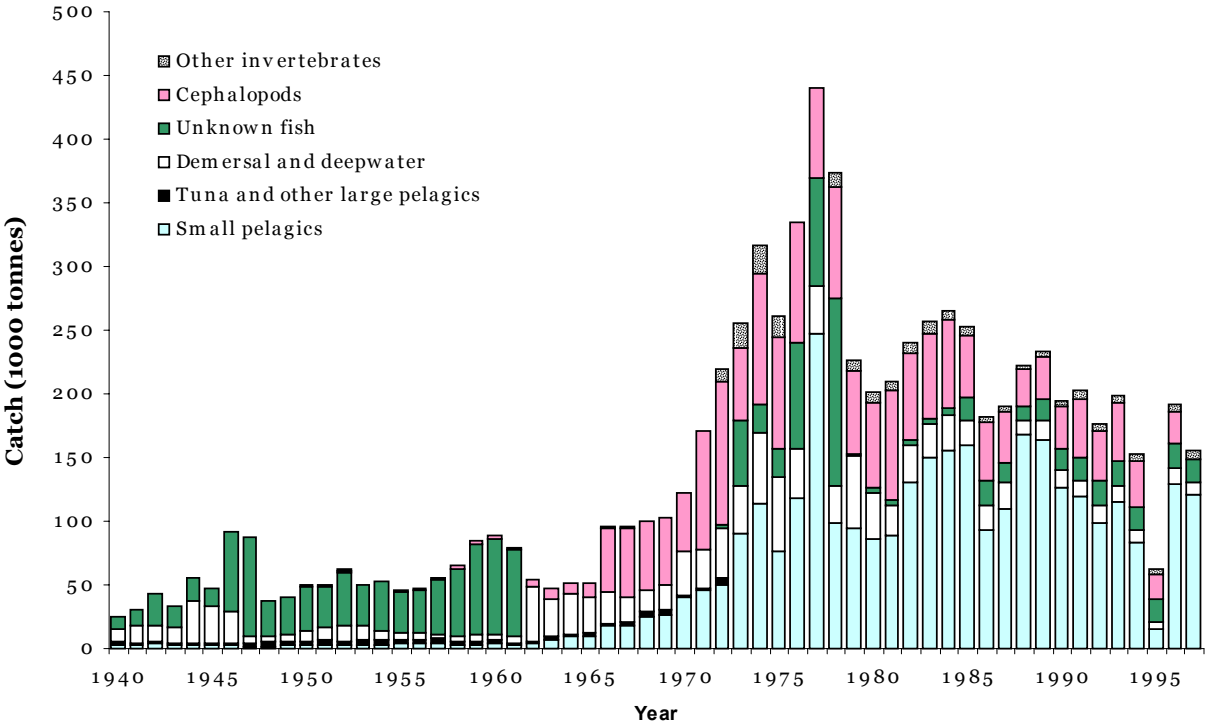

Figure 2. Spanish landings taken on the Saharan coast from 1940 to 1997.

The sardine fishery

Spanish vessels started fishing sardines, *Sardina pilchardus* (Clupeidae), along the northern Atlantic coast of Morocco in the North zone (32°N-36°N) in 1920 (García Santamaría, 1995). The only available data series on landings from this fishery starts in 1988 and indicates that currently the most important species in the catches is the anchovy (*Engraulis encrasicolus*), followed by the sardine, the mackerel (*Scomber japonicus*) and the horse-mackerel (*Trachurus* spp.). In the 1930s, the construction of ports in Safi and renovation of Essaouira attracted Spanish, Portuguese and French fleets further to the South (zone A, between 29°N and 32°N), which had a larger sardine stock than the north coast of Morocco. An artisanal Moroccan fleet also started to fish sardines around that time. In the 1950s, sardine catches were increasingly landed in Arrecife (Canaries) which had a canning plant. Then, in the 1960s, a fleet was established in the Canaries. Both Canarian and Spanish mainland fleets concentrated their effort in zone B (Saharan and Moroccan coasts, from 26°N to 29°N).

Looking at the series of global landing statistics for the Spanish fisheries in Morocco and Sahara reconstructed by combination of data from different sources, a sudden increase is observed in the 1960s. This increase in landings is very likely linked to the establishment of a fleet in the Canaries supplying raw fish to the canning factories which also facilitated the gathering of better statistics. In fact, the catch location is difficult to determine when all landings of larger boats were made in continental Spain, thus, statistics are not reliable before the 1960s. From the 1960s onwards, they correspond to catches made in zones B and C (zone C is in the Saharan coast between 22°N and 26°N) exclusively. According to these statistics, sardine landings from the Spanish fleet have remained high over the years, with an average yearly catch of 114 thousand tonnes between 1976 and 1993. Other species of small pelagics caught in the fishery, especially in the 1970s but little since, include the chub mackerels, mackerels, anchovy (Figure 3).

Since the end of the 1980s, access to the fishing grounds for the Spanish fleet has been increasingly restricted and the catches reduced accordingly. In 1995 the protocol between the European Union and Morocco led to the replacement of the Spanish fleet with the Moroccan fleet in zone B. The Spanish vessels were displaced further south (zone C), which had always been the active fishing area of other countries, principally the former USSR and other Eastern European countries. The dramatic decline in landings observed in 1995 is due to the seven months of inactivity of the Spanish fleet during the period of negotiation of a new fishing agreement between the European Union and Morocco.

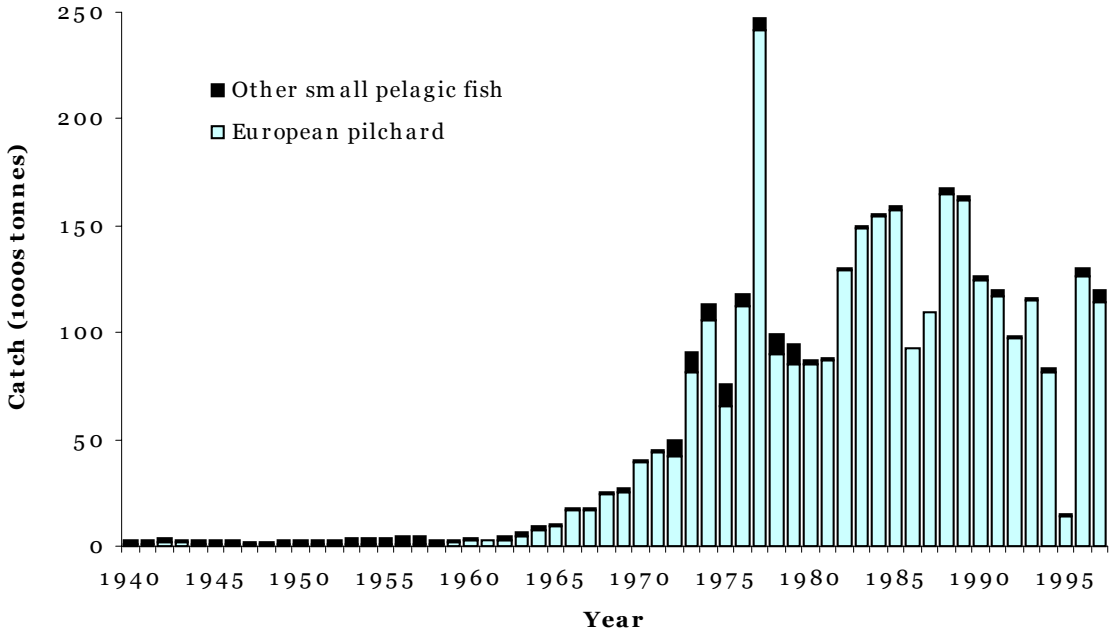

Figure 3. Spanish landings of small pelagics from the coast of the Sahara.

Some discrepancies between the FAO data and the Spanish official statistics have been observed for these fisheries (Figure 3) in the period 1982 to 1985 and from 1994 onwards. For the 1980s, the differences between datasets are unclear but they are most likely a result of transcription errors or reporting inaccuracies. For the 1990s, official statistics were not available thus, landings were estimated by FAO (Luca Garibaldi, FAO, Rome, pers. comm.). Considering this, we are more confident on the accuracy of data from the working groups as provided by the IEO which is based on individual surveys of every single Spanish vessel landing at the Canarian ports.

The cephalopod fishery

Cephalopods were always caught as a by-catch of the Saharan demersal fishery (between 21ºN and 28ºN) but it was only in the 1960s that significant markets opened for these species (Balguerías *et al.*, 2000). The Spanish cephalopod fishery started in 1963 in the region of Dakhla (located between Cap Blanc (21ºN) and Cap Bojador (26ºN)) using trawlers which, initially, were delivering their catches to processing boats. By 1969, the Spanish fleet had 39 freezer trawlers and very soon became completely autonomous from the processing boats. The number of Spanish vessels increased to 297 boats in 1980, then gradually decreased to around 80 in 1999 due to the restrictions introduced in successive fishing agreements between the European Union and Morocco. In parallel, the activity of the Moroccan fleet which started fishing for cephalopods in the region in 1978, increased continuously to 324 boats in 1991, decreasing slightly down to 300 boats during the last decade (Lamboeuf, 1997a).

Data on landings of cephalopods by Spanish vessels have been prepared using Spanish official statistics for the period 1933-1972 and statistics collected by the IEO and submitted to the various working groups for the period 1973-1997. The series shows that the fishery had its strongest years between 1973 and 1983, with an average yearly catch of 75 thousand tonnes (Figure 4). The average catch between 1984 and 1996 decreased substantially to 39 thousand tonnes, mostly due to the reduction in the number of vessels authorized to fish. Octopus (*Octopus vulgaris*), represents an average of 65% of the total catch in the period of the specialized fishery (1963-1996). Squids, mainly *Loligo vulgaris*, and cuttlefishes, mainly *Sepia hierredda*, constitute secondary targets. Their proportions in the catch vary considerably between years (Figure 4).

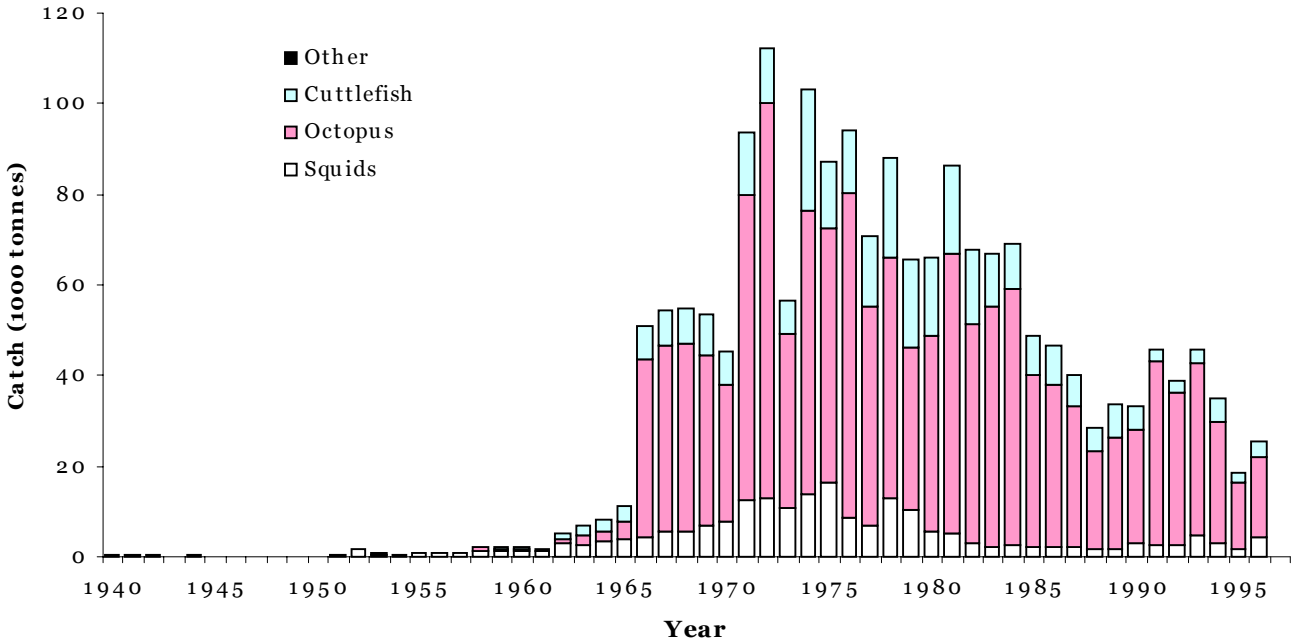

Figure 4. Breakdown of the cephalopod landings from the coast of the Sahara.

The hake and shrimp fishery

Two species of hake are found along the coasts of Morocco and Sahara. The white hake, *Merluccius merluccius*, is distributed approximately from the Strait of Gibraltar (36°N) to Cap Blanc (21°N). The Senegalese hake, *Merluccius senegalensis* has a more southerly distribution. It is found mixed with *M. merluccius* starting at Cap Cantin (33°N), and occurs together with the black hake (*Merluccius polli*) in latitudes south to Cap Blanc (21°N).

Spanish trawlers started to fish on the Moroccan coast in the middle of the 19th century, although the fishery developed rapidly only after the Spanish Civil War (1936-1939) (Sobrino, 1998). The boats presently in use were built in the 1940s, and target both hake and the deepwater shrimp *Parapenaeus longirostris* (Crustacea, Penaeidae). The secondary species caught vary among landing sites and include blue whiting (*Micromesistius poutassou*), scarlet prawn (*Plesiopenaeus edwardsianus*) and Norway lobster (*Nephrops norvegicus*). The effort of the Spanish trawlers has declined over the years as fishing activity has become increasingly restricted in the successive agreements between the European Union and Morocco (Ramos *et al.*, 2000).

The use of gillnets started in 1977, developed particularly in 1992 and 1993, and decreased in 1994 after monofilament was banned. The main gillnet target is white hake although an important augmentation has been observed in catches of the Senegalese hake during the last years, probably due to the extension to the south of the traditional fishing grounds. Secondary species caught in the fishery are seabreams (*Pagellus* spp., *Dentex* spp.), anglerfishes (*Lophius* spp.) and John dory (*Zeus faber*).

Spanish longliners started fishing in Moroccan waters in 1982. Their main fishing grounds extend between 31°N and 36°N. The target species of the fleet is white hake, followed in importance by Senegalese hake and Atlantic pomfret (*Brama brama*). The latter species seems to have become more abundant and a part of the fleet is now targeting them exclusively. Their main fishing grounds extend between 31°N and 36°N but during the last years they have extended their activity to grounds along the Saharan coast (21°N-28°N) which is reflected in the augmentation of catches with the Senegalese hake.

There is also a specialized fishery targeting *Merluccius senegalensis* which is exclusively by Spanish trawlers in Saharan waters. Bycatch species in this fishery are mostly seabreams (*Dentex* spp.), John dory and anglerfishes.

The landing series of hake (*Merluccius* spp.) and shrimp (*Parapenaeus longirostris*) from all the Spanish fisheries (trawlers, gillnetters and longliners) in the Moroccan and the Saharan coasts have been prepared using the Spanish

official statistics (from 1940 to 1972) and the statistics collected by the IEO and submitted to the various working groups (from 1973 to 1997) (Lamboeuf, 1997c). Catches of hakes increased substantially in 1970 and remained high for several years while those of *Parapenaeus longirostris* have been relatively high in the period 1958-1969 and slightly lower but stable ever since (Figure 5). Nevertheless, the initial increase in hake landings may be attributed to improvements in reporting rather than actual catch increases, as catch estimates of any of these species before 1970 are considered unreliable (Anon., 1978c) and do not include the landings made in Andalusia where most of the fleet was based. The hake fisheries decreased somewhat in the mid and late 1980s before increasing again in the early 1990s (Figure 5). These latter changes are expected considering the concurrence of imposed restrictions by fishing agreements of the Spanish fleet in terms of number of vessels allowed to fish and the simultaneous establishment of new fisheries targeting hake (gillnetters, longliners).

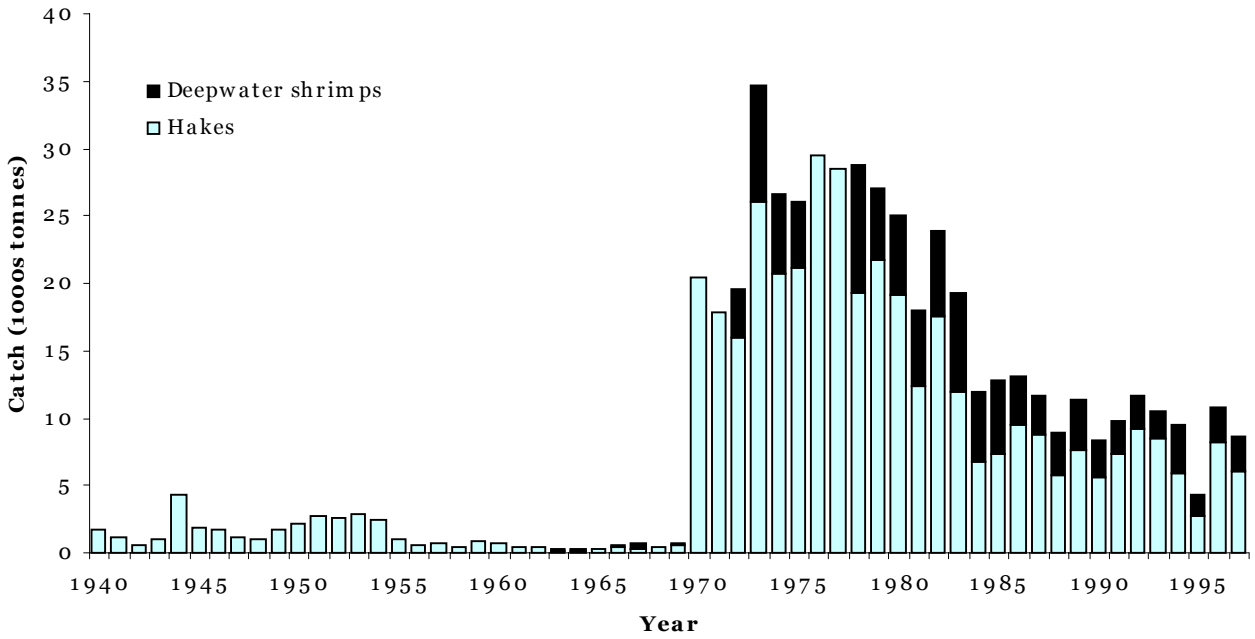

Figure 5. Landings of the Spanish hake and deep water shrimp (rose shrimp) fishery on the coast of Sahara.

Sparids and other demersal fish (except hake)

Sparids are targeted by hook and line and trap fishers operating from the Canaries. This artisanal fishery which occurs in Saharan waters (21°N-26°N) started in the 15th century and was exclusively exploited by Canarian fishers until the middle of the 20th century. During the Second World War many trawlers displaced from their traditional fishing grounds went south to operate in the Sahara fishing for finfish. After the war the activity of these industrial fleets consolidated and diversified in the course of the years giving place to more specialized fisheries (e.g., cephalopods, hake). Meanwhile the Canarian artisanal fishery became gradually less important in relation to the newly established fisheries (Balguerías, 1995).

Consequently, nowadays sparids and other demersal fish are target species only for the Canarian artisanal fleet operating the Saharan coast, but are also fished incidentally by other industrial fleets working both the Moroccan and the Saharan coasts (Anon., 1986). Taking these circumstances into account, it is difficult (if not impossible) to reconstruct the catch series for these demersal species since most of them are not declared or recorded in the landings of the industrial vessels. Even when reported, these demersal species are usually grouped under the heading 'other fish'. This is clearly the case for Spanish fisheries occurring in the Moroccan coast (28°N-36°N).

Regarding the Spanish fisheries in the Sahara, there is a series of landing data extracted from the Spanish official statistics (from 1940 to 1972) and the statistics collected by the IEO (from 1973 to 1998, and submitted to the various working groups). The former provides information on global catches by species or group of species from

all fleets operating in the region. The latter has been gathered by fleet, but pools species in general groups except for the Canarian artisanal fleet for which there are complete records by species for the period 1980 to 1998. Major catches of this fleet are the Sparids *Dentex gibbosus* (30% on average over the total catch in the whole period) and *Spondyliosoma cantharus* (16%) and the Haemulid *Plectorhinchus mediterraneus* (14%). Other species have accounted for less than 10% of the total catch in the period 1980-1998. The importance of these annual catches in terms of weight is negligible compared to those of the industrial fleets. Annual catches range from a minimum of 1,100 tonnes in 1995 (due to the seven months of inactivity during the re-negotiation of the fishing agreement between the European Union and Morocco) to a maximum of 3,100 tonnes in 1993, with an average catch of around 2,000 tonnes over the whole period.

Landings of demersal fish by the Spanish freezer trawlers fishing for cephalopods on the Saharan coast from 1973 to 1998 have varied between 3,900 tonnes and 15,500 tonnes with a mean annual value of 9,700 tonnes. Most of these catches (around 20% in weight) were constituted of flatfishes (Pleuronectiformes, especially *Solea vulgaris* and *Dicologoglossa cuneata*), while sparids account for only 2% to the total catch in the period considered. The remaining Spanish industrial fleets operating in the area (trawlers, longliners and gillnetters fishing for hake) have smaller by-catch of demersal fish in their landings

Another apparent source of bias in estimating actual catches of demersal fish by Spanish vessels fishing off the Moroccan and Saharan coasts are discards. This practice has only been assessed in the Spanish cephalopod fishery occurring in the Sahara. Several experiments carried out on the subject in 1976, 1977, 1989 and 1990 showed that the mean percentage of discarded animals and plants in the fishery was approximately 62%. These discards were mostly comprised of invertebrates other than cephalopods and some sparid species (Balguerías, 1997). However, dramatic changes can be observed in discards depending on the season and the geographic location of the hauls. Discards in hake fisheries are unknown but they are believed to be much smaller giving the selectivity of some of the gears employed (specially the longlines) and the smaller biodiversity and abundance of other fish species at the depths where fishing takes place. No discards or negligible discards have been recorded in the Canarian artisanal fishery, based on observer coverage on some vessels of the fleet.

Looking at the complete catch series of demersal fish (except hake) from the Sahara, it seems that sparid landings have been periodic, with high values in the mid-1940s and the 1960s (Figure 6). This trend is most likely related to the establishment of the trawling fishery after the Second World War and the beginning of the cephalopod fishery. Catches of other demersals are low in comparison. Those of drums or croakers (Sciaenidae) and grunts (Haemulidae) have decreased since the 1960s, while those of flatfishes (Pleuronectiformes) have increased proportionally (Figure 6) because of their higher commercial value and their abundance in the cephalopod fishing grounds.

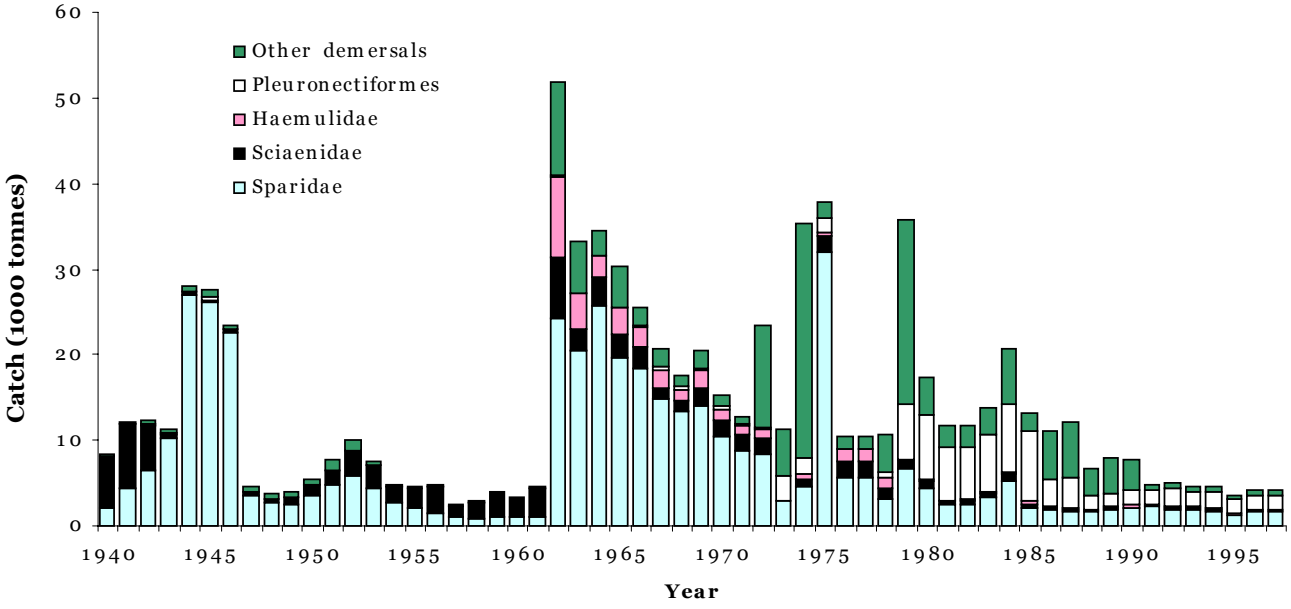

Figure 6. Landings of the Spanish demersal fishery on the coast of Sahara.

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FISHERIES OF THE AZORES (PORTUGAL), 1982-1999

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ABSTRACT

Catch statistics are presented for the Azores Islands (Portugal) by type of fishery. These data were compared with the official ICES statistics (STATLANT) for the years 1982-1999. This represents the time period for which detailed catch statistics have been collected in the Azores. For each fishery, the proportion of under-reported catch is estimated. The fisheries in the Azores are dominated by tuna landings, although several demersal and deep-water species are also targeted. The latter have increased in importance in recent years.

INTRODUCTION

The Azores archipelago (Figure 1) is a group of nine volcanic islands situated on the Mid-Atlantic ridge. The islands and their contiguous shelf (< 500 m depth) have an estimated area of 412 km², which represents only 0.4% of the Azores EEZ of about one million km², while seamounts (< 500 m depth) account for an additional 0.3% (Isidro, 1996). Thus, the shelf is narrow or absent, and fishing grounds are scattered.

Fisheries in the Azores started in the 1600s, long after the colonization of the islands in the early 15th century. Scientific studies in the early 1900s indicated that fish abundances were higher at that time. The present fisheries exploit about 50 species of the 500 fish species composing the ecosystem. The fishery is characterized by small-scale vessels using gillnets, traps and various forms of hook and line. Until 2000, trawlers have never been used around the Azores. Fishing grounds are limited because of topography and technology, and in practice fishing occurs only around islands (about 50 nm) and nearby seamounts (Figure 1).

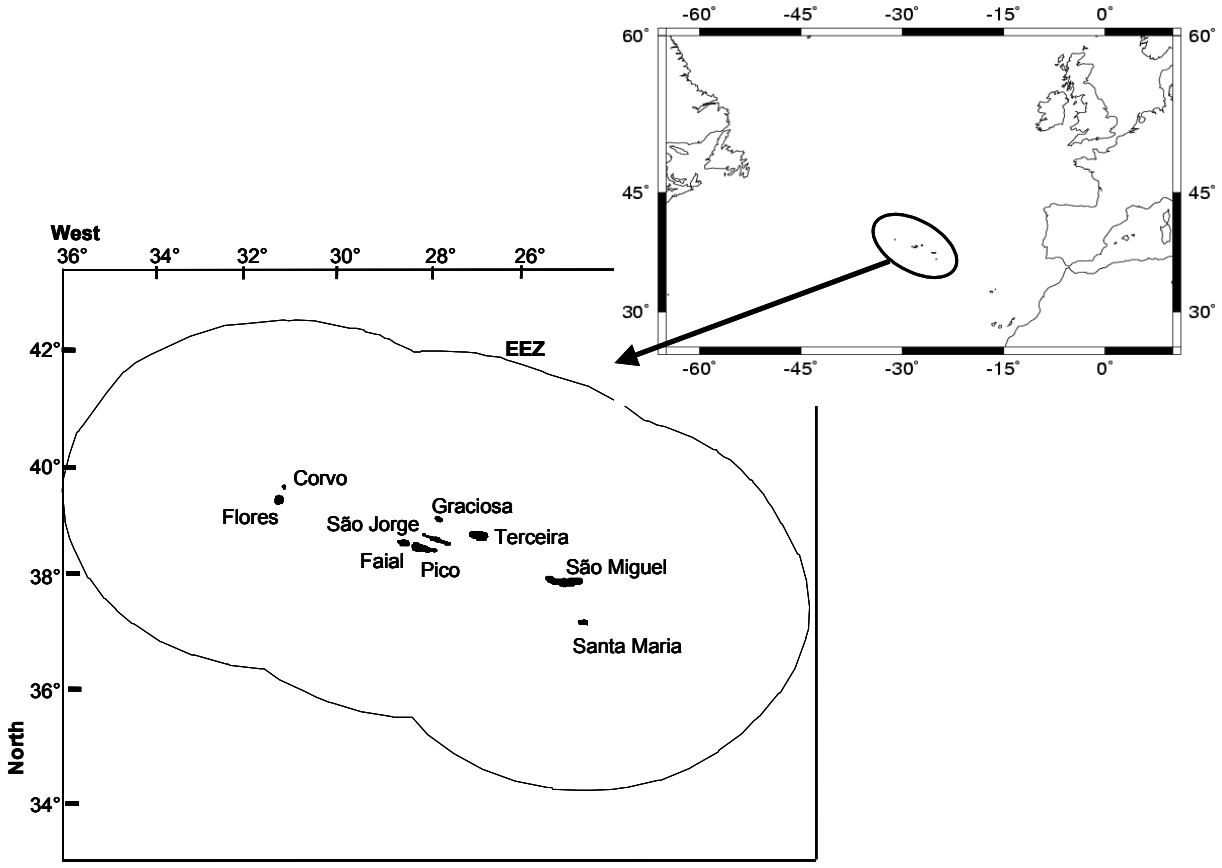

Figure 1. Map of the Azores archipelago and its 200 nm EEZ.

There are about 900 people fishing in the Azores and slightly over 3,000 fishery-related jobs, representing 4.4% of the Azores population of approximately 94,000 (Helder Silva, Megapesca Lda., Portugal, pers. comm.). Ten percent of the jobs are tuna-related while 90% are in the artisanal sector. On average, fishers are active 48% of the year. Tuna are the most important functional group in terms of catch, followed by demersal fish and small pelagic fish (Figure 2).

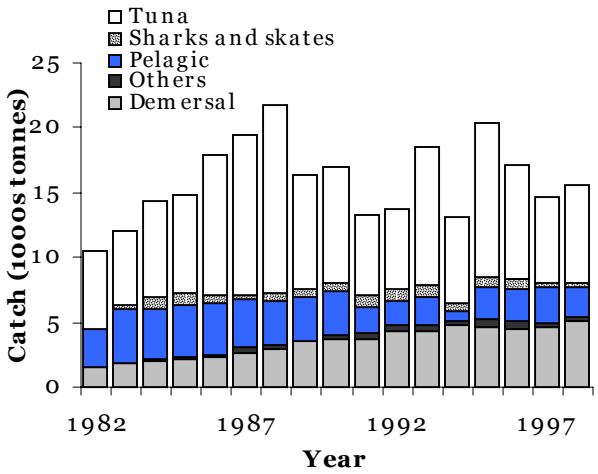

Figure 2. General composition of total catch in the Azores, 1982-1999. The grouping 'others' includes lobster, *Loligo* spp., octopus, seaweeds, swordfish, other benthos and various fishes.

FISHERIES

Tuna

Tuna are seasonally present in the area, migrating and feeding around the islands and seamounts. Adult big-eye tuna (*Thunnus obesus*) is present during April to June. They are caught at an average length of 1 m and 25 kg. Skipjack tuna (*Katsuwonus pelamis*) are caught from June to October at a length of 45 cm (~ 3 kg). Bluefin tuna (*Thunnus thynnus*) is caught in small quantities all year round, while a few yellowfin tunas (*Thunnus albacares*), a more tropical species, are captured in July (Figure 3). The majority of the tuna catch is canned, yielding low value. However, the industry is increasingly targeting the fresh tuna market which yields better prices. Attempts to encourage high-value sashimi grade processing have not yet succeeded (Pereira, 1995; Feio and Dias, 2000).

Tunas are fished with pole-and-line, usually with water spray and live bait. Only 30 Azorean boats fish within the EEZ. Boats are generally 28-32 m long, open-deck, and wooden, although there are a few made of steel or fiberglass. Boat size has increased through time (Pereira, 1995) and recently seven new boats were built and fishing power increased, all supported by subsidies. It is worth noting that although 20 tuna vessels from Madeira are licensed to fish in the Azores, only four went out in 2000, as catch rates decreased. In fact, the tuna fishery, which traditionally caught over 5,000 tonnes in a good year, has seen its catches fall to less than 3,000 tonnes recently. (Figure 3). Fishing success is influenced by two factors: abundance and variation in migration routes. Depending on the currents, tuna will migrate either through the Archipelago or else at a distance from it, thereby preventing the fishers from reaching them (Rogério Feio, Dept. Oceanography and Fisheries [DOP], University of the Azores, Horta, Azores, pers. comm.).

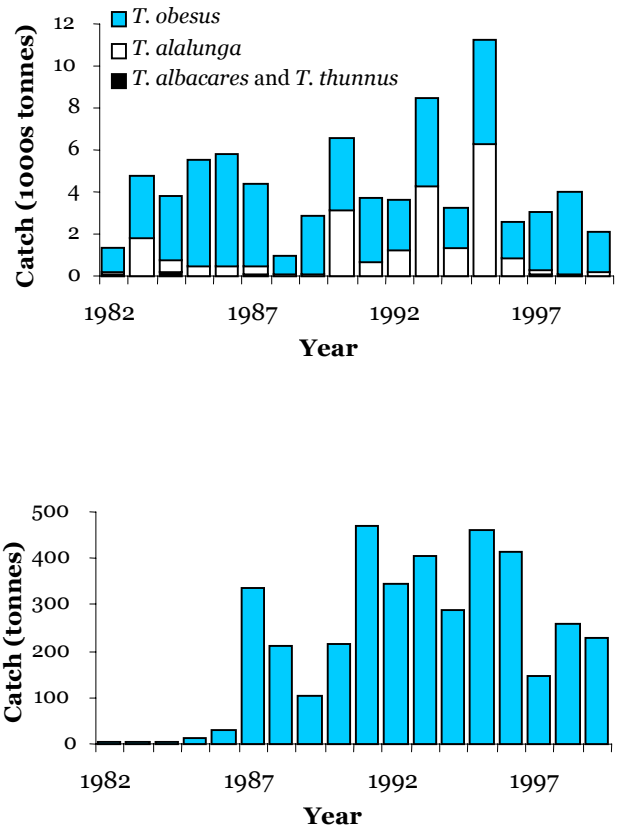

Figure 3. Composition of tuna (top panel) and swordfish catches (bottom panel).

Although bycatch is very low for the tuna fishery, there are some concerns about the demand for bait fishery and cetaceans. To this effect, a collaborative project (POPA) between the industry, the Government of the Azores and the University has been investigating by-catch, using on-board observers covering 50% of the fishing effort (Joao Gil and Rogério Feio, DOP, pers.

comm.). The tuna catch locations were plotted in 40-60 km rings around the islands. The average fishing trip lasted 5 days (range: 1-7 days) and most of the trip was spent looking for shoals. Bottlenose dolphins have the greatest interaction with the tuna fishery by making tuna dive and thus interfering with the fishing activities. However, this only occurred in 5% of the fishing sessions; the data confirmed the official dolphin-safe status of the fishery.

The POPA project also estimated that about 200 tonnes of bait, or 2-3% of the tuna catch in weight, are taken each year for the tuna fishery. The species used are blue jack mackerel (*Trachurus picturatus*, 70%), European pilchard (*Sardina pilchardus*, 10%), chub mackerel (*Scomber japonicus*, 10%), and blackspot seabream (*Pagellus bogaraveo*, 10%). These four species form a very important part of the total catches. Prior to 1991, they accounted for more catch than all other fish species caught in the Azores combined, excluding tuna. Blue jack mackerel of all sizes (10-25 cm) keep well in bait tanks and, together with chub mackerel, are used to catch big-eye tuna. Blackspot seabream of 6-8 cm long and European pilchard are used as bait for skipjack tuna. European pilchard became more abundant in the area in 1999 and thus was used as bait to replace blue jack mackerel (Joao Gil and Rogério Feio, DOP, pers. comm.). However, sardines were taken in larger quantities than blue jack mackerel as they do not keep as well in bait tanks. The bait fish are caught using purse seines, lift nets, or seines, depending on the season and targeted species. The big blackspot seabream and blacktail comber (*Serranus atricauda)* caught in the process (about 30 kg per trip, maximum of 155 trips) were retained for personal consumption.

Swordfish

Swordfish (*Xiphias gladius*) are caught using near-surface longlines and boats divided into three size categories: small open-deck boats, cabin boats and large 30 m vessels (Alexandre Silva, DOP, pers. comm.). The fishery began in the 1980s, and boat size has increased over time. Annual catches of swordfish reached an average of 400 tonnes from 1991 to 1996 and then declined sharply to less than 200 tonnes as a result of problems outside the Azores (Figure 3). In open waters within the EEZ and at its border, several foreign countries (Korea, Spain, Japan) illegally fish large quantities of swordfish. There is also much fishing in adjacent international waters.

The bycatch generated by this fishery is very large. On average, ten large sharks, mainly blue shark (*Prionace glauca*) and shortfin mako (*Isurus oxyrinchus*), are taken for every swordfish hooked. Very large shark specimens were often caught up to ten years ago but have declined since then, perhaps as a consequence of bursts of 'finning' (catching sharks for their fins only) by the Taiwanese in the early and mid-1990s. Billfishes were also taken in fair numbers, but information is rather scarce. Turtles are hooked on swordfish lines, possibly in large numbers. Their chances of survival depend on how deep the line was set, but transmitters placed in the stomachs of 200 turtles suggest a high mortality rate and a possible change in behavior (Helen Martins, DOP, pers. comm.). There appears to be no information about seabird bycatch on the longlines.

Deep water longline

This fishery includes mid-water (200-600 m) and deep-water (600-1200 m) sectors using longlines and individual hand lines. These data are considered poorly represented in the ICES data set. Azorean boats are generally 18 m although a few larger boats were recently added to the fleet. Madeiran boats (25m) come to the area for black scabbard fish (*Aphanopus carbo*), a specialized fishery occurring in waters deeper than 1000 m.

The traditional targets are blackspot seabream, forkbeard (*Phycis phycis*), wreckfish (*Polyprion americanus*), blackbelly rockfish (*Helicolenus d. dactylopterus*), offshore rockfish (*Pontinus kuhlii*), conger eel (*Conger conger*), and the alfonsinos (*Beryx splendens* and *B. decadactylus*). Newer targets include the silver scabbard fish (*Lepidopus caudatus*) and deeper water species (> 1000 m) like the black scabbard fish, greater forkbeard (*Phycis blennoides*) and common mora (*Mora moro*). The fishery generates considerable by-catch. For example, although black scabbard fish have been targeted only since 1997-98, earlier catches of this species were discarded with little reporting. Before 1997, the catches of black scabbard fish were relatively small, because the gear used and the depth range explored were not appropriate for this species. Furthermore, 50% of the blackbelly rockfish caught were discarded due to their size.

Lobster

Locust lobster (*Scyllarus latus*) is caught by traps and hand-picked by divers, both from very small inshore boats. An average of 0.5 tonnes per year is sold at the auction but it is estimated that three

times this amount are landed and sold directly, and are thus not reported. The stock is believed to be depleted, and average size has declined. There is not much information on the other species caught in the Azores: Common spiny lobster (*Palinurus elephas*), toothed rock crab (*Cancer bellianus*), Mediterranean spiny spider crab (*Maja squinado*) and Sally Lightfoot crab (*Grapsus grapsus*).

Squid

Loligo forbesi is the only species of squid caught commercially in the Azores. It is caught with very small boats close to shore, using jigs in daytime at depths of 80-100 m (Porteiro, 1994). The catch is largely unreported, and displays huge inter-annual fluctuations (50 to 450 tonnes, Figure 4).

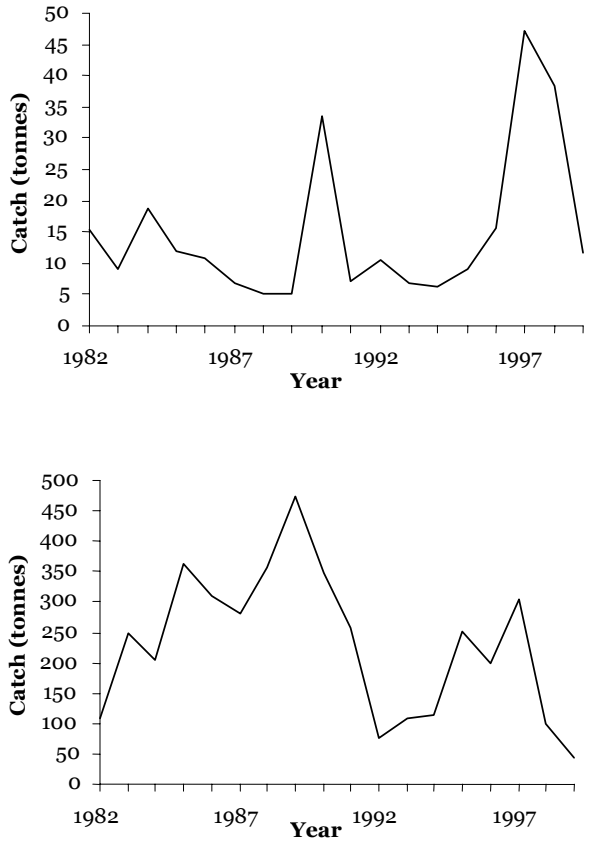

Figure 4. Catch of octopus (top panel) and *Loligo* spp. (bottom panel) in the Azores.

Octopus

Octopus (*Octopus vulgaris*) is collected by snorkel divers and iron traps. 95% of the total catch is landed in São Miguel and destined for local consumption. In theory, licenses are mandatory, but the catch is largely unreported. For example, in Faial, one fisher out of 15 sells as much as 4 t a year in auctions. Carreira (2000), mentioned that 57.4 t of octopus was landed in São Miguel alone which would lead to a total of about 64 t for the whole Archipelago (Figure 4).

Small purse seine

Blue jack mackerel (*Trachurus picturatus*), chub mackerel (*Scomber japonicus*) and European pilchard (*Sardina pilchardus*) are caught with small purse seines pulled to shore or from small boats. This fishery is especially important around the Island of São Miguel. An average of 450 tonnes a year (range of 227 to 798 tonnes) are landed in the Archipelago.

Shrimp

Bottom traps are used to catch shrimp. The catch is generally used for local consumption, but it is largely unreported. To some extent this is still an experimental fishery. The principal species found in the area are *Plesionika narval*, *Plesionika edwardsii*, and *Heterocarpus* spp. (Martins and Hargreaves, 1991).

Limpet harvest

The limpet harvest peaked at 95 tonnes in 1984 and rapidly declined afterwards due to a possible 'limpet disease' in the 1980s and never recovered (Figure 5.). There are closed seasons and areas, some closed areas being 20 years old on some islands. The level of success varies between closures (Ferraz *et al.*, 2001).

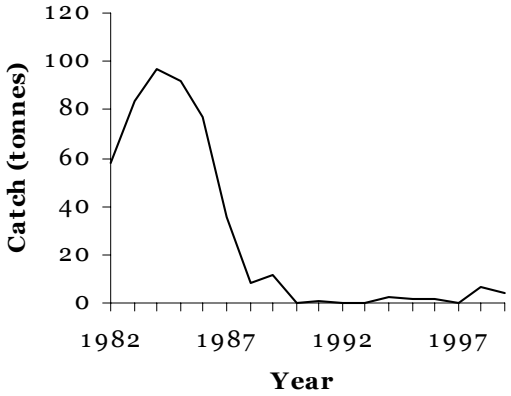

Figure 5. Catch of limpets (*Patella* sp.) in the Azores.

Experimental fisheries

Three new experimental fisheries have started, the trawl Orange Roughy (*Hoplostethus atlanticus*) fishery, deep water sharks ('sikis'), and deepwater crab, *Chaceon affinis*. Deepwater crabs are fished using traps (Pinho *et al.*, 2001). It is interesting to note that although Orange Roughy is thought to be abundant, experimental fishing with trawls around seamounts started only in the winter of 2001.

Artisanal fisheries

It is believed that at least 50% of the catch in this sector is unreported. Gillnets have been the object of a special study (Fontes *et al.*, 2000). Landings are difficult to estimate as catch reporting is poorly controlled, irrespective of the status of the fisher (with or without a permit). They catch mainly Atlantic bonito (*Sarda sarda*), yellowmouth barracuda (*Sphyraena viridensis)*, thicklip grey mullet (*Chelon labrosus*), and some species only caught with gillnets, e.g., parrot fish (*Sparisoma cretense*) and salema (*Sarpa salpa*). The importance of gillnets in this sector is variable due to their bad reputation, and fisheres often switch to hand lines. Early catches of gray triggerfish (*Balistes carolinensis*) were discarded and not reported. However, more recently a small scale fishery targeting this species has developed and is increasing in importance. This sector also includes spearfishing and rod fishing for Atlantic bonito, yellow-mouth barracuda and bluefish.

Recreational fishery

There appears to be no system to gather statistics from Azorean recreational fisheries. On the island of Faial there are 12 boats which troll for big game such as billfishes, blue marlin (*Makaira nigricans*), white marlin (*Tetrapturus albidus*), longbill spearfish (*Tetrapturus pfluegeri*), wahoo (*Acanthocybium solandri*), bluefin tuna, dolphinfish (*Coryphaena* spp.), Atlantic bonito and sharks. It has been noted that large fish are now becoming rare.

Shoreline recreational fishing with hook and line is not quantified and concerns several species among which *Diplodus sargus*, *Pagellus bogaraveo* and *P. acarne*, *Trachurus picturatus* and *Pagrus pagrus* are the most common species. These are followed by *Sparisoma cretense*, *Scomber japonicus*, *Serranus atricauda*, *Sphyraena viridensis*, *Pseudocaranx dentex* and *Pomatomus saltator* (listed in decreasing proportions: Pedro Afonso, University of the Azores, Horta, pers. comm.).

Seaweed harvest

The seaweed harvest, for food and agar production, is declining and very small.

ILLEGAL/UNREPORTED FISHING

Foreign boats from Spain, Taiwan and Japan come to seamounts north and south of the Azores and stay for a few days. They are rarely detected, but recreational fishing boats often see them. These boats often use unmarked monofilament gill nets and small drift nets which are abandoned when they are detected. A new Portuguese navy frigate has recently started fishery patrol duties, apparently improving the situation. In international waters just outside of the EEZ, vessels from Taiwan, Spain, Japan and France commonly set large drift nets. They catch many species of fish, marine mammals and seabirds. Estimates of illegal and unreported fishing have not yet been made.

COMPARISON WITH ICES DATA

Portuguese catches in the official ICES dataset (STATLANT) for Fisheries Statistical Area X includes both continental Portuguese and Azores vessel data (Figure 6). Comparison of ICES data with the Azores dataset shows that the total tonnages are similar (Figure 7). However, closer examination reveals that several species caught in small quantities are not reported separately in the ICES dataset (Appendix 1). These species may or may not have been included in the miscellaneous fish group which is very large in the ICES data set (Figure 8). Other species such as sharks have been included correctly in the ICES data set, but under larger categories, while the Azores file is more explicit and include *Lamna nasus*, *Dalatias licha*, *Isurus oxyrhinchus* and *Hexanchus griseus* (Figure 9).

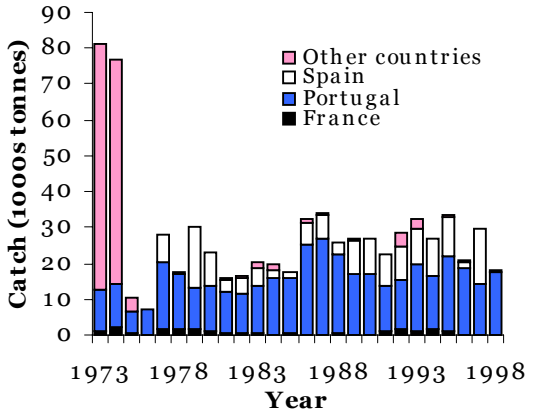

Figure 6. Catch by country in ICES Fisheries Statistical Area X. Other countries include USSR, Latvia, United Kingdom and the Faroe Islands. Data source: ICES STATLANT.

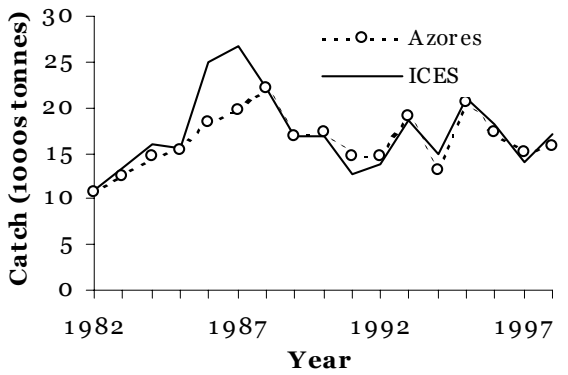

Figure 7. Comparison of ICES and Azores catch data in ICES Area X.

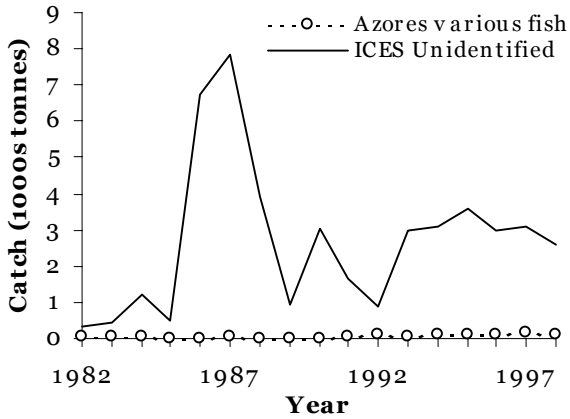

Figure 8. Comparison of Azores and ICES unidentified catches.

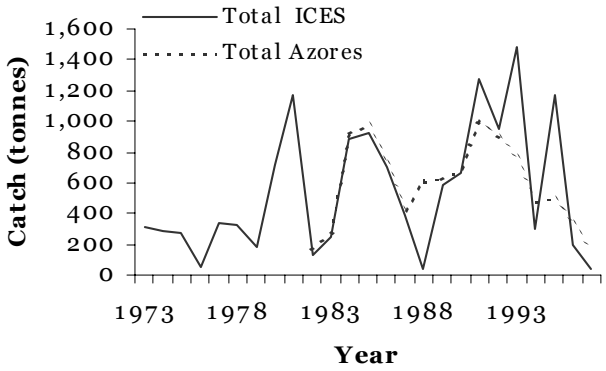

Figure 9. Composition of sharks catches in ICES and Azores data.

ACKNOWLEDGMENTS

This work would not have been possible without the collaboration of the Secretary of Agriculture and Fisheries of the Azores who generously provided the datasets, and several researchers at the Department of Oceanography and Fisheries (DOP) of the University of the Azores who kindly shared their knowledge with us. Thus, we would like to thank Rogério Feio and João Gil Pereira (tuna), Alexandre Silva and Pedro Duarte (swordfish and sharks), Gui Menezes, Eduardo Isidro and Mário Pinho (deep-water fishes), Helen Martins, and Rogério Ferraz (lobsters, shrimps, limpets), Jorge Fontes and Miguel Machete (artisanal fishery), Filipe Porteiro, João Gonçalves and Gilberto Carreira (squids, octopus), and Dália Reis and Angela Canha (landings database). We would like to thank the Pew Charitable Trusts, Philadelphia, USA, for funding the *Sea Around Us* project, which made this collaboration possible. Tony Pitcher acknowledges the support of DOP for attendance at the 'Semana das Pescas 2001' conference.

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APPENDIX 1

List of species caught by Portugal for the period 1982-1999, and compared between ICES and Azores data sets. The list is not exhaustive.

Species that are absent from the ICES database (and the tonnage reported for these species in the Azores data set): *Cancer bellianus* (9 t), *Chelon labrosus* (15 t), *Coris julius* (14 t), *Coryphaena* spp.(mainly *C. hippurus*) (5 t), *Diplodus sargus cadenati* (45 t), *Epinephelus marginatus* (37 t), *Grapsus grapsus* (crab, 1.2 t), *Helicolenus dactylopterus* (386 t), Labridae (21 t), *Megabalanus tintinabulum* (1.4 t), Muraenidae (59 t), *Mycteroperca fusca* (0.41 t), *Patella* spp. (28 t), *Phycis phycis* (incl. *P. blennoides*) (354 t), *Pontinus kuhli (59 t), Pseudocaranx dentex* (13 t), *Ruvettus pretiosus* (2 t), *Sarpa sarpa* (43 t), *Scorpaena scrofa* (29 t), *Scyllarides latus* (0.7 t), *Seriola* spp. (23 t), *Sparisoma cretense* (16 t), *Sphyraena viridensis* (36 t), *Spondyliosoma cantharus* (2.3 t), *Thaio haemastoma* (0.6 t), *Trachinotus ovatus* (5.6 t), and *Trachurus picturatus* (2215 t).

Species present in the ICES database, but not in the Azores Data set: *Argyrosomus regius, Epinephelus guaza, Engraulis encrasicolus,* Gadiforms, *Merluccius merluccius, Pollachius pollachius, Scomber scombrus, Sparus aurata,* and *Trachurus trachurus* (could represent *T. picturatus*).

Species for which both datasets report the same catch: *Boops boops, Conger conger, Katsuwonus pelamis, Lepidopus caudatus, Loligo forbesi, Lophius piscatorius, Maja squinado, Mullus surmuletus, Octopus vulgaris,* and *Pagellus bogaraveo*.

For the following species/groups higher catches were reported in the ICES database than in the Azores data: Other crustacea, *Belone belone,* Mollusca, Tunas, and unidentified fish.

For the following species the ICES dataset was considered incomplete: *Aphanopus carbo, Beryx* spp., *Molva dypterygia, Pagellus acarne, Pagrus pagrus, Palinurus elephas, Phycis blennoides, Polyprion americanus, Pomatomus saltator,* and *Sarda sarda*.

FISHERIES IN THE CANARY ISLANDS, SPAIN

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ABSTRACT

This report briefly describes the fishery around the Canary Islands, Spain. Given that fisheries data are not routinely collected in the Canaries, the results we present here come from a partial survey of the year 1982, in accordance to the law passed in 1979 ordering evaluation of stocks and determination of the fleet capacity for the Canarian fishery. Since the survey covered only eight months of the year, we summarize the results of the landings survey, and propose a minimal estimate of the catch for the whole year.

FISHING METHODS IN THE CANARIES

The Canaries are a small island archipelago off the coast of north-west Africa, and are part of Spain. Hook and line, along with vertical longlines, bottom longlines and traps are the main gear types used in the fisheries, and catch a large number of species, with species composition varying considerably between fishing days. Pole fishing is more selective, and used mainly to catch tuna. These methods use a variety of bait. The most common live baits used are the mackerel *Scomber japonicus*, *Boops boops* (Sparidae) and in some places squids (e.g., La Graciosa). These species, as well as others, are also used as dead bait. For fishing tuna, *B. boops* and *S. japonicus* are most commonly used, followed by the sardine *Sardina pilchardus* (Clupeidae). Purse seines, using a light to concentrate the fish, are utilized to catch small pelagic fish such as mackerel and sardine. Typically, each primary fishing boat is accompanied by 2-3 auxiliary boats (Delagado de Molina *et al.*, 1983).

In the province of Santa Cruz de Tenerife, the fishery is multi-species and entirely artisanal. In 1982, boats were 3-5 m long with 3-15 hp outboard motors, and generally without any navigational equipment (La-Roche Brier *et al.*, 1983). The crew is typically composed of 2-3 persons. In periods of low tuna abundance, tuna fishers also fish for demersal species (La-Roche Brier *et al.*, 1983). Although the landings are quite low, the fishing sector is considered of high social and economic importance.

In the province of Las Palmas there is no tuna fleet *per se*. The same boats fish for tuna part of the year and target other species for the rest of the year. Boats are usually 6-15 m long with a crew of 2-5. Progressively, more 10-14m boats equipped with live-fish tanks and purse seines are bought to replace old vessels. Again, navigational instruments are not generally used. Fishers target small schooling fish to be used as live bait, as well as tuna, which they catch with poles or lines (Barrera Luján *et al.*, 1983).

These artisanal fisheries sell all the species they catch. There are some exceptions such as *Conger conger*, which is very bony and only worth selling when large. Therefore, many small specimens of this species caught as a by-catch of the trap fishery, are discarded.

DATA COLLECTION

During 1982, total catch by species was recorded for fishes, cephalopods and crustaceans on islands of both provinces. The province of Santa Cruz de Tenerife includes the western part of the archipelago: La Palma, El Hierro, La Gomera and Tenerife. The survey covered seven months, from March to September. The province of Las Palmas includes the eastern part of the island chain: Lanzarote, Fuerteventura, and Gran Canaria. Survey months were March to November.

On each island, the most important landing points were monitored by technicians. These ports were selected based on their total catch landings, though this selection was in some cases dependent on where the fisheries organizations would permit monitoring. Secondary points of landing, of various importance, could not be covered. These include landings for personal use and for sales directly to local restaurants.

Tuna catch data, providing annual landings, were taken from a different source. This source is maintained by technicians of the Instituto Español de Oceanografía based at the most important landing sites, and was established in 1975 to supply ICCAT with information on tuna catches from the Canary Islands. In general, fishing effort was calculated as the length of time the gear was in the water.

CATCH DATA

Pelagic fishes accounted for 91% of the 9,752 t total catch in the Canary Islands, mainly comprised of tuna species (*Katsuwonus pelamis*, 35%; *Thunnus obesus*, 15%; others, 9%), *S. japonicus* (23%) and *Sardina pilchardus* (6.5%) (Table 1; Figure 1). Tunas are caught with poles and lines, as well as longlines. Small pelagic fish are caught almost exclusively with purse seines. Demersal fishes accounted for 8% of the total, mainly comprised of Sparids (4%) and *Sparisoma cretense* (2%, Scaridae). Fifty percent of the demersal fish catches were taken with gillnets or hook and line. Cephalopods (0.6%, mostly *Octopus vulgaris*), barracudas, sharks and rays (0.1%) and crustaceans (0.1%, mostly shrimp, *Plesionika narval*) made up the remainder of the catch (Table 1).

Table 1. Landings (tonnes) of the Canary Islands fishery in 1982, from all gear types.

Target group	Landings (t)[a)]
Pelagic fish	8,858.4
Tunas	5,762.0
Demersal fish	812.3
Barracudas, sharks and rays	13.2
Cephalopods	56.1
Crustaceans	11.7
Others	3,096.4
Total	9,751.8

[a)] The annual tuna landings were taken from ICCAT. All other data are the sum of monthly landings from March through November, surveyed at major ports on the islands.

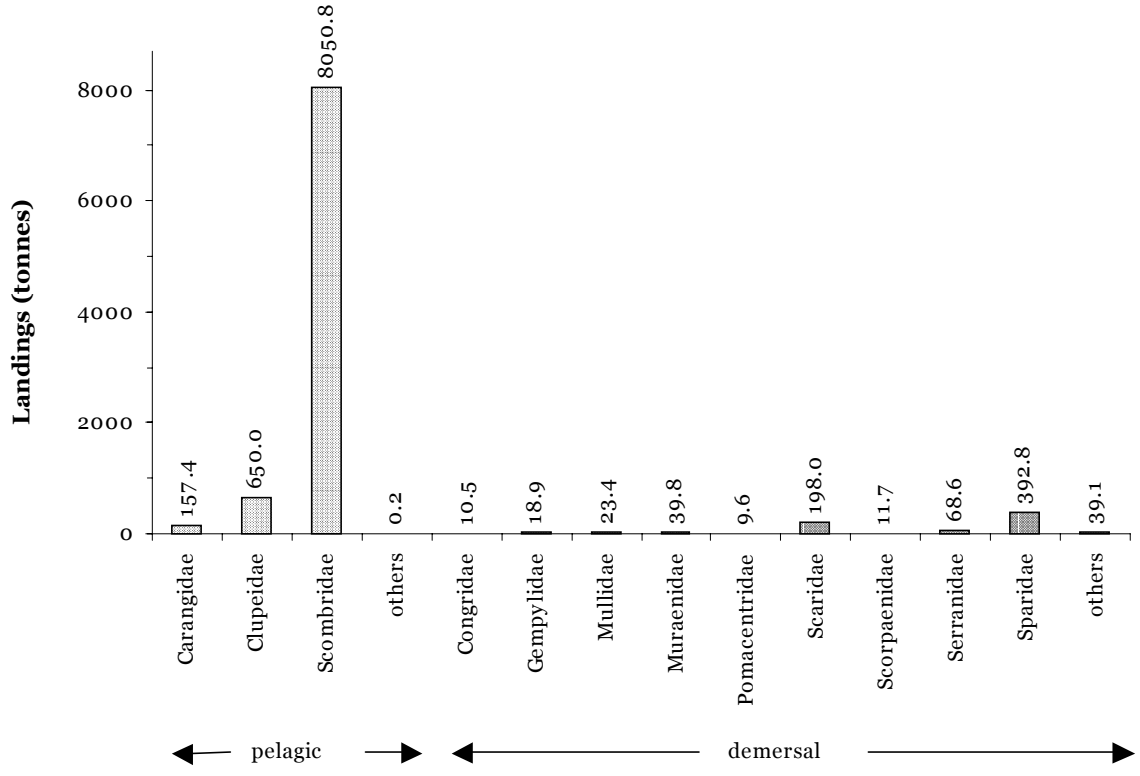

Figure 1. Catches of pelagic and demersal fish of the Canary Islands fishery in 1982, from all gear types. The annual tuna landing for 1982 was taken from ICCAT. All other data are the sum of monthly landings from March through November, surveyed at major ports on the islands. Catch data are given above the bar for each fish family.

Monthly catches, excluding tuna, were clearly different between the two provinces, especially regarding pelagic fish (Figure 2). The catch of pelagics in the province of Santa Cruz de Tenerife was substantially higher in the months from March through September. Catches of demersal species, conversely, were quite similar between provinces. Cephalopod catch was greater in Las Palmas, though there was less barracuda, shark and ray, and a very scarce crustacean catch from this province (Figure 2).

In Santa Cruz de Tenerife, the total catch between March and September, excluding tuna, was 2,887 t. There were a total of 18,132 trips and 126,924 h of fishing, with an average catch/effort of 3.41 kg/boat/h (Delagado de Molina *et al.*, 1983). At one site on the island of La Palma, Santa Cruz de La Palma, the catch/effort reached 9.0 kg/boat/h, probably because more than 50% of the total catches were from gillnets and surrounding nets.

As the species targeted and the amount of effort spent on fishing vary between months and between provinces, it is very difficult to estimate the total annual catch for the entire archipelago. The total annual catch of 1982 presented here is under represented as, with the exception of tunas, data were not collected for all months of the year. For example, monthly landings of *B. boops* were lowest between March and June. They increased in July, and in November this species was caught more than all other demersal fish species, despite not even being recorded in Santa Cruz de Tenerife. It is unknown whether this relatively large catch continued in the next three months. Of the pelagic fish species, *S. japonicus* was caught more than any other species between March and November, with its greatest monthly landing in March. If the fishing season before March was strong, then the annual catch would likewise be under-represented.

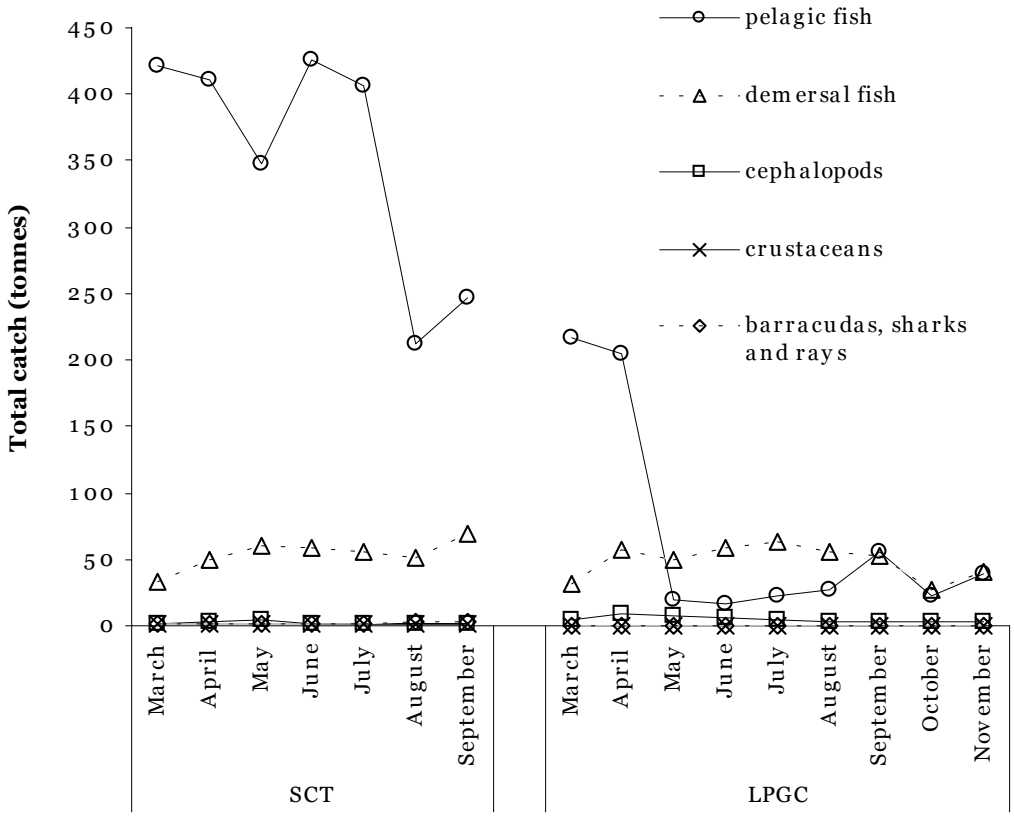

Figure 2. Monthly catches by province of the Canary Islands fishery in 1982, from all gear types. Data are only available from March through September for Santa Cruz de Tenerife (SCT), and from March through November for Las Palmas de Gran Canaria (LPGC). Tuna data are not available by month or by province, and thus are not included here.

To better estimate the actual annual catch for each of the major groups (pelagic fish, demersal fish, barracudas/sharks/rays, cephalopods, crustaceans), we extrapolated for those months for which landings were not monitored. For a conservative estimate, the total catch of each group for each missing month in each province was estimated as being equal to the month with the smallest catch in that province for that group. The estimated annual catch for the entire archipelago then becomes 11,133 t, a 14% increase from the measured catch over 7-8 months. These predicted total annual landings are, for each group: pelagic fish, 9,967 t; demersal fish, 1,063 t; barracudas, sharks and rays, 17 t; cephalopods, 69 t; and crustaceans, 16 t.

Even if data were collected year-round, the amount of unreported catch is difficult to estimate because of the large number of unmonitored landing sites for personal consumption and sales of various species directly to restaurants. In Lanzarote the amount of unreported catch could amount to 15-20% of the reported landings (P. Martín-Sosa, unpublished data). It may not be possible to extrapolate this percentage to other islands as the number of informal landing sites may vary.

ACKNOWLEDGEMENTS

We would like to thank the Pew Charitable Trusts, Philadelphia, for funding the *Sea Around Us* project at the Fisheries Centre, University of British Columbia.

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PART IV: WESTERN NORTH ATLANTIC

KEY FEATURES OF COMMERCIAL AND RECREATIONAL FISHERIES STATISTICS FROM THE US ATLANTIC COAST

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ABSTRACT:

This contribution briefly describes the major features of the database of fisheries catches from the Eastern USA, from Maine in the North to the tip of the Florida peninsula in the South, i.e., excluding the Gulf of Mexico. The two major databases for commercial and recreational catches created by the National Marine Fisheries Service are described, along with a number of related efforts both at Federal and States' level. Also, some of the scattered contributions devoted to estimating discards, and misreported catches are discussed, with emphasis on their potential by the *Sea Around Us* project for generating high-resolution catch maps.

INTRODUCTION

The *Sea Around Us* project, through the University of British Columbia Fisheries Centre, aims to provide a broadly based integrated analysis of the impacts of fisheries on marine ecosystems, and to devise policies that can mitigate and reverse harmful trends whilst ensuring the social and economic benefits of sustainable fisheries. The North Atlantic fisheries served as our first case study. One of the project's major activity has been mapping the distribution of fisheries catches, as one step toward a transition to ecosystem-based management (Pauly and Pitcher, 2000; Watson *et al.* this volume). For this to serve any useful purpose, however, the true catches must be known or at least approximated, i.e., officially reported catches must be corrected to account for items usually not covered by national or international fisheries statistical systems. Such items include, e.g., discarded bycatch, illegal catches, the catches of small-scale fisheries or other 'unmandated catches' (see Pitcher and Watson, 2000).

This brief account discusses key features of the statistical database of the USA, as we perceived them, both to serve as background to the extraction and processing of US catch data by the *Sea Around Us* project, and to guide the steps we still have to implement.

NMFS'S DATABASE OF COMMERCIAL FISHERIES LANDINGS

The database of commercial landing statistics for the Eastern USA was created by the National Marine Fisheries Service (NMFS; Fisheries Statistics and Economics Division, Silver Spring, Maryland, USA), a part of the National Oceanic and Atmospheric Organization. Here are its key features:

1) The database covers all commercial fisheries in US waters, i.e., from the inshore waters (i.e., including States' landings) to the outer limits of the US Exclusive Economic Zone (EEZ);
2) Discards are not included (see below);
3) The temporal coverage of the database extends from the late 1940s to the present, and hence the database is compatible with the FAO database, and that of the *Sea Around Us* project, which both start in 1950;
4) Most of the content of the database is available online at *www.st.nmfs.gov/st1/commercial*, and can be downloaded.

With regards to (1), we should note that data on foreign fishing in the US EEZ are available from the Fisheries Statistics of the US 1981-1995 (NMFS, 1981-1995). Records were not kept before this time. Foreign fishing ended with enactment of the Magnuson-Stephens Act (1976) and establishment of the 200-mile EEZ. These days, vessels fishing within the US EEZ must have at least 50% US national ownership.

FISHING EFFORT AND LOCATION STATISTICS FOR U.S. EAST COAST

Fishing effort is only collected on a fishery-by-fishery basis, through logbook programs, and the results are generally not in the public domain. Moreover, access is limited by resources (time spent on assembling data). Further, contact with the different State Governments would be required for information about their inshore state-managed fisheries (largely for

invertebrates). Issues of confidentiality and resources (to do the compilations) restrict what can be accessed. The data are summarized for stock assessments and may be found in highly aggregated form in published reports. The data are also provided to the Regional Management Councils, as needed.

Examples of fisheries for which logbook programs exist are:

- bluefin tuna (in NE);
- large pelagics (swordfish, sometimes tuna and pelagic sharks);
- sharks (when caught by midwater or bottom longline);
- snapper/grouper complex;
- coastal pelagic (king and Spanish mackerel);
- Gulf of Mexico reef fish (same species as snapper/grouper complex);
- wreckfish (small fishery);
- Golden crab (off Florida).

Another group of fisheries are required to provide detailed Vessel Trip Report (VTR), which include information on catch composition and fishing location, time of the day, etc. VTRs are provided by the fisheries exploiting the multispecies complex in the Northeast such as scallop, squid, butterfish, Summer flounder, and others.

The logbook data are mostly supplied to the NMFS Fisheries Science Centre in Woods Hole and used for stock assessments, and/or forwarded to the relevant Regional Fisheries Management Council.

NMFS'S DATABASE OF RECREATIONAL FISHERIES CATCHES

NMFS's database of recreational fisheries is unique in the world, and reflects the huge economic (and hence political) importance, in the US, of this segment of the fisheries sector, compared with the commercial sector.

The database, which is based mainly on extensive phone interviews, is considered largely complete for the 1980s and 1990s, except for 'headboat' catches from the 'South Atlantic' [headboats carry a number of heads, i.e., angling tourists]. Caution must be exercised when combining catches in this database with those of the above mentioned database, as the (common) names used for species identification are not fully standardized. Most angling records enumerate the catch and an average weight must be assumed to calculate the weight of landings. The database can be accessed at *www.st.nmfs.gov/st1/recreational/data.html*

Catches for the period prior to the 1980s could possibly be reconstructed (albeit with less temporal and spatial resolution) by accessing a number of unpublished reports on US recreational fisheries available in the NMFS archives held at its Silver Spring headquarters.

THE ATLANTIC COASTAL COOPERATIVE STATISTICS PROGRAM (ACCSP)

The ACCSP is often mentioned as a potential data source when discussing US Atlantic fisheries The ACCSP is a joint effort of NMFS, the US Fish and Wildlife Service, three regional Fisheries council (North, Mid and South Atlantic), and 15 states (see *www.accsp.org*).

So far, the ACCSP has spent several years (and about US$ 1.5 million per year) "developing standards" and designing an extremely complex and detailed database to which (maybe) all US Atlantic states will later contribute catch and fleet data. Presently, however, the ACCSP has access to only two large data sets, the commercial and recreational catch databases created by NOAA and mentioned above. By the program's director's own reckoning, it will take up to five years before ACCSP will have a system in place that includes new data. Moreover, the ACCSP will not attempt to reconstruct past series, nor analyze their own data.

We note, as an aside, that U.S. states bordering the Gulf of Mexico (but not Texas) are developing a data base similar to ACCSP, and have in fact adopted some of their standards (contract: Gulf States Fisheries Commission).

BYCATCH AND DISCARD STATISTICS

It is now widely recognized that bycatch can have severe impacts on exploited or protected populations and should be included in stock assessments.

While the USA has no procedure for systematic capture and documentation of bycatch or discard data comparable to that for commercial or recreational landings, numerous (mainly federal) initiatives exist which deal with this issue. These have led to a number of important contributions, notably: Alverson *et al.* (1994), Cramer (1996), Murawski (1996), and Crowder and Murawski (1998), and others. Most of these are based on

observer data. However, not all fishing vessels are required to maintain a federally funded onboard observer. Thus, the manager of the Observer Program attempts to sample representative subsets of particular fisheries dependent on anticipated needs for data on particular bycatch species, often marine mammals or birds, and, more recently, some groups such as sharks.

On the other hand, due to the *ad hoc* nature of the Observer Program and the absence of reporting standard, a federal database does not exist that collates the available bycatch data. Thus, an external group– such as the *Sea Around Us* project attempting to deal with the bycatch issue on a broad basis, e.g., along the entire US Atlantic coast – would have to create the required database, based on data extracted from scattered reports, and/or assembled from a variety of smaller databases.

USE OF DATA

Data from US commercial and recreational fishing have already been incorporated into a number of ecological models representing the East coast of the US prepared at the Fisheries Centre. These data are currently being enriched by documented additions of bycatch and discards reports. Once complete, this dataset will be used to represent US catches along the East Coast within the context of the global dataset being complied by the project from a number of sources, principally the capture dataset made available by the Food and Agriculture Organization of the United Nations (FAO).

ACKNOWLEGMENTS

We wish to thank Lore Ruttan, who initiated this investigation, the US agency staff who so kindly responded to our various queries, both during a December 2000 visit on the US East Coast (DP) and by phone (TR, RW), notably John Hoey, Margaret MacBride, Joseph E. Moran, Tom Nies, John Poffenberger, Greg Power, Derek Orner and Maury Osborn. Ahmed Gelchu and other graduate students at the Fisheries Centre contributed to obtaining data and data sources. Our thanks also to the Pew Charitable Trusts, Philadelphia, for funding the *Sea Around Us* project.

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FOUR-HUNDRED YEARS OF FRENCH COD (*GADUS MORHUA*) FISHERY IN NEWFOUNDLAND (1550-1950)

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ABSTRACT

We present a summary of the historical French cod fishery off the coast of Newfoundland, based mainly on landings and vessel data from a study by Hersart de la Villemarqué published by IFREMER in 1995. Cod landings and the number of boats increased periodically from 1550-1914. The onset of the First World War resulted in a dramatic reduction in the number of boats in the fleet, which never recovered. However, an increase in the average landings per boat, resulting from an increase in the average vessel tonnage, compensated for the decrease in number of boats so that landings remained high until the Second World War.

DATA SOURCES AND CORRECTIONS

Hersart de la Villemarqué (1995) has compiled a set of cod landings data and fleet information for the French cod fishery in Newfoundland from 1550-1950. The author indicated that the data from the 16th century were incomplete, as some archives have been destroyed. Furthermore, many historic data sources were not exhaustive. Although Newfoundland had rich fishing grounds several centuries before the period considered here, the beginning of the traditional French cod fishery was considered to be in the 16th century (Hersart de la Villemarqué, 1995).

The author estimated the weight of dried and salted cod landed in French ports until 1799 in 'quintaux', an ancient unit in use until the 18th century, and converted it to metric tonnes (1 quintal = 48.5 kg). Since 1800, the data were given only in tonnes. After compiling the data from different tables (Tables 3-7 in Hersart de la Villemarqué, 1995) and constructing the graph for years 1550-1950, we noted that the catch was inexplicably high for some years, notably in 1786 (Figure 1).

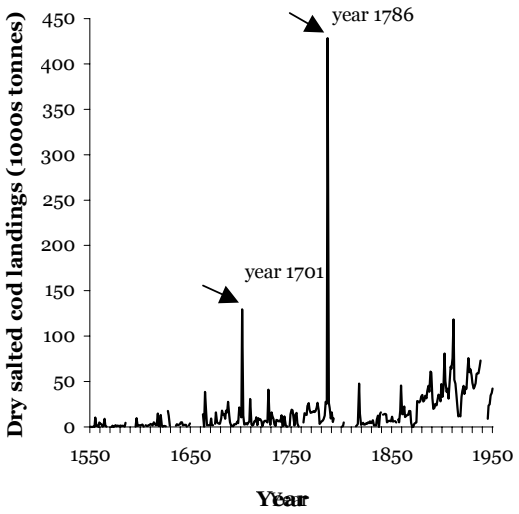

Figure 1. French landings of dry salted cod caught in Canadian waters from 1550-1950, after Hersart de la Villemarqué (1995).

In order to detect a possible cause for the presence of these 'outliers', we recalculated the landings in metric tonnes and compared them with those given in Hersart de la Villemarqué (1995). The differences were generally small (less than 0.1%), and likely due to rounding errors. When differences were greater (generally an order of magnitude), they were likely due to typing errors in the original tables. When the landings measures in tonnes and 'quintaux' for a given year were not equivalent, determining the incorrect measure was straightforward, simply by comparing both measures to the landings of the few years before and after the year in question. For example, measures in tonnes for the years 1701, 1709 and 1786 were ten times greater than those of neighbouring years. Similarly, the landing weights in 'quintaux' for the years 1788 and 1789 and the weight in tonnes for 1558 were ten times lower than the surrounding years. In total, the landing weights in tonnes from Figure 1 were corrected for outliers for the years 1558, 1649, 1701, 1709 and 1786. It was not possible to do the same verification after 1799 even if a year (such as 1817, 1859, and 1911) looked like an outlier, as the catch was only given directly in metric tonnes.

EVOLUTION OF THE FRENCH COD FISHERY IN LANDINGS AND VESSELS, 1550-1950

From 1550 to 1950 there seems to be much year to year variability in French cod landings (Figure 2). Over the longer timescale of these four hundred years, however, landings increased, especially after 1815, which marked the end of

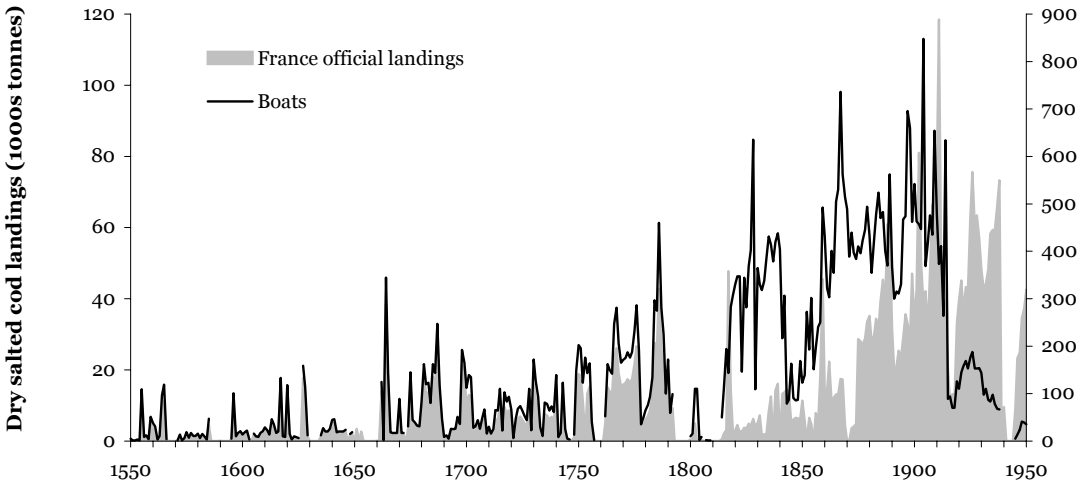

Figure 2. French landings of dry salted cod caught in Canadian waters after data are corrected for outliers. The number of boats in the fishery are also plotted, after Hersart de la Villemarqué (1995).

very low fishing activity during the French revolution (1789-1792) and Napoleonic wars (1804-1815) (Hersart de la Villemarqué, 1995). The number of boats in the fishery was also variable in the short term and increased in the long term, until the time of the First World War when they decreased sharply and remained low (Figure 2). Despite this decrease, cod landings after the war remained comparable to landings before the war due to a dramatic increase in landings per boat during the 1920s and 1930s (Figure 3a). The boats increased in size right before the same period (Figure 3b) and used improved technologies. For example, the steam trawlers and diesel-powered boats slowly increased in the early 20th century, replacing sailing ships as the primary fishing vessels. In 1914, 97% of French cod fishing vessels were sailboats, while only 1.7% were steam or diesel-propelled. By 1931, the use of sailboats had already decreased to 63%, with steam or diesel engine boats increasing to 37% (Statistiques des Pêches Maritimes, in Hersart de la Villemarqué, 1995). The French cod fishery suffered again during the Second World War, with little fishing taking place.

The apparent close relationship between cod landings and the number of boats in the French fishery before 1800 (Figure 2) is deceiving. For over 50% of the years prior to 1700 and 27% of the years between 1700 and 1800, the cod landings data presented in Hersart de la Villemarqué (1995) were not measured, but were simply estimated from the number of boats.

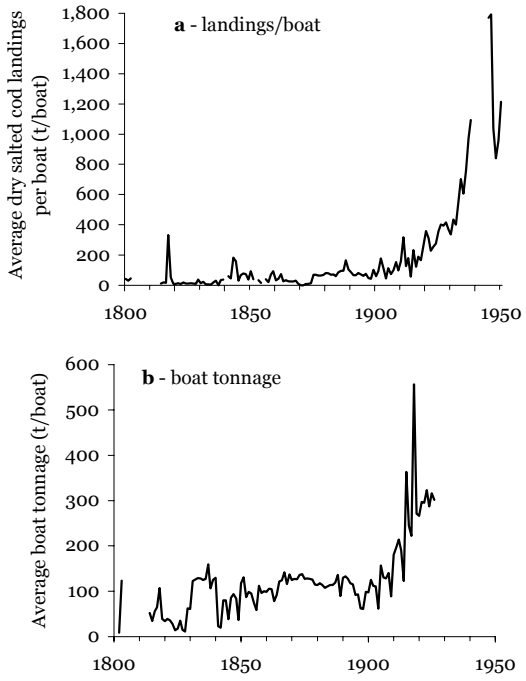

Figure 3. French landings per fishing vessel of dry salted cod caught in Canadian waters, 1800-1950 (a), and average tonnage of vessels in the French fleet, 1800-1926 (b), after Hersart de la Villemarqué (1995).

THE NEXT 50 YEARS

Following WW II, several French ports did not take up cod fishing again, and the fishery never regained its earlier presence off Newfoundland as a result of a decrease in the demand for cod (Hersart de la Villemarqué, 1995). French cod landings data from NAFO for the second half of the 20th century provides a continuation of the Hersart de la Villemarqué (1995) data set. As NAFO provides landings estimates in wet weight, we converted the dry salted cod landings from Hersart de la Villemarqué (1995) into wet weight using the conversion factor of 1 kg of dried and salted cod equals 3.8 kg of wet weight (Hutchings and Myers, 1995), an average of 2.7 for heavily salted (green) cod and 4.9 for lightly salted dry cod. French cod landings in the 1960s were lower than what they had been prior to WW II, and they have decreased substantially since the late 1960s (Figure 4).

Hutchings and Myers (1995) continue this story by presenting an overview of the Atlantic cod fishery in Newfoundland since the 16th century, with particular focus on the stock declines and subsequent collapse during the later part of the 20th century.

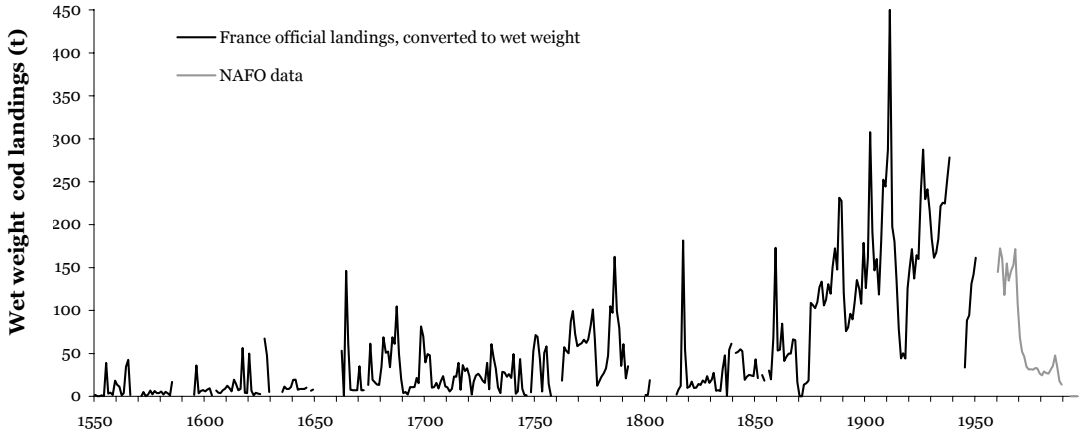

Figure 4. Dry salted cod landings converted to wet weight (1550-1950) and NAFO data (1960-1996) of French cod landings in Canadian waters. A conversion factor of 1 kg dry salted cod : 3.8 kg wet weight was used (Hutchings and Myers, 1995).

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SPANISH ATLANTIC COD (*GADUS MORHUA*) FISHERIES IN NEWFOUNDLAND IN THE SECOND HALF OF THE 20TH CENTURY

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ABSTRACT

Atlantic cod (*Gadus morhua*) has been an economically and culturally important food in Spain for hundreds of years. The Spanish cod fishery in Newfoundland waters developed slowly over time, and was sometimes erratic in its operation. The demand for dried salted cod was always high, and what was not caught by the Spanish fleet was imported. Fishery development accelerated after WW II, but the fleets then faced economic difficulties during the 1970s and 1980s. Catch levels of cod in the Northwest Atlantic declined during this time due to overfishing and a reduction in the number of boats in the fleet. Although cod has always been the target of the fishery, fishers in recent years have increasingly caught other species as well, especially with the introduction of freezer trawlers into the fleet. The demand for salted cod has remained high, however, despite the increasing importance of other target species and the growing competition with fresh fish. Although data sources in the Spanish fisheries often underestimate landings and rarely identify where fish were caught, Atlantic cod catch data taken from the Spanish Fishery Yearbooks fit closely with NAFO-FAO data. However, discards since the 1970s and non-reported catches may each represent up to 25% of the weight of cod landed. Thus, Spanish cod catches are probably substantially underestimated.

INTRODUCTION TO THE SPANISH COD FISHERIES IN NEWFOUNDLAND

Spain has been in close contact with the fishing resources of Newfoundland since the first third of the 16th century, when Basques began whaling and fishing cod in those waters. Although the great Spanish cod fishery fell in the later years of that century and had almost disappeared by 1650, the connection with Newfoundland was not lost. References of trips from Spain to the Grand Banks in the following decades are known. A few also took place in the 18th century, but it is commonly admitted that the Spanish presence in Newfoundland waters was nominal after the mid 17th century. In any case, the decline of the Spanish fisheries in the Northwest Atlantic did not greatly affect Spain's cod consumption, as Spain became a significant importer of Newfoundland's salted cod since then (Ryan, 1985; Zabala, 1994). Newfoundlanders, the British and the French supplied the high Spanish demand for cod and dominated the Spanish markets until the 20th century, when other European producers (both Nordics and Spanish) displaced them. There are no quantitative records of national imports until the 1850s, and calculating the cod consumption before then is nearly impossible. Nevertheless, alternative sources, such as local reports or series of imports and sales of salted-cured cod in various Spanish cities during the 18th and early 19th centuries, reflect the importance of its commerce and consumption in earlier times (López Losa, 2000a).

Since the 18th century, many attempts to rebuild the Spanish cod fishery were planned, but until the mid-1920s, none of them were carried out. Following the tariffs imposed over cod imports in 1922, new projects were developed, and in 1924, Spanish trawlers began to fish cod in the North West Atlantic grounds and off the Northern Norwegian coast (Giráldez Rivero, 1997; Barkham and López Losa, 1999; López Losa, 2000a) On the eve of the Spanish Civil War, the cod trawling fleet, owned by a fishing company called PYSBE, was composed of six trawlers of about 1,200 GRT each, landing a total of 9,000-10,000 metric tonnes of green cod. This production amounted to a quarter of the total salted-cured imports to Spain in 1935 (Giráldez Rivero, 1996; López Losa, 2000a). After World War II, diminishing returns in the European grounds caused the displacement of a great number of small pair trawlers towards the Grand Banks. In the following years, the cod landings in Spain grew rapidly, and with support from the Spanish government, a new trawling fleet of higher catch capacity was constructed to meet the demand of a large Spanish cod market. Fish transportation and preservation problems largely subsisted until the 1960s, and the cod continued playing its role as a cheap and easily kept source of animal protein (López Losa 2000b).

Catches of the Spanish fleet declined rapidly during the 1980s as a result of overfishing in the North West Atlantic grounds, the increasing production costs due to price rises of basics

inputs, the depreciation of the peseta in the 1970s, the 200 nautical mile EEZ and, later, the annual decrease in the number of licences and quotas for Spain in other North Atlantic areas. Cod, the main target of the Spanish fishery in the Northwest Atlantic, constituted the largest catch (Figure 1). Other species were caught and processed as well (Table 1), although, because of their lower salting quality, they were not very well accepted by Spanish markets. In the 1970s new freezer trawlers joined the classical trawling fleet, composed of both pair- and single-trawlers in which cod was processed 'green' (see below). Although some of the new vessels worked for a time in cod fisheries, most of them fished for squids and for larger, white demersal fishes such as Greenland halibut (*Reinhardtius hippoglossoides*).

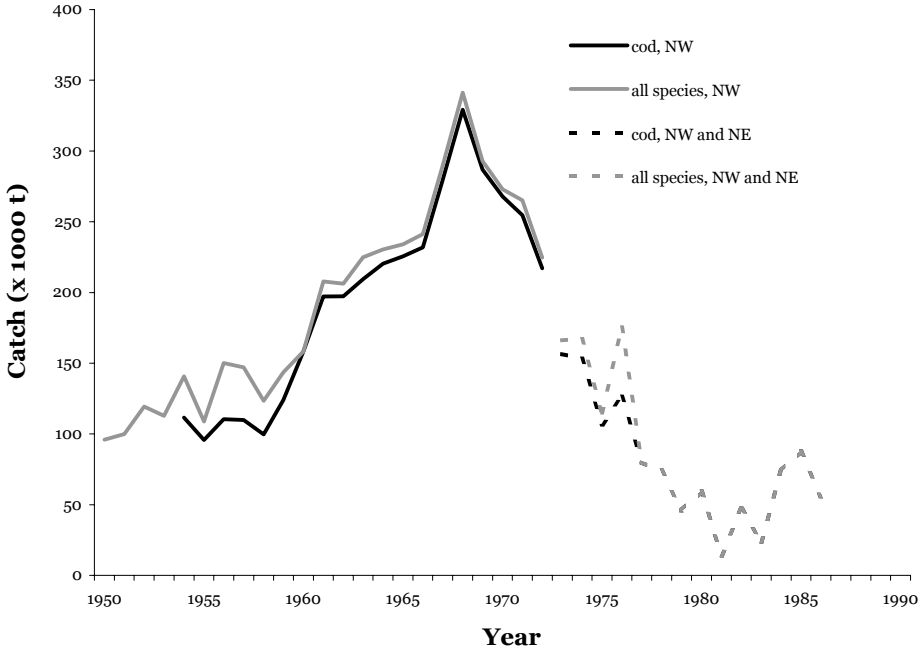

Figure 1. Spanish cod fishery catches, 1950-1986. Until 1972, data are for the Northwestern Atlantic only (NAFO zones), and after 1972 totals are summed for the Northwest and Northeast Atlantic (NAFO and ICES zones). Data are taken from the Spanish Fishery

It is interesting, in a historical context, to ask why, for centuries, cod has been so popular throughout Spain. Attempts to answer this question might help us to understand the scale and the scope of the Spanish cod fisheries in the second half of the 20th century. Traditionally, Catholic influences were largely responsible for the high level of fish consumption in Spain and, in particular, the demand for cod. Obviously, in a country where the number of days per year during which eating other meat was forbidden fluctuated between 60 and 120, depending on the century and the geographical area, the fish trade had many opportunities to increase. Nevertheless, the fresh fish market faced many problems, mainly linked to the limits of pre-industrial transport in Spain and the great difficulty in preserving fresh fish for storage. Confronted with these problems, salted and cured cod presented many advantages: it kept for a long time in all weather conditions, it was quite easy to transport, and its price was usually similar to that of fresh fish in inland markets even though the quantity consumed in the end was generally higher than for fresh fish. (Before being consumed, salted cod is soaked in water for nearly 24 hours to remove the salt and to recover its natural aspect. In this process, salted cod usually increased its weight by 25 or 30 per cent. Moreover, unlike fresh fish, all of the salted cod weight purchased can be consumed.) To some extent, these arguments can help explain the preference for cod in the Iberian Peninsula and around the Mediterranean Basin. Since the 18th and 19th centuries the demand for cod has increased, as it had become very popular among working classes and the peasantry, and often acted as a substitute for beef and other meat when prices rose quickly. Despite the rise of fresh

Table 1. Main species caught in Spanish cod fishery in Newfoundland.

Spanish	English	Scientific Name
Bacalao	Atlantic cod	*Gadus morhua*
Eglefino/Lubina	Haddock	*Melanogrammus aeglefinus*
Barbudo/Locha	White hake	*Urophycis tenuis*
Palero/Carbonero	Pollock	*Pollachius virens*

fish consumption in the early 20th century, the consumption of cod in Spain appears to have remained stable. While the demand of the urban population decreased - probably because of the growing competition with fresh fish, whose market increased with more efficient transportation - the countryside consumption increased and compensated for the urban losses. Nevertheless, the presence of cod in the diet of the Spanish population for many centuries has created customs and habits of consumption that have maintained a high demand until the present.

Spanish statistics present another particular characteristic linked to the way cod was treated before being landed and how it was statistically represented. After being caught, the cod was processed on board, and after removing heads, bones, guts etc., it was lightly salted and piled up in the vessel's hold. After reaching the Spanish coast, it was transferred to the factories where the curing process was completed (López Losa, 2000a, b; Rodríguez Martín, 1967). When landed, the fish was 'green', which is why it was known as 'green' cod.

AVAILABILITY AND RELIABILITY OF SPANISH COD FISHERIES DATA

The Spanish Fishery Yearbooks ('Estadística de Pesca', and later 'Anuario de Pesca Marítima') contain the best data available for the Spanish cod fishery in Newfoundland between 1950 and 1986, the year of the last published issue. Although the way the data are presented and the scope of the information gathered change during this period, the lack of reasonable alternatives favors their use. Other Spanish official bodies, such as Francoist Syndicates, collected fisheries data, but their range is shorter in terms of both time and scope of the data collected. From 1950 to 1953, the statistics are incomplete, especially with respect to representing areas for the whole fleet. Various other firms such as PYSBE and PEBSA do not even offer landing statistics computed by species (although we can estimate the catches by species for these years by using the species proportions from following years). These alternative data sources only offer complete data on fishing effort, fleets and fishing zones for the period of the Spanish fisheries in the Northwest Atlantic, 1954-1972. Since then, statistics have changed dramatically, and unlike previous years, there is no indication about effort, origin of fish (Newfoundland or from North European grounds), or any other species besides cod. In addition, their scope is much narrower, and doubts regarding their quality arise after comparing them with other sources thought to be more reliable, such as FAO and NAFO data (the same data are used by both organizations). Until 1975, there is almost no difference between Spanish official cod landings data and NAFO-FAO data. However, between 1976 and 1985 the Spanish official cod landings data are on average 144% higher than the NAFO-FAO cod data (Figure 2), likely because the Spanish data in this second period are the sum of the Northeast and Northwest Atlantic cod catches.

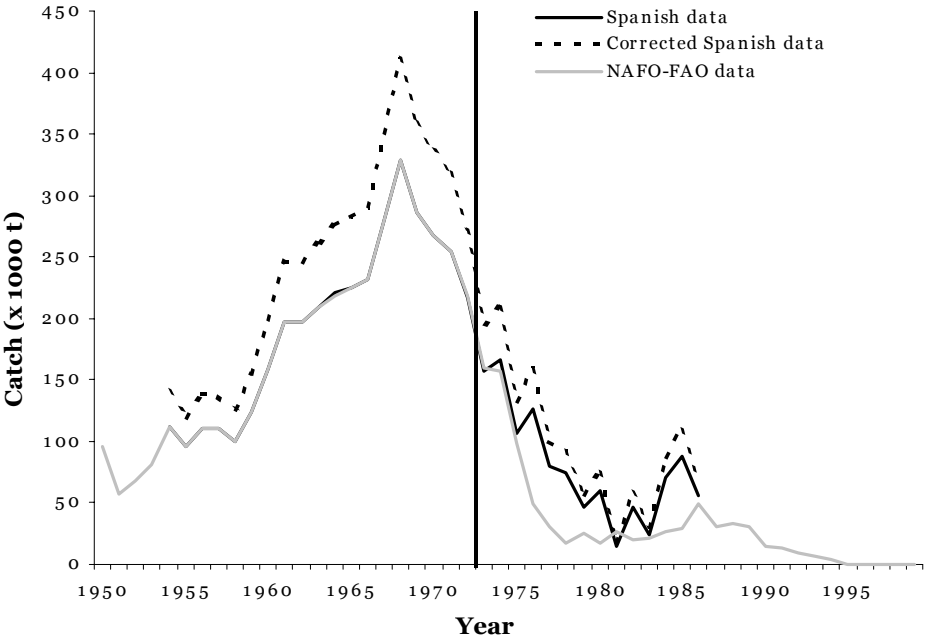

Figure 2. Spanish Atlantic cod catches in the Northwest Atlantic, 1950-1999. Spanish data are corrected for an estimated 25% non-reported catches. Until 1972, Spanish data are for the Northwestern Atlantic only (NAFO zones), and after 1972 totals are summed for the Northwest and Northeast Atlantic (NAFO and ICES zones). Spanish data are taken from the Spanish Fishery Yearbooks, and NAFO-FAO data from the FAO-Fishstat database.

LANDINGS, CATCH ESTIMATES AND DISCARDS

In the Spanish statistics, catches are estimated from landings using period-specific conversion factors (Table 2). The reason for the use of different factors is unclear, but it is likely due to variations in processing methods. A conversion factor of 3 kg of live weight fish to 1 kg of landed 'green' cod (3:1) was maintained from 1953 until 1978 when, without any complementary information, official records reported the change from 3:1 to 2.2:1, which was used until 1986, the last published data. This change in weight conversion might partly explain the dissimilarities between the Spanish and International catch data.

Table 2. Conversion factors of wet weight caught to 'green' cod landed, by period and fishing company or source. Data are taken from the Spanish Fishery Yearbooks.

Company/Source	1950	1951	1953-1977	1978-1986
PYSBE, S.A	2.5:1	-	-	-
PEBSA	1.89:1	2.5:1	-	-
COPIBA	2.14:1	1.7:1	-	-
Pairs of Trawlers	-	1.7:1	-	-
Other	-	-	3:1	2.2:1

It is commonly admitted that Spanish fishery statistics are underestimated. Apart from unknown amounts of discards, which are not even recorded in the data series, fishers may hide or significantly underestimate catch figures when reporting data to authorities, particularly in the case of trawling fisheries. Although printed records obviously do not exist, information collected from former skippers of trawlers engaged in cod fisheries suggests that the landings declared to official fishery boards should be increased by about 20-25%.

With reference to discards, we know that the traditional Spanish market was primarily for salted fish, and even then only the large fish were suitable. Around the period of 1940-1965, the catch was likely not yet dominated by small fish, and discard rates were probably no greater than 25%. In later trawling years (1970s to mid-1980s), fish populations fluctuated through low abundance periods, when small fish would have been particularly abundant. The technology was capable of taking them, but the markets were just then beginning to accept them. For this latest period, the discard rate may have exceeded 25% in some years or areas, but the overall rate may have been lower (P. Fanning, Department of Fisheries and Oceans, Halifax, Canada, pers. comm.).

Finally, the official Spanish data indicate that the number of fleets fishing in Canadian waters and their cod landings fluctuated widely between 1946-1986 (Figure 3). There was an increase in the number of boats in the early 1950s, although this was not associated with increased landings. After this, however, the increase in the number of boats between 1955 and 1968 resulted in a simultaneous increase in landings. The rapid decrease in cod landings after 1968 was probably a combined result of the decrease in the number of boats, as well as overfishing.

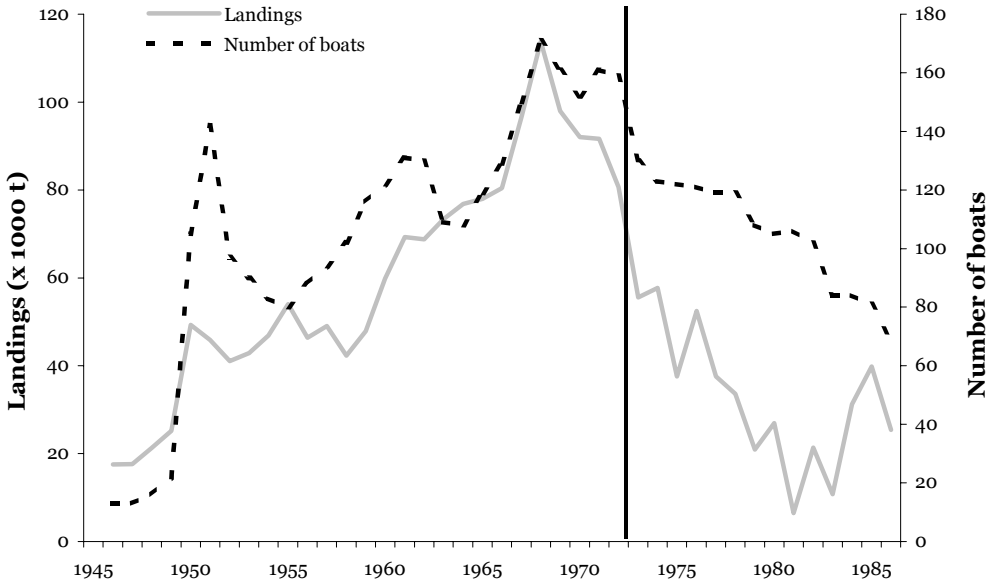

Figure 3. Number of boats and cod landings (green cod) of the Spanish cod fishery, 1946-1986. Until 1972, data are for the Northwestern Atlantic only (NAFO zones), and after 1972 totals are summed for the Northwest and Northeast Atlantic (NAFO and ICES zones). Data are taken from the Spanish Fishery Yearbooks.

ACKNOWLEDGEMENTS

I would like to thank Villy Christensen and Sylvie Guénette for their invitation to take part in this project and also for the patience they showed with me. Furthermore, I would like to thank the Pew Charitable Trusts, Philadelphia, for funding the *Sea Around Us* project.

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PORTUGUESE CATCHES OF ATLANTIC COD (*GADUS MORHUA*) IN CANADA FOR THE PERIOD 1896-1969: A COMPARISON WITH NAFO DATA

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ABSTRACT

From 1896 to 1934, Atlantic cod (*Gadus morhua*) landings from the Portuguese fishery in Canadian waters were relatively low. However, they increased gradually, and were closely related to the number of boats ('lineships') in the fishery. This fishery was highly selective for larger-sized cod, which resulted in few discards. After 1936, trawlers appeared in the fishery, and became increasingly used until they finally outnumbered the lineships in 1969. As a result, both the catch and value of the cod fishery increased dramatically during this period. The cod catch data fit very closely with NAFO data after they are converted from dried salted weight to wet weight caught. Discards and non-reported catches were likely minimal as a result of Portuguese fishery policy measures, which are discussed.

INTRODUCTION

The historical Portuguese cod fishery was concentrated on several well-known banks south and south-east of Newfoundland (including the Flemish Cap), west of Greenland, east of Labrador and to a lesser extent off Nova Scotia (Boavida, 1950; Monteiro and Lima Dias, 1969; DGPA, 2000). Here, we describe the fishery for the period 1896 to 1969.

THE YEARS 1896 TO 1934

The data were compiled from the annual statistical publications entitled *Estatística das Pescas Marítimas. Comissão Central de Pescarias: Ministério da Marinha* as:

1. Yearly summaries by ship; and
2. Global statistics of the Portuguese cod fishery in the Northwest Atlantic.

Considerable effort was applied to correct the apparent discrepancies between the two data sets within the same publication, such as missing or mismatch of ship name, GRT, or port of registry. Cod landings and value were not modified, but variables found in the report such as 'Ship-value', 'Gear', and 'Gear-value' (Table 1) were modified, as these data did not appear to have been collected very consistently and are thus of limited use.

Table 1. Information available in the *Estatística das Pescas Marítimas*, official source of information for Portuguese fisheries in Canadian waters during the 20th century.

Variable	Unit	Comment
Year	-	-
Fish. area	-	Fishing area – Newfoundland (Terra Nova), Greenland or both (TNG)
Start	month	Start of fishing trip
Finish	month	End of fishing trip
Port	-	Port of register
Name	-	Name of ship
GRT	-	Gross Registered Tonnage
Crew	number	Number of crew
Boats	number	Number of boats (dories)
Ship-value	escudos	Value in 'Escudos' from 1912 on. Before 1912 in 'Reis'
Gear	number	Number of lines
Gear-type	-	-
Gear-value	escudos	Value in 'Escudos' from 1912 on. Before 1912 in 'Reis'
Cod landings	kg	-
Cod-value	escudos	Value in 'Escudos' from 1912 on. Before 1912 in 'Reis'
Cod-oil	kg	-
Cod-oil-value	escudos	Value in 'Escudos' from 1912 on. Before 1912 in 'Reis'

The revised catch data by ship cover the years 1896 to 1934. After revision, it appears that there is good overall consistency between the two data sets (Figure 1). The trend in landings during this period appears to be closely related to that of the number of boats in the fishery.

THE YEARS 1934 TO 1969

For the period 1934 to 1969, the yearly summaries by ship were not available, which coincides with the establishment of the Cod Regulatory Commission in 1934 (Comissão Reguladora do Comércio de Bacalhau, CRCB) (Garrido, 1997a, b, 1999). A comparison of data from different sources, including yearly official statistics and data given in Garrido (1997a, referring to the bulletins of the CRCB and the 'Instituto Nacional de Estatística'), yielded good overall consistency. The catch and value of the cod fishery increased considerably after 1936 (Figure 2) as a result of trawlers appearing in the Portuguese fishery in Canadian waters (Figure 3). They remained high, though decreased slightly from 1966 to 1969.

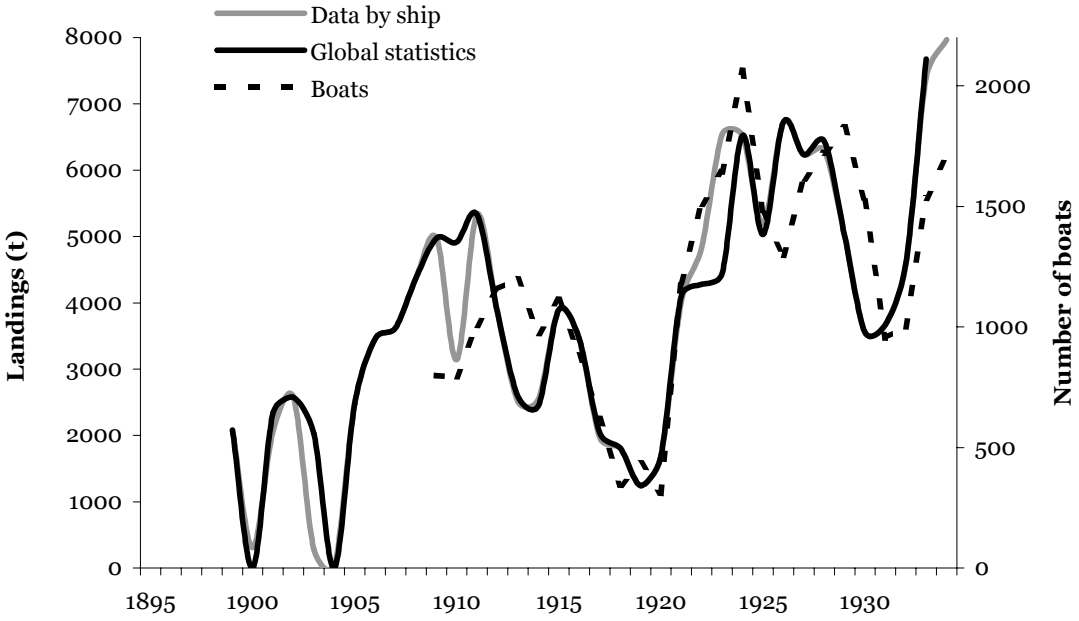

Figure 1. Comparison of Atlantic cod landings between 1899-1934 from two different data sets within 'Estatística das Pescas Marítimas', and number of boats in the fishery (as of 1909).

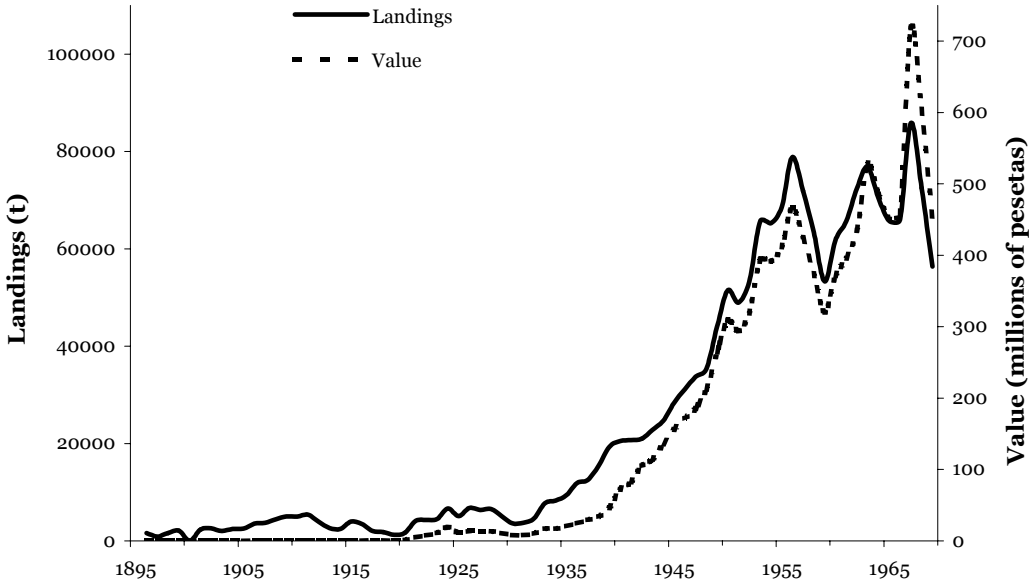

Figure 2. Atlantic cod landings and value of the Portuguese cod fishery from 1899 to 1969.

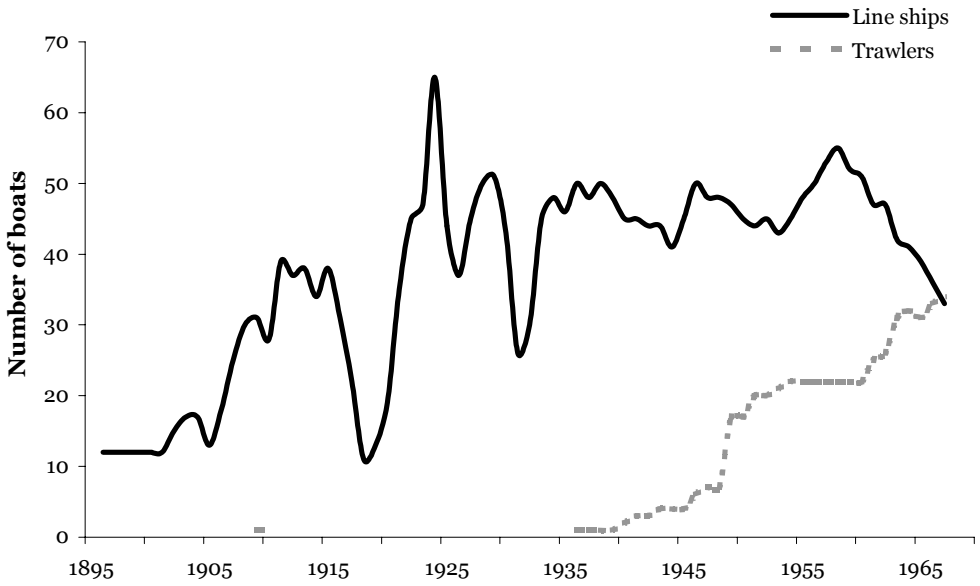

Figure 3. Effort deployed by Portuguese fleets fishing Atlantic cod in Canadian waters, 1896-1967.

COMPARISON WITH NAFO DATA

A proper comparison between Portuguese and NAFO data requires a conversion of the Portuguese data from dry-salted landings to wet weight caught. NAFO data are already reported as wet weight. The conversion factor of 1 kg landed cod to 2.5 kg real catch (wet weight) is based on the estimate for the year 1950 of PSYBE, S.A., a Spanish fishing company (Estatística de Pesca, 1950). This factor was chosen instead of conversion factors from other companies because it is closer to the conversion factor of 3.8 from Hutchings and Myers (1995). It was applied to all years until 1952. For subsequent years, a conversion factor of 1:3 quoted in the Spanish Fishery Yearbooks was used (Estatística de Pesca, 1953-1969). After conversion, the Portuguese cod data fit very well with the NAFO cod data, which are taken from all NAFO areas (Figure 4).

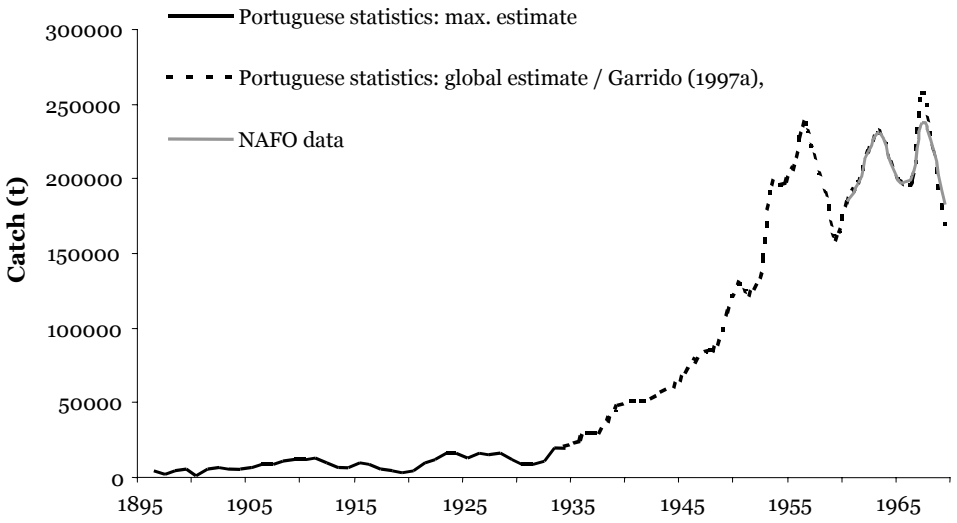

Figure 4. Comparison of data sources for Atlantic cod catches of the Portuguese cod fishery in Canadian waters, 1896-1986. The Portuguese catch statistics were obtained by converting the dried and salted cod landings into wet weight.

DISCARDS AND UNREPORTED CATCHES

There are no direct data sources regarding discards and unreported catches in the cod fishery, but we assume discards were minimal until 1967, which is the year that the market was liberalized (Garrido, 1997b, 1999). Originally, and exclusively until 1936, the fishery consisted of 'lineships', which did not start to decrease in number until 1957 (Figure 3). This fishery is characterized by line fishing from dories, and was selective for larger cod. Thus, discards are considered minimal until 1936. During this period, the fishery developed in both catch and effort, except for an interruption during WW I (Figures 1 and 3).

Starting from 1957, the total catches appear to have reached a maximum, and then fluctuated around 70,000 tonnes, even though trawlers became more dominant in the fishery. This was caused by competition with other fleets, decreasing catch rates, and problems related to the economic profitability of the fishery. This has contributed to the increase in discarding and under-reporting as a result of competition and market prices.

Considering the fierce competition between fleets, the importance of cod in the national economy, and the interest in protecting the cod sector, a number of policy measures were adopted in connection with the establishment of the CRCB in 1934. These included subsidies, fixed prices according to different categories of cod (e.g., larger than 2 kg, at least 800g, smaller than 300g, damaged fish larger than 300g, damaged fish smaller than 300g, etc.). Thus, the government was interested in securing a market for national production and sale of these products, before determining the amount of cod that could be imported to satisfy national demand. As part of this system, not only were the fishing operators obliged to report all catches, it was also in their best interest to do so (Silva, 1957; Garrido, 1999). Furthermore, there was a market for damaged fish, such as the fishmeal industry, which reduced the need to discard.

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Our sincere gratitude to Prof. Álvaro Garrido, historian of the University of Coimbra, for providing valuable references and guidance on the history of the Portuguese cod fishery. Furthermore, we would like to thank the Environment Program of The Pew Charitable Trusts, Philadelphia, for their funding of the *Sea Around Us* project.

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OBSERVATION AND INSPECTION DATA: DETERMINING CATCH AND BYCATCH BY FOREIGN FISHERIES ON THE GRAND BANK OUTSIDE THE CANADIAN EEZ

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ABSTRACT

The purpose of this project was to assess if the 'Foreign Fisheries Information Service/Canadian Fisheries Information Network' (FFIS/CFIN) databases on foreign fishing vessels in Northwest Atlantic waters, maintained by the Canadian Department of Fisheries and Oceans (DFO), could yield information that might permit the creation of an index of fish extractions from areas outside of the Canadian Exclusive Economic Zone (EEZ) around the Grand Bank. To facilitate this work, staff from DFO (St. John's, Newfoundland) provided consulting services on the history of the fisheries, the purpose and contents of the databases, and the actual exploration of the data itself. FFIS and CFIN are now an integrated database that links information collected by various observation platforms, including the Canadian Coast Guard and DFO Patrols, with Northwest Atlantic Fisheries Organization (NAFO) and Canadian inspections of fishing vessels off Canada's coast. The database contains a large number of variables, not all of which are reported on at all times. The data sets that have been collected for the *Sea Around Us* project are described here. In addition, a method is suggested for linking and integrating the datasets, to allow the building of a new dataset of actual extractions by foreign fishing vessels outside of Canada's territorial waters. This report represents only a preliminary investigation of the use of observation and inspection data.

BACKGROUND

The 'Foreign Fisheries Information Service' (FFIS) was created in the late 1980s as a way for fisheries officers to keep track of vessel sightings and the duration of their stay in Canadian and near Canadian waters of the Northwest Atlantic. Initially, it was an entirely manual system, but was computerized in the early 1990s. Although records for the 1980s have reportedly been entered into the computer database, the records now appear to be lost or are not being made available. DFO staff in Ottawa have made little effort to locate them despite repeated requests from the regional DFO office in St. John's. Therefore, only data from the 1990s were examined in this project. During the 1990s, data collection became more sophisticated. Starting in the early 1990s, the data set included sightings from airplanes and from other vessels, in addition to physical vessel inspections. By the mid 1990s, the data set was again expanded to include 'hails' (required radio contacts) from vessels crossing between NAFO divisions.

The 'Canadian Fisheries Information Network' (CFIN) data set began in the early 1990s, and appears to supercede the pre-existing FFIS data. CFIN is a relational database using ORACLE, providing linkages between data fields to describe boat observations. Because neither CFIN nor FFIS were designed to keep track of fish extractions *per se* the data fields had to be examined individually to see which ones contain useful variables for the *Sea Around Us* project.

DATABASE APPROACHES

An attempt was made to use the database interface to extract data such that an historical record of boats and their activities/catches would be produced. The main difficulty in the creation of a new unified data set was the existence of overlapping records in the CFIN database. For example, if a ship was sighted by a Canadian Coast Guard vessel, and also by a NAFO inspection, both records would appear in the database. However, the inspection data would be more comprehensive, accounting of the boat's activities and its catch. Thus, it is conceivable that for long inspections, there could be many overlapping sightings. In the creation of a unified data set, overlap of information is the first of three problems that had to be addressed. The second problem arose from gaps between sightings. Because there are gaps in the records of sightings, a protocol has to be invoked to decide how big a time gap to allow before a vessel was deemed to have gone to port to unload, or was simply unsighted. The third problem arises from discontinuous variable records, which pervades the whole data base.

Furthermore, in order to create a useful data subset, assumptions have to be applied to the observation and hail data to account, for each vessel, what it was doing and how much it was

catching. These assumptions are based on information on that vessel, or vessel type, derived from the inspection data set. This process required more time that was available for the first phase of the work (Dec. 2000-Feb. 2001). Therefore, *in lieu* of creating a unified data set, the decision was made to extract the data fields most suitable for estimating fisheries extractions and bycatch, for later examination. The data fields chosen from the FFIS/CFIN database were:

1. Inspection logs: an account of what the boat was doing at sea based on log books;
2. Inspection: an account of the vessels inspected in terms of identification and gear;
3. Position: an account of the position of vessels based on observations and hails.

These data tables (*www.fisheries.ubc.ca/projects/SAUP*) are described in Appendix 1. A first summary of the catches of groundfish retained versus discarded by foreign vessels between 1990 and 2000, based on the available observation/inspection data is presented in Figure 1, while the overall average discard rates (%) for all species are indicated in Figure 2. Discard estimates are from reports by ships' captains. In order to better calculate extractions from areas beyond Canada's 200 mile EEZ, the following steps are recommended. Calculate trip length, species composition, catches, and discards, for gear types by vessel, by country and by year, using the inspection and inspection log data, then, given this information, generate indices about vessel and gear characteristics to enrich the position data set. The only requirement to do this, is that enough information exists within the position data set to accurately determine when boats were fishing. To do this it will also be necessary to address the time gap issue. For instance, DFO uses the assumption that if a vessel is not sighted for 15 days, then 2.5 days of effort were added to the last recorded time fishing. This problem should not exist for data after the mid 1990s because vessel 'hail' were included.

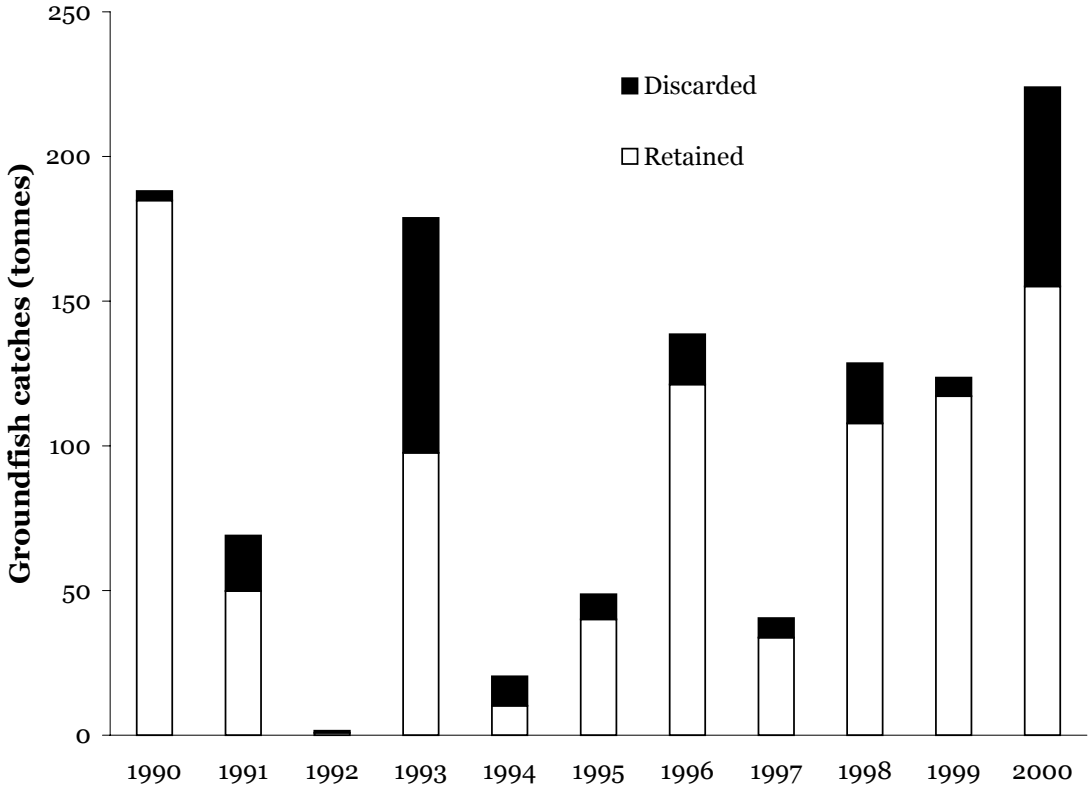

Figure 1. Estimation of catches and discards of groundfish by foreign vessels fishing outside the Canadian 200 nm EEZ between 1990 and 2000, based on the FFIS/CFIN database.

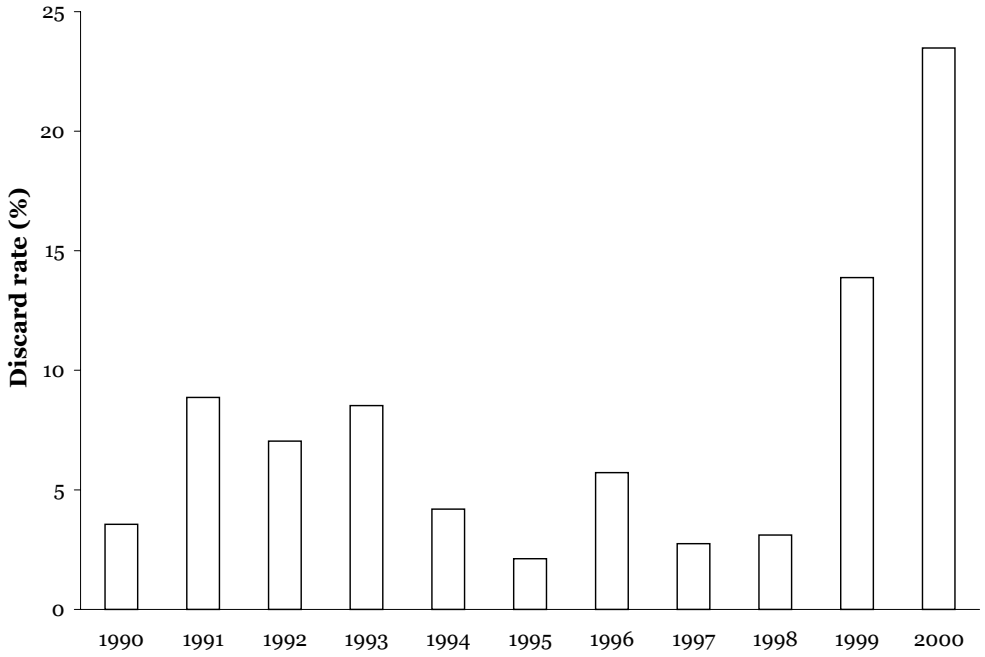

Figure 2. Estimated average discard rates (all species) for foreign vessels fishing in international waters (outside Canada's 200 nm EEZ) between 1990 and 2000, based on FFIS/CFIN data.

The implication is that the position data set will have to be manipulated to transform it into a record of each vessel's activities during the 1990s. This new data set can then be enriched by the inspection log data. It is recommended that the position data be the starting point to which all the other information should be added, to reduce the confounding effect of trying to account for overlapping data. This would require a two-track approach whereby the inspection and inspection log data sets are modified to produce vessel and gear information designed to fit into the position data set. Alternatively, the inspection log data-set provides another choice for acting as a skeleton upon which the information on extractions from the other data sets can be added. However, it might not be as good a choice, since the frequency of inspections has declined somewhat towards the end of the 1990s.

General characteristics of the fishery

The present summary is based on an interview and discussions with Tony Blanchard, a DFO fisheries inspector. The major species targeted in the 1990s is 'turbot', i.e., Greenland halibut (*Reinhardtius hippoglossoides*), which is the only species with a NAFO quota for the area concerned in this project. Grenadiers (*Macrourus berglax* and *Coryphaenoides rupestris*), hake (*Merluccius bilinearis* and *Urophysis chuss*), redfish (*Sebastes* spp.), and skates (*Raja* spp.) are secondary species also caught. Average trip length for EU trawlers is approximately 5 months, whereas shrimp trawlers (nationality not specified) tend to stay out for about 1 month. The average vessel length is 70m, with a crew of 12-24, and a capacity of 400-1,000 t. Boats recorded as 'not fishing' are likely fishing (usually trawling) within 24 hours of the record. Misreporting seems to have declined from the early to mid 1990s but then increased again to the late 1990s . For example, a vessel with a 10 t turbot quota might report a catch of 10 t turbot and 10 t dogfish. Upon inspection it is discovered that there are, in fact, 15 t turbot and 5 t dogfish. Any adjustment protocols that will be applied to create an extraction data set will have to account for these factors and determine their usefulness.

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I would like to thank the DFO staff at St. John's, in particular Peter Shelton, Tony Blanchard and Peter Quinlan, for their time and assistance, and the Pew Charitable Trusts, Philadelphia, for funding the *Sea Around Us* project.

APPENDIX 1

Table 1. List of species in the FFIS/CFIN database, provided by Peter Quinlan (DFO, ST. John's). Note that the species codes appear to be similar to those used by NAFO, though they are not the same.

Code	Abbreviation	Description	Scientific Name
100	COD	COD	*Gadus morhua*
101	GRC	ROCK COD	*Gadus ogac*
102	ARC	ARCTIC COD	*Boreogadus saida*
103	LIN	LING COD	*Molva molva*
110	HAD	HADDOCK	*Melanogrammus aeglefinus*
120	RED	REDFISH	*Sebastes* spp.
130	HAL	ATLANTIC HALIBUT	*Hippoglossus hippoglossus*
140	PLA	AMERICAN PLAICE	*Hippoglossoides platessoides*
141	YEL	YELLOWTAIL	*Limanda ferruginea*
142	WIT	WITCH	*Glyptocephalus cynoglossus*
143	FLW	WINTER FLOUNDER	*Pseudopleuronectes americanus*
144	GHL	GREENLAND HALIBUT	*Reinhardtius hippoglossoides*
149	FLX	FLOUNDER	Pleuronectiformes
169	WOL	WOLFISH-UNSPECIFIED	*Anarchichas* spp.
170	POK	POLLOCK	*Pollachius virens*
171	HKW	WHITE HAKE	*Urophysis tenuis*
172	HKS	SILVER HAKE	*Merluccius bilinearis*
173	USK	CUSK	*Brosme brosme*
174	CAT	CATFISH	Siluriformes
175	TOM	TOMCOD	*Microgadus tomcod*
176	LUM	LUMPFISH	*Cyclopterus lumpus*
177	ANG	MONKFISH	*Lophius americanus*
178	SAN	SAND EELS	*Ammodytes* spp.
179	RNG	ROUNDNOSE GRENADIER	*Coryphaenoides rupestris*
180	HKR	RED HAKE	*Urophysis chuss*
181	HKB	BLUE HAKE	*Antimora rostrata*
182	RHG	ROUGHHEAD GRENADIER	*Macrourus berglax*
183	SLA	SANDLANCE	-
184	EEL	EELPOUTS	*Lycodes* spp.
185	WST	WOLFFISH	*Anarchichas spp.*
186	WSP	WOLFFISH	*Anarhichas minor*
187	WNO	WOLFFISH	*Anarhichas lupus*
188	ALF	ALPHONCINOS	*Beryx* spp.
190	GF	GROUNDFISH	-
191	GFL	GROUNDFISH	-
193	GFO	OTHER GROUNDFISH	-
195	GXC	GROUNDFISH	-
197	GRC	GROUNDFISH	-
198	GXA	GROUNDFISH	-
199	GRO	GROUNDFISH-UNSPECIFI	-
200	HER	HERRING	*Clupea harengus*
249	BSF	BLACK SCABBARDFISH	*Aphanopus carbo*
250	MAC	MACKEREL	*Decapterus macarellus*
251	SWO	SWORDFISH	*Xiphia gladius*
252	ALB	TUNA-ALBACORE	*Thunnus alalunga*

Table 1. (continued)

253	BET	TUNA-BIGEYE	*Thunnus obesus*
254	BFT	TUNA, BLUEFIN	*Thunnus thynnus*
255	SKJ	TUNA-SKIPJACK	*Euthynnus alletteratus*
256	YFT	TUNA, YELLOWFIN	*Thunnus albacares*
257	HMK	HORSE MACKEREL	*Trachurus* sp.
259	TUN	TUNA, UNSPECIFIED	Scombridae
260	SAU	BILLFISH	Istiophoridae
287	BUM	BLUE MARLIN	*Makaira nigricans*
289	BAM	BLACK MARLIN	-
299	PEL	PELAGIC FISH	-
350	ALE	ALEWIVES	*Alosa pseudoharengus*
351	ARG	ARGENTINE	*Argentina* spp.
352	ELA	EELS	Notacanthidae
354	SAL	SALMON (ATLANTIC)	*Salmo salar*
355	SHA	SHAD	*Alosa sapidissima*
356	SKA	SKATE	Rajidae
357	SMR	SMELTS	*Osmerus mordax*
358	STB	STRIPED BASS	*Morone saxatilis*
359	STU	STURGEON	Acipenseridae
360	CAP	CAPELIN	*Mallotus villosus*
361	CHR	CHAR	*Salvelinus* spp.
362	DGX	DOGFISH-UNSPECIFIED	*Squalus* sp.
363	TRO	TROUT	Salmonidae
364	SSA	SILVERSIDES	Atherinidae
365	---	SALMON/CHAR	Salmoniformes
369	SPO	SHARK	Lamnidae
370	SGR	SHARK	-
371	SBA	SHARK	-
372	SBL	SHARK	-
376	SHO	SHARK	-
377	SHM	SHARK	-
379	SHX	SHARK	-
399	FIN	OTHER FINFISH	-
600	CLB	BAR CLAMS	-
601	CLS	SOFT SHELL	*Mya arenaria*
602	CLQ	QUAHAUG	*Arctica islandica*
604	CLP	CLAMS-PROPELLER	-
608	CSS	CLAMS-STIMPSON SURF	*Spisula polynyma*
609	CLX	CLAMS	Bivalvia
610	MUS	MUSSELS	*Mytilus* sp.
611	OYA	OYSTERS(AMERICAN)	Ostreidae
612	SCX	SCALLOP	Pectinidae
613	SQU	SQUID	*Loligo* sp.
614	PER	WINKLES	*Busycon* sp.
615	SQI	SQUID-ILLEX	*Illex* sp.
616	SQL	SQUID	*Loligo* sp.
617	WHE	WHELK	-
618	WHB	WHELK	-

Table 1. (continued)

678	OCT	OCTOPUS	-
699	MOL	MOLLUSCS	Bivalvia
700	LBA	LOBSTER	Decapoda
701	BAI	BAIT	-
702	PRA	SHRIMP (PRAWN)	-
703	CRJ	JONAH CRAB	-
704	CRK	ROCK CRABS	-
705	CRQ	SNOW CRABS	Majidae
706	CRR	RED CRABS	-
707	CRA	CRAB	Crustacea
708	KCT	STONE CRAB	-
710	BOR	SHRIMP	*Pandalus* sp.
711	MON	SHRIMP	*Pandalus* sp
712	SHR	SHRIMP	Pandalidae
799	CRU	CRUSTACEANS	Crustacea
800	ROC	ROCK	-
801	BAI	BAIT	-
898	BAI	BAIT (COD)	-
899	BAI	BAIT	-
900	---	DULSE	-
901	---	IRISH MOSS	-
902	---	KELP	-
905	---	OTHER SEAWEEDS	-
909	URC	SEA URCHINS	-
910	WOR	WORMS	Polychaeta
911	---	COD LIVERS	-
912	---	HALIBUT LIVERS	-
913	---	SWORDFISH LIVERS	-
914	---	TUNA LIVERS	-
915	---	PRESERVED COD	-
916	---	SHARK LIVERS	-
919	---	UNSPECIFIED LIVERS	-
920	---	TONGUES	-
921	---	HERRING SCALES	-
922	---	ROES	-
923	---	FISH FINS	-
924	---	LIVER OIL	-
925	---	SHARK FINS	-
926	---	SHARK LIVER	-
927	---	CAVIAR	-
928	---	LUMPFISH ROE	-
930	---	SEAL SKIN,HARP,W.COA	-
931	---	SEAL	-
932	---	SEAL SKIN,HARP,BEATE	-
933	---	SEAL SKIN,HARP,BEDLA	-
934	---	SEAL SKIN,HARP,OLD	-
935	---	SEAL SKIN,HOOD,YOUNG	-
936	---	SEAL SKIN,HOOD,OLD	-
937	---	SEAL SKIN,HOOD,JAR	-

Table 1. (continued)

938	---	SEAL	-
939	---	SEAL OIL	-
940	---	WHALE, FIN	*Balaenoptera physalus*
941	---	WHALE, SEI	*Balaenoptera borealis*
942	---	WHALE, SPERM	*Physeter macrocephalus*
943	---	WHALE, OTHER	Mysticeti
944	---	WHALE, MINKE	*Balaenoptera acutorostrata*
945	---	WHALE, POTHEAD	*Globicephala macrorhynchus*
946	PWS	WHALE, PILOT	*Globicephala melaena*
947	PWL	WHALE, PILOT	*Globicephala melaena*
950	---	SKATE	-
963	---	SEAL, GREY	*Halichoerus grypus*
996	PSH	PURCHASE	-
997	NON	NONE	NULL
998	OTH	OTHER	OTHER
999	UNS	UNSPECIFIED	UNSPECIFIED

Table 2. Gears in the FFIS/CFIN database.

Gear Type	Mobile / Fixed	Description
FDR	F	FIXED DREDGE
FTR	F	FIXED TRAP
FEW	F	FIXED WEIR
FGS	F	FIXED GILLNET (SET)
MLA	M	MOBILE LAMPARA
MPS	M	MOBILE PURSE SEINE
MDS	M	MOBILE DANISH SEINE
RAR	M	ROD AND REEL
CRP	F	CRAB POTS
FLD	F	FIXED LONGLINE (DRIFT)
FSJ	F	FIXED SQUID JIGGER
MBT	M	MOBILE BOTTOM TRAWL
MHS	M	MOBILE HARPOON/SPEAR
MMT	M	MOBILE MIDWATER TRAWL
MPT	M	MOBILE PAIR TRAWL
MTL	M	MOBILE TROLLER LINES
SDM	M	MOBILE SCALLOP DRAG
TLP	M	TENDED LINES (PELAGICS)
FPT	F	FIXED POT
FLS	F	FIXED LONGLINE (SET)
MSS	M	MOBILE SCOTTISH SEINE
FGD	F	FIXED GILLNET (DRIFT)

Table 3. Countries in the FFIS/CFIN database.

Code	Country	NAFO member	EU member
MOR	MOROCCO	N	N
NLD	NETHERLANDS	N	Y
NOR	NORWAY	Y	N
PAN	PANAMA	N	N
PHI	PHILLIPPINES	N	N
POL	POLAND	Y	N
POR	PORTUGAL	Y	Y
ROM	ROMANIA	Y	N
SVI	ST. VINCENT & GRENADINES	N	N
SAF	SOUTH AFRICA	N	N
SPA	SPAIN	Y	Y
SWE	SWEDEN	N	N
UKI	UNITED KINGDOM	Y	Y
USR	USSR	Y	N
VEN	VENEZUELA	N	N
CUB	CUBA	Y	N
CYP	CYPRUS	N	N
FRA	FRANCE	Y	Y
USA	USA	N	N
CAY	CAYMAN ISLAND	N	N
CHI	CHILE	N	N
DEN	DENMARK	Y	Y
EGY	EGYPT	N	N
FAR	FAROE ISLANDS	Y	N
GRE	GREENLAND	Y	N
GDR	GER. DEM. REP.		N
ICE	ICELAND	Y	N
IRE	IRELAND	N	N
JAP	JAPAN	Y	N
KOR	KOREA	Y	N
LIB	LIBERIA	N	N
MEX	MEXICO	N	N
BAH	BAHAMAS	N	N
GER	GERMANY	Y	Y
HON	HONDURAS	N	N
MAL	MALTA	N	N
RUS	RUSSIA	Y	N
LAT	LATVIA	Y	N
EST	ESTONIA	Y	N
LIT	LITHUANIA	Y	N
SIL	SIERRA LEONE	N	N
UKR	UKRAINE	N	N
NZL	NEW ZEALAND	N	N
CAN	CANADA	Y	N
BUL	BULGARIA	Y	N
BEL	BELIZE	N	N
SPM	FRANCE - SPM	Y	N
ITA	ITALY	Y	Y
MAU	MAURITANIA	N	N
ANT	ANTIGUA & BARBUDA	N	N

Table 4. Definitions of key variables in the 'position' table from FFIS/CFIN.

Variable	Definition
VESSEL_ID	Call sign of vessel
LATITUDE	Latitude at time of sighting
LONGITUDE	Longitude at time of sighting
POSITION_DTT	Date-time stamp of vessel sighting
TYPE	**sighting**: vessel seen by observer. **zen:** time of zone entry **msn**: message sent reporting zone entry **zex:** zone exit **msx:** message sent reporting zone exit **pen:** port entry **pex**: port exit
PLATFORM	from which boat was sighted
ACTIVITY_CODE	**1)** fishing **2)** jogging **3)** steaming **4)** fishing-operational **5)** transshipping **6)** in port
DIVISION	NAFO division

Table 5. Definitions of key variables in the 'inspection logs' table from FFIS/CFIN.

Variable	Definition
INSPECT_NO	inspection number
SPECIES	species code
START_DT	date of start of fishing for target species
END_DT	date of end of fishing for target species
DIVISION	NAFO div
TONNAGE	tonnage caught
DISCARDS	Tonnage discarded
DAYS_FISHED	end - start
CATCH_RATE	from log (t/day)

Table 6. Definitions of key variables in the 'inspection' table from FFIS/CFIN.

Variable	Definition
VESSEL_ID	Call sign of vessel
INSPECTION_TYPE	NAFO/Canadian.
PATROL_VESSEL	Patrol vessel name
BOARDING_DTT	Boarding/inspection date-time
GEAR_TYPE	Fishing gear
VIOL_IND	Records of violations
HOLD_MEASURE_IND	Was the hold measured?
DEPART_VESSEL_DTT	Date and time of departure from vessel
COMPLETE_IND	Data entry from inspection complete?
INSP_PORT	Port of inspection
START_DT	Start date of inspection
END_DT	End date of inspection

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