ISSN 1198-6727

Fisheries Centre Research Reports

2007 Volume 15 Number 4

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Growth and distribution of port-based global fishing effort within countries' EEZs from 1970 to 1995[a]

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Fisheries Centre Research Reports 15(4)
99 pages © published 2007 by

The Fisheries Centre,
University of British Columbia

2202 Main Mall
Vancouver, B.C., Canada, V6T 1Z4

ISSN 1198-6727

[a] Cite as: Gelchu, A., Pauly, D. 2007. Growth and distribution of port-based global fishing effort within countries' EEZs from 1970 to 1995. Fisheries Centre Research Reports 15(4). Fisheries Centre, University of British Columbia [ISSN 1198-6727].

Fisheries Centre Research Reports 15(4)
2007

GROWTH AND DISTRIBUTION OF PORT-BASED GLOBAL FISHING EFFORT WITHIN COUNTRIES' EEZS FROM 1970-1995

by
Ahmed Gelchu and Daniel Pauly

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DIRECTOR'S FOREWORD

This report is based on a PhD thesis completed in the fall of 2006, under the supervision of this author.

The purpose of this exercise, conducted under the auspices and with technical and financial support from the *Sea Around Us* Project, was to show that sufficient information is available on global fishing effort to allow for mapping its distribution globally, and to identify major features of its growth and geographic expansion.

This report covers only the years 1970-1995. We have still to gather information similar to that presented here for 1950 to 1969, and from 1995 onward, to obtain a database matching that of our catches. Also, we still need to cover distant-water fleets, and the fleets exploiting the large pelagic fishes of the high seas. Finally, we need to account for the fishing effort by small-scale fishers, not (fully) covered in the FAO and other databases used for the present study.

However, these will be only extensions of the present study, which, in its approach and in the units it used ('horsepower-day'), defines how we will proceed.

In the meantime, we present this report, to help us reflect on the enormous expansion of fishing effort that occurred in the quarter-century covered here, which left us with the enormous overcapacity we now have, and which, somehow, we have to find a way to reduce.

Daniel Pauly

May 2007

ABSTRACT

Analyzing the spatial dimension of global fishing effort provides insights into the mechanisms driving its expansion through time. It also enables confronting the spatio-temporal trends of fishing effort with the well-documented global depletion of major commercial fish stocks.

This report presents analyses of the evolution and spatial distribution of port-based global fishing effort from 1970 to 1995, a period of global fisheries expansion. A model involving qualitative filter criteria and quantitative weighting of fishing grounds was developed to predict the spatial distribution of port-based global fishing effort within the EEZs of all maritime countries of the world. These were then grouped into four sets for regional analyses, and pooled for an overall analysis of global trends.

The results of these analyses showed that, on a global scale, effective fishing effort grew by 500% in the period between 1970 and 1995. This growth led to reduction of total catch per unit of effort (CPUE) by 70% over the same period. The prediction of spatial distribution of port-based global fishing effort showed that fishing effort covered all continental shelves in the 1990s, with intensely fished areas clustered along the coasts of all major fishing nations. In addition to the offshore range expansion implied here, the results revealed that the centers of fish catch and effort concentrations gradually moved southward by 20^{o} and 10^{o}, respectively.

Additionally, the fuel consumption of port-based global fishing fleets was estimated, using an independent estimate of global fisheries fuel consumption. The result gave a fuel consumption rate of 0.1-0.3 liters per horsepower-hour. When this is applied to time-series of global fishing effort, this results in the fuel consumption of global fishing fleet growing by 85 % (2.2% per year) during the period from 1970 to 2000.

INTRODUCTION

Fishing is one of the oldest human activities. Since time immemorial, the coasts and the seas were 'hunting' grounds in which humans caught fish. Thus, it is not a coincidence that human settlements flourished on coastlines around the world oceans (Brandt, 1972; Weber, 1994; Lear, 1998; UN, 2005a).

Fishing began as a simple form of production in which small quantities of fish were caught using rudimentary gears. But as human population grew, it became necessary to switch from catching single fish to catching fish in bulk (Brandt, 1972). The opportunity for such mass fish production led to development of fishing fleets and, over time, increasing demand for inexpensive food continued driving the emergence of larger fishing fleets. The power and size of fleets showed remarkable increases around the last decades of the 19^{th} century, during the first industrialization of fisheries, especially in Europe and North America (Brandt, 1972; Cushing, 1988; Pauly *et al.*, 2002).

The first industrialization and expansion of fisheries (1870s-1950)

The industrial revolution took hold of much of Europe in the late 18^{th} century, bringing massive changes in sectors such as agriculture and transportation. However, industrialization did not much affect the fisheries sector until the late 19^{th} century, when the first steam trawler was introduced to the North Sea in 1875 (Gulland, 1974). The reason for the lag was that the winds that had propelled the pre-industrial fishing fleets were free, but coal cost money (Cushing, 1988). After this delayed introduction, mechanization and expansion of fishing fleets grew steadily, especially in countries bordering the North Atlantic region and in Japan, until the outbreak of the First World War (WW I) in 1914 (Gulland, 1974; Cushing, 1988, Pauly *et al.*, 2002; Swartz, 2004). This growth was mainly driven by high demand for fish due to increases in population, income, and urbanization (Gulland, 1974; Cushing, 1988).

WW I brought a sharp end to the fleet expansion trend in much of Europe (Gulland, 1974), and the North Atlantic stocks benefited from four years of fisheries closure (Gulland, 1974; Pauly *et al.*, 2002). However, increased catches in the war's aftermath resulted in a new fleet expansion, leading to depletion of several stocks, which in turn brought about financial difficulties for several fisheries (Gulland, 1974; Hilborn *et al.*, 2003). The difficulties of the fishing fleets caused by diminished catches were further compounded by the general economic depression of the 1930s (Gulland, 1974). Fishers responded to economic hardships by moving farther into offshore grounds to maintain high catch rates, leading to another cycle of competitive race for further expansion of fishing fleets (Gulland, 1974, Cushing, 1988).

Similar trends occurred in other parts of the world such as China, Japan, Australia and other countries (Solecki, 1966; Asada *et al.*, 1983; Bian, 1985; Fujinami, 1989). Though demand for fish and the rate of expansion differed from place to place, the common outcome was increased mechanization and expansion of fishing fleets worldwide.

In the years leading up to WW II, the increasing trend in mechanized fleet expansion continued despite signs of overfishing and the creation of several international organizations to deal with overfishing concerns, (Gulland, 1974). WW II had the same effects as WW I for the stocks of the affected regions. After WW II, catches were very high and this led to massive fleet constructions leading to the 'second industrialization' of fisheries.

The second industrialization and expansion of fisheries (1950 - circa 1980)

In developed countries, the second industrialization of fisheries began in the 1950s and lasted until the introduction of 200-nautical mile limits, known as Exclusive Economic Zones (EEZs), in about the late 1970s (Cushing, 1988; Miles, 1989). The beginning of this era corresponds to the aftermath of WW II, and is characterized by a remarkable expansion of fishing effort, driven by demand for fish and incentives from the post-war economic recovery (Gulland, 1974; Pauly *et al.*, 2002).

In developing countries, fisheries industrialization began during this era, mainly as a result of FAO projects, technology transfers from developed countries through bilateral development aid, and non-government organizations (Chidambaram, 1963; Panayotou, 1985; Thiele, 1999). By the 1950s, most of the pre-WWII steam trawlers were scrapped and replaced by diesel-powered vessels. The resulting powerful new fleets, with ample fuel storage tanks, had more mobility, and consequently, they expanded their range of operation from homeports (Gulland 1974; Stump and Batker, 1996). An intense race for fish and resulting declines in coastal stock abundances led to the evolution of huge floating 'factory' vessels capable of staying at sea for weeks and processing large catches at sea (Gulland, 1974; Anon, 2005). The first such factory trawler, named *Fairtry*, was built in Scotland in 1954; it was 280 feet long and had a capacity of 2600 GRT (Stump and Batker, 1996). *Fairtry's* successors, modern factory supertrawlers, can be longer than a football field and capable of catching and processing into various products up to 200 tonnes of fish daily (Anon, 2005). By the mid-to-late 1950s, mass production of these huge trawlers occurred in all major fishing nations of the world (Stump and Batker, 1996).

The other important development of this era is the stern-trawling, an innovation introduced by the designers of the *Fairtry* (Gulland 1974). Stern trawling led to greater towing power and improved gear handling, enabling these vessels to haul bigger nets and catch more fish than traditional side-trawlers (Gulland 1974; Stump and Batker, 1996). Likewise, as fishing techniques improved and the size of vessels grew, so did the sizes of gears. This is captured by the cliché that the biggest modern trawl could an engulf more than a dozen Boeing 747 jumbo jets (Anon, 2005). Similarly, a modern longliner can hang thousands of hooks and a modern seine net, assisted by sophisticated fish finding sonars for locating schools of fish, can encircle huge fish schools. All these developments greatly enhanced the fishing power of fishing fleets and the technology quickly spread around the world, even to some developing countries, notably to Cuba, South Korea, Taiwan and Thailand (Panayotou, 1985; Thiele, 1999).
Massive construction of fishing fleets by all major fishing nations continued throughout 1960s. With national jurisdictions extended only to 12 miles, beyond which there were virtually no constraints on access by these highly effective fleets, and no international regulations to comply with, the fishing fleets continued pursuing fish anywhere they wanted, causing extensive pressure on the resource base (Thiele, 1999). For instance, the situation in the northwest Atlantic was described by Stump and Batker (1996) as "for anyone crossing the Northwest Atlantic fishing grounds at night, the concentration of factory ships was often so great that their lights resembled floating cities". During these days modern industrial fishing fleets were divided into specialized categories comprising fishing, processing and transport vessels, each category performing specialized duties.

The combination of fleet expansion, efficient technologies, fleet specialization and high demand for fish products led to spectacular collapses of some important fisheries notably the Californian sardine (*Sardinops sagax*), North Atlantic herring (*Clupea harengus*), North Sea mackerel (*Scomber scombrus*), Atlantic menhaden (*Brevoortia tyrannus*) and Peruvian anchovy (*Engraulis ringens*) in the 1960s and 1970s (Gulland, 1974; Radovich 1982; Rogers and Van Den Avyle, 1983; Pauly, 1998; Pauly *et al.*, 2002; Bjomdal, 2003).

By the 1970s, despite efforts made by international organizations to mitigate this problem, it became evident that overfishing had seriously depleted many of the world's fish stocks. The need for some sort of management, especially effort control, was publicly called for in different parts of the world (Garcia and Newton, 1997). The debate on how to mitigate overfishing led to the extension of state jurisdictions to 200 miles.

The emergence of state jurisdiction regime in fisheries management (1970s-1980s).

By about the mid 1970s, long distance fishing fleets roamed the entire world's continental shelf areas and also began appearing on the coasts of distant countries (Parsons and Beckett, 1995; Pauly *et al.*, 2003). This expansion, with virtually no geographical limit, was a clear result of the prevailing open access policy, which treats fish as a 'free for all' resource (Rogers, 1995; Stump and Batker, 1996). The open access regime primarily benefited few countries, which had the capital and the technology to own modern powerful fleets (Thiele, 1999). Coastal developing countries generally gained smaller shares; in many cases they were harmed by foreign fleets catching fish at their doorsteps (Thiele, 1999). This inequitable sharing of wealth being as it was, the cumulative effects of the expansion led to severe depletion and collapses of several important fisheries around the world (Parsons and Beckett, 1995; Stump and Batker, 1996).

The spectacular declines of important fisheries, the growing sense of failure of international efforts to manage marine resources and increasing recognition of overfishing led to serious questioning of the wisdom behind the principles of open access to fisheries resources, on which long distance fleets based their expansions (Gordon, 1954; MacSween, 1983; Miles, 1989; Garcia and Newton, 1997). Finally in 1974, at the first session of the Third

United Nations Conference on the Law of the Sea (UNCLOS III) in Caracas, the effectiveness of the principles of open access in achieving sustainable use of fish resources was openly challenged (Miles, 1989). This convention paved the way for unilateral declaration of EEZ by many countries in the late 1970s.

Under the EEZ regime, vast ocean shelf areas with an enormous wealth of natural resources, that were traditionally open to all coastal nations, were turned into assets of coastal states (Pauly *et al*., 2002). The countries operating distant-water fleets were excluded from their traditional fishing grounds now under the jurisdictions of different countries (MacSween, 1983; Garcia and Newton, 1997). An important consequence of this new regime was that virtually all of the world's demersal and coastal pelagic fish and shellfish populations became encompassed within these zones of extended jurisdictions (Miles, 1989). Further, coastal states were given exclusive authorities to manage fisheries occurring within their extended jurisdictions, with the exception of stocks shared among states and 'highly migratory' species (Miles, 1989). This change in international access regime forced coastal countries operating distant-water fleets to limit the deployment of their fleets to their own EEZ and international waters (MacSween, 1983; Garcia and Newton, 1997).

The intended effect of the EEZ regime was the mitigation of resource depletion caused by the open access regime, which encourages investment in fishing capacity in order to extract a larger share of the resources (Gordon, 1954; Miles, 1989; Pearse, 1996; Pauly *et al.,* 2002). However, the EEZ regime brought about an unintended effect. Most countries, which expelled foreign fleets, turned around and engaged in exactly the same fleet development as the expelled countries had (Rogers, 1995; Pauly and Watson, 2003; Hilborn *et al*., 2003). Many countries pursued such a policy of massive development of their domestic fleets in order to fully exploit fish resources within their national jurisdiction, through direct or indirect subsidies (MacSween, 1983; Hanna *et al*., 2000; Pauly and Maclean, 2003; Pauly and Watson, 2003). Others acquired huge ocean-going vessels capable of offshore processing (MacSween, 1983; Stumper and Batker, 1996; Hanna *et al*., 2000). Subsidies, which had been estimated at $2.5 billion per year for the North Atlantic alone (Munro and Sumaila, 2002; Pauly and Maclean, 2003), and, globally in the order of $14-20 billion per year (Milazzo, 1998), but which were recently re-estimated at 30-34 billion per year (Sumaila *et al*, 2006), have greatly exacerbated the problem of fishing capacity build up arising from the open access regime. The effect was further expansion of the already over- expanded global fishing fleets, leading to a large global overcapacity (MacSween, 1983; Hanna *et al*., 2000; Hilborn *et al*., 2003; Pauly and Watson, 2003).

Fishing effort overcapacity

As described so far, the global race for fisheries development has led to large increase in fishing effort capacity, well in excess of the global capacity needed to exploit fisheries at optimal levels (Mace and Gabriel, 1999; Hanna *et al*., 2000). Overcapacity is the presence of too many boats in number of fishery, leading to overfishing (Thiele, 1999; Munro and Sumaila, 2002; UN, 2005b). Thus, the European Union could cut their fishing capacity by 40%, Norway by 60%, with no reduction in catches, while the largest U.S fishery, the Seattle-based trawlers targeting the North Pacific pollock (*Theragra chalcogramma*), had the capacity to catch 2-3 times the total allowable catch (Stump and Batker, 1996). In every major fishing nation, the situation is the same: too much fishing pressure on depleted stocks was fueling the downward spiral of fisheries resources (Stump and Batker, 1996; UN, 2005b).

From the point of view of society as a whole, overcapacity equals economic waste, harmful from both conservation and economic efficiency points of view (Gordon, 1954; Rogers, 1995; Christy, 1997a; Thiele, 1999). From a conservation point of view, overcapacity is capable of depleting all fish populations in the oceans. From an economic efficiency perspective, it is a wasteful economic activity, as equal amount of catches could be achieved with much smaller fishing effort (Rogers, 1995; Christy, 1997a; Thiele, 1999; UN, 2005b). Global estimates put economic loss due to overcapacity somewhere between $50 billion and $60 billion US dollars per year (Stump and Batker, 1996; Christy, 1997a).

Fishing effort definition in this study

Fishing effort is a surrogate variable representing all inputs used to catch fish (Gréboval, 1999). Thus, it can be defined as the means by which fishers achieve a catch during a given period (Le Pape and Vigneau, 2001). Quantitatively, effort can be divided into nominal effort (f), representing the overall effort used during a given period and effective effort (f_e), representing the pressure exerted by fishers on fish stocks. These two concepts can be linked to vessel size and power as:

$$f_e = f * p \qquad \text{...1.1)}$$

where f_e = effective fishing effort;
f = nominal fishing effort (number of vessels x number of fishing days);
p = vessel fishing power (horsepower[1]).

It is generally assumed that the fishing power of a boat is proportional to its engine power or tonnage capacity (Gulland, 1983; Wilson, 1999; Marchal *et al*., 2002). Following this general rule, fishing effort in this study was estimated as the product of the number of vessels in a vessel class, times the mean annual number of days fished by a vessel class and the mean engine power of the vessels in that class, summed over all vessel classes. The unit used is thus horsepower-days. Other than serving as a proxy for fishing power, another advantage of including engine power in the computation of fishing effort is that effort levels can be related to the energy consumption of fisheries (Wilson, 1999; Tyedmers *et al*., 2005). This provides a means of comparing fishing effort between diverse fisheries in terms of fuel consumption, or the amount of energy consumed per kilogram of fish caught (Tyedmers *et al*., 2005).

The role of fishing effort parameter in fisheries management

Fishing effort plays a pivotal role in stock abundance, fishing mortality and fishing cost estimations. Traditionally, greater attention has been put on the analysis of catches, while minimal concern was given to the analysis of fishing effort dynamics (Hilborn and Walters, 1992). Such lack of emphasis is due to a ill-advised consensus that treats fishing effort as a policy variable that can be adjusted by managers at will (Hilborn and Walters, 1992).

In recent years, however, fisheries scientists begun to recognize that fishing effort is indeed a dynamic variable that responds to spatio-temporal changes in resource abundance and management regulations in a predictable fashion. As a result of this important recognition, there have been several studies based on modelling the spatial distribution of fishing fleet (Hilborn and Walters, 1992; Gillis *et al.,* 1993; Gray and Kennedy, 1994; Oostenbrugge *et al.,* 2001; Caddy and Carocci, 1999; Walters and Bonfil, 1999; Walters and Martell, 2004).

The rationale for studying spatio-temporal evolution of global fishing effort

The rationale for studying temporal evolution of fishing effort is that, ideally, fishing effort is expected to respond to changes in the abundance (assumed proportional to profitability) of the fish it targets. In such an ideal world, historical trends in fishing effort could be an indicative of the direction of historical abundance changes in target stocks. But in the real world, where subsidies and application of fish finding technologies mask the decline of target fish abundances, the trajectory of fishing effort can temporarily become disconnected from the fluctuating abundances of target stocks. However, studying the long-term evolution of fishing effort can unravel long-term trends in abundance. Also, doing this on a global scale enables confronting the results of the analysis with the well-documented fact of overall global depletion of major commercial stocks.

There are several additional reasons why modeling spatial distribution of fishing effort is critically important. The first is the fact that different fishing grounds usually receive differential fishing pressure,

1) Horsepower (UK) = 0.7457 Kilowatt (kW)

due to differences in the distance of fishing grounds from major ports and differences in relative productivity of fishing grounds (Hilborn and Walters, 1992; Walters and Martell, 2004): offshore grounds are believed to have acted as a 'refuge' or buffers against overfishing (Pauly *et al.*, 2002; Walters and Martell, 2004). In the face of rapid developments in vessel sizes, fishing technologies and cost-cutting mechanisms, these refuge grounds are not inaccessible anymore, so that fisheries scientists now face the challenge of assessing the likely consequences of fisheries expansion to remote grounds (Walters and Martell, 2004). The second rationale why spatial modeling is important is the fact that fisheries are embedded in ecosystems, and thus information on the spatial distribution of fisheries is essential to understanding the underlying ecosystem dynamics and the effects of fishing on ecosystems (Pauly *et al.*, 2003b). Thirdly, spatial representations of fisheries (maps) are very efficient tools by virtue of their power of conveying huge amounts of information.

Approaches used for modeling spatial distribution of fishing effort

Traditionally, spatial models used to predict fishing effort distribution are based on three major approaches. One is the gravity model that distributes total effort to available grounds based on an index of attractiveness, variable among different grounds. The index of attractiveness is some value that is estimated as a function of fish abundance at any given ground, or a combination of abundance (assumed proportional to revenue) and cost of fishing in each ground (Caddy, 1975).

The second approach is based on the concept of Ideal Free Distribution Theory (IFD) (Fretwell, 1972). In the fisheries context, the IFD approach draws parallels, in the way they pursue their prey, between the behaviour of fishers and that of natural predators (Hilborn and Walters, 1992; Gillis and Peterman, 1998; Walters and Martell, 2004). This approach presumes fishers' 'ideal' knowledge of resource abundance, differences in catch rates between different grounds, and 'free' movement of fishers between fishing grounds (Gillis *et al.*, 1993; Gillis and Frank, 2001; Oostenbrugge *et al.*, 2001). It assumes that the fishers redistribute their effort so that no ground stands out in productivity, i.e., grounds with high catch rate are fished harder and thus fishers drive down local density of fish, while grounds with low catch rate are avoided (Gills and Peterman, 1998; Walters and Bonfil, 1999).

The third approach is the individual-based modeling approach (IBM), in which detailed information on fishers' decision rules are obtained and represented formally, then used to predict individual responses. Individually predicted responses are then summed up to give total effort predictions (Walters and Martell, 2004).

These models vary in complexity and data requirements. However, the superiority of any of these models in predicting fishing effort distribution has not yet established (Wilen *et al.*, 2002; Walters and Martell, 2004).

This study is based on the gravity model approach and extends on it by including several qualitative filter criteria before the quantitative gravity model is applied. The filter criteria are: 1) the technical capacity of fleets to reach fishing grounds; 2) the geographical location of homeports; 3) bilateral access rights to fishing grounds and 4) the 'fishability' of fishing grounds (impacted, e.g. by sea ice cover). These qualitative filter criteria are imposed to determine the most likely area(s) where fishing fleets, operating from known ports, are likely to operate, before the actual quantitative model is applied. Thus, this model captures fundamental factors relevant to spatial extent of fishing operation in addition to the factors usually considered in traditional gravity models.

When the filter criteria are met, the quantitative model assumes that the port-based fishing effort distribution is determined by fish abundance (assumed to be inversely proportional to the logarithm of water depth) in different fishing grounds and costs of fishing at each fishing ground (assumed to be proportional to distance of fishing grounds from homeports). The rationale for using the inverse of log(depth) as proxy for fish abundance is that deeper grounds are usually less productive than shallow ones (Lonhurst and Pauly, 1989)[2]. Similarly, distance from port is also assumed to be an important linear

[2] In the PhD thesis which forms the basis of this report (Gelchu, 2006), it was primary productivity which was used to identify areas with potentially high catch rates. This was replaced here by shallow areas (as in offshore banks) to avoid the effort distribution maps presented here from relying in any way on biological parameters (they also do not rely on catch data). This will enable these maps to be compared with primary production (and catch) maps without the danger of circularity.

contributor to fishing cost (Walters and Martell, 2004). The assumed linearity between distance from port and fishing cost is related to fuel consumption. Fuel consumption is generally believed to account for a significant proportion of total fishing cost; in some fisheries it accounts for as high as 60% of total fishing cost (Sumaila, *et al*., 2006). Further, as coastal stocks became depleted, fleets expanded their range of operation in pursuit of offshore resources. As a result, fuel cost is expected to increase as a function of distance from port.

There is obviously a strong positive relationship between distance from ports and depth. Hence, their simultaneous increase leads to offshore banks and similar shallow offshore features, accumulating high effort levels.

As function of these two variables, the model generates gravity weights for each fishing ground. Finally, the total fishing effort is allocated to fishing grounds in proportion to the gravity weights to generate the fine scale distribution of fishing effort within the area(s) determined by the filter criteria. The results of the analyses are displayed in GIS format maps.

Study area

The geographic span of the study was delimited by countries' EEZs. Further, due to the broad spatio-temporal scale of this study, it is not appropriate to present the results of the analysis on country-by-country basis. Rather, the countries of the world were grouped into four different regions based on geographical proximity and/or rough similarity in the technical capacity of their fishing industry. Following FAO, four different regions were defined: Europe[3]-North America[4], Asia-Pacific, South America-Caribbean and Africa (Fig. 1.1). It should be noted here that some countries do not fit well into these geographic categories, due to their technical development and/or history. Examples include Australia, New Zealand and Japan in the Asia-Pacific region and South Africa and Namibia in the African region. The peculiarities of these exceptional countries will be described when discussing the results for different regions. Associated information, such as exploited shelf (shallow shelf areas of about 200 m depth, exploited year-round) and unexploited shelf areas (shelf areas not exploited year-round due to sea ice), which will be used in the discussions on spatial patterns of global fishing effort distribution, are depicted in Fig. 1.1.

[3] 'Europe' includes the Far East regions of Russia.
[4] 'North America' does not include Mexico.

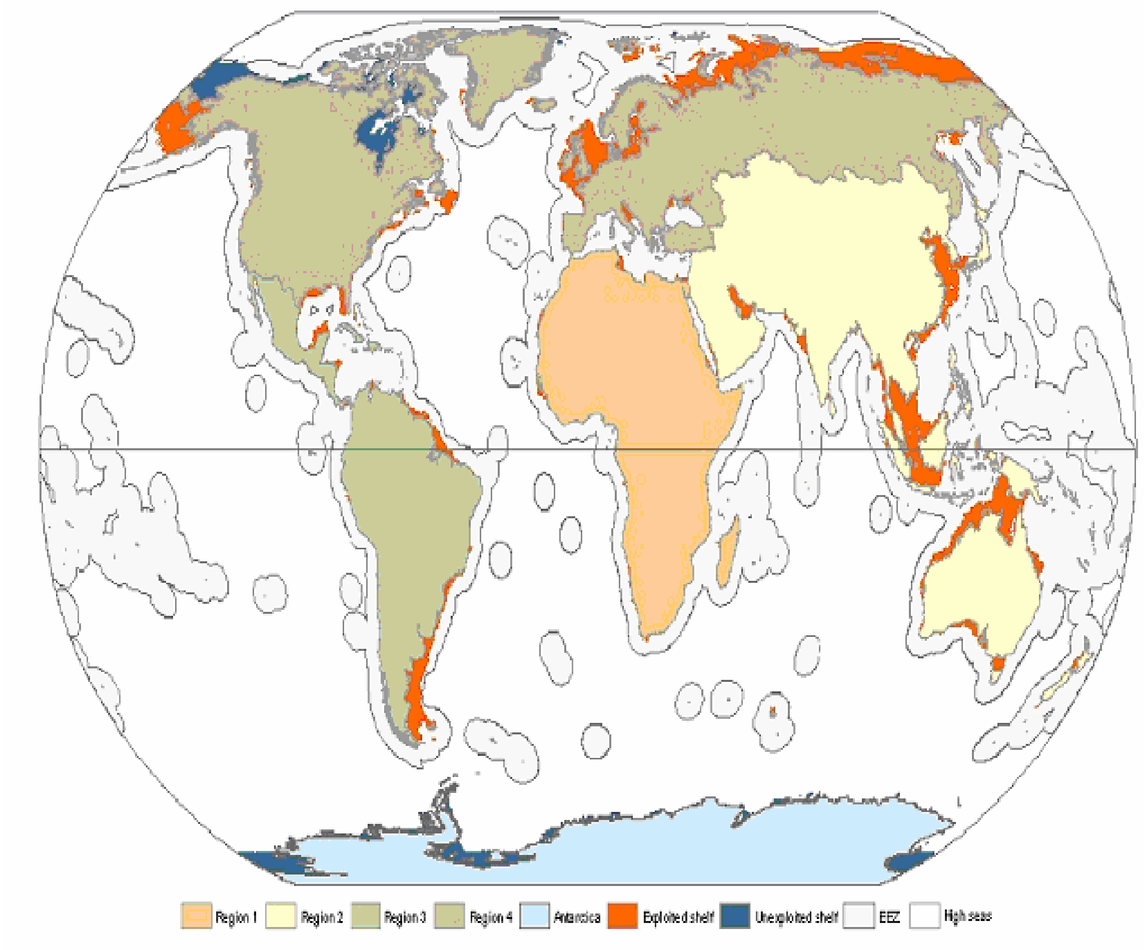

Fig. 1.1. The four regions defined in this study (areas within EEZ; Region 1 = Africa; Region 2 = Asia-Pacific; Region 3= South America-Caribbean; Region 4= Europe-North America) with exploited shelves in red and unexploited shelves in dark blue.

Scope of the study

This study comprises two parts. The first deals with the temporal evolution of fishing effort in the period 1970-1995, and is aimed at evaluating long-term changes (on an annual or decadal basis) in fishing effort capacity evolution as opposed to short-term changes (on days/months basis) in fleet deployment activities or fleet tactics.

The second part deals with modeling the spatial distribution of fishing effort for the same period. As these fisheries are often targeted by different gear types spatial analyses are performed for groundfish fisheries and small pelagic fisheries separately, in order to better capture the dynamics of the effort targeting them.

Aims of the study

The aims of this study are to:

1. Trace the evolution of fishing effort over time in different parts of the world, and investigate the patterns in relation to resource depletion over time;
2. Analyze patterns in catch rates over time;
3. Develop a method of modeling fishing effort distribution that is independent of catches;
4. Apply the model and map out global fishing effort distributions for the world's major fisheries;
5. Analyze spatial patterns in fishing effort concentration.

Materials

Assembling global fishing effort database

FAO began collecting detailed vessel statistics data from member countries from 1970 on (FAO, 1998). Fishing fleet data were downloaded from FAO online global fishing fleet database for 1970-1995 (FAO, 2006). The data contain time series of vessel statistics by country, tonnage range, gear type and total tonnage (GRT). Mean tonnage capacity for each tonnage range-gear type category was estimated by dividing the total tonnage reported by the number of vessels reported in respective tonnage range-gear type category.

The following exceptions were considered: i) some countries reported vessels data by tonnage range and gear type without associated total tonnage. For these, mean tonnage per tonnage range were estimated from similar tonnage range in the dataset in the same year, or from nearest year. Then, total tonnage was re-calculated as the product of mean tonnage and number of vessels; ii) one country reported only total tonnage without boat number for two tonnage ranges. In this case, mean tonnage for each tonnage range was assigned from similar tonnage range in the dataset in the same year or from nearest year and boat numbers were re-estimated as the ratio between total tonnage and mean tonnage. For all countries, new tonnage classes were assigned to each category based on calculated mean tonnage (see Table 2.1).

Table 2.1. Tonnage and horsepower categories adopted by the *Sea Around Us* Project, and used here to structure national fleet statistics.

Gear code	Gear class description
10	Bottom trawlers
15	Midwater trawlers
21	Mobile nets
31	Surrounding nets
41	Gill nets and entangling nets
51	Hooks and lines
61	Traps and liftnets
71	Dredge
81	Grappling and wounding gears
90	Other gears

Generally, based on the specificity of data they report to the FAO, countries can be grouped into four major categories:

Category 1: Under this category are countries which reported few gear types or which reported most of them as 'multipurpose vessels[5]' or 'fishing vessels unspecified/other fishing vessels'. In such cases, the reported gear types were kept while the dataset without gears was assigned to gears based on the *Sea Around Us* Project catch-by-gear-type database (Watson *et al.*, 2006a; Watson *et al.*, 2006b). The minor gear types reported in the *Sea Around Us* Project catch-by-gear-type database were regrouped under the major gear type categories based on their mode of operation. For example, different types of lines (troll lines, longlines, set lines) or different types of seines (beach seines, purse seines, boat seines, genuine seine nets etc) are grouped under the major gear categories of hooks/lines and surrounding nets respectively (see Table 2.2).

[5] Fishing vessels rigged so that any two or more different fishing gears can be used with minor modification to the vessel or its outfit.

Table 2.2. Gear class categories adopted from the *Sea Around Us* Project

Gear code	Gear class description
10	Bottom Trawlers
15	Midwater trawlers
21	Mobile nets
31	Surrounding nets
41	Gill nets and entangling nets
51	Hooks and lines
61	Traps and liftnets
71	Dredge
81	Grappling and Wounding
90	Other gears

Category 2: This includes countries which reported all of their data without specific gear types (i.e., the entire data were reported as 'multipurpose vessels' or 'fishing vessels unspecified/other fishing vessels'). In such cases, the entire dataset without gear were assigned to gears based on the *Sea Around Us* Project catch-by-gear-type database (Watson *et al*., 2006a; Watson *et al*., 2006b).

Category 3: Under this category are countries, which reported all of their dataset under a single gear type (usually trawl) and reported no 'multipurpose vessels' or 'fishing vessels unspecified/other fishing vessels'. In such cases, the species composition in the catch of these countries were analyzed to check if the single gear type reported could explain the catch composition of the countries involved. In almost all cases, the single gear that was reported could not explain the catch composition. Hence, the reported gear was ignored and the data re-assigned to gears based on the *Sea Around Us* Project catch-by-gear-type database (Watson *et al*., 2006a; Watson *et al*., 2006b).

Category 4: Under this category are countries which reported most of their data by gear types, but which also reported small datasets without specific gear types. In such cases, data reported without gear types were redistributed proportionally among the reported gear types.

FAO's online database does not include fleet data for some maritime countries. For these countries, data were gathered from various online sources and compiled in the same format as the main FAO dataset. The procedures used and assumptions made are documented in the database and accompanying documentations.

Disaggregating former Soviet Union, former Yugoslavia and South African fleets

a) Former Soviet Union (ex-USSR)

In the FAO global fleet database (1970-1995), three of the ex-USSR's component maritime republics, i.e., the Russian Federation, Lithuania and Estonia jointly reported their fishing fleet until 1990. The Russian Federation began reporting separately in 1991, while Lithuania and Estonia began in 1992. The remaining maritime ex-USSR republics (Ukraine, Latvia and Georgia) reported their own data separately since 1970. A methodology was developed to disaggregate the USSR fishing fleet from 1970-1990, and assign it to the three maritime countries of the ex-Soviet Union (Estonia, Lithuania and the Russian Federation), which reported on their fleet jointly, as described below.

We assumed that the distribution of fleets between the first three countries in the first few years of separate reporting reflected the approximate composition of fleet sizes in the USSR fleet prior to 1990. Since reported data immediately following separate reporting may be inaccurate, we based the proportions to assign to each country on a period of four years (1992-1995). We are aware that this assumption may not accurately reflect historic developments of fishing fleets in these three countries. Since gear type profiles reported in different vessel size classes (tonnage classes) in the separate data after 1992 did not match the gear profiles reported for the USSR, proportions were estimated at tonnage-class level and applied to gears reported under respective tonnage classes using the equation:

$$P_{i,c} = \frac{\sum_{j=1992}^{j=1995} F_{i,c}}{\sum_{j=1992}^{j=1995} F_{i}} \qquad \text{...2.1)}$$

where P=proportion i=tonnage class, j= year, c=country, F=fleet.

Then, the share of each country was in turn computed as:

$$S_{i,c,g} = P_{i,c} * V_{i,g} \qquad \text{...2.2)}$$

where S=share allocated, c=country, g=gear, i=tonnage class and V= fleet reported by the ex-USSR.

b) Yugoslavia

In the FAO global fleet database (1970-1995) the three maritime republics of the ex-Yugoslavia (Croatia, Slovenia and Montenegro[6]) jointly reported their fishing fleet until 1989. Separate reporting began in 1990. Yugoslavia's data for 1970-1989 were also disaggregated following a similar method as for the USSR. The proportions to assign to each ex-Yugoslavia component was based on a period of five years, from 1990-1995, for the same reason as explained above and the same equations (2.1 and 2.2) were used to compute the share of each country. The following exception was made: Montenegro did not report tonnage class 1 (TC1) vessels after separation and Slovenia did not report tonnage class 2 (TC2), while these tonnage classes were reported in the former fleet of the former Yougoslavia. Thus, for these two tonnage-classes, total fleet size by countries was used to estimate proportions.

C) South Africa

South Africa used to include Namibia until Namibia's independence in 1990. Thus, the South African fleet includes that of Namibia in the period 1970-1990. In order to estimate the Namibian share of the South African fleet prior to the independence of Namibia we took advantage of the time series of catch data by gear types available for both countries since 1950s (Watson *et al*., 2006a; Watson *et al*., 2006b). We made the basic assumption that relative difference in the catch-by-gear types between the two countries approximately reflects the development of fleets over the same period. For every year, the relative composition of South Africa-Namibia catches by gear types was computed and this relative composition was used as a weighting index to split the former South African fleet. The computation was done as follows:

$$P_{y,g,k} = \frac{C_{y,g,k}}{\sum C_{y,g}} \qquad \text{...2.3)}$$

where P=proportion, y=year, g=gear class, c=catch, k=country.

[6] We disregarded Bosnia-Herzegovina, which has only a minuscule coastline.

Then, the share of each country was in turn computed as:

$$S_{y,g,k} = P_{y,g,k} * F_{i,g} \qquad \text{...2.4)}$$

where S=share allocated, F=former South African reported fleet, and the other variables are as defined above.

The next task was to dissect the data of every country to find missing data points at tonnage class-gear class level in the period between 1970 and 1995. Whenever missing data points were found, linear interpolation was used to fill these in. The interpolated data points were assigned a unique code to allow for replacement if actual data are obtained in the future.

Vessel engine power (hp) was estimated from mean vessel tonnage capacity based on the relationship observed between vessel tonnage capacity and its engine power, as depicted in Fig. 2.1.

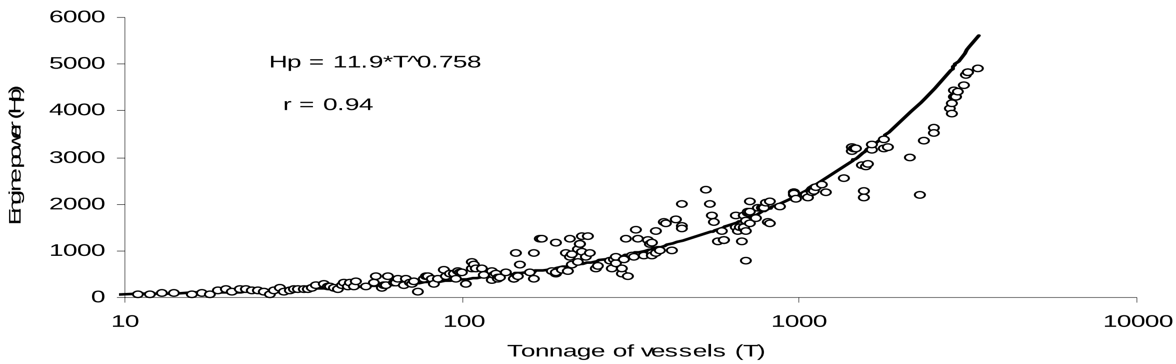

Fig. 2.1. Relationship between tonnage capacity (tonnes) and engine power (hp). Data from Lloyd's Register (accessed in 1999).

Visual inspection of the scatter plot and the fitted line in Fig. 2.1 shows that there is a close exponential relationship between tonnage capacity of vessels and their engine power. This relationship was used to estimate the engine power of vessels from their mean registered tonnage capacity. For all countries, new horsepower classes (Table 2.1) were assigned to each category, based on calculated mean engine power.

Table 2.1. Tonnage (A) and horsepower (B) categories adopted by the *Sea Around Us* Project, and used here to structure national fleet statistics.

A)

T. Class	Tonnage (GRT)	T. Class	Tonnage (GRT)
1	0-24.9	4	150-499.9
2	25-49.9	5	500-999.9
3	50-149.9	6	1000-1999.9

B)

HP. Class	Engine power (HP)	HP. Class	Tonnage (HP)
1	1-30	4	201-500
2	31-100	5	>500
3	101-200	-	-

Data on mean number of days fished per year

Information on mean number of days fished per year by vessels of different gear classes was compiled from FAO reports on economic performance of fishing fleets from selected countries of each region in the years 1995 and 2000 (Le Ry *et al.*, 1998; Tietze *et al.*, 2001, Table 2.3). Mean number of days fished information from these countries were assumed to represent average fishing activities in the region and were therefore used to assign mean days fished per year for corresponding gear class categories in vessel statistics for all other nations of the region for which this particular data were missing.

Table 2.3. Mean days fished per year by vessel class and regions, as used in this study.

Vessel type	**Mean days**	**Regions (remarks)**
Pelagic trawlers Liners Seiners Bottom trawlers Gill netters Drift nets Traps Dredges	270 180 148 180 150 150 150 180	Africa: Data were not found for drift netters in African region; assumed equal to gill netters. Data were not found for traps in African region; assumed equal to gill netters. Data were not found for dredges in African region Assumed equal to trawlers.
Drift netters Gill netters Dredge Bottom trawlers Traps Pelagic trawlers Liners Seiners	207 207 180 233 180 196 213 181	Asia-Pacific. Data were not found for drift netters in Asia-Pacific region; assumed equal to gill netters.
Bottom trawlers Pelagic trawlers Drift netters Seiners Dredgers Gill netters Liners Trappers	231 294 161 181 200 150 185 120	Europe and North America Dredgers based on ICES data average
Drift netters Dredgers Gill netters Pelagic trawlers Gill netters Liners Bottom trawlers Traps Seiners	163 213 163 209 163 163 213 111 209	South America and Caribbean: Data were not found for drift netters in S. America-Caribbean region; assumed equal to gill netters mean days fished data. Data were not found for dredgers in S. America-Caribbean region; assumed equal to trawler data. Data were not found for pelagic trawlers in S. America-Caribbean region; assumed equal to seiners data.

Finally, fishing effort for each gear class-vessel class category in each country was calculated as:

$$Effort_{i,j,k} = VesselNumber_{i,j,k} * MeandaysFished_{i,j,k} * EngineHP_{i,j,k} \quad \text{...2.5)}$$

where: $Effort_{i,j,k}$= fishing effort of tonnage class i using gear class j in year k; $VesselNumber_{i,j,k}$=total number of vessels of a tonnage class i using gear class j in year k; $Meandaysfished_{i,j,k}$=mean days fished by tonnage class i using gear class j in year k; and $EngineHp_{i,j,k}$=mean engine power of tonnage class i using gear class j in year k.

Overall, in order to assess how much coverage of global motorized fishing fleet size has been achieved for these regions, independent data from the literature were sought for some countries for comparison or validation. Such data were gathered for 10 countries over different time periods. Assuming that data from independent sources, which often came from national fisheries authorities, were better estimations of the actual fleet size of a country the data compiled for this study were compared on country-and-yearly basis with the data from independent sources as shown in Table 2.4.

Table 2.4. Fishing effort data comparison with data from independent sources.

Country	Year	FAO vessels # (this study)	Vessels # from indep. sources	Coverage of effort (%)	Sources of independent data
Norway	1970	26508	26504	100	William and Hammer (1998)
	1980	8454	17392	49	William and Hammer (1998)
	1998	12500	13252	94	William and Hammer (1998)
China	1970	23603	13903	170	Zhong and Power (1997)
	1980	36485	49769	73	Zhong and Power (1997)
	1990	214816	244154	88	Zhong, and Power (1997)
Indonesia[a]	1980	18467	18467	100	Priyono and Sumiono (1997)
	1990	46535	46542	100	Priyono and Sumiono (1997)
Malaysia	1980	23311	43492	54	Abu Talib and Allas (1997)
	1990	22073	39541	56	Abu Talib and Allas (1997)
Philippines	1970	1999	2061	97	Barut et al. (1997)
	1980	2400	2366	101	Barut et al. (1997)
Sri Lanka	1980	3140	10325	30	Maldeniya (1997)
	1987	2402	13218	18	Maldeniya (1997)
Thailand[b]	1970	3062	3206	96	Eiamsa-Ard and Amornchairojkul (1997)
	1980	12683	15037	84	Eiamsa-Ard and Amornchairojkul (1997)
Ghana	1995	147	340	43	Bennet (1995)
Namibia	1990	108	254	43	Dierks (1995)
Tanzania	2000	21	20	100	Berachi(2003)
Peru	1989	6124	6144	100	Mesinas (1992)
Total or Mean	-	464838	565987	80	This study-

a) In both years, the vessel data include medium and large vessel; small-scale vessels were not included;
b) In both years, trawlers were used in the comparison;

As can be seen from Table 2.4, the coverage of effort ranges from 18% to 100%, with an overall mean of 80%. Note that Chinese vessels figure reported to FAO in 1970 was well in excess of the figure from the independent source, and that of the Philippines was also slightly higher than given by the independent source in 1980. Such discrepancies were assumed to have arisen from reporting errors. Assuming that the overall average motorized reporting rate of 80% (Table 2.4) represents the average fleet data coverage rate for all countries, the global fishing effort database compiled for this study covered about 80% of global motorized fishing fleet size. It must be emphasized here that even though vessels as small as 5 GRT are represented in this database, it is believed that the bulk of artisanal crafts in the developing world, with an unknown proportion of motorized boats, are under-represented. This is mainly because most countries either under-report or never report the statistics of their artisanal (Chuenpagdee *et al.* 2006). Thus, the global coverage of 80% mainly refers to coverage achieved of medium size port-based global fleets.

The fishing effort data assembled for each region were compiled independently of catch information, i.e., inferences about the magnitude of fishing effort of countries were not derived from catch data. This was intentional, in order to allow for later comparison with spatio-temporal patterns of catches mapped by the *Sea Around Us* Project.

Global maritime ports database

The maritime ports data were retrieved from "The Global Maritime Ports Database™ CD-ROM" obtained by the *Sea Around Us* Project from the US National Aeronautics and Atmospheric Administration (NASA). It contains ports in GIS format, i.e., with the latitude and longitude coordinates of their locations. However, for some countries, some major fishing ports are not included. In those cases, the latitude and longitude coordinates of the ports were entered, as determined using a GIS software (Arcview 3.2). The distribution of global marine ports is shown in Fig. 2.2.

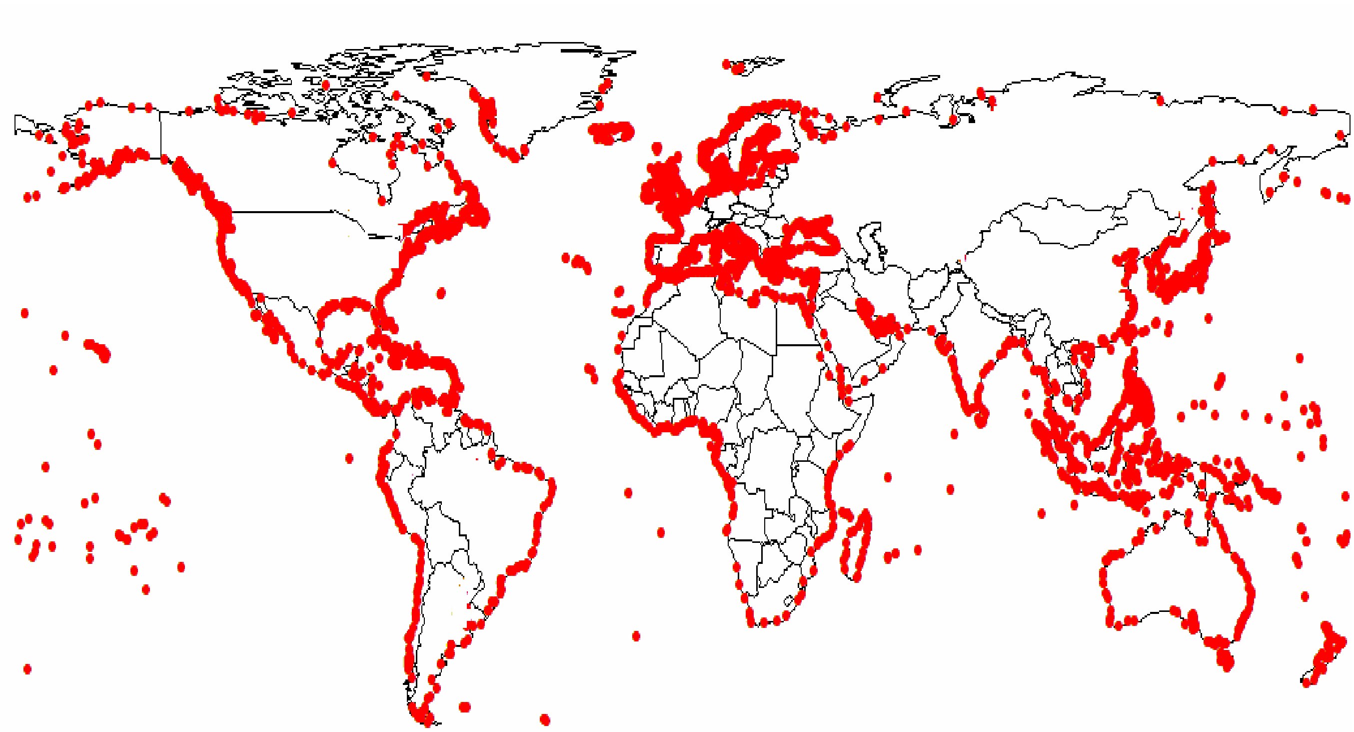

Fig. 2.2. Global distribution of marine ports along the coasts of the world's maritime countries.

METHODS

Estimating temporal changes in the efficiency of fishing fleets

During the period under investigation, the applications of technologies such as fish finding electronics and GPS devices have strongly increased the average fishing power of fleets. In assessing the effective pressure fishing effort exerts on fish populations, it is important to consider technology effect, i.e., 'technology coefficient', in order to correct for potential changes in catchability coefficient (q) resulting from the introduction of new technology (Fitzpatrick, 1996; Garcia and Newton, 1997).

In determining technology effect, important factors that need to be considered include the materials used to construct fishing gear, navigation equipment, design and construction of fishing vessels (Fitzpatrick, 1996). By taking into account these factors, and based on a workshop with fisheries practitioners, Fitzpatrick (1996) estimated the relative value of technology coefficients for 13 different types of fishing vessels ranging from small canoes of 10 m to super trawlers of 120 m for years 1965, 1980 and 1995, taking the value of 1980 as a base (Table. 2.2). On average the value has increased from 0.53 in 1965 to 1.98 in 1995 (Table. 2.5), representing about 274% increase over 25 years period (an approximately 3-fold increase in efficiency). Even though, the estimation of these coefficients involved a subjective technique based on fishers` perception of relative increases in the efficiency of their boats due to application of new technologies , the evolution of these relative coefficients approximate the changes in the efficiency of these vessel types from technological point of view (Garcia and Newton, 1997).

Table 2.5 Estimated technology coefficients of fishing vessels by vessel types (data from Fitzpatrick, 1996).

Vessel type	**Length (m)**	**Technology coefficient**		
		1965	1980	1995
Super trawler	120	0.6	1	2.5
Tuna seiner	65	n.a	1	1.6
Freeze trawler	50	0.7	1	2.0
Tuna long liner	65	0.5	1	2.3
Purse seiner	45	0.6	1	2.0
Stern trawler	35	0.6	1	1.9
Long liner	35	0.4	1	2.8
Multi-purpose vessel	25	0.6	1	2.5
Shrimp trawler	25	0.5	1	2.2
Gillnetter	15	0.4	1	1.5
Trawler	13	0.5	1	1.8
Fast potter	10	0.3	1	1.4
Pirogue (canoe)	10	0.6	1	1.3
Average	-	0.53±0.23 (2*SD)	1	1.98±0.93 (2*SD)

By averaging the technology coefficient values over the range of vessels types seen in Table. 2.5, annual rate of increase in vessel efficiency due to application of technology was estimated as shown in Fig. 2.3.

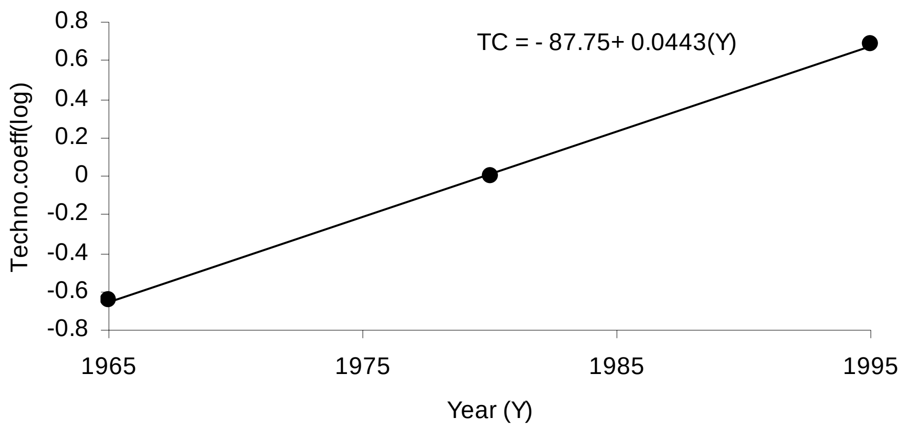

Fig. 2.3. Rate of increase in the efficiency of fishing vessels due to application of technology, suggesting an i of 4.43% per year.

Fig. 2.3 shows that efficiency of fishing vessels increases by an average annual rate of about 4.4%. This figure is reasonable when compared with results from similar studies on the increase in fishing power. For instance, a 5% rate of increase in fishing power has been estimated for Australian shrimp trawlers (Robins *et al*., 1998), while higher values have been reported from seiners (Gascuel *et al.* 1993).

With an annual increase of 4-5 % per year, the efficiency of fishing vessels doubles every 15 to 16 years. Garcia and Newton (1997) combined these technology coefficients with data on world fleet size to estimate the likely increase in fishing pressure (Garcia and Newton, 1997).

Modeling spatial distribution of port-based fishing effort

The methodology used for modeling spatial distribution of fishing effort is accomplished in three consecutive steps:

1. Effort break down by ports (Gravity model 1);
2. Application of qualitative filter criteria;
3. Final prediction of fine scale spatial distribution of fishing effort (Gravity model 2).

Fishing effort breakdown by ports (Gravity model 1)

The spatial model discussed below presumes availability of fishing effort data by ports. In order to break down the fishing effort data by ports of countries, a port-weighting index was developed as explained below.

Relative Importance of Maritime Ports

Since ports generally vary in size, it was necessary to develop port-weighting indices that reflect relative differences in the sizes of fishing ports. The weighting indices are meant to represent differences between ports in the number of fishing vessels based therein; this is here referred to as port relative importance factor (PRIF). Ideally, a port-weighting index can be estimated from the number of vessels reported from various homeports. Such data were unavailable for most countries. In such cases, landings by ports were used as a proxy variable to attach differential weight to fishing ports. The rationale for using landings by ports as a proxy for port size is that differences in total landings between ports should reflect relative differences in the number of fishing vessels stationed in ports. Landing data by ports also account for fleets landing their catches in ports other than their homeports by boosting the weight assigned to such ports. Technically speaking, such fleets operate in the vicinity of the ports where they land their catches (landing ports). A typical example is the Seattle-registered US fleet fishing in Alaska, which land its catches in Alaskan ports, relatively near to where it operates. For North America, data for estimating port weighting indices were obtained from the Canadian DFO (for the Atlantic Provinces) and the U.S National Marine Fisheries Services (NMFS of NOAA). For all other countries (and for the Province of British Columbia, Canada) data from various online sources, including and FAO country profiles were used. There were several cases when port size information was available for major ports of a country, but missing for minor ports. In those cases, minor ports were assigned a weight equal to half the size of the smallest known port. In a few countries, no port size information was found. In those countries, ports were assumed to be of equal importance (equal PRIF).

For every country, the PRIF is estimated as the ratio of the number of vessels stationed in a port to the total number of vessels stationed in all ports or, alternatively, as a ratio of total landings in a port to total landings in all ports for any given country, i.e.,

$$PRIF_{i,k} = \frac{V_{i,k}}{\sum_{i=1}^{n} V_{i,k}} \qquad \text{...2.6)}$$

where $PRIF_{i,k}$=Relative importance of port i in country k; $V_{i,k}$=number of vessels or landings, in port i in country k; and n= total number of ports of country k.

The PRIF was assumed stable over time. Therefore, it can be used to break down the compiled effort data by ports over years and different vessel types, using:

$$EffortPort_{i,f,j,k} = Effort_{f,j,k} * PRIF_{i,k} \qquad \text{...2.7)}$$

where: $EffortPort_{i,f,j,k}$=effort of fleet f, stationed at port i in year j in country k; $effort_{f,j,k}$=Total effort fleet f, reported in year j by country k; and $PRIF_{i,k}$=the relative port importance factor for port i of country k.

Application of qualitative filter criteria

Before directly applying the quantitative fishing effort distribution model, four qualitative filter criteria were applied. The criteria are formulated by taking into consideration factors such as temporal changes in the geographic range of fleet operation, and physical and legal factors that contribute to the identification of area(s) exploited by fishing fleets stationed at given ports. This approach is expanded from simpler method based on assigning scores to fishing grounds, under development since 1998 (FAO, 1998b). These criteria are imposed, as a set of rules, to define the spatial extent of a given fishery and thereby determine area(s) where actual fishing activity most likely occur for a fleet segment stationed at a known port, targeting a known group of fish.

Broadly, the criteria are the following:

1. Fishing ground accessibility: An area that is accessible to the fleet segment, i.e. it must be located within the operational range of the boats stationed in known homeports (**Accessible region**);

2. Fishing ground fishability: A subset of accessible region that is fishable, i.e. ice free area (**Fishable region**);

3. Legal authority on fishing grounds: A subset of fishable region where the fleet segment have legal authority to fish, in both space and time (**Authorized region**);

4. Geographic overlap: Finally, a subset of authorized region defined by the overlap of the above four geographical regions which determine the actual fishing area (**Fishing region**).

Each criterion is determined as briefly described below.

Filter criterion 1 (Accessible region): this criterion refers to fleet operational range. Except for freezer ships, the operational range of a typical fishing vessel (or vessel endurance) is determined by the time it requires to fill its load capacity (which in turn depend on target abundance and fish detection technology), the amount of fuel it can carry, its cruising speed and by the fact that fishers must return to port within a few days from their first catch, so that it will not be spoiled and become worthless. Essentially all these features are expressions of the physical capacity of a fishing vessel (Grzywaczewski et al., 1964; FAO, 1985; Bower, 1985; Wilson, 1999). The average physical size of fishing fleet is expected to change over time in response to variability in the availability of fish along coasts. In this regard, as fisheries develop over time, inshore stocks are the first to be depleted. The inshore depletions were usually compensated for by deploying larger boats, capable of fishing further offshore, leading to increase in the average tonnage capacity of fishing vessels in most parts of the world (see below). Thus, the operational range of a port-based fishing fleet in any country is assumed proportional to average tonnage capacity of its component vessels over time. This assumption will capture the aspect of fisheries offshore expansion contributed by increase in the sizes of vessels.

However, the potential operational range of a fleet that can be realized as a function of average tonnage capacity can be affected by secondary factors such as the geographic location/latitude and relative size of homeports. The effects of these secondary factors are considered in order to further adjust the operation range of fleets, as discussed below.

The homeport geographic location factor is important because in tropical climate zones, the deeper waters are generally poor in detritus and nutrients due to accelerated bacterial degradation of organic substances before they sink to the bottom (Longhurst and Pauly, 1987). This phenomenon, which leads to regenerated production, represents the amount of recycling in the upper water column and is very high in open tropical oceans (Longhurst and Pauly, 1987). As the result, the density of bottom fish is low in deep tropical waters (Crutchfield and Lawson, 1974; Longhurst and Pauly, 1987). This climatic factor is expected to affect the operational range of fleets stationed in ports located in different climatic zones, as fishers adjust their fishing operations accordingly. This factor is referred to as a latitude factor (LF) in the proceeding discussions.

To capture the LF, a latitude-specific (port location-specific) port weighting procedure is applied to ports in order to account for the effect of latitude on fleet operational range. The weighting system applied uses an assigned range of values. Since the weighting values are only approximate, they cannot accurately reflect the port location factor on operational range of fleets. For this reason, the influence of LF is kept minimal by setting a weight of 1 to the average latitude (N or S), where average latitude represents the N or S latitude along which the bulk of global fishing effort is concentrated or major ports are located. This average latitude was determined by plotting total fishing effort by ports data versus port latitude locations as shown in Fig. 2.4.

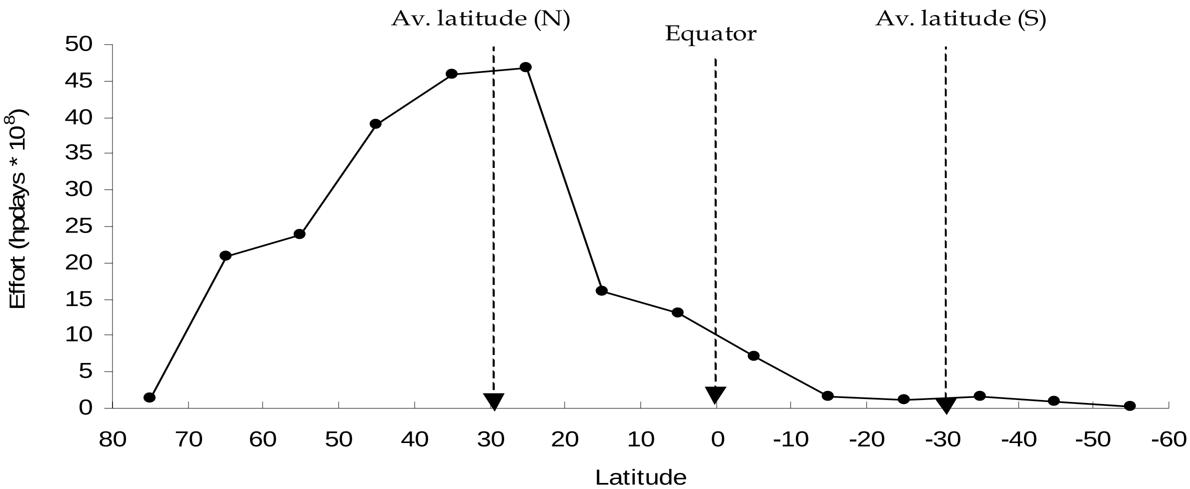

Fig. 2.4. Global fishing effort concentration by latitude.

As shown in Fig. 2.4, global fishing effort is concentrated along 30°N latitude. In the Southern hemisphere, peak fishing effort concentration appears to occur slightly South of 30°S. Since there is much less fishing effort in the Southern hemisphere, the northern peak of |30°| was taken as an average latitude for both the Northern and Southern hemispheres. Thus, average latitude (30°N or S) was used as an anchor to formulate a linear function for assigning LF values (Fig. 2.5).

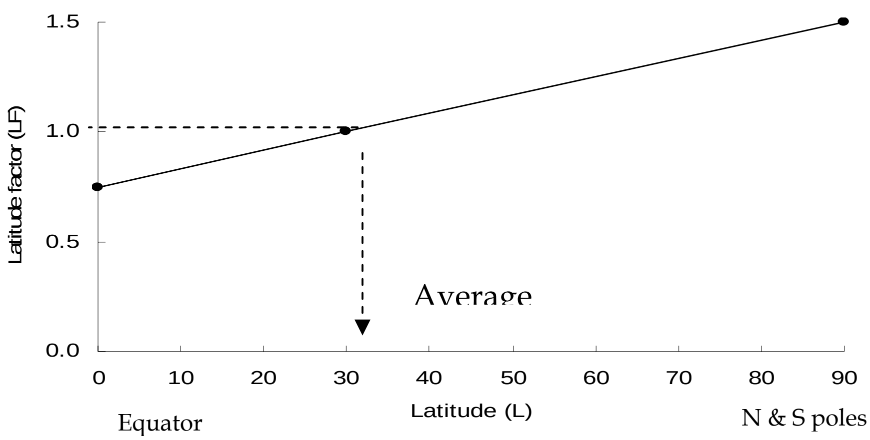

Fig. 2.5. Assignment of LF values to latitudes of ports, to simulate the effect of latitude on the operational range of fleets.

Thus, $LF = 1$ for ports at average latitude (30°N or S). For the remaining ports, the LF values were determined using a linear function that passes through the average latitude location of (30, 1) coordinate points, i.e., $LF = 0083 * |L| + 0.75$. As can be seen from Fig. 2.5, the range of LF values determined by this function range between 0.75 at equator and 1.5 at the poles. The LF values are applied as a multiplicative function of the average tonnage size of fleets over time, and hence it plays the role of decreasing potential fleet operational range in low latitudes and boosting it in higher latitudes, while it has no effect in ports of mid-latitudes where the bulk of global fishing effort is concentrated (Fig. 2.4). To control the range boosting effect of the LF function in high latitudes, an additional maximum range cap was established as will be discussed at the end of this section.

The other secondary factor that affects operational range of fleets is the distribution of vessels of different size classes in different ports of varying sizes. Ports vary not only by their relative sizes, which is a function of the total number of vessels they host, but also in the distribution of vessels of different size classes in different ports. To account for this variability, it is assumed that large vessels tend to prefer large ports, as these usually provide better facilities. This can cause increased competition in near-port areas, forcing some fleets to travel further from ports. Thus, fleet operational range is expected to be wider around large ports and narrower around small ports. Hereafter, this factor is termed as port size factor (PSF). In order to quantify the PSF, another port size specific weighting function is attached to different ports. For the same reason mentioned in conjunction with LF, the PSF effect is also modeled by identifying an average port, determined from a plot of global fishing effort by ports against the number of ports. When global fishing effort was broken down by ports, based on port relative importance, as discussed in section 2.2.2.1, the size of fishing effort in different ports showed a wide variability. To minimize the variance and identify a measure of central tendency, fishing effort by ports data were transformed to log scale and the transformed data were plotted against number of ports as shown in Fig. 2.6.

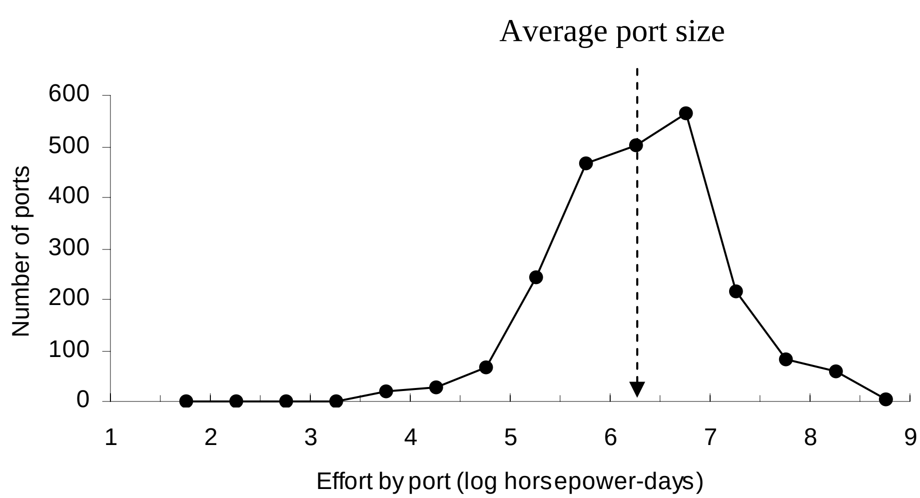

Fig. 2.6. Global fishing effort concentration by ports.

Fig. 2.6 shows that most ports have an average capacity of about 6.25 on log scale, which has an antilog of about 1.8 million horsepower-days. To put into perspective the size of such an average port, it can be thought of as a port that hosts about 200 boats with an average engine power of 50 horsepower, fishing about 180 days a year. Ports with such capacity are considered average ports and assigned a PSF value of 1, while the remaining ports receive PSF values in proportion to their capacity (i.e., fishing effort they host). The procedure is shown graphically in Fig. 2.7.

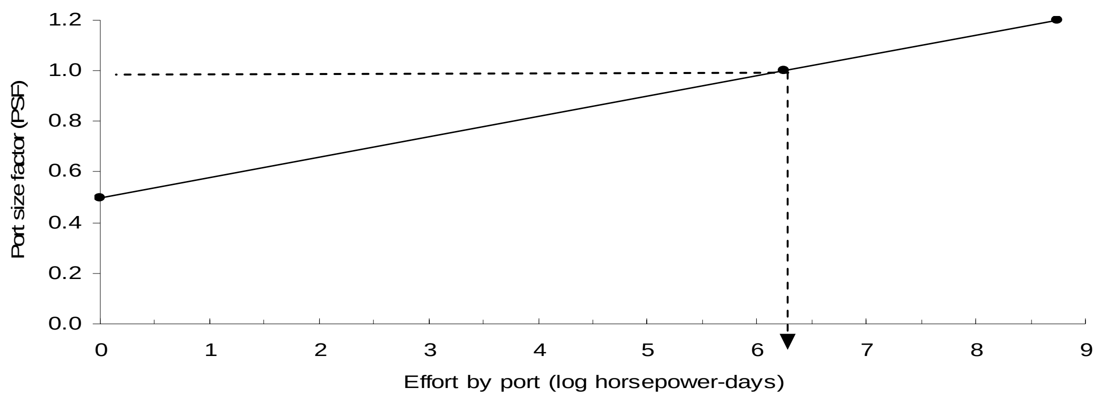

Fig. 2.7. PSF value assignment to ports based on port size as defined by the size of fishing effort they host, to simulate the effect of port size on operational range of fleets.

Thus, $PSF = 1$ for ports of average size (1.8 million horsepower-days), while for the remaining ports, PSF values were determined using a linear function that passes through the anchor average port coordinate points (6.25, 1), i.e., *PSF = 0.08*log(effort by port) + 0.5*. As can be seen from Fig. 2.7, the range of PSF values determined by this function range between 0.5 for the smallest port and 1.2 for the largest port.

As in LF, the PSF values are applied as a multiplicative function of the primary determinant of fleet operational range, the average tonnage size of fleets over time. Hence, it plays the role of decreasing potential fleet operational range in small ports and boosting it in larger ports, while it has no effect in ports of intermediate size in which much global fishing effort is concentrated (Fig. 2.6).

Thus the resultant port location-specific, port size-specific and year-specific operational range of fleets is estimated as:

$$R_{f,p,t,k} = T_{f,p,t,k} * \left(LF_p * PSF_p\right) \quad \text{.... (2.8)}$$

where $R_{f,p,t,k}$ = Operational range of fleet f, in port p, in year t, in country k;
$T_{f,p,t,k}$=Average tonnage capacity of fleet f, stationed at port p, in year t, and country k;
LF_p= Latitude factor at port p; and
PSF_p= Size factor of port p.

Finally, the bulk of port based fishing fleets are composed of short-range and medium-range vessels. The vast majority of such vessels do not have the powerful engine and/or tonnage capacity that is needed for very long fishing trip, and neither are they equipped with refrigerating plants for preserving their catches. However, many of them have insulated fish holdings and carry ice to preserve their catch for short durations. Thus, it is reasonable to assume that most port-based fleets operate within the EEZ of their own countries, i.e., up to 200 nm (approx. 370 km). Therefore the operational range of fleet defined by equation 2.5 is capped at maximum range of 200 miles. This capping essentially controls the range boosting effects of LF and PSF in high latitudes and large ports respectively.

Filter criterion 2 (Fishable region): This criterion is required to exclude ocean regions that are permanently covered by ice and hence not available for fishing (50% ice coverage year round by 0.5° by 0.5° cells). The global ice coverage data used here were obtained from the United States National Snow and Ice Data Center (NSIDC) at the University of Colorado, USA. Other potential factors that could prevent fishing, such as bottom type, no-fishing zones, oil rigs and shipping lanes, were not considered in this study.

Filter criterion 3 (Authorized region): This criterion is required to determine areas where countries' fleets are legally allowed to fish. The data are obtained from countries' bilateral access agreements database maintained by the *Sea Around Us* Project (Watson *et al*., 2001a).

Filter criterion 4 (Fishing region): This region is determined by the overlap of the above four regions. It represents the area where actual fishing activity most likely happened for a fleet that fulfils criteria 1-4. A computer program (in Visual Basic) was developed to impose these criteria at each level.

The criteria were imposed on fleet segment by fleet segment basis; thus, the next task was to define fleet segments. In order to define fleet segment, it was necessary to define fish groups commonly targeted by different fleet types, referred to as 'target groups'. The target groups defined were: (i) groundfish; (ii) small pelagics and (iii) large pelagics. Through analysis of catch composition by gear types in the *Sea Around Us* Project gear database and literature review, major gear types used to target each group were identified as summarized in Fig. 2.8.

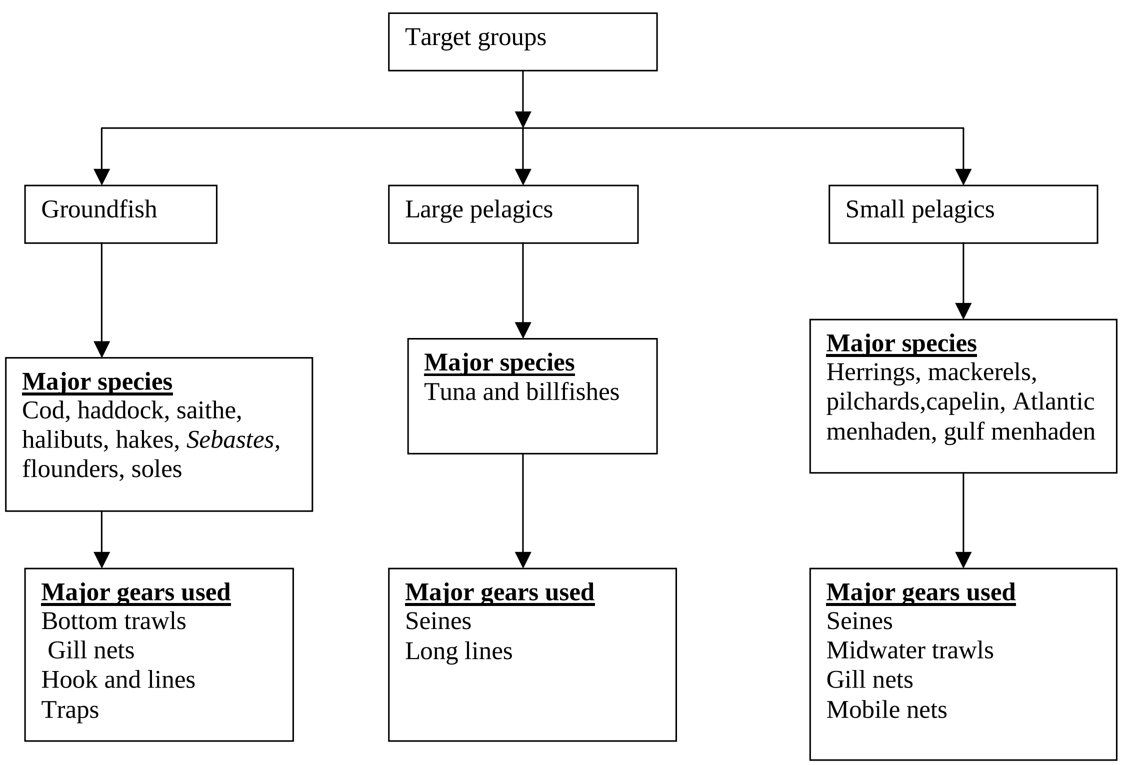

Fig. 2.8. Three major target groups and major gear types targeting these groups.

As can be seen from Fig. 2.8, fleet segments were defined based on multi-gear and multi-species scheme. Thus, a group of vessels using a variety of gears but targeting a given target group is defined as a 'fleet segment'. A fleet segment is assumed to catch a mixture of species within each group, i.e., we are dealing here with multi-species and multi-gear fisheries. A broader gear classification is used, i.e., bottom trawlers, midwater trawlers, surrounding nets, gillnets/entangling nets etc., (see Table 2.2), without getting into detailed gear characterization such different types of bottom trawls (side, stern) or different types of seiners (beach seines, Danish seines) etc. It should be emphasized that the fleet segments described above are not exclusive as gears usually overlap with regard to the species groups they catch. Large pelagic fishes were not analyzed in this study, as fleets targeting this group are largely port-independent, ocean-going vessels, often operating outside of countries' EEZs..

Since target groups were defined on the basis of fish groups, as opposed to single species, the spatial distribution of target groups was not used as a criterion. This is because, at least, some member of each target group will always occur within 200 miles off the coast of maritime countries, thus qualifying the area as a fishing region.

The logical interrelationship among these rules can be diagrammatically expressed as in Fig. 2.9:

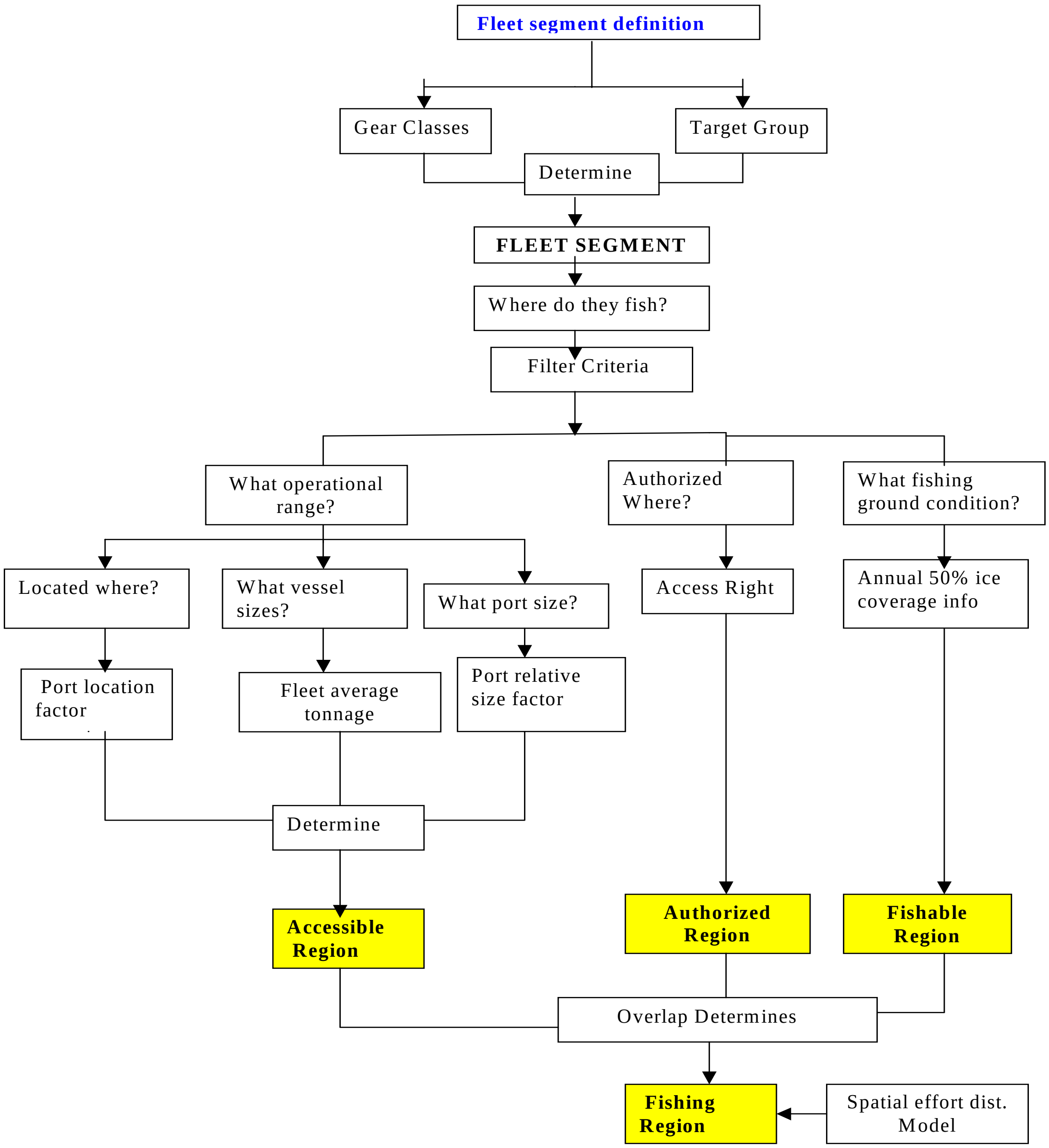

Fig. 2.9. Logical interrelationship between the rules used in the filter criteria.

As shown in Fig. 2.9, after the area(s) where a given port-based fleet segment was most likely operate was determined through the application of the above outlined geographic filters, the quantitative spatial effort distribution model was applied to simulate fishing effort distribution within the area determined by the overlap of the filter criteria, i.e., the fishing region.

Distribution of port-based fishing effort (Gravity model 2)

The model used here has its roots in the gravity model originally proposed by Caddy (1975) and thereafter widely used for modeling fishing effort distribution (Gills and Peterman, 1998, Walters and Bonfil, 1999). The following equation (2.9) used in this study was formulated in collaboration with Dr. C.J. Walters (Fisheries Centre, UBC, pers. comm.). In this study, spatial cells of a 0.5° by 0.5° resolution were used for mapping the results (subscripts identifying country and year were avoided for clarity):

$$E_{x,f,i} = \frac{W_{x,i}}{\sum_{1}^{n} W_{x,i}} * Et_{f,i} \qquad \text{...(2.9)}$$

where $E_{x,f,i}$ = effort exerted on cell x, by fleet segment f, stationed at port i;
$W_{x,i}$ = is a weight or a measure of attractiveness attached to cell x, that is under the influence of port, i;
$Et_{f,i}$ = total effort of fleet f, stationed at port i, n= number of cells under the influence of fleet segment f, stationed at port i.

Model parameterization: gravity factor ($W_{x,i}$)

The gravity factor is estimated as a function of the inverse of log (depth) of a cell and its distance from any given port (distance = proxy for fishing cost). The rationale for using an inverse of log depth as a gravity factor for fishing effort concentration is that shallow areas are usually associated with high productivity and thereby sustain high fish production (Nanda, 1986; Longhurst and Pauly, 1987). Similarly, the cost of fishing at different fishing ground was assumed proportional to the distances of fishing grounds (cells) from ports.

The equation used to estimate the gravity factor ($W_{x,i}$) is:

$$W_{x,i} = \frac{1}{\log D_{x,i}} * \exp(-F_{x,i}) * \exp(-C_{x,i}) \qquad \text{...2.10)}$$

where $D_{x,i}$ = depth at cell, x under the influence port i;
$F_{x,i}$ = mean fishing mortality of the target group at cell x under the influence port i;
$C_{x,i}$ = cost of fishing at cell x, from port i.

The key idea of the gravity model is captured by equation (2.10), i.e., the overriding factors that account for differences in spatial concentration of fishing effort are the cost of fishing at a given fishing ground and the depth of that ground.

Equation 2.10 has two unknown variables $W_{x,i}$ and $F_{x,i}$. Hence, an iterative technique is used to estimate the final value of $W_{x,i}$. This is done as follows:

1) Set the value of all F initially to an arbitrary value of 0.1;

2) Calculate $W_{x,i}$ from equation 2.10 above;

3) Calculate effort ($NewEffort_{x,i}$) for each location from equation (2.9) above.

For each iterations >1, (for first iteration $EffortLast_{x,i} = NewEffort_{x,i}$ for each location), re-calculate an updated estimate of effort ($EffortLast_{x,i}$) for each location from the following 'relaxation' equation (C.J. Walters, Fisheries Centre, UBC, pers. comm.):

4) $$EffortLast_{x,i} = \lfloor W * NewEffort_{x,i} + (1-W) * EffortLast_{x,i} \rfloor \quad \text{...2.11)}$$

where W = a weight factor (value between 0 and 1);
and $NewEffort_{x,i}$, and $EffortLast_{x,i}$, are effort at cell x under the influence of port i;

5) Re-estimate F for each location as:

$$F'_{x,i} = \frac{EffortLast_{x,i}}{A_x} \quad \text{...2.12)}$$

where $A_x =$ relative size of cell x.

6) Set F= $F'_{x,i}$ and return to step 2 until effort estimates stop changing.

Tests showed that this procedure converges after 10 to 21 iterations.

After the relative attractiveness of different cells was determined through the procedure described here, the total fishing effort exerted by fleets stationed in ports of countries was allocated to each cell in proportion to the relative attractiveness of each cells (equation 2.9) within the fishing region determined by the filter criteria (fishing region). As the model assumes port-dependence of vessels, vessels with tonnage capacity of >=500 grt are assumed port-independent and, therefore their distributions were not analyzed here. The results of the analysis for the four regions identified and the consolidation of regional results on a global scale are presented in Chapters 3 and 4 respectively.

Results and Discussions

The European-North American region fisheries

Background: Industrialization of fisheries in Europe-N. American Region

Fishing in Europe and North America has a long history going back centuries (Cushing, 1988; Hutchings, 1995b; Rich, 2005). Fisheries statistics are available as far back as 1903 and for some countries even earlier (ICES, 1906; Anon, 2002a). The first phase of the industrialization and expansion of fisheries in this region occurred in the mid 19th century, when hemp nets were replaced by machine-made cotton nets (Cushing, 1988; Hutchings, 1995b). This was followed by introduction of steam drifter vessels (mainly in the Northeast Atlantic, to catch herring) that enabled boats to reach ports independently of the wind (Gulland, 1974; Cushing, 1988). Until WW II, catches were predominately taken by these drift netters, but later, trawlers became dominant (Cushing, 1988).

The second, and perhaps most important, phase of expansion and industrialization occurred after WW II (Solecki, 1979; Cushing, 1988; Lear, 1998; Pauly *et al.*, 2002). During the decades following WW II, the exploitation of marine fish stocks greatly increased, mainly fueled by successful economic rebuilding, coupled with the development of filleting and quick-freezing technologies and elaborate transportation network, which enabled fish product distribution over greater distances (Lear, 1998). As a result, large new markets were opened for fishmeal and animal feed products due to the simultaneous intensification of animal husbandry, which depended on fishmeal as an essential part of animal feed (Cushing, 1988). This further stimulated the demand for fish products (Arnason and Felt, 1995; Cushing, 1988).

In response to this demand, extensive industrial fisheries for fishmeal involving fleets of trawlers were introduced in Europe beginning in the early 1950s (Anon, 2002a). From the 1960s, they were complemented by industrial purse seiners and large pelagic trawlers which replaced the driftnets fleets (Arnason and Felt, 1995; Anon, 2002a). At about the same time, there was a steady increase in bottom trawlers targeting groundfish for human consumption (Arnason and Felt, 1995; Anon, 2002a). Other major technological developments that affected fisheries in this region during and after the 1960s were development of sonar systems, navigation and communications equipment as well as new gear technologies (ICES, 2001). As a result, the modern purse seiners, with their 'high tech' electronic equipment, gained a new capability for locating schools of fish (Arnason and Felt, 1995; Lear, 1998).

During this era the former Soviet Union (USSR) was by far the largest investor in fishing capacity development. The USSR had multiple objectives for their catches, which included providing fish for domestic consumption, providing feed for animal husbandry, supply other industrial sectors (such as margarine production, pharmaceutical, soap and textile industries) with fish products and maintaining a positive export trade balance (Solecki, 1997). In order to fulfill such multifaceted, but centrally planned fish production objectives, the former USSR embarked on extensive fishing vessel construction in their shipyards and as well as the purchase of deep-sea fishing vessels from former Soviet bloc countries, such as Poland, the German Democratic Republic and others (Solecki, 1979). For instance, in the decade from 1956 to 1965, 80% of all Soviet investments in fishing sector went to building the fleet, the ports and ship repair shops, thus causing an overall qualitative change in the profile of the fleets (Solecki, 1979).

In general, the fishing fleets in the region grew both in number and vessel size. The largest among the factory trawlers in the USSR and other major fishing nations in the region were capable of fishing at great depths and distances in almost all weather conditions (Solecki, 1979; Cushing, 1988; Arnason and Felt, 1995). As a result the fishing fleets expanded operations from coastal to offshore grounds (Solecki, 1979; Cushing 1988; Parsons and Beckett, 1995). The newly accessed offshore grounds traditionally acted as a 'refuge' or buffers against overfishing by providing groundfish shelter far offshore, beyond the operational range of traditional fleets (Pauly *et al.*, 2002; Walters and Martell, 2004). Currently, there are hardly any offshore grounds left to act as a refuge for the heavily-exploited groundfish stocks of the region (Cushing, 1988; Hutchings, 1995b).

On the other hand, the incremental improvements in vessels and gears technologies meant that the capability to catch fish has increased slowly, but consistently over time in the entire region. Such increase in the efficiency of the region's fleets is believed to have caused the collapse of numerous fish stocks, such as North Sea mackerel (*Scomber scombrus*), North Sea herring (*Clupea harengus*), Atlantic menhaden (*Brevoortia tyrannus*) and, recently, Northern cod (*Gadus morhua*) off Newfoundland and Labrador, besides leading to the depletion of many more stocks (Cushing, 1988; Arnason and Felt, 1995; Anon, 2002a).

As a response to fish stock collapses and loss of fishing grounds for long distance fleets (due to introduction of EEZs), stricter effort regulations were implemented (mainly in Europe), resulting in overall decline of regional fishing effort from the 1970s onward. The decline was further extended into the 1990s, as a result of the European fishing capacity reduction policy (MAGP), which had been introduced in 1983 to address concerns about overfishing of major commercial stocks and resulting overcapitalization in fleet capacity (Laurec and Armstrong, 1997; Lindebo, 1999), and the decline of fisheries in Russia and East European countries after the collapse of USSR (Anon, 1994; Newton and Garcia, 1997). The decline of fishing effort in European sub-region is believed to have contributed to the recent recovery of the North Sea herring and mackerel stocks (Anon, 2002a).

Still, in light of the depleted state of several stocks of the region and lingering overcapacity, there is a need to understand the spatio-temporal dynamics of fishing effort, and assess the likely consequences of fisheries expansion.

This section is dedicated to assessing the spatio-temporal evolution of fishing effort in the European and North American region. Before directly dealing with the main theme of this section, an overview is given of the status of countries as measured by their fishing capacity.

Relative status of countries in European-N. American region fisheries

In order to shed some light on countries' relative participation in marine capture fisheries, the overall capacity of their fleets was evaluated. A vessel's tonnage capacity or, alternatively, the horsepower of its engine, is usually considered a principal determinant of its fishing capability (Gulland, 1983; Marchal *et al*., 2002). Accordingly, the relative contribution of countries to the total effort in the region under consideration was measured by the total tonnage of their motorized fleets in 1995. The top ten countries are identified as depicted in Table 3.1; they accounted for about 84% of the region's fishing capacity.

Table 3.1. Fishing capacity of the top ten countries in European/North American region, based on data for 1995.

Rank	Country	Relative fleet capacity (% tonnage)
1	Russian Fed	29
2	USA	16
3	Spain	12
4	Canada	7
5	Ukraine	5
6	Norway	4
7	United Kingdom	4
8	Italy	3
9	France	2
10	Portugal	2
11-38	Others (27)	16

The Russian Federation alone accounted for about 29% of the total fishing capacity of the region in 1995. This is mainly because Russia inherited most of the former Soviet Union's vessels, which once constituted the world's largest fishing fleet (Solecki, 1979; Fitzpatrick and Newton, 2005). Next are the USA and Spain, with shares of about 16% and 12% respectively. The other countries in Table 3 .1 accounted for very small shares, ranging from 2 to 7%, while the remaining countries of the region (not included in Table 3.1) jointly accounted for only 16% of the region's fishing capacity.

Russia, thus is by far the single most important country, with the potential to have significant impact to the fish stocks of the region. Likewise, other countries such as the USA and Spain had fishing capacity equivalent to the capacity of 28 European countries combined. Spain, however, took measures to cut back the size of its fishing fleets in the 1990s (Tietze *et al*., 2001).

Evolution of fishing effort in European-N. American region fisheries

Trends in total fishing effort (in horsepower-days) was analysed in order to investigate the consequences of fishing effort expansion on the fish stocks. The latter will be discussed in the last section of this study. Here, total fishing effort is defined as the product of vessel number, fishing activity and fishing power. Fishing activity is the amount of time a fishing vessel is actively engaged in fishing. Ideally, fishing activity should be defined as fishing days minus transit time, search time and gear handling time (Walters and Martell, 2004). However, details on times not used for fishing are not available. Thus, in this study, fishing activity is represented by the annual number of days fished. Fishing power is the ability of a vessel to catch fish and is a complex variable involving vessel capacity (tonnage and engine power), gear size and crew size (Alvarez, 1999). Since data on gear size and crew size are not readily available, fishing power is often represented by mean engine power of the vessels (Gulland, 1983; Wilson, 1999; Marchal *et al*., 2002).

Therefore, in any given year, total fishing effort exerted by a fleet segment is estimated as the sum of these products over all gears and vessel class combination. The results of temporal analyses of total fishing effort of the region, over the period 1970-1995, are shown in Fig. 3.3 and 3.4.

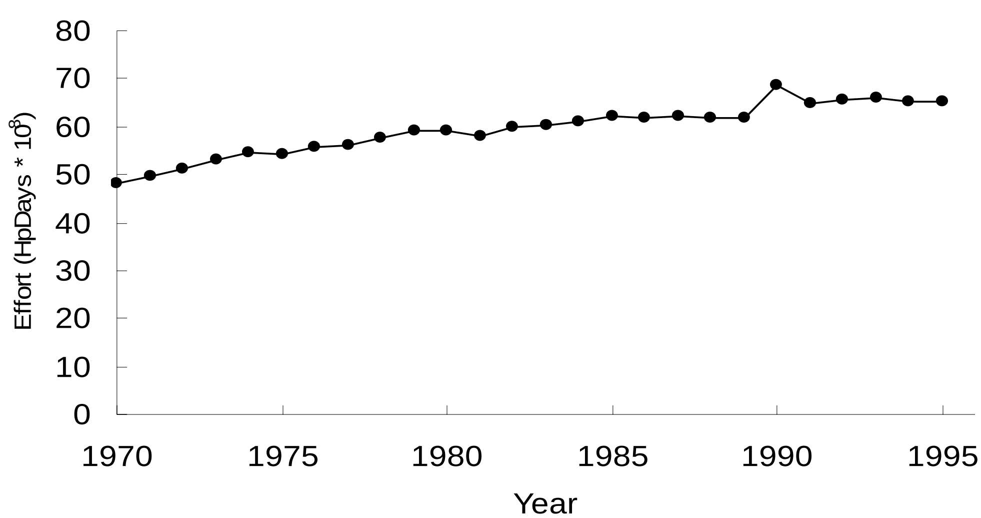

Fig. 3. 1. Temporal trends in total fishing effort in European-North American region.

Fig. 3.1 shows that total fishing effort for the region has been increasing until the 1990 and stabilized in the early 1990s. The overall regional trend shown in Fig. 3.1 is the result of cumulative effects of temporal changes that occurred in North American and European fisheries. This lumping of data makes it difficult to identify the fleet composition dynamics that occurred in individual countries. Thus, to better explain the observed trend, the dataset were split into three sub-categories of nations based on some rough similarities in their fisheries management histories and geographical proximity: North America[7], 13 European Union member countries (EU13[8]) and non-EU member nations[9]. The results are shown in Fig. 3.2.

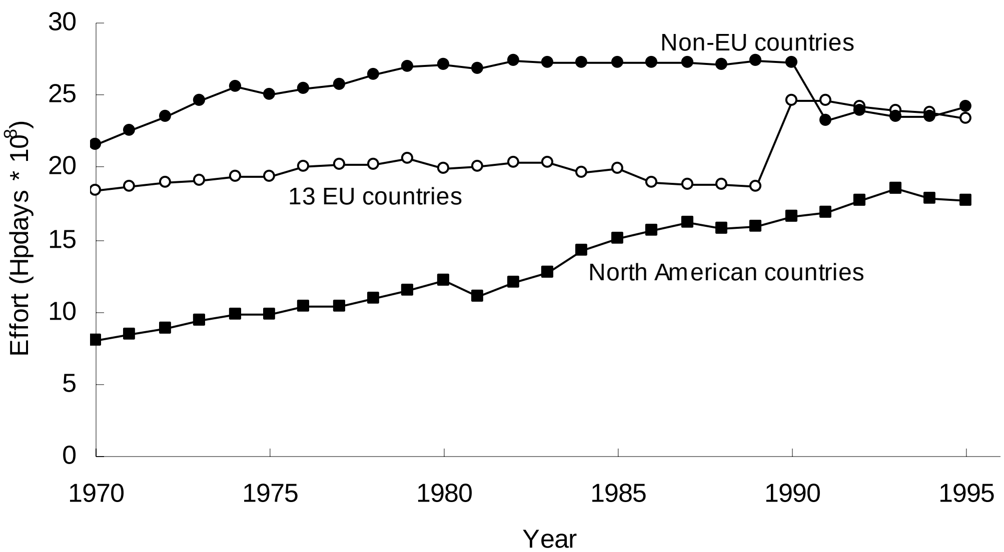

Fig. 3.2. Temporal trends in total fishing effort in North America, EU13 states and non-EU member states.

In non-EU countries category, fishing effort has been growing at a moderate pace in the period from the 1970s to the late 1980s. The overall fishing effort in this category is also higher, owing to the fleets of fisheries giants like the Russia and, to a lesser extent, Norway and Iceland. Fishing effort capacity growth in this sub-region, over the period between the 1970s and 1980s, can most likely be attributed to two factors: the expansion of fishing fleets, primarily of former USSR fleets, and the introduction EEZs by coastal states in the mid 1970s. Until its collapse in the early 1990s, the USSR had the world's single largest fishing fleet (Fitzpatrick and Newton 2005), a result of the former USSR's centrally planned fisheries economic policy, which was geared toward maximizing catches (Solecki, 1979; MacSween, 1983). This policy might have been further fueled by competition among the various Soviet republics for rewards for exceeding the planned 'production quotas' allocated to them (Pautzke, 1997). The USSR policy had an international influence in encouraging investment in fishing fleets in other East European socialist states, whose economic policies were built on the Soviet model (Garcia and Newton, 1997; Christy, 1997a).

The second likely factor that caused fishing effort expansion in this period was the declaration of EEZ limit. To fully exploit fish resources, within their newly granted national jurisdiction, many countries in this sub-region pursued policies of development of their domestic fleets through direct or indirect subsidies, and a policy of acquiring ocean-going vessels capable of processing at sea (MacSween, 1983,

[7] 'North America' consist here only of the U.S. and Canada;

[8] Landlocked nations are excluded. The EU13 countries considered are: Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden and UK;

[9] All non-EU member European nations and newly-recruited EU member states of the former Soviet Bloc are included. Since their membership is relatively recent, EU policies on effort management are not expected to have affected their fleet capacity in any significant way.

Hanna *et al*., 2000, Hilborn *et al*., 2003). The USSR, despite fishing access regime changes that excluded its fleets from most of their traditional overseas fishing grounds (Schmidt, 1977; MacSween, 1983; Garcia and Newton, 1997), continued expanding its fishing capacity in the period 1976-1980, partly by re-deploying the fleets in their own waters and partly by engaging in agreements with other countries for access to their EEZs (Schmidt, 1977). Similarly, extensive fishing effort expansion programs supported by various forms of subsidies were adopted by other major fishing countries in non-EU states such as Norway and Iceland (Isaksen, 2000; Schrank, 2003; Hermansen and Flaaten, 2004). As a result, fishing effort expansion in non-EU states continued until 1990.

Nonetheless, following the collapse of the former USSR and Yugoslavia, the fishing effort of this sub-category decreased in early 1990s. During this period, the East European nations were faced with various challenges including dealing with an oversized fishing fleet they were left with, reduced access to the EEZs of various countries they traditionally fished in, and decreases in both subsidized energy supplies and export demand from the former USSR republics (Anon, 1994). This combination of factors, forced the Baltic States to reduce or idle much of their fleets (Anon, 1994). The situation was similar in Russia, where most of the fleets became obsolete (Garcia and Newton, 1997). Also, the remaining fleets ceased to be competitive as the government was no longer able to supply cheap fuel or funds for their repair (Pautzke, 1997).

Even though the total size of non-EU fishing effort is much smaller than what it was in the 1980s, the trend is picking up again, partly fuelled by the overall economic recovery of East European countries in the late 1990s (Papp, 20005). This was particularly due to direct investment in fishing capacity redevelopment schemes, funded through various loans and aid packages aimed at supporting economic reforms of these countries (Anon, 2005).

In EU13 countries, fishing effort has been increasing until the mid 1970s and then showed signs of decline in the 1980s. The North Sea, the Baltic and Mediterranean Seas, which are the main fishing grounds of EU13 nations, had been fished for centuries and the fish resources were depleted long before the mid 1970s (Gulland, 1974: Cushing 1988). Since the turn of 20th century fishing effort had been increasing in this sub-region (Cushing, 1988). Especially after 1950s, fishing effort expansion was further fueled by the need for successful economic rebuilding after the WW II coupled, as elsewhere, with population growth that resulted in increased demand for fish and fish products (Cushing, 1988, Arnason and Felt, 1995).

The effects of this fleet expansion began taking its toll as early as in the mid 1970s, with the collapse of North Sea herring and mackerel stocks (Cushing 1988, Anon, 2002a) and subsequent deterioration of the status of several stocks in the region (Arnason and Felt, 1995). Recent reports showed that 62-91% of important commercial stocks are overexploited[10] in NE Atlantic, while the figures for the West coast of Ireland, the Baltic and the Mediterranean are 100%, 75% and 65-70% respectively (Anon, 2002b). However, in 1990s the fishing effort of EU13 category has relatively increased, which mainly involve increases in the number of small-tonnage vessels (usually <30 GRT). This increase is probably associated with recent recovery of several small pelagic stocks in the region (Anon, 2002a). Despite this relative increase, the overall trend in the early 1990s showed a sign of decline for fleets operating in these areas. The declining trend in total fishing effort in the 1990s for EU13 countries can be a likely result of the EU fishing capacity reduction policy (MAGP).

However, parallel to its capacity reduction program, the EU has a subsidy program for vessel renewal and construction, aimed at the modernization of EU fleets (Stump and Batker, 1996; Christy, 1997a; Linbedo, 1999, Munro and Sumaila, 2002). For example, the EU increased spending on its commercial fleets from $80 million in 1983 to $500 million in 1990, one-fifth of which went to vessel building or refitting (Stump and Batker, 1996). This vessel renewal and modernization scheme could potentially have an opposite effect from the capacity reduction schemes in that replacement of old inefficient vessels with new or modernized, more efficient vessels has a potential for increasing effective fishing effort. Even subsidies that are used for fleet decommissioning programs can have unintended negative effect if fishers can foresee them coming. In which case, the decommissioning subsidies can be considered as the collateral, which banks require for new vessel purchase (Munro and Sumaila, 2002; Pauly *et al*., 2002). Thus, for the

[10] The exploitation rates were estimated as the ratio of the number of overexploited stocks to the number of commercially thriving stocks (Anon, 2002b).

EU MAGP to achieve its intended goals, close monitoring of the effects of vessel construction and modernization programs is of paramount importance.

On top of concerns about fleet modernization programs, for their potential for increasing effective fishing effort, there are concerns about the effect of growing fishing effort in non-EU countries. The non-EU countries share several resources with EU13 countries, for example in the North Sea (Williams, 2005). The temporal trend of fishing effort seen in these countries was that of increasing in the 1990s (Fig. 3.2), i.e., fishing effort capacity reduction, mainly achieved by Spain (Anon, 2002b), seen in EU13 countries is offset by increase in total fishing capacity of non-EU countries. Therefore, at least for the shared stocks, the effort reduction in EU13 countries may not lead to a corresponding improvement in the status of fish stocks in the region.

In North America, fishing effort has been growing from 1970 up to about the early 1990s. The early years of this period saw fisheries expansion as the result of declaration of EEZs. In the 1980s, substantial financial assistance was given to the local fishing industries for fleet renovation and construction meant to modernize and increase the productive capacity of the fisheries (Manchester, 1970; Angel *et al*., 1994; Parsons and Beckett, 1995; Arnason and Felt, 1995; Rogers, 1995). For instance, in 1983, the U.S government supplied nearly $65 million in low-interest loans to finance construction of fleets for the Arctic Alaska Fisheries Corporation in which 80% of vessel constructions were financed (Stump and Batker, 1996). Similar financial supports were granted for fishing capacity building in Canada (Pauly and Watson, 2003; Schrank, 2003). In addition to these subsidies, the expansion of fishing effort capacity was fueled by open access regime that encouraged fishers to invest in fishing capacity in order to get a larger share of the resources (Angel *et al*., 1994; Rogers, 1995, Pearse, 1996; Christy, 1997a). The result was large fishing effort capacity expansion in the sub-region (Manchester, 1970; Arnason and Felt, 1995; Harris, 199; Hanna *et al*., 2000; Hilborn *et al.,* 2003; Pauly and Maclean, 2003).

Nevertheless, after the early 1990s, fishing effort in this sub-region levelled off, or began declining at a modest rate. By this time, the region's fishing fleet had developed to the full or overcapacity, putting many stocks under stress to the extent that about 33% of USA stocks were overexploited (Hanna *et al*., 2000; Hilborn *et al*., 2003), and the abundance of several Canadian stocks were declining, leading to collapse of at least one important stock, the Northern cod (Moore *et al*., 1993; Nicholson, 1996; Pearse, 1996; Lear, 1998; DFO, 2000).

At about this time, the crisis of fisheries began to be recognized by the broader public, and environmental groups began voicing their concerns, putting management authorities under intense pressure (Hanna *et al*., 2000). As a response to these pressures, management regulations involving quota and limited entry programs were implemented. In addition, stricter rules such as complete exclusion or reduction of flag vessels (Hanna *et al*., 2000), restrictions on the power and efficiency of vessels, gear restrictions, vessel replacement rules, area closure and vessel buyback schemes were implemented (Angel *et al*., 1994; Stump and Batker, 1996; Pearse, 1996). As a result, and also due to dwindling return on expenses and profit dissipation by over-expanded fleets, fishing effort of the sub- region showed signs of contraction in the period from the early 1990s to 2000.

Distribution of fishing effort in European-N. American region fisheries

As has been discussed in Section 1, modeling spatial distribution of fishing effort is important: a) to document the differential fishing pressure received by different fishing grounds due to differences in the distance of fishing grounds from major ports and differences in relative productivity (Hilborn and Walters, 1992; Walters and Martell, 2004); and b) to analyze the inevitable impacts of differential fishing pressure on spatial ecosystem structure (Pauly *et al*., 2003b). The results of spatial analyses for groundfish and small pelagic fisheries are presented separately, in order to better explain fishing effort spatial dynamics, as these fisheries are often targeted by different gear types.

Groundfish fisheries

Groundfish are bottom-living fish such as the gadid family and the flatfishes. These species tend to be abundant on broad continental shelves, e.g., in the North Atlantic. In this part of the world, groundfish fisheries commonly target demersal species such as Atlantic cod (*Gadus morhua*), flatfishs (Pleuronectidae), haddock (*Melanogrammus aeglefinus*), hakes (*Merluccius* spp.), pollock (*Pollachius* spp.) and numerous other species. The data in spatial cells were broadly aggregated (in two classes) in order to highlight regional fishing hotspots. The results of analyses of groundfish fishing effort distribution are shown in Fig. 3.3, on a decadal basis from 1970 to 1990.

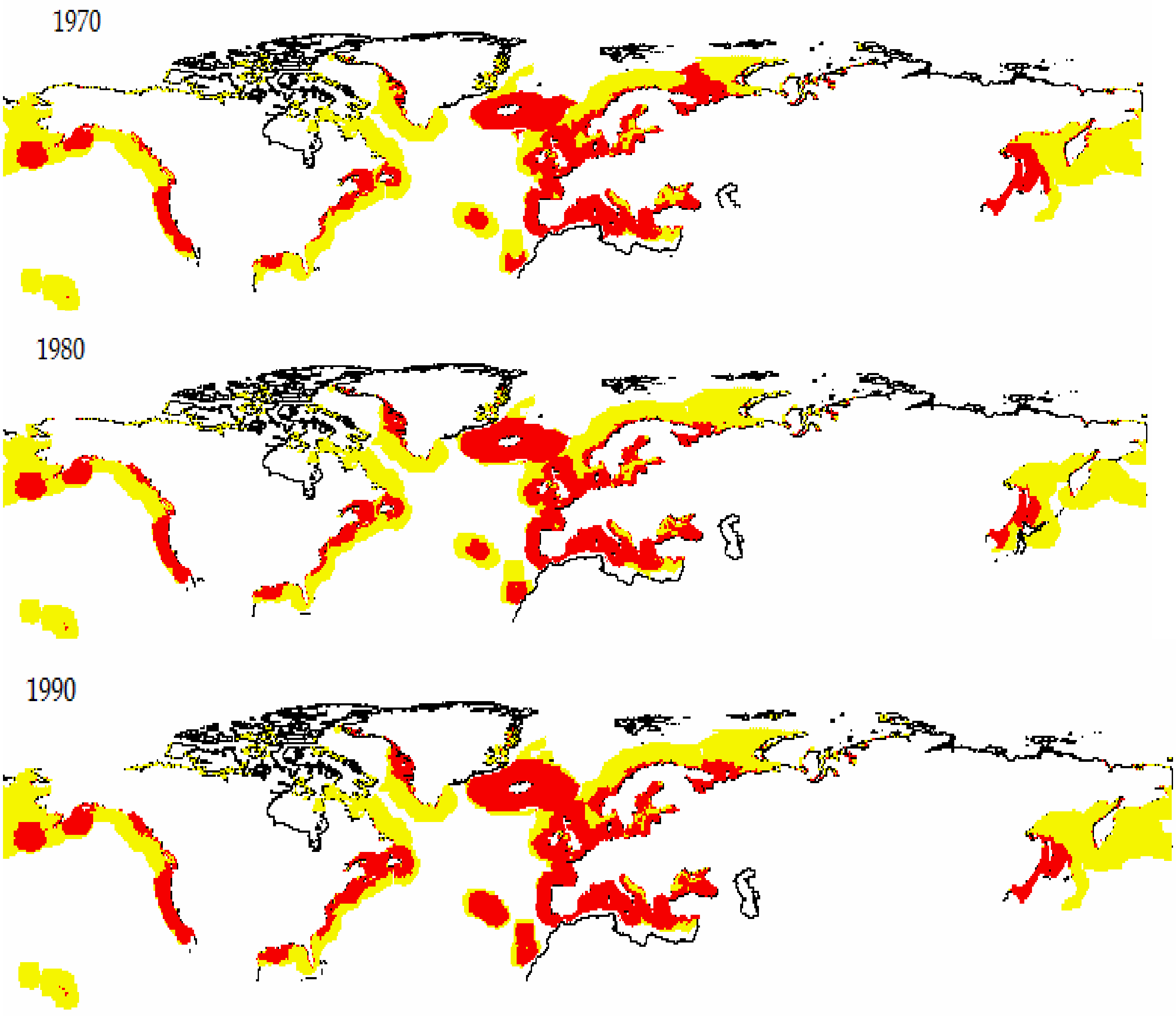

Fig. 3.3. Predicted spatial distribution of fishing effort targeting groundfish in North American and European fisheries. Yellow: 0.0-2.6 log hpdays per km^{-2}; red: 2.61-14.3 log hpdays * km^{-2}.

An important feature evident from the maps is that fishing operations covered the vast area of the continental shelves of the region in as early as the 1970s. In the European sub-region, groundfish fisheries expansion to offshore grounds is the result of decades-long, heavy exploitation that eventually led to depletion of inshore groundfish stocks (Cushing, 1988; Arnason and Felt, 1995; ICES, 2001; Anon, 2002a). This forced fishers to expand their operations from the inshore areas of North Atlantic to offshore grounds, to pursue stocks that were unexploited or under-exploited during the 1950s and 1960s (Anon, 2000). However, in some grounds, such as the Barents Sea, the offshore effort concentration showed moderate decline since 1980s. The 1980 observation is most likely linked to a temporarily reduced activity of the former USSR fleets, after their retreat from international grounds due to full enforcement of the new access regime. The 1990 observation, on the other hand, is linked to the 1989 collapse of the USSR, which caused most of USSR's fleets to become obsolete (Garcia and Newton, 1997), and the active ones non-competitive as the government was no longer able to supply cheap fuel or funds for repair of the fishing fleets (Pautzke, 1997).

In North America, offshore expansion has been continuous since the 1970s. The offshore expansion can be attributed to the combined effects of the fleet capacity growth, especially following the declaration of EEZs, and the depletion of coastal groundfish (Hanna *et al*., 2000). Other studies have documented a similar time frame of expansion of fisheries to offshore grounds in North American region (Hutchings and Myers, 1995; Hanna *et al*., 2000).

Small pelagic fisheries

Small pelagic fishes are species that inhabit the water column, but tend to remain on continental shelves for the most part of their life histories. Commercially important small pelagic species in the region include herrings (*Clupea* spp.), capelin (*Mallotus villosus*), anchovies (*Engraulis* spp.), mackerels (*Scomber* spp.), menhadens (*Brevoortia* spp.) and sardines (*Sardina pilchardus* and *Sardinella* spp.). The results of analyses of fishing effort distribution targeting small pelagic fish are shown on a decadal basis from 1970 to 1990 in Fig. 3.4.

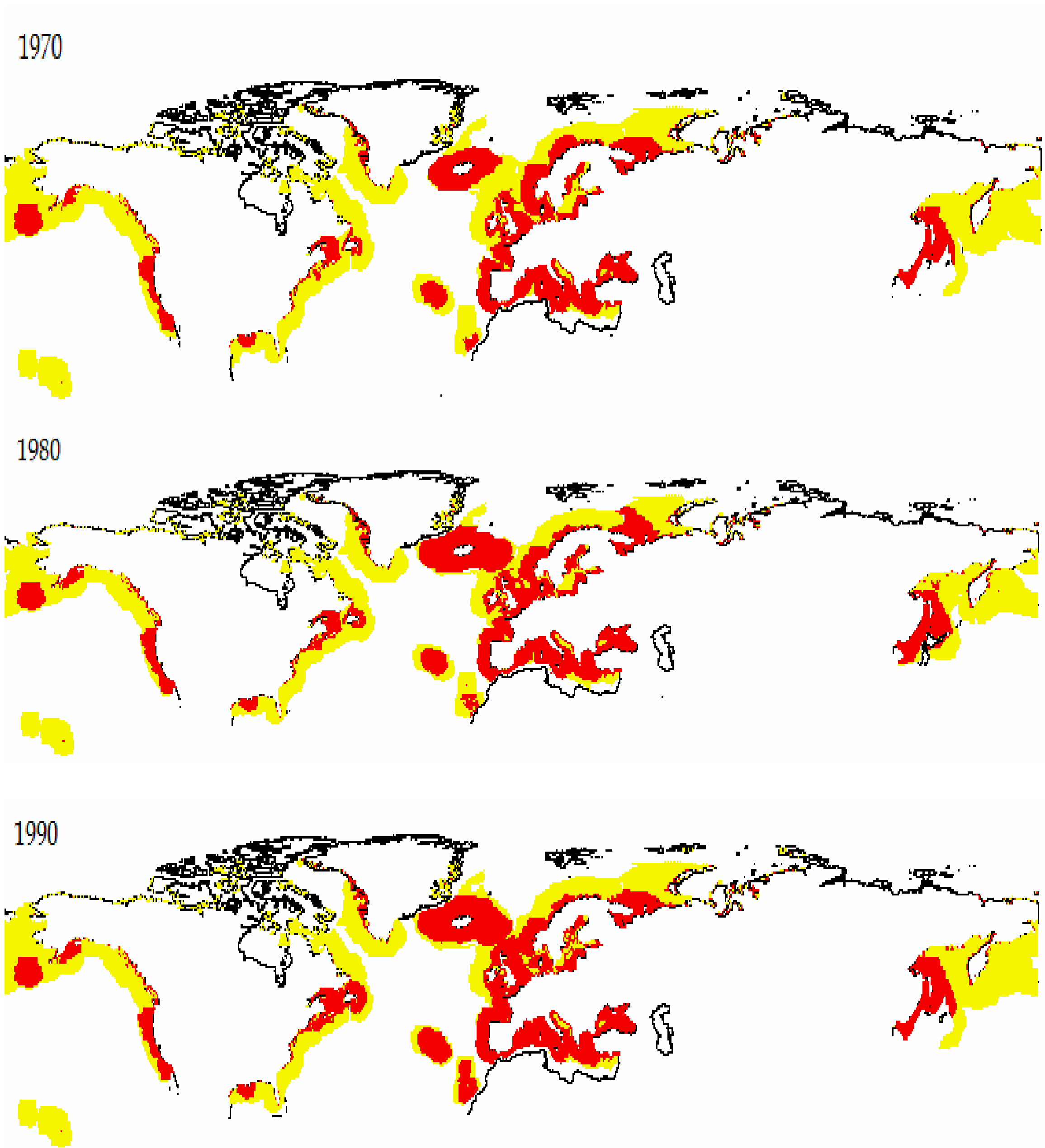

Fig. 3.4. Predicted spatial distribution of fishing effort targeting small pelagic fisheries in North American and European region. Yellow: 0.0-2.3 log hpdays per km^{-2}; red: 2.31-14.4 log hpdays * km^{-2}.

The overall pattern of spatial distribution of fishing effort, targeting inshore small pelagic fisheries, is similar to the groundfish effort distribution pattern (Figs. 3.3 and 3.4). This is due to the fact that, in most cases, both groundfish and small pelagics are concentrated in shallow areas. On the temporal scale, the intensity of small pelagic fishing effort expanded around the coasts of several countries (Fig. 3.4). This geographic expansion of fishing effort targeting small pelagic fisheries is attributed to depletion of several inshore stocks of small pelagic fisheries, such as North Sea mackerel and North Sea herring (Cushing, 1988; Bjomdal, 2003), Atlantic menhaden (Rogers and Van Den Avyle, 1983) and, more recently, Pacific herring and Barents Sea capelin (FAO, 1997).

In recent years, a considerable increase in the contribution of small pelagics to the catches of the region has been reported (Anon, 2002a). An increase associated with the recent recovery of several small pelagic stocks in the region (Anon, 2002a). The increased catches could also be related to enhanced fleet mobility, coupled with state-of-the-art electronic gears, the combination of which allow the fleets to track schools of fish and maintain high catch totals even at low stock levels (Stump and Batker, 1996).

Overall, the model predicted high effort intensity in traditionally rich fishing grounds of the Northern Hemisphere, which include inshore areas of the Norwegian Sea, the coast of Barents Sea, Spitzbergen, the Skagerrak and Kattegat, the North Sea, the coast of Iceland, the English and Bristol Channels, the Bay of Biscay, inshore areas of Portuguese waters and the Mediterranean Sea. Similarly, it predicted high effort intensity in traditional Northwest Atlantic fishing grounds including the Grand Bank, the Scotia-Fundy shelf, the Gulf of Maine, Georges Bank and New England shelf in the north, down to the Gulf of Mexico in the south. In the Northwest Pacific, high effort intensity is predicted around inshore areas of the Washington-Oregon coast and in the Strait of Georgia, in the Gulf of Alaska, Bering Sea and the Sea of Okhotsk.

The overall pattern seen in the spatial fishing effort distribution maps is that fishing effort intensity decreases with increasing distance from homeports and for similar distances, intensity is highest in shallow areas. Of course, this pattern is generated because of the assumption built in the model that treats fishing effort distribution pattern to be governed by cost (proxy: distance from ports) and anticipated catches (approximated by depth). Thus, if the model assumptions are correct, it shows that the concentration of fishing intensity remains inshore, despite significant expansion in the overall range of fleet operation. Similar inshore fishing effort concentration pattern has been documented in Northwest Atlantic, in which the northern cod fishing grounds relatively remained inshore for several years (1954 to 1990) despite inshore cod stock depletion (Hutchings and Myers, 1995). This could be due to several reasons, including: (i) relatively high catch rate at low stock levels as a result of efficiency of fishing gears; (ii) relative safety and low cost associated with fishing close to home; (iii) fishers prefer to fish in their traditional inshore fishing grounds rather than taking the risk of going offshore for uncertain reward, and (iv) the vast majority of region's fleets are composed of small vessels.

On the other hand, even though the inshore grounds carry the greatest fishing pressure, the offshore grounds also experienced increasing fishing pressure in the period under consideration. Offshore grounds are traditionally assumed to act as a refuge for heavily exploited fish species, and are thought to serve as a buffer against overfishing (Walters and Martell, 2004), especially where target species large parts of their distribution out of the range of fishing operation (Pauly *et al.*, 2002). With increasing expansion of fishing effort to these offshore grounds, the buffering effect of offshore grounds have been lost leaving no refuge for Northern cod (Guénette, 2000) and other fishes.

Finally, it is acknowledged that the model does not predict fine scale dynamic variations in fishing effort intensity as dictated by actual year-to-year changes in target stock abundance or distribution. As will be shown in model validation section (Section 4.5.1), the overall pattern of fishing effort distribution predicted by the model, however, roughly in agreement with independent spatial data on fuel use.

Conclusions

With the exception of EU13 countries in the 1980s, there were two distinct phases in the evolution of fishing effort of the Europe-North American region. Phase 1 (1970s to 1980s), represented the continuation of effort expansion of post WW II era. The expansion was further intensified by domestic fleet development policies adopted by countries after UNCLOS III. In this phase, the fishing effort of North America and non-EU countries had grown significantly, while that of EU13 began declining.

Phase 2, from the 1990s on, represented an effort contraction phase. In this phase, with exception of non-EU countries, the trend in North America had stabilized or showed a sign of decline, while the EU13 countries showed a further decline. However, for non-EU countries, except for a brief period in the early 1990s, fishing effort continued expanding.

The overall pattern of total fishing effort evolution, for the entire region as a whole, showed continuously increasing trend from the 1970s to the late 1980s. After this time, the total size of the fleets was reduced in the early 1990s, but the trend has been picking up again. This is mainly because the small decline achieved by EU13 countries had been offset by effort build up in non-EU countries, and to lesser extent, in North America. EU13 and non-EU countries share several stocks in the Baltic, North Sea and Mediterranean Sea. Consequently, an EU13 effort reduction could not have resulted in any significant improvement in overall status of fish stocks in the region.

As a result, the region's fishing effort is still expanding, despite numerous studies showing continuous declining of the abundances of traditional major commercial fish stocks in the region. This increasing trend in fishing effort is the direct result of fishing capacity development programs adopted during phase 1 of fishing effort expansion, which that provided various types of subsidies for construction of fishing vessels and gears. As of 1995, the situation was as eloquently described by Michael L. Weber with reference to the US fisheries (Hanna *et al.*, 2000):

"The biggest problem we are facing is that the marine fisheries have been the equivalent of the cold war. We built up enormous fleets with societal encouragement, and now we are faced with this enormous task of building down. It is like deciding what to do with these warheads."

With regard to spatial distribution of fishing effort, fishing effort intensity is highest in inshore grounds close to homeports. At the same time, fishing operations have expanded geographically and covered the entire range of distribution of major groundfish and small pelagic species in this region over time. If the *status quo* is maintained, further depletion of already depressed stocks is inevitable.

The Asian-Pacific region fisheries

Background: industrialization of fisheries in Asian-Pacific region

For several centuries, fishing has been a very important economic sector on which a large fraction of the Asia-pacific region populations depended on for food and income. It is estimated that approximately 33 million fishers depend on fisheries for their livelihood in this region (FAO, 1996). Driven by growing demand for fish, the fishing industry of the region experienced dramatic expansion in the last three decades, although with differing rate in individual countries (Hongskul, 1999). The variability in growth of fisheries range from rapid development in countries like China, South Korea, Japan, Australia and New Zealand (APO, 1988; FAO, 1999; Klaer, 2001) to relatively slow developments in several other Asian nations (FAO, 1989) and the virtually non-existent local commercial fishing industry in some Pacific islands (Kent, 1980).

Countries such as China, South Korea and Japan motorized their fishing vessels and expanded the numbers of their fishing fleets even before WW II (Solecki, 1966; Asada *et al.*, 1983; Fujinami, 1989), while in most developing Asia-Pacific countries, fleet expansion took off after WW II (Panayotou, 1985).

In Japan, fishery products play an important role in the traditional diet. As a result, the fishing industry enjoys considerable attention and investment from the government (Takayama, 1963; Milazzo, 1998). Japanese investment in fleet motorization and expansion began far back with the Sino-Japanese War (1894-95) and the Russo-Japanese War (1904-05), marking the first phase of the motorization of Japanese fishing fleet (Takayama, 1963, Swartz, 2004). Later, WWI (1914-1918) further expanded Japan's overseas territories and fishing interests in the Pacific, from the Bering Sea to the South China Sea and to the South Pacific, underpinning the need for investing in fishing fleets (Swartz, 2004). With onset of the 1920s, highly efficient offshore vessels were introduced by the Japanese fishing industry (Asada *et al.*, 1983; Fujinami, 1989; Swartz, 2004). Since this period, both the total number of Japanese vessels and the rate of motorization have been growing continuously.

The effects of WWII on Japanese fisheries were devastating. Allied bombing of the Japanese mainland destroyed port facilities and Japanese vessels were confiscated by the military and used as mine sweepers and transportation supply vessels for the military (Swartz, 2004). During this period, Japan also experienced a shortage of fuel and gears for its fishing fleets; this, coupled with a navigation ban imposed on Japanese vessels, resulted in the termination of all fishing activities in 1945 (Swartz, 2004).

After WW II, the expansion of Japanese fishing industry was very rapid, owing to the concerted efforts made by the Japanese government to fill the huge food deficit which emerged in the late 1940s (Asada *et al.*, 1983; APO, 1988). As a result, in less than a decade, motorized vessels accounted for 40% of the total Japanese fishing fleet (Chidambaram, 1963). However, after the late 1970s, Japanese long distance fleet capacity declined as a result of both the fuel price hike of the early 1970s, and the subsequent establishment of EEZ regimes by most maritime countries, which reduced access to traditional fishing grounds of the Japanese distant water fleets (Swartz, 2004). However, their domestic fleet capability development saw no significant decline (Asada *et al.*, 1983; APO, 1988). Currently, the large Japanese domestic fishing fleet fulfils multiple roles, including food supply and providing a major employment in rural fishing communities (MAFF, 2005).

In China, the importance of marine fishing industry received recognition as far back as the 12th century (Solecki, 1966). During the final years of the Chinese empire, at the beginning of the 20th century, the imperial government tried to modernize the fishing industry through purchase of western vessels and ice storage facilities, which would have enabled the Chinese fishing industry to operate in coastal waters (Solecki, 1966). However, the fleet modernization program ran into trouble with the fall of the Ch`ing dynasty, the civil war that followed and the subsequent Japanese invasion (Solecki, 1966). The combination of setbacks left the country without much of its fishing fleet, a situation that persisted until the ascendance of the Chinese communist party to power in 1949 (Solecki, 1966; Jia and Chen, 2000).

The new Chinese government strongly promoted increased marine capture fisheries (Jia and Chen, 2000, Pang and Pauly, 2001). To that end, it implemented various programs for fishing vessel constructions, repairs, modernization and vessel purchases from abroad (Milazzo, 1998). As a result, the Chinese fishing industry saw a rapid expansion, implemented over three distinct phases. The initial phase of Chinese fisheries expansion occurred in the period from 1950 to 1959 and is known as 'the period of initial development' (Jia and Chen, 2000). At the beginning of this period, there were few motorized vessels in the Chinese fleet (Jia and Chen, 2000), but toward the end of this period, both the rate of motorization and the number of Chinese fishing vessels grew rapidly (Solecki, 1966; Zhong and Power, 1997; Jia and Chen, 2000).

The second expansion phase occurred in the period from 1960 to 1976. During this second phase, also known as 'the period of stagnant development', two political disasters hit China, the 'great leap forward' and the 'cultural revolution' (Jia and Chen, 2000; Pang and Pauly, 2001). Even though political turmoil interrupted overall Chinese economic development, the fishing fleet expanded remarkably both in number and power during this period as well (Jia and Chen, 2000).

The third phase of Chinese fishing capacity expansion was implemented in the period from 1977 to 1999. During this period, the number of fishing vessels grew strongly and the number of non-powered vessels diminished (Jia and Chen, 2000). The rapid growth in fishing fleet during this phase, especially after 1985, has been attributed to two major events occurred during this period. The first of these is the relaxation of price control on fish products, which improved the financial situation of some fleets that were otherwise unprofitable in the past, providing incentive for fishers to invest in fishing vessels (Pang and Pauly 2001). The second event was the mass migration of farmers to coastal cities due to loss of farmlands and also in search of a better life in coastal cities. These landless farmers eventually became small-scale fishers along the coasts (Hinrichsen, 1995; Pang and Pauly 2001).

After the mid 1980s, Chinese official catch statistics increased exponentially (Pang and Pauly, 2001). This exponential growth in Chinese catch statistics was largely based on over-reporting of catch figures by local officials in an attempt to justify increased fishing effort or increased government allocation of resources to their units or area (Pang and Pauly, 2001; Watson and Pauly, 2001). As a response to this reporting fraud, the Chinese central government implemented a 'zero growth' policy in marine capture fisheries since 1998, the result of which was to freeze reported catches at the 1998 level, making the Chinese recent catch statistics unreliable (Pang and Pauly, 2001; Watson and Pauly, 2001). The fleet statistics may be less unreliable, however.

Generally, over the past three decades, Chinese fleet mechanization exhibited a remarkable expansion (Zhong and Power, 1997). Currently, despite some largely unsuccessful effort control measures taken by authorities and stagnant or declining CPUE trend recorded in almost all Chinese fishing grounds, Chinese fishing fleet continue expanding (Zhong and Power, 1997; Milazzo, 1998; FAO, 1997a; Pang and Pauly, 2001; Watson and Pauly, 2001).

In South Korea, a rapid expansion occurred between the 1970s and the early 1980s (Asada *et al.*, 1983). Most of the expansion in the 1970s and 1980s was the result of deep-sea fishing operations (Anon, 2005e). Like the trends observed in Japan and China, the size of non-motorized fleets has been diminishing, while the number of motored units increased. For instance, South Korean motorized fishing vessels constituted about 12% of the total fleet in the early 1960s, while this figure was 79% in the early 1980s (Anon, 2005e).

In developing Asia-Pacific countries, fleet motorization and total capacity expansions began after WW II (Chidambaram, 1963) with more rapid increases since the 1960s (Panayotou, 1985; Silvestre and Pauly, 1997). The rate of fleet mechanization in these developing Asia-Pacific countries showed wide variations. For example, in the early 1960s, the shares of mechanized vessels in some Asia-Pacific developing countries ranged from 2.5% in India to 84% in Philippines (Chidambaram, 1963). In the early 1980s, motorization in these countries significantly increased, ranging from 7% in India to about 97% in the Philippines (Asada *et al.*, 1983). Parallel to fleet mechanization programs, there has been a simultaneous fishing gear modernization, which began with the introduction of large trawls first to Thailand and then to neighboring countries, such as, Malaysia, Indonesia and the Philippines (Asada *et al.*, 1983; Silvestre and Pauly, 1997; Pauly and Chuenpadgee, 2003), leading to the emergence of large offshore fleets in developing Asian countries.

Fleet expansion and mechanization in these developing countries were mainly funded by various government-sponsored development assistance programs in the form of provision of soft loans, direct subsidies and even outright distribution of boats and engines at low prices and through foreign joint venture projects (Ahmad, 1985; Panayotou, 1985; FAO, 1989). These programs were all aimed at boosting domestic fishery catches, primarily through supporting fishing effort developments (FAO, 1989).

In Australia, a rather rapid fishing capacity expansion occurred after WW II (Bian, 1985). The initial pulse was initiated through fleet expansion programs implemented in the 1970s and the early 1980s as a result of EEZ declaration and stable high fish prices that encouraged further investment (Bian, 1985; Klaer, 2001). Similarly, in New Zealand, fishing effort capacity development began to grow in the 1960s, triggered by the appearance of foreign fishing vessels off the coasts of New Zealand, which was perceived as a threat to the commercial interests of domestic fishers (FAO, 1999). Consequently, the government removed restrictions on fishing effort applied earlier to local fishers and encouraged expansion of fishing effort as well as guaranteed loans for fishing vessel purchases (FAO, 1999). This led to overcapitalization in some fisheries. For instance, in 1984, the inshore sector was overcapitalized by an estimated $NZ 28 million (approx. 17.36 million USD) and in some areas, overcapitalization was estimated to represent about 44% of existing fishing capacity (FAO, 1999).

For the region as a whole, the fishing effort expansion policies implemented by various countries have resulted in growth in fleet size, increased efficiency and geographic expansions to offshore grounds, which translate into excessive pressure on fish stocks of the region (Menasveta, 2000). Consequently, numerous coastal stocks of the region were depleted by overfishing (Ahmed *et al.*, 2003; Christensen *et al.*, 2003; Pauly, 1989; Silvestre *et al.*, 2003). On the other hand, the Pacific, especially the South Pacific, is a deep ocean with limited shelf areas, and thus unfavourable for fishing (Kent, 1980). With such limited shelf areas, the fishing effort in the region--except that directed at tunas--is concentrated narrow coastal shelves.

In light of the limited geographic extent of shelf areas, investigating the evolution and distribution of fishing effort of the region is important. This study is part of an attempt to shed light on this critical issue. As has been done in previous section, an overview is given on the status of countries as measured by their fishing capacity, prior to dealing with the evolution and distribution of total fishing effort.

Relative status of countries in Asian-Pacific region fisheries

As was done for the European-North American region, the countries' fishing capacity is measured in terms of the tonnage capacity of their motorized fleets (Table. 3.2). The top ten countries together accounted for about 96% of the region's fishing capacity. The relative share of each country is shown in Table 3.2.

Table 3.2. Fishing capacity of the top ten countries in Asia-Pacific region, based on data for 1995.

Rank	Country	Relative fleet capacity (% tonnage)
1	China Main.	48
2	Japan	13
3	Korea Rep	7
4	Taiwan	6
5	Korea D P Rp	6
6	India	5
7	Indonesia	4
8	Thailand	3
9	Malaysia	3
10	Pakistan	1
11-58 (47)	Others	4

As can be seen from Table 3.2, China heads the list of regional fishing giants, accounting for 48% of the total tonnage capacity of the region. It is remotely followed by Japan, accounting for 13 of the region. The share of other countries in the top ten list range from 1% to 7%, while that of the remaining 47 countries not listed here, together, accounted for only 4% of the region's fishing capacity.

One important lesson that could be drawn from this result is the importance of China in the fishing sector of Asia-Pacific region. China's large capacity is the direct result of various economic, social and political measures taken by the government to ensure the growth of fisheries (Solecki, 1966; Milazzo, 1998; Pang and Pauly, 2001).

In the face of declining abundance of major commercial stocks in the Chinese waters (Jia and Chen, 2000; Xianshi, 2000; Pang and Pauly, 2001), the current fishing capacity is largely an over-capacity from an economic perspective. On the other hand, the negative impact of Chinese fishing capacity is not limited to Chinese fish resources alone. China shares several fish stocks with its neighboring countries (Menasveta, 2000). The Chinese fishing capacity, therefore, has a significant implication for the fish resources that are shared with other neighboring countries. There is no realistic quota management regime between China and its neighbors for shared stocks (Menasveta, 2000; Rosenburg, 2005), making the influence of Chinese fleets on shared stocks very significant.

Evolution of fishing effort in Asian-Pacific region fisheries

As discussed in Section 1., fishing effort is defined as the product of number of vessels, fishing activity and fishing power, i.e., in any given year, fishing effort is estimated as the product of fleet size, fleet activity and power summed over all gears and vessel classes. The results of temporal analyses of fishing effort of the region, over the period 1970-1995, are shown in Fig. 3.5 and 3.6.

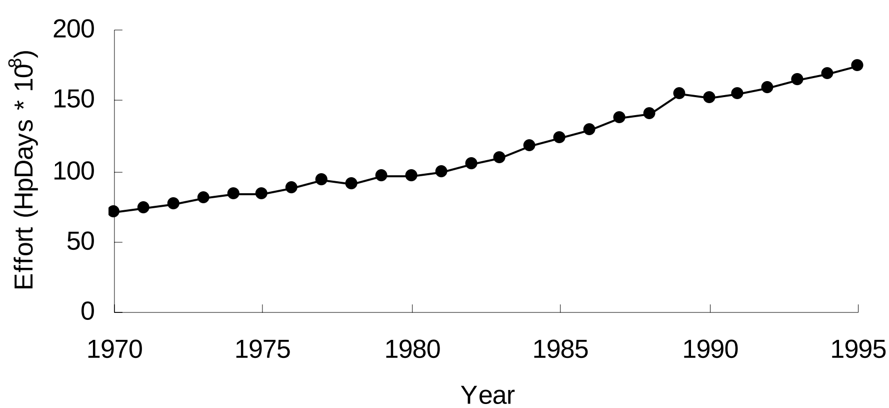

Fig. 3.5. Temporal trends in fishing effort in the Asia-Pacific region.

Fishing effort in the region has been growing since the 1970s (Fig. 3.5). This steady growth is consistent with fisheries expansion policies implemented by most Asia-Pacific nations in the second half of the 20th century as documented in Section 3. To better understand the trend in Fig. 3.5 and also discern major countries deriving the regional trend, traditional fishing countries of the region (Japan, South Korea and China) were isolated and that of all remaining countries were aggregated for trend analysis (Fig. 3.6).

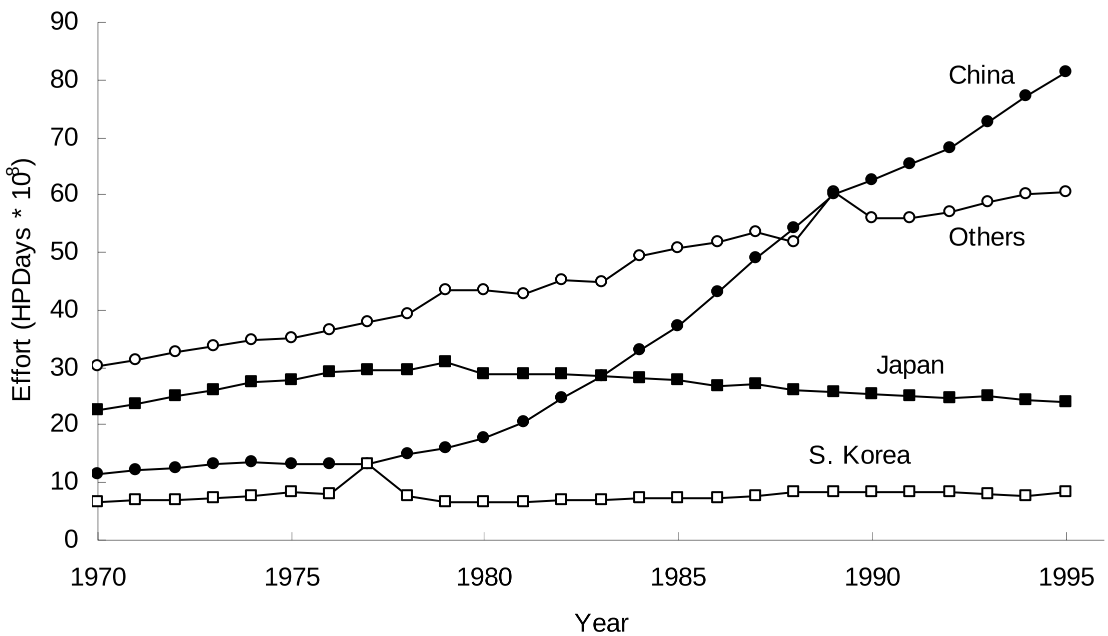

Fig. 3. 6. Temporal trends in fishing effort in selected countries and all other countries in the Asia-Pacific region.

Fig. 3.6 shows that fishing effort was continuously growing in China and in the countries grouped in the 'others' category, while the trend was declining in Japan and did not change much in South Korea. In China, the period after 1970 roughly coincides with the Chinese third fisheries 'developmental phase', during which, a rapid expansion of effort occurred (Jia and Chen, 2000), with serious repercussions for the fish stocks (Zhong and Power, 1997; Milazzo, 1998; FAO, 1997a; Pang and Pauly, 2001; Watson and Pauly, 2001). Catch per unit of effort (CPUE) declined, resulting in utilization of five tonnes of fuel to catch one tonne of fish (Jia and Chen, 2000). Also, catches increasingly consisted of 'trash' fish or juveniles and catches of high valued fish dropped sharply (Milazzo, 1998; Pang and Pauly, 2001). Despite such alarming decline in the CPUE, Chinese fishing effort continued to expand as Chinese authorities reacted to this decline by developing new capacity for deep-sea fishing (Zhong and Power, 1997, Milazzo, 1998; Pang and Pauly, 2001). However, China also reported an initiative to scrap 30,000 fishing vessels and relocate some 300,000 fishers by 2010 (Rosenburg, 2000).

In the 'others' category, steady growth in fishing effort was seen since the 1970s (Fig. 3.6). With the hope of maximizing benefit from their fisheries, developing Asia-Pacific countries heavily invested in the sector from the 1960s on (Panayotou, 1985). Initially, the fleet expansion programs succeeded in increasing catches and this temporary success motivated further extension of the subsidy programs well into the 1970s, covering larger number of fishers (Panayotou, 1985). Therefore, the overall growth in fishing effort in this group of countries is the direct result of the investments in fishing capacity development policies funded through various kinds of subsidies. Further, the fishing effort expansion in this catagory is aggravated by high fish demand due to increasing population, expanding fishing communities and associated lack of alternative livelihood, advances in fishing technology and accelerated development of industrial fisheries (Silvestre and Pauly, 1997). For instance, in the Philippines, the level of fishing effort exceeded what was required to catch the maximum economic yield by 150-300% and maximum sustainable yield by 30-130% in as early as the mid 1980s (Silvestre and Pauly, 1997).

On the other hand, fishing effort has been declining in Japan since the late 1970s. As has been mentioned earlier, the decline in Japanese fishing effort is due to the decision taken by Japan not to rescue all of its long distance fleet after full enforcement of EEZ regimes (Park, 1974; Asada *et al.*, 1983; Fujinami, 1989; APO, 1988). Similarly, the South Korean fishing fleet did not show a comparable growth with fish demand, and the industry has been failing to meet both domestic and export fish demands in recent years (Anon, 2003). For instance, the share of fish in the total South Korean exports dropped by about 5-fold over the same period (Anon, 2003).

Distribution of fishing effort in Asian-Pacific region fisheries

Groundfish fisheries

Groundfish are bottom-living fish, which tend to occur on broad continental shelves. The most spectacular groundfish catches in this region are made of species such as small yellow croaker (*Larimichthys polyactis*), hairtails (*Trichiurus* spp.), Pacific cod (*Gadus macrocephalus*) and Alaska pollock (*Theragra chalcogramma*) (Menasveta, 2000). The results of the analyses of distribution of fishing effort targeting groundfish in Asian-Pacific region are shown on decadal basis from 1970 to 1990 in Fig. 3.7.

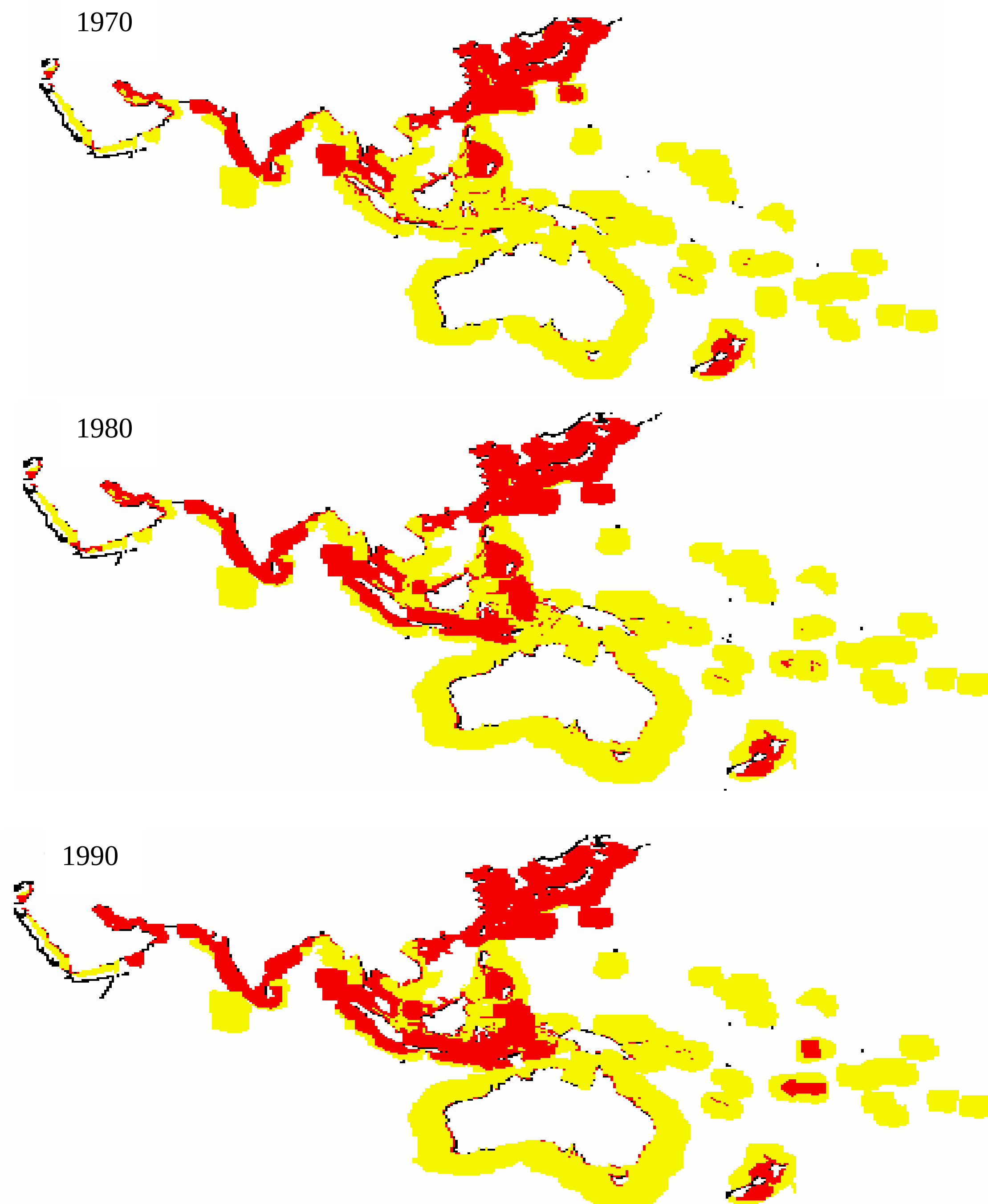

Fig. 3.7. Predicted spatial distribution of fishing effort targeting groundfish in Asia-Pacific region fisheries. Yellow: 0-2.7 log hpdays*km^{-2}; red: 3.71-16.39 log hpdays*km^{-2}.

The overall trend depicted by Fig. 3.7 is that in 1970, heavy fishing was concentrated on limited fishing grounds along the coasts of few countries (the Sea of Japan, the Yellow Sea, the East China

Sea, the Gulf of Thailand, the Bay of Bengal and the Indian coast of Arabian Sea). However after 1980s, heavy fishing covered all potential fishing grounds along Southeast Asian coasts.

The high fishing effort concentration in the Sea of Japan, the Yellow Sea, the East China Sea and the inshore areas of the South China Sea is partly attributed to the fact that these grounds lie within operational range of several giant fishing nations of the region (notably China, Japan, South Korea and the Philippines) and also are among productive fishing grounds of the world (NOAA, 2004).

Historically the East China Sea provided about 50% of Chinese marine landing (Zhong and Power, 1997). In recent years, however, the fishing power of fleets operating in the East China Sea increased significantly in the 1990s (from China alone), resulting in a decline of CPUE by a factor of 3 (FAO, 1997a; Jia and Chen, 2000; Xianshi, 2000). Similarly, in the South China Sea, overexploitation of coastal resources due to massive increase in fishing effort has been well documented (Thuoc and Long, 1997; Cheung *et al*., 2002). Indeed, overfishing in the coastal areas of the South China Sea led to shift in catch composition from large demersal and pelagic predator fishes to pelagic herbivorous fish and increased volume of juvenile fish in the catches (FAO, 1997a; Pang and Pauly, 2001; Cheung *et al*., 2002). The picture along the Yellow Sea coast is not any different. The Yellow Sea has been fished heavily, and its fish stocks have been reduced to very low levels, making the fisheries of the Yellow Sea economically unsustainable (NOAA, 2004). High fishing effort intensity also occurs in Japanese waters. Along the Japanese coasts high fishing intensity has been reported, leading to decline in the catches of important groundfish species such as Alaskan pollock and Pacific cod (FAO, 1997a).

Likewise, in the Southeast Pacific and the Indian Ocean, high fishing effort concentration is predicted for the Gulf of Thailand, the Indonesian Sea, the Bay of Bengal and the Indian coast of Arabian Sea. In the Gulf of Thailand, massive increase in fishing effort occurred since the 1960s, resulting in decline of CPUE from about 300kg/hour in the early 1960s to about 50 kg/hour in the 1980s to only about 20-30 kg/hour in the 1990s (Pauly and Chuenpagdee, 2003). In India, the fisheries expansion began during WW II when demand for fish increased because of allied forces based in India (Bhathal, 2005). This shortage eventually led to a development of the fisheries sector, but the expansion began well after India's Independence in 1947 (Bhathal, 2005). Following Independence, several fisheries expansion programs were implemented through successive 'Five Year National Plans' involving construction of large vessels and extensive canoe motorization (Bhathal, 2005). As a result, Indian fishing grounds are among the most heavily fished areas of the region. Similarly, the fisheries of the South coast of Central Java are characterized by increased fishing pressure (FAO, 1997a). Overall, the predicted results roughly reflect the reported historical fishing effort concentration patterns as briefly summarized here.

Small pelagic fisheries

The most popular small pelagic fish catches in this region include anchovies (*Engraulis and Stolephorus* spp.), South American pilchard (*Sardinops sagax*), Japanese jack mackerel (*Trachurus japonicus*), chub mackerel (*Scomber japonicus*), scads (*Decapterus* spp.), Pacific saury (*Cololabis saira*), Indian oil sardine (*Sardinella longiceps*) and Indian mackerel (*Rastrelliger kanagurta*) (Sugiyama *et al*., 2004). The results of analyses of fishing effort distribution targeting small pelagic fish in the Asia-Pacific region on decadal basis from 1970 to 1990 are shown in Fig. 3.8.

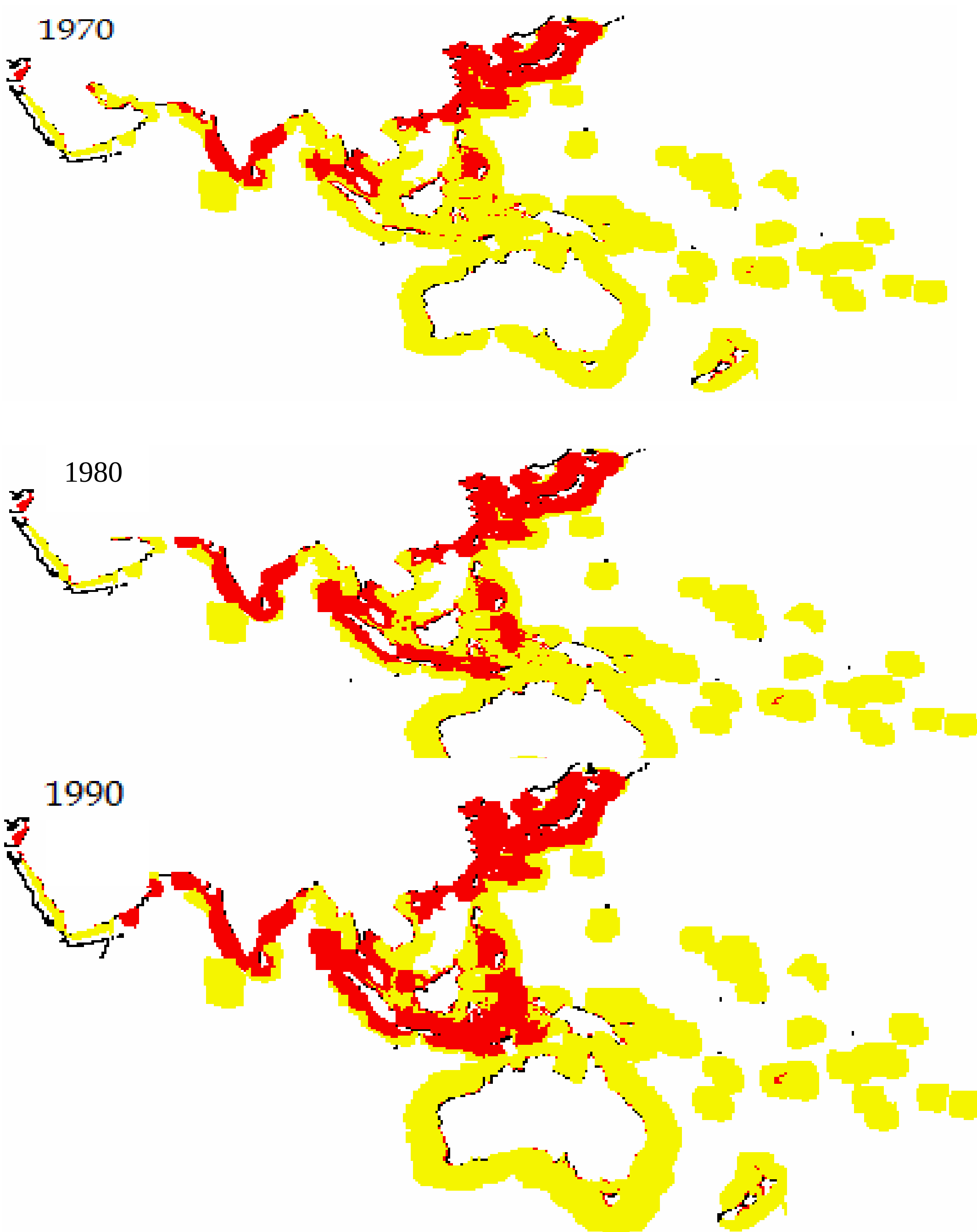

Fig. 3.8. Predicted spatial distribution of the fishing effort targeting small pelagic species in the Asia-Pacific region fisheries. Yellow: 0.0-2.5 log hpdays*km^{-2}; red: 2.51-15.5 log hpdays*km^{-2}.

As for groundfish, the model predicted high fishing effort concentration for the Chinese Seas (the Yellow, the East and the South China Seas), the Japan Sea, coasts of India, the Gulf of Thailand and the Indonesia Sea (Fig. 3.8). Each of these areas, with high predicted effort intensity, are known major fishing grounds for small pelagic fisheries in the region (Menasveta, 2000). For instance, the Yellow Sea small pelagic stocks are among the most intensively exploited resources in the world (Sugiyama *et al*., 2004). Thus, the results of the prediction appeared to roughly mirror the reported spatial concentration of small pelagic fishing effort in the region.

Evidences from trawl surveys, ecosystem modeling and Large Marine Ecosystem (LME) studies previously done in the region indicated that the abundance of small pelagic stocks in most of the region have been much reduced (FAO, 1997a; Sugiyama *et al*., 2004). For instance, the catch of the Japanese pilchard (sardine) dropped by 4.1 million tonnes since 1988, representing a decline of 76% (FAO, 1997a). High fishing intensity of small pelagic fisheries came about partly due to the fact that the region's fishing effort had switched to targeting small pelagic species as large demersal species have been depleted, leading to the catches of the region being dominated by small pelagic marine species (FAO, 1997a; Menasveta, 2000; Jia and Chen, 2000; Xianshi, 2000; Pang and Pauly, 2001; Pauly and Chuenpagdee, 2003; Sugiyama *et al*., 2004). This relative shift in catch composition is a classic example of what Pauly *et al*., (1998) called "Fishing down the marine food web", wherein total catch is increasingly dominated by small pelagic fish, as predatory large demersal and large pelagic fish are serially depleted.

On temporal scale, in the 1970s, high fishing effort concentration was limited to grounds, such as the Yellow Sea, the East China Sea and the Indian coasts for both the groundfish and small pelagics. But after the 1980s, the fishing fleets of the region grew in size and expanded its geographic operation, covering the entire range of the shelf areas in the Gulf of Thailand and the Indonesian Sea (Fig. 3.8).

However, the bulk of the region's fleets still operate in inshore areas, not far from where they operated back in the 1970s. This results from a combination of low fish densities in deep waters, which characterizes tropical ecosystems (Longhurst and Pauly, 1987), also assumed in the model used here, and the fact that the major portion of the fishing fleets of the region is still composed of small vessels, thus incapable of operating in the open waters. This concentration of effort in the inshore areas has been a major cause of conflicts between artisanal and industrial fisheries over resources in several developing Asia-Pacific countries (Panayotou, 1982).

Conclusions

With the exception of Japan, Australia and New Zealand, fishing effort of the countries in the Asia-Pacific region has been continuously growing over the period covered by this study. Factors believed to have caused this large expansion include uncontrolled fishing fleet capacity expansion programs implemented by countries in the region and open access regime, which encourages poor people (especially in Southeast Asia) to fish when other means of livelihood are scarce (Pauly, 1997). The impact of the open access regime was further compounded by population movements to coastal cities, as in China, eventually joining the already crowded fishing sector as fishing remains a major means of livelihood.

Accounting for the bulk of the nominal capacity of the region, China is mainly responsible for fishing effort capacity expansion observed in this region, especially after 1990, as the other countries showed declining trends. Various reports, on the status of fish stocks show that high levels of fishing effort depleted almost all commercial stocks of the region. Against this backdrop, maintaining the current fishing effort level might lead to further deterioration of the status of fish stocks, resulting in decline of overall catches.

High fishing effort intensity is predicted in inshore grounds. Given the narrowness of the shelf areas in most countries of the region, the concentration of effort inshore areas will continue to fuel conflicts between different fisheries subsectors.

The South American-Caribbean region fisheries

Background: industrialization of fisheries in the S. American- Caribbean region

The South American-Caribbean region fishing industry showed little expansion until the second half of 20th century (Christy, 1997). Before this period, fisheries in this region were limited to subsistence and artisanal levels, as it been the case initially in all developing countries (Pauly and Zeller, 2003). While development of some fisheries go as far back as 1602 (Freire, 2003), there were only isolated attempts of industrialization, e.g., in Peru for canned products in the 1930s (Doucet and Einarsson, 1966). Otherwise, in most of the countries in the region fisheries development attempts remained rare until the mid 20th Century (Christy, 1997).

The period after the WW II is characterized by a global demand for fish and fish products (Cushing, 1988), and several countries in the region catered to this demand by fully conditioning their fisheries industrialization policies upon export markets (Doucet and Einarsson, 1966; Deligiannis, 2000; Rudd, 2003). In the process, several countries embarked on major fisheries development schemes in the 1950s and the 1960s, involving fishing capacity expansion, fleet mechanization and fishing gear technology acquisition (Christ, 1997; Prado and Drew, 1999; Freire, 2003; Mohammed and Joseph, 2003; Mohammed *et al.*, 2003; Mohammed *et al.*, 2003a; Mohammed and Rennie, 2003; Mohammed and Shing, 2003; Mendoza *et al.*, 2003). To illustrate the export driven rapid expansion of fishing industry in this part of the world, the rise and sudden collapse of the Peruvian anchoveta fishery can serve as an example.

The Peruvian anchoveta fishmeal industry was established through a joint venture arrangement between a company from San Francisco and a Peruvian investor in 1950 (Parraga, 1986). From the early 1950s to the early 1960s, the Peruvian anchoveta industry took a leading position in the world's fishmeal production, landing annual catch of nearly one million metric tonnes (Doucet and Einarsson, 1966; Deligiannis, 2000). Catch continued growing in the 1960s and early 1970s, hitting a peak of about 12.5 million tonnes in 1970, with a fishing effort of anywhere between 1,400 to 1,800 boats (figures vary between sources) crewed by 21,700 fishers (Deligiannis, 2000). The fishery was the largest single species fishery in the world, but it suddenly collapsed in the early 1970s (Clark, 1976; Pauly and Tsukayama, 1987; Csirke, 1989). The collapse was caused mainly due to overfishing by an over-expanded fleet, though at the time it was largely attributed the 'El Niño' event of 1972-73 (Clark, 1976; Longhurst and Pauly, 1987; Csirke, 1989; FAO, 1996; FAO, 1997b; Christy, 1997; Deligiannis, 2000).

The impact of this collapse was immense. Both the fishing fleet and the processing plants lost their resource base (Csirke, 1989). The spectacular decline of the total fishing effort targeting Peruvian anchoveta stock in Peru is shown in Fig. 3.13.

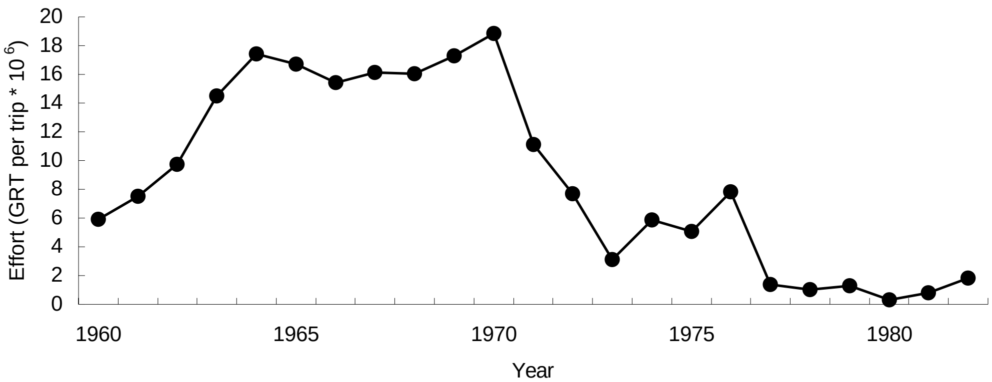

Fig. 3.8. Trajectory of Peruvian fishing effort targeting Peruvian anchoveta (Csirke, 1989).

Fig. 3.8 shows that during the collapse of the anchoveta fishery directed fishing effort was reduced by about a factor of 6 from its level in the late 1960s.

Comparable, but less spectacular, pelagic fisheries boom and bust occurred in neighboring Chile as well. The Chilean Northern pelagic fishery underwent rapid expansion in the 1970s and quickly depleted the anchovy stock in Northern Chile, plunging the fleet into a financial crisis that led to privatization of the fleet in the late 1970s (Thorpe and Reid, 1999). The bankrupted fleet switched partly to fishing other pelagic species, such as jack mackerel (*Trachurus murphyi)* and South American pilchard (*Sardinops sagax)* and partly moved southwards into then under-exploited fishing grounds (Thorpe and Reid, 1999). Chilean subsidized fisheries investments extended into the early 1980s, leading to overfishing of new fisheries (Basch *et al*., 1995; Thorpe and Reid, 1999), despite government attempts to mitigate overfishing through application of minimum catch size and closed areas (Thorpe and Reid, 1999). Similarly, the pelagic fishery in Southern Chile nearly collapsed in the 1990s (Basch *et al*., 1995; Aguilar *et al*., 2003). The biomass of the jack mackerel species, which constituted about 90% of the catches of the pelagic fishery in Southern Chile, dropped by about 30% of 1980s level (Aguilar *et al*., 2003), while the fishing effort targeting this stock continued growing (Basch *et al*., 1995). Total collapse of this fishery was averted by timely management intervention, involving cut back in fishing capacity to the level of 1986, and imposition of strict quota system (Basch *et al*., 1995; Aguilar *et al*., 2003).

In most countries of the region, similar fishing effort expansion policies were implemented, if at a slower pace. In the 1970s, especially after the declaration of the EEZ regime, fisheries expansion gained increasing attention and several countries in the region opted to further expand their offshore fleet capacities by involving quasi-governmental enterprises, some of which funded by the Inter-American Development Bank (Christy, 1997) and local banks (Mohammed and Joseph, 2003). As a result, several countries, such as Brazil, Mexico, Cuba, Ecuador, Colombia, Nicaragua, Panama, Peru and Venezuela implemented government-sponsored fisheries expansion programs (Weidner and Hall, 1993; Christy, 1997). Suriname, Trinidad, Colombia, Cuba, Guyana, Mexico, Nicaragua, Peru and Uruguay even established government fishing companies that promoted fishing industry expansion (Christy, 1997). Similarly, huge subsidization programs in the 1970s, involving loans for vessels, gear purchases and fuel tax rebates, were implemented in several Caribbean islands (Mohammed, 2003; Mohammed and Joseph, 2003; Mohammed *et al.,* 2003; Mohammed *et al.,* 2003a; Mohammed and Rennie, 2003; Mohammed and Shing, 2003). Parallel to these offshore fleet expansion programs, the inshore fleet sector also expanded, as was to be expected under an open access regime (Christy, 1997).

As the result, the impact of the expansion was considerable throughout the region. Adding to the collapse alluded to above, sardine stocks (*Sardinella brasiliensis*) along the Brazilian coast have collapsed (Vasconcellos, 2000; Freire, 2003), and the abundance of other pelagic fish and of several groundfish species, such as Argentine hake (*Merluccius hubbsi*) and Patagonian toothfish (*Dissostichus eleginoides*), were heavily exploited by the fleets of the region (Basch *et al*., 1995; FAO, 1997b; Christy, 1997; Thorpe and Reid, 1999; FAO, 1997b; Renato *et al*., 2004). Similar trends, characterized by declines in CPUE, reduction in the size of fish caught and changes in species composition became common experiences of fisheries in the Caribbean section of the region as well (Anon, 2005c; Baisre *et al*., 2003; Mohammed, 2003, Mohammed *et al.,* 2003a; Mohammed and Joseph, 2003, Mohammed *et al.,* 2003; Rudd, 2003)).

As the result of declines in the fish resources, the giant state-run fishing companies of the region did not achieve the intended goals of increased productivity, but rather turned into financial liabilities in most of the countries (Christy, 1997). For instance, in the 1970s and 1980s, the nationalized fishing companies in Peru incurred a huge deficit, forcing the government to provide hundreds of millions of dollars in subsidies (Weidner and Hall, 1993). The general failure of state-run fishing companies led to privatization of most fishing companies in the region (Christy, 1997).

Despite such poor economic performance of the fishing industries and increasingly declining catch per unit of effort (CPUE), fishing fleets continued expanding throughout the 1990s in many countries in the region (Christy, 1997; Mohammed, 2003; Mohammed and Joseph, 2003; Mohammed *et al.,* 2003; Mohammed *et al.,* 2003a; Mohammed and Rennie, 2003). As the result, since the late 1980s, the fishing industry of the region became overcapitalized and increasingly characterized by conflicts (Thorpe and Reid, 1999).

This section deals with the issue of fishing effort spatio-temporal expansion in the region from 1970 to 1995. Before directly analysing the evolution and distribution of total fishing effort in the region, an overview of the status of countries of the region, as measured by their fishing capacity, are presented below**.**

Relative status of countries in S. American-Caribbean region fisheries

As has been done for other regions in the preceding sections, the relative status of countries is measured in terms of the tonnage of their motorized fleets (Table 3.3). The top ten countries together accounted for about 87% of the region's fishing capacity in total tonnage (Table 3.3).

In stark contrast to the European-North American and the Asia-Pacific regions, where one dominant country could be singled out, the fishing industry of the S. American-Caribbean region is not dominated by any single country. Rather, Mexico accounts for about 19% of the total tonnage capacity of the region, with Panama, Peru and Argentina following closely (Table 3.3). The share of other countries in the top ten list range from 3-9%, while that of the remaining 30 countries not listed here, together, accounted for only 13% of the region's fishing capacity.

Table 3.3. Fishing capacity of the top ten countries in South American-Caribbean region, based on data for 1995.

Rank	Country	Relative fleet capacity (% tonnage)
1	Mexico	19
2	Panama	11
3	Peru	10
4	Argentina	10
5	Puerto Rico	9
6	Chile	8
7	Cuba	7
8	Venezuela	5
9	Brazil	4
10	Ecuador	3
11-40	Others (30)	13

Mexico's concerted effort in expanding its fisheries began in the 1970s, when the Mexican government fostered fisheries expansion through creation of fishing cooperatives (284 cooperatives nationwide, with more than 39,000 members) and construction of new plants for freezing and processing fish (FAO, 1997b; Anon, 2005a). From the mid 1980s on, the fisheries expansion program was further boosted with infusion of $5 billion expansion subsidy to expand the offshore fleet and increase output by more than 30% between 1985 and 1990 (Anon, 2005a). The expansion programs for offshore industrial fisheries, coupled with inshore fleet expansions, mainly driven by the open access regime prevalent in Mexican fisheries, resulted in increase of fishing effort, leading to overfishing of important commercial stocks and overcapitalization of fishing fleet in Mexico (Defeo, 2003; Anon, 2005c).

In Panama, industrial-scale expansion of the small pelagic fishery began in the 1950s, and later diversified by targeting large pelagics (FAO, 2005a). Also, Panama exerted concerted effort to modernize its fishing industry through motorization of its coastal fisheries. For instance, in the early 1990s alone, Panama introduced about 13,000 marine outboard motors for the purpose of promoting the coastal fishery (Anon, 1998). As a result, there has been continuous increase in the number of vessels and expansion of the artisanal fisheries (FAO, 2005a).

Peru is the major fishing nation of the region with established industrial fishing fleets as explained earlier. In Argentina, after the country emerged from its defeat in the 1982 Falkland War, the government revitalized the fisheries sector through various subsidies involving exemption of fishing vessels from trade taxes, nationalization of foreign fleets and replacement of old fishing vessels by modern ones (Thrope and Reid, 1999). These incentives, coupled with promise of economic stability, led to large investment in fishing fleet expansion throughout the late 1980s (FAO, 1996; Thrope and Reid, 1999; UNEP, 2002). The drastic expansion of fishing fleet, however, led to overfishing of many commercial stocks, with one important stock, the Argentine hake, collapsing in the 1990s (FAO, 1996; Thorpe and Reid, 1999).

Similar fisheries expansion programs were implemented in all countries in the above list though with varying degree of commitments (Christy, 1997; Thorpe and Reid, 1999; Freire, 2003; Mendoza *et al*., 2003; Mohammed, 2003; Mohammed and Joseph, 2003; Mohammed *et al*., 2003; Mohammed *et al*., 2003a; Mohammed and Rennie, 2003). This trend has been a common phenomenon in most countries of the region as well (Christy, 1997; Thorpe and Reid, 1999). As the result, the fisheries of the region are characterized by overcapitalization, stock depletions and conflicts (Thorpe and Reid, 1999).

Evolution of fishing effort in S. American-Caribbean region fisheries

As also done in previous sections, fishing effort here is defined as the product of number of vessels, fishing activity (mean annual number of days fished) and fishing power. The results of temporal analyses of total fishing effort of the region, over the period 1970-1995, are shown in Fig. 3.9 and 3.10.

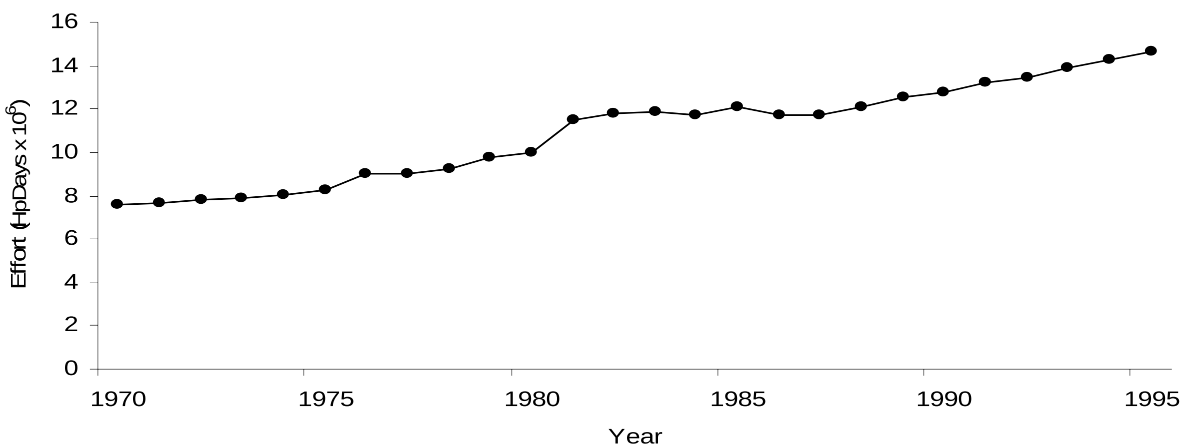

Fig. 3.9. Temporal trends in fishing effort in the South American-Caribbean region.

Total fishing effort in this region has been growing since 1970 (Fig. 3.9), though development trajectories in individual country may take a slightly different route as exemplified by Peru (Fig. 3.10).

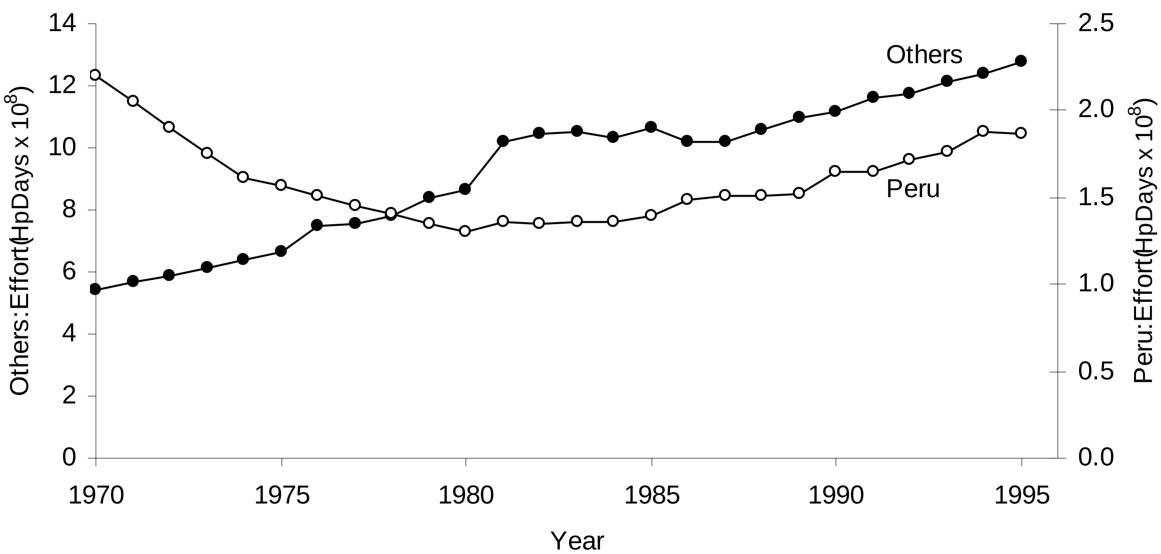

Fig. 3.10. Evolution of total fishing effort in Peru and the South American-Caribbean region.

The decline in Peruvian fishing effort in the early 1970s is due to the collapse of the Peruvian anchoveta fishery, which led the Peruvian government to nationalize the purse seiner fleet in 1973, and reduce excess capacity in the following years (Csirke, 1989; Anon, 2005b). However, after the 1980s, Peruvian fishing effort increased again, a result of the recovery of anchoveta stocks. Also, and vessels originally granted permission to fish for either human consumption or to target other underexploited pelagic stocks were allowed to target anchovies (FAO, 1996, Gelchu, 2006).

Until the early 1980s, the S. American-Caribbean region, especially the Southwest Atlantic, was among the few major fishing areas of the world with a large potential for expanding total catches (FAO, 1996). However, expansion of fishing effort, mostly by mechanized fisheries, has occurred since. As a result, most fish stocks in the region are now considered fully exploited, while some have been overexploited over the past few years (FAO, 1996). Despite the overall decline in the status of stocks, the fishing effort of the region continued to rise.

Distribution of fishing effort in the S. American-Caribbean region fisheries

The results of spatial analyses of groundfish and small pelagic fisheries are presented separately as described in the following sections.

Groundfish fisheries

The largest groundfish catches in this region consist of Argentine hake (*Merluccius hubbsi*), Southern blue whiting (*Micromesistius australis*), South Pacific hake (*Merluccius gayi gayi*), Patagonian grenadier (*Macruronus magellanicus*), Argentine croaker (*Umbrina canosai*) and various species of weakfishes (*Cynoscion* spp.) (FAO, 1997b).

The results of the analyses of distribution of fishing effort targeting groundfish in South American-Caribbean region are shown on decadal basis from 1970 to 1990 in Fig. 3.11.

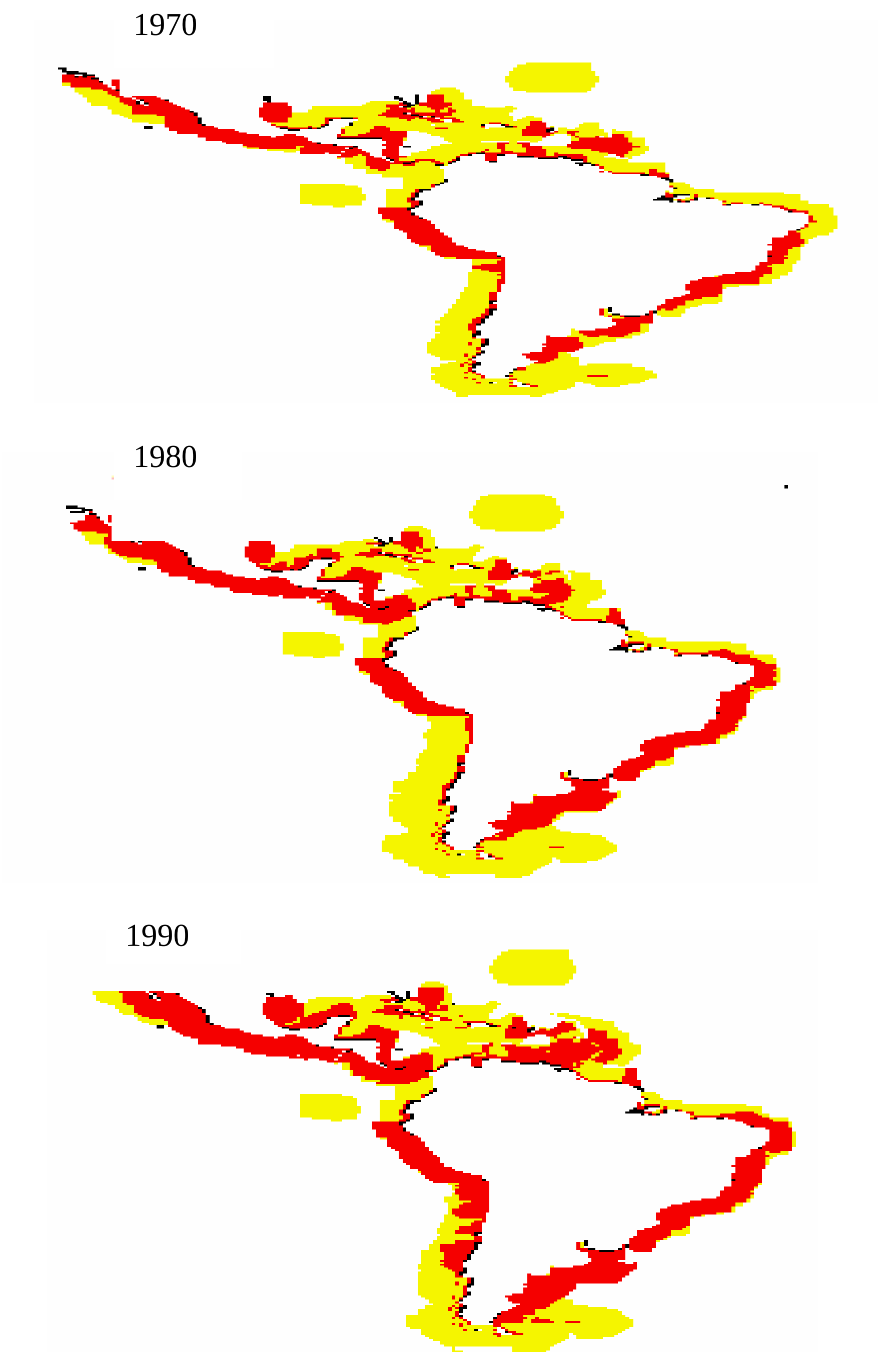

Fig. 3.11. Predicted spatial distribution of fishing effort targeting groundfish species in the South American-Caribbean region. Yellow: 0.0-1.9 log hpdays*km^{-2}; red: 1.91-13.4 log hpdays*km^{-2}.

In the Eastern Central Pacific, high fishing intensity is predicted for the Gulf of California and inshore areas of Baja California, inshore areas of Central Americas (Fig. 3.11). The Gulf of California is a rich Mexican fishing ground, accounting for about 40% of Mexican catches (Anon, 2005c). In the Gulf of Mexico increasing fishing pressure causes overfishing not through the targeted catch, but through the by-catch (of the shrimp fisheries), which consists mainly of juvenile groundfish (FAO, 1997b).

In the Southeast Pacific, high fishing effort intensity is predicted along the inshore coasts of Ecuador, Peru and South Central Chile. The areas with high predicted effort concentration roughly coincide with most productive trawling grounds off Northern Peru and South-Central Chile along the west coast of South America. In these areas, the continental shelf is rather narrow, except for some limited areas off Southern Ecuador, Northern Peru and Southern Chile, where the shelf might reach a maximum width of 120 km (FAO, 1997b). In these areas, high fishing effort concentrates on heavily exploited stocks of hake. Other groundfish species such as the Patagonian grenadier, the Patagonian hake and some toothfishes are considered fully exploited, with some of them giving signs of over-exploitation in the 1990s (FAO, 1997b).

In the South Central Atlantic, high fishing effort is predicted in Mexico's Yucatan Gulf, the inshore areas of Cuba, Puerto Rico, Venezuela, Guyana and the Caribbean coasts of Central Americas. As for other countries in the region, these countries, particularly Cuba, Mexico and Venezuela, had expanded their fishing fleets in the 1970s and 1980s (Baisre *et al*., 2003; Christy, 1997). The effort expansion programs resulted in fishing effort accumulation in their major fishing grounds as shown in Fig. 3.11. As a result, the fisheries of these areas have been characterized by generally increasing catches in recent decades, with serious consequences for vulnerable species such as Nassau grouper (*Epinephelus striatus)* (FAO, 1997b).

In the Southwest Atlantic, high fishing effort intensity is predicted in inshore areas of Southern Brazil, Uruguay and Southern Argentina, Patagonia (Fig. 3.11). In the last decades, the countries in this sub-region have also developed industrial fleets that had a major impact on the groundfish stocks (FAO, 1996). Available assessments and information on exploitation rates indicate that the Argentine hake stock is fully exploited, and probably tends toward overexploitation, while the stocks of the other major groundfish species, such as Southern blue whiting and Patagonian grenadier are moderately-to-fully exploited (FAO, 1997b).

Small pelagic fisheries

This region produces high catch of small pelagics, due to high primary productivity, resulting from the occurrence of major wind-driven upwelling systems of the Californian Current, along the northern Pacific coast, and the Humboldt Current in the South (Bakun *et al*., 1999). The coastal areas are dominated by coastal upwelling, making this area a rich fishing ground (Csirke, 1989; FAO, 1996; FAO, 1997b; Christy, 1997; Deligiannis, 2000), which attracts a large fishing effort.

The most abundant small pelagic fish catches in this region are made of Peruvian anchoveta (*Engraulis ringens*), the South American sardine (*Sardinops sagax*), horse mackerels (*Trachurus* spp.), Pacific jack mackerel (*Scomber japonicus*), Pacific anchoveta (*Cetengraulis mysticetus)* and California anchovy (*Engraulis mordax)* (FAO, 1996; FAO, 1997b).

The results of analyses of fishing effort distribution targeting small pelagic fish in S. American-Caribbean region are shown on decadal basis from 1970 to 1990 in Fig. 3.12.

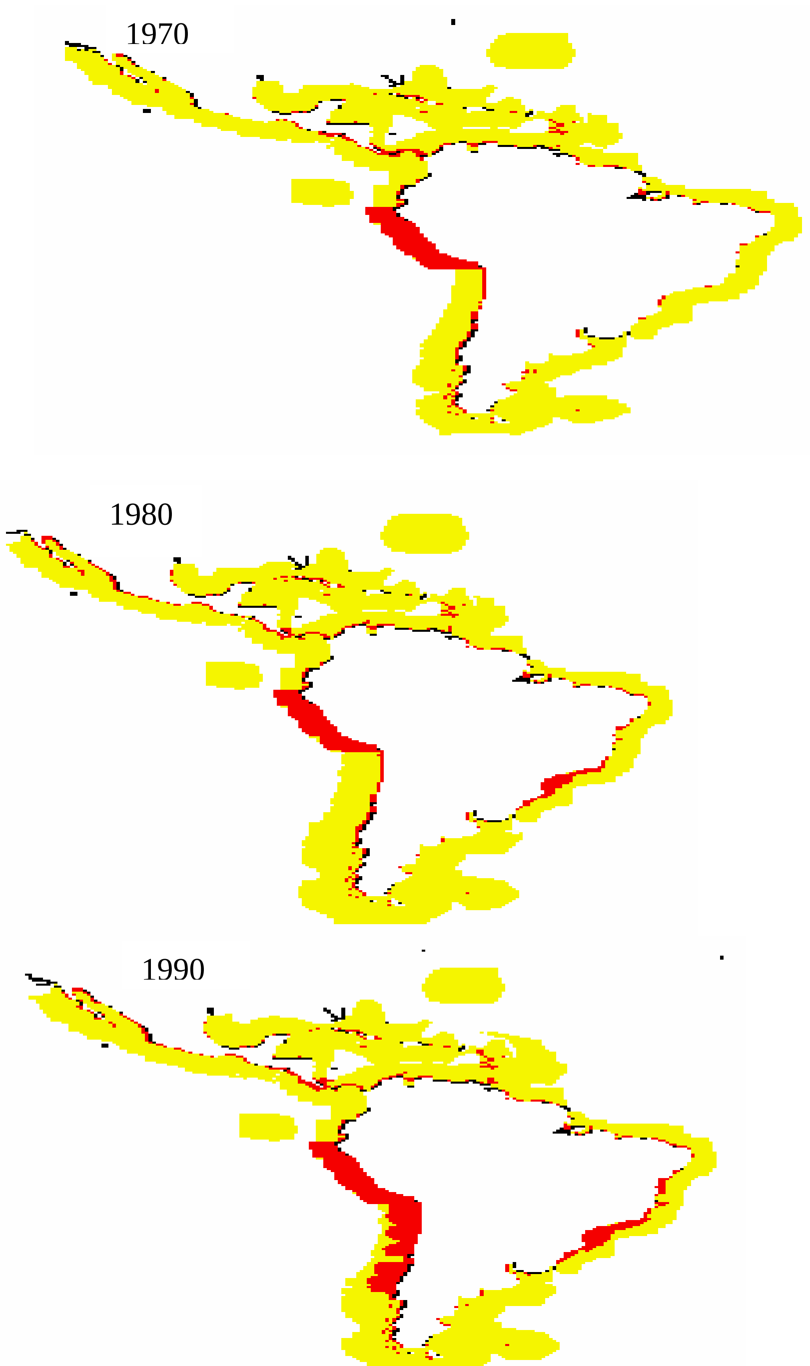

Fig. 3.12. Predicted spatial distribution of fishing effort targeting small pelagic fishes in the South American-Caribbean region fisheries. Yellow: 0.0-2.9 log hpdays*km^{-2}; red: 2.91-12.9 log hpdays*km^{-2}.

One clear pattern observed in fig.3.12 is that fishing effort targeting small pelagics is concentrated in the Southeast Pacific along the coasts of Peru and Northern Chile. This is an expected result given that the area is under the influence of two major surface current systems: the California Current in the north and the Humboldt Current in the south (FAO, 1997b; Bakun *et al.*, 1999) . The pattern in Fig. 3.12 is also consistent with reports documenting overexploitation of several local stocks of small pelagics (FAO, 1997a; FAO, 2005a). The impacts of such high fishing effort intensity have been widely documented in FAO and other documents. As far back as the early 1970s, heavy fishing pressure in this area had played a major role in the collapse of anchoveta fisheries off Peru (Longhurst and Pauly, 1987; Csirke, 1989; Deligiannis, 2000). In the late 1970s, the coincidence of favorable environmental conditions and controlled fishing allowed the stock to recover, but that recovery was short-lived and soon met with resumption of heavy fishing by fleets previously targeting other pelagic stocks (FAO, 1996 and 1997b). Likewise, the anchovy stock on the northern coast of Chile was depleted by an over-expanded Chilean Northern pelagic fleet in the 1970s (Thorpe and Reid, 1999).

Similarly, the South American sardine was heavily exploited and even disappeared from some areas (FAO, 1997b). Total biomass and total catch of this species has been declining since the mid 1980s, which is believed to be due to combination of heavy fishing and environmental variability (FAO, 1997b). Likewise, fishing pressure on the Chilean jack mackerel has also been increasing rapidly and the stock was characterized as moderately-to-fully exploited, with increased chance of becoming over-exploited (Basch *et al.*, 1995; FAO, 1997b; Renato *et al.*, 2004). In Chile, where Jack mackerel constitute the bulk of their pelagic catches, the decline of the stock triggered a series of regulatory measures involving area closure, license limitation and catch quotas by Chilean authorities in the 1990s to reduce Chilean fishing effort (Basch *et al.*, 1995; Renato *et al.*, 2004).

The other area that experienced high effort concentration is the inshore areas of Southern Brazil in the Southwest Atlantic after 1980s. Brazil developed industrial fleets over the years, causing depletion of several small pelagic stocks in the areas, including the Brazilian sardinella, which has been overfished for several years (FAO, 1996; FAO, 1997b; Vasconcellos, 2000).

Generally, for both the groundfish (Fig. 3.11) and small pelagic fisheries (Fig. 3.12), the bulk of the region's fishing fleets still operate inshore, with the familiar consequences of conflicts with artisanal fisheries, as discussed in previous sections.

Conclusions

Fishing effort in this region evolved through a stage of neglect, followed by a rapid expansion. Two major factors can be identified for the over-expansion of fishing effort in this region. Government-sponsored fisheries expansion policies implemented in the 1970s and 1980s, and the open access regime prevalent in most countries of the region. This is further compounded by population increase and coastward migration and eventual entry into the fishery sector, as a livelihood of last resort. Drastic depletion of major commercial stocks, even in the areas where stocks were considered lightly exploited in the early 1980s, appear to have been linked to the large fishing effort expansions in the region throughout the last three decades.

Spatially, high fishing effort is predicted in inshore areas along the coasts of major fishing nations of the region. Except for the Patagonian shelf and Falkland, where the continental shelves extend well beyond 370 km, most of the continental shelves in the region are narrow strips of less than 120 km (FAO, 1997b). Thus, the fleets have the entire distribution of the targeted stocks within their operational range, denying the fish any natural refuge offshore. This increases the risk of recruitment failure, as offshore spawning fish are all within the range of the fisheries.

The African region fisheries

Background: Industrialization of fisheries in African region

Coastal Africans depend heavily on fish for animal protein, with varying degree of dependence among sub-regions and countries. The continent as a whole is second only to Southeast Asia in dependence on fish for animal protein (Haakonsen, 1992). However, Africa accounts for about 8% of global fish catches (Tvedten and Hersoug, 1992), with considerable regional variation. The Western and Southern sub-regions account for more than 80% of the continent's marine catches (Tvedten and Hersoug, 1992). In the following paragraphs, the evolution of African fishing industry is briefly described, with emphasis on the Western and Southern sub-regions, where the fisheries are most important.

Although the commercial exploitation of northwest African fish resources was started at the end of 19th century, with the initiation of the Moroccan pelagic fishery for pilchard (*Sardina pilchardus*), it was only in the late 1950s that African industrial fisheries expanded south of the Gulf of Guinea (Troadec, 1983). Before the mid 1950s, with the exception of the Republic of South Africa, whose industrial fleets were launched in the 1920s (Scott, 1951; Goodisan, 1992), African fish resources were only exploited by artisanal fisheries (Johnson, 1992; Tvedten and Hersoug, 1992). However, this state of affairs began to change when some colonial powers, such as Spain, Portugal, Italy and France, began commercially exploiting the waters of their colonies (Njifonjou and Njock, 2000; Alder and Sumaila, 2004). The emergence of high demand for frozen fish and progressive development of freezing technologies prompted some European fleet owners to move part of their fleets to African colonies, such as Senegal, Guinea, Equatorial Guinea, Angola, Mozambique, Mauritania, the Côte d'Ivoire and Benin in the early 1950s (Njifonjou and Njock, 2000). As the result, the commercial exploitation of the fish resources of the continent was dominated by these colonial powers, which accounted for up to 70% of the catches in West Africa (Crutchfield and Lawson, 1974).

In the late 1950s and 1960s, when decolonization began, the newly emerged African countries embarked on fisheries expansion programs, mainly by copying the strategies of developed countries (Lawson and Kwei, 1974; Troadec, 1983; Haakonsen, 1992; Tvedten and Hersoug, 1992). In most African countries, fisheries industrialization was primarily initiated by the locally based European owners of small fleets (Troadec, 1983; Njifonjou and Njock, 2000). The then popular expectation, promoted by the retreating colonial powers, was that the traditional indigenous artisanal fisheries were inefficient and would eventually give way to the supposedly more efficient industrial fisheries (Troadec, 1983). The artisanal fisheries in these schemes were, tacitly or not, assumed to serve as source of experienced fishers to the industrial fisheries (Troadec, 1983; Pauly, 1996).

This strategy was embraced by enthusiastic new African countries eager to free themselves from foreign economic dependence by exploiting their own natural resources (Lawson and Kwei, 1974). To that end, subsidies by local governments and international development agencies were provided for development of industrial fleets (Haakonsen, 1992; Jul-Larsen, 1992; Tvedten and Hersoug, 1992). As a result, fleets of medium-sized trawlers and purse seiners quickly emerged and expanded, primarily in Northwest and West Africa (Troadec, 1983). However, despite concerted efforts to establish industrial scale fisheries, only a handful of countries, such as Angola, the Côte d'Ivoire, Senegal, Morocco, Mauritania and Nigeria managed to build a semblance of industrial fleets (Lawson and Kwei, 1974; Crutchfield and Lawson, 1974; Haakonsen, 1992; Tvedten and Hersoug, 1992). Most of the fishing companies in West African countries suffered financial crises and went bankrupt (Lawson and Kwei, 1974; Haakonsen, 1992 and Kebe, 1993). For instance Senegalese, the sardine trawler fishing fleet was reduced to nine vessels in the early 1990s (Kebe, 1993).

Only Ghana was successful in establishing an industrial fleet and, at time, even engaged in distant-water fisheries. In the 1950s and 1960s Ghana was an important industrial fishing nation in West Africa (Atta-Mills *et al*., 2004). During this period, the Ghanaian fleets grew from 12 large vessels in 1954 to 384 in 1969, representing a 32-fold increase over 15 years (Lawson and Kwei, 1974), and operated in all West African waters (Atta-Mills *et al*., 2004). However, the decline of Ghanaian distant-water fishing began in the 1960s, when some African countries expelled the Ghanian fleet citing security reasons (Atta-Mills *et al*., 2004). In the subsequent years, the decline was further aggravated by financial difficulties (following the expulsions and decline of catches from their own EEZ) and finally squeezed out of distant-water fishing by more competitive foreign fleets, mainly from the Western Europe, Russia and China (Atta-Mills *et al*., 2004). The collapse of Ghanaian distant-water fishing heavily impacted the stocks in its EEZ with serious consequences for the country's resources and economy (Atta-Mills *et al*., 2004; Koranteng and Pauly, 2004)

Overall, the absence of infrastructure for local industrial fleets, along with lack of skilled personnel and managerial/administrative capabilities, high operation cost and the absence of local markets gave a competitive advantage to foreign distant-water fleets and even to local small-scale fisheries (Crutchfield and Lawson, 1974; Troadec, 1983; Haakonsen, 1992; Hersoug, 1992). In addition, the lack of secure resource base, conflicting goals, politics, absence of property rights and the emergence of EEZ regimes were cited in the literature to explain the failure of local industrial fisheries in Africa (see Crutchfield and Lawson, 1974; Troadec, 1983; Haakonsen, 1992; Hersoug, 1992 for details).

Due to the near total absence of local industrial fisheries in most African countries, foreign distant water fleets largely dominated the West African total catches since the 1960s (Crutchfield and Lawson, 1974; Alder and Sumaila, 2004). They continued to dominate as European and Asian countries redeployed their excess fleets through bilateral agreements after the establishment of the EEZ regime (Troadec, 1983; Njifonjou and Njock, 2000; Kaczynski and Fluharty, 2002; Alder and Sumaila, 2004). The impacts of foreign fleets on African fish resources and the role of long-distance fishing nations in influencing fisheries management decisions in Africa are subjects of real concern (see Alder and Sumaila, 2004 for insight into foreign fishing in African waters). However, the analysis of distant water fleets is outside the scope of this study. (See the detailed account of distant water fleets in Bonfil *et al*., 1998).

Disappointed by the failures of development attempts directed at developing local industrial fisheries in the 1950s and the 1960s, many African countries later turned their attentions to modernizing their inshore artisanal fisheries through introduction of modern fishing gears and motorization of canoes (Troadec, 1983; Haakonsen, 1992; Jul-Larsen, 1992; Pauly, 1997). Official policies underpinning the need to invest in small-scale fishing communities began to surface. These include the need to redistribute the national wealth to underprivileged population, the need to directly promote rural development, to expand the geographical distribution of economic activities and counteracting urban migration (Troadec, 1983). To that end, many countries directed their aid programs to the small-scale fisheries sector (Haakonsen, 1992; Jul-Larsen, 1992).

The magnitude of subsidies provided to modernize small-scale fisheries varies from country to country. To illustrate the scale of the canoe modernization efforts, total subsidies provided by four West African countries (Nigeria, The Gambia, Senegal and the Côte d'Ivoire) in the 1970s and early 1980s are summarized here based on a report by Mabawonku (1986). The Nigerian government provided credit through the Nigerian Agricultural and Cooperative Bank at low interest rate, built landing jetties, cold storage facilities, refrigerated trucks for fish distribution and established training facilities for fishers. Between 1979 and 1983, the value of inputs distributed was approximately 42,000 USD, half of which represented a transfer to fishers. Credit granted to fishers averaged approx. 112,000 USD between 1980 and 1983, while the subsidy element was about approx. 17,000 USD. In Gambia, subsidies involved the provision of engines, nets and floats on the one hand and provision of loans to fishers by the Gambian Commercial and Development Bank at low interest rates. Loans had been granted as far back as the 1970s. Between 1980 and 1985, total lending to fishers was approx. 25,000 USD. Estimated transfer to fishers, given the differential interest rates, was approximately 3,200 USD or 13% of the loans, assuming a payment period of two years. In Senegal, the major subsidies are cheap fuel and the waiving of duties on export of fish and fish products. The total of transfer payment for the period 1980–1985 was approx. 33.6 million USD. In the Côte d'Ivoire, subsidies involved loans for fishing vessel purchase and provision of subsidized fuel. Loans for purchase of fishing materials were also granted by the National Bank for Agricultural Development.

For the most part, these projects were successful in modernizing the inshore small-scale sector. The success can be illustrated by the rate of canoe motorization in selected African countries (Table 3.4) and especially in Ghana (Fig. 3.20).

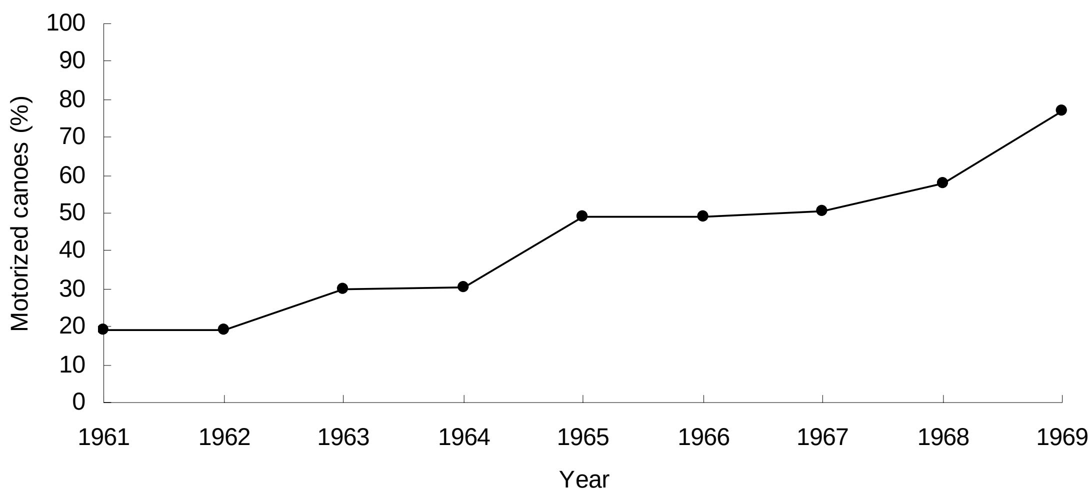

Fig. 3.13. Motorized canoes as percentage of total canoes in Ghana. Data from Lawson and Kwei (1974).

Fig. 3.13 shows that Ghanaian canoe fleet constituted only 20% of motorized canoes in 1961, while this number grew to 77% over a short period of 8 years. With some variations, similar motorization rate were achieved in other African countries (Table 3.4).

Table 3.4. Motorized canoes, in percentage of all canoes, in various West African marine fisheries (data from Haakonsen, 1992).

Year	Country	Motorization rate (%)	Year	Country	Motorization rate (%)
1987	Mauritania	90	1987	Guinea-Bissau	35
1986	Senegal	64	1988	Benin	35
1987	Togo	56	1984	Cape Verde	34
1986	Côte d'Ivoire	55	1984	Cameroon	33
1983	Gabon	52	1986	Liberia	30
1986	Ghana	52	1979	Sao Tome & Principe	20
1984	Gambia	48	1979	Congo (Ex-Zaire)	11
1985	Congo	48	1981	Sierra Leone	10
1986	Nigeria	40	1985	Eq. Guinea	3
1985	Guinea	38			

Table 3.4, shows that the rate of motorization range, in the 1980s, from 3% in Equatorial Guinea to 90% in Mauritania, with an overall (unweighted) mean of 40%.

In parallel with the motorization of artisanal fleets, the size of inshore/artisanal fleets was continuously growing, mainly driven by natural increase in the number of fishers and partly due to population movement to the fisheries sector from other sectors, as in many parts of developing world (Troadec, 1983; Johnson, 1992; Platteau, 1992; Pauly 1997; Baylon, 1997; Weber, 1997).

This is particularly evident in areas prone to repeated natural and other disasters, such as countries visited by recurring droughts (Platteau, 1992) and in countries devastated by civil wars (Johnson, 1992) and countries with high unemployment rates (Troadec, 1983). Studies indicate that the number of fishers in African coastal states grew by 79% between 1975 and 1993 (FAO, 1996c). This high growth rate presumably includes increases from within the fishing communities, plus new entrants. As a result, artisanal fisheries accounted for over 40% of the total catch of the continent by the mid-to-late 1980s (Tvedten and Hersoug, 1992).

On top of such domestic population movement dynamics, African fisheries are characterized by inter-regional migration of fishers, often during seasons of low agricultural production, from countries with a long tradition of fishing to countries without such tradition (Njifonjou and Njock, 2000). Fisher movements have been reported from Senegal to Mauritania and Guinea, from Ghana to the Côte d'Ivoire, Guinea or Cameroon and from Nigeria and Benin to Congo, Gabon and Cameroon (Njifonjou and Njock, 2000). For instance, in 1993, of the 20,000 traditional fishers in Cameroon, 80% were foreigners and among these, Nigerians, Beninese and Ghanaians formed the major components (Theodore, 1993). Trans-border ethnic ties, a mobile lifestyle and unique African hospitality by host communities were cited as reasons driving inter-regional fisher migration (Kebe, 1993, Diaw, 1992). Further, the large-scale canoe mechanization efforts achieved by African nations have also directly contributed to long-distance migrations by boosting fisher mobility (Kebe, 1993).

These complex interactions of various factors driving fishing effort expansions did impact the resource base of the continent. In particular, the combination of uncontrolled small-scale fishing effort expansions, coupled with heavy exploitation by local industrial fleets (e.g., in South Africa and Morocco) and foreign distant-water fleets, began to take its toll on several important commercial fisheries in as early as the 1960s. For example, the South African pilchard (*Sardinops ocellata*), Cape lobster (*Homarinus capensis*) and hake (*Merluccius capensis*) fisheries have been severely depleted since the late 1960s, triggering a series of effort reduction measures by the Republic of South Africa (Plessis, 1971; Goodisan, 1992; Sauer *et al*., 2003). In Ghana, the Ghanaian-Ivorian stock of sardinella (*Sardinella aurita*) collapsed twice in the 1970s due to intense exploitation from the small-scale fishery, and the Ivorian shrimp fishery nearly collapsed due to recruitment failures caused by heavy exploitation from Ivorian small-scale fishery (Troadec, 1983). As the result of such resource depletions, some small-scale fisheries, which were faring well in the 1970s, such as the Senegalese canoe fishery, later faced economic crises (Troadec, 1983).

The problem of inshore stock depletions in African inshore grounds is compounded by encroachment by large-scale industrial fleets, often resulting in competition and conflicts between small-scale and large-scale fisheries, further complicating the dynamics of African inshore fisheries (Crutchfield and Lawson, 1974; Theodore, 1993; Doumbia, 1993; Njie, 1993; Léon, 1993; Mensah and Koranteng, 1993; Kebe and Ndiaye, 1993; Pauly, 1997, Koranteng and Pauly, 2004; Alder and Sumaila, 2004). The conflicts involve physical destruction of fishing gears and competition for labor, for access to capital and market (Kebe, 1993). In almost all of these conflicts, artisanal fishers are the victims. For instance, in Cameroon, annual loss involving net destruction by industrial trawlers is estimated at about US $200,000 per annum (Theodore, 1993). Between 1988 and 1992 in the Dakar and Thies regions of Senegal, artisanal fisheries suffered a loss worth about 77,000 USD (Kebe, 1993). Satia and Horemans (1993) gave detailed analyses of conflicts among different sectors of African fishing fleets.

In other parts of Africa, such as along the Mediterranean shores of North Africa and in East Africa, fisheries are least important, partly due to a poor resource base, reluctant government policies and culture (Tvedten and Hersoug, 1992; FAO, 1997). As a result, there has been a gap between potential and actual catches, especially off the Horn of Africa and in the Red Sea region (Tvedten and Hersoug, 1992). However, this gap is increasingly being filled by both legal and illegal foreign fishing (FAO, 1997; Coffen-Smout, 1999).

With regard to illegal fishing, it may be appropriate to briefly highlight the situation prevailing in Somalia after the fall of the central government in 1991, after which the country came under the rule of warlords and militia. The country became lawless and its people as well as its resources, including fish, were without any protection. Several international fleets have taken advantage of this lawlessness and turned the Somali coasts into a truly free access 'gold mine', often based on controversial fishing license agreements given by warlords (Coffen-Smout, 1999). With or without the approval of these self-appointed rulers, a number of countries exploited Somali fish stocks to the extent of engaging in armed confrontation with local fishers (Musse and Tako, 1998). Since 1991, more than 200 illegal foreign fishing vessels have been seen fishing in Somali waters, some fishing as close as 5 miles from the coast (Musse and Tako, 1999).

Fishing vessels known to operate off Somali coasts include the following flags: Belize (both French or Spanish-owned purse seiners operating under flag of convenience to avoid EU regulations), France (purse seiners targeting tuna, licensed to the food company Cobrecaf), Honduras (EU purse seiners targeting tuna under flag of convenience), Japan (longliners now operate under license of the Republic of Somaliland, i.e., Northern Somalia), Kenya (Mombasabased trawlers), Korea (longliners targeting swordfish seasonally), Pakistan (trawlers, but also targeting shark), Saudi Arabia (trawlers), Spain (purse seiners targeting tuna), Sri Lanka (trawlers, plus longliners targeting shark under license from the Republic of Somaliland and based in Berbera, Somaliland), Taiwan (longliners targeting swordfish seasonally), Yemen (trawlers financed by a seafood importer in Bari, Italy), China, India, Portugal, Britain, Russia, Thailand and Germany (Coffen-Smout 1999; Musse and Tako, 1999). Estimated loss to illegal fishing was about $300 million US annually (Anon, 2005d).

Some of the illegal foreign vessels have also been using destructive fishing techniques such as dynamite and drift netting, and are also reportedly engaged in destruction of coral reefs, nets and traps set by local fishers (Musse and Tako, 1999). On top of illegal resource extraction and ecosystem destruction, another type of problem facing the failed Somali state is the issue of hazardous waste disposal, which allegedly include nuclear waste, dumped by foreign firms in Somali waters (Musse and Tako, 1999). It has been reported that occasionally large amount of dead fish, sometimes stretching over 45 km, has been seen floating in near shore waters, killed by toxic chemicals disposed in Somali waters by foreign firms (Musse and Tako, 1999).

Overall, the situation in Africa has been characterized by fierce competition between different fleets for increasingly declining fish stocks, high population growth rate (3-3.5%) and prevalence of free entry to fisheries (Hersoug, 1992; Alder and Sumaila, 2004). This section attempts to shed some light on the issue of fisheries expansion in Africa by analyzing the evolution and distribution fishing effort in the period 1970-1995.

Relative status of countries in African region fisheries

The relative status of countries was measured based of the total tonnage capacity of their fleets (Table 3.5).

Table 3.5. Fishing capacity of the top ten countries in African region, based on fleet tonnage data for 1995.

Rank	Country	Relative fleet capacity (% tonnage)
1	Morocco	25
2	South Africa	10
3	Namibia	9
4	Egypt	9
5	Ghana	8
6	Nigeria	5
7	Mauritania	5
8	Senegal	5
9	Algeria	4
10	Angola	3
11-41	Others (31)	18

Table 3.5 shows that Morocco tops the list of African fishing nations, accounting for about 25% of the total capacity of the continent. This is followed by South Africa and Ghana, both with 10% capacity each. The other seven countries in the list each accounted for <10% of the continent's fishing capacity, while the remaining 31 countries shared only 18%.

Morocco has been an important fishing country since the 1930s (Feidi, 1998). The fishing industry experienced tremendous growth during the 1980s (Anon, 2006). In the 1990s, the Moroccan government implemented a set of measures, including financial incentives and port improvement, to further expand the fishing industry (Feidi, 1998; Anon, 2006). As the result, the modern Moroccan fishing industry consists of large mechanized fleets, and its fisheries are largely export-oriented catching high-value fish for export markets (Feidi, 1998).

Similarly, South Africa developed diverse, privately owned modern commercial fleets for both pelagic and demersal resources since the 1940s (Scott, 1951). In the 1950s and 1960s, despite restrictions, the fishing industry had been operating under open access regime resulting in fleet expansion (Sauer *et al.*, 2003). However, since the 1970s, South Africa implemented a series of effort control measures to allow for recovery of the heavily exploited commercial stocks (Plessis, 1971; Goodisan, 1992; Sauer *et al.*, 2003). This led to a decline of fishing effort, as will be discussed in Section 3.4.4. Likewise, Ghana was one of those handfuls of West African countries which managed to operate a fleet of medium-sized trawlers and purse seiners, as described earlier.

Evolution of fishing effort in African region fisheries

Trends in total fishing effort (in horsepower-days unit) was analyzed in order to evaluate overall effective fishing effort capacity of the region.

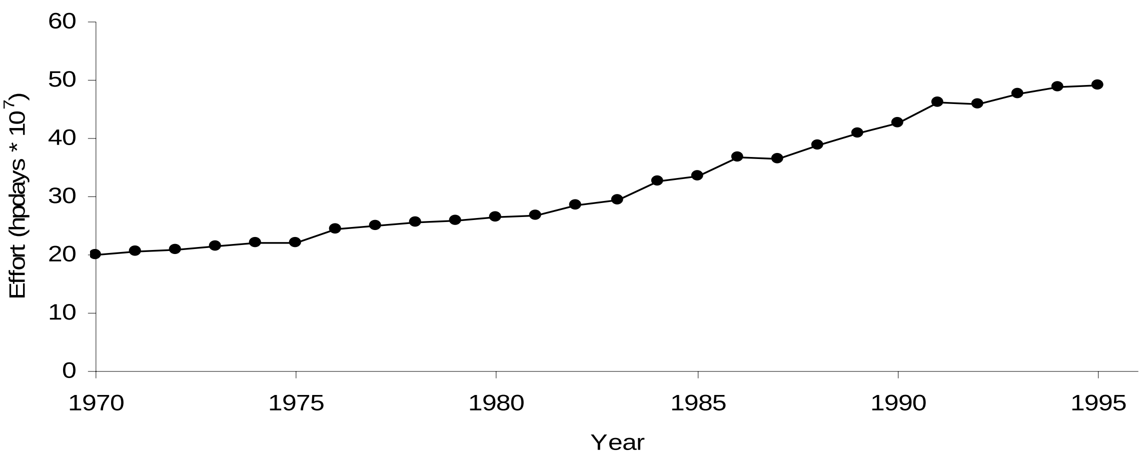

Fig. 3.14. Temporal evolution of total fishing effort in African fisheries.

Fig. 3.14 shows that African total fishing effort showed a steep increase since 1980. To better explain the trend, the data plotted in Fig. 3.14 were spilt into sub-regions: Northern Africa, Western Africa, Southern Africa and Eastern Africa (Fig. 3. 15).

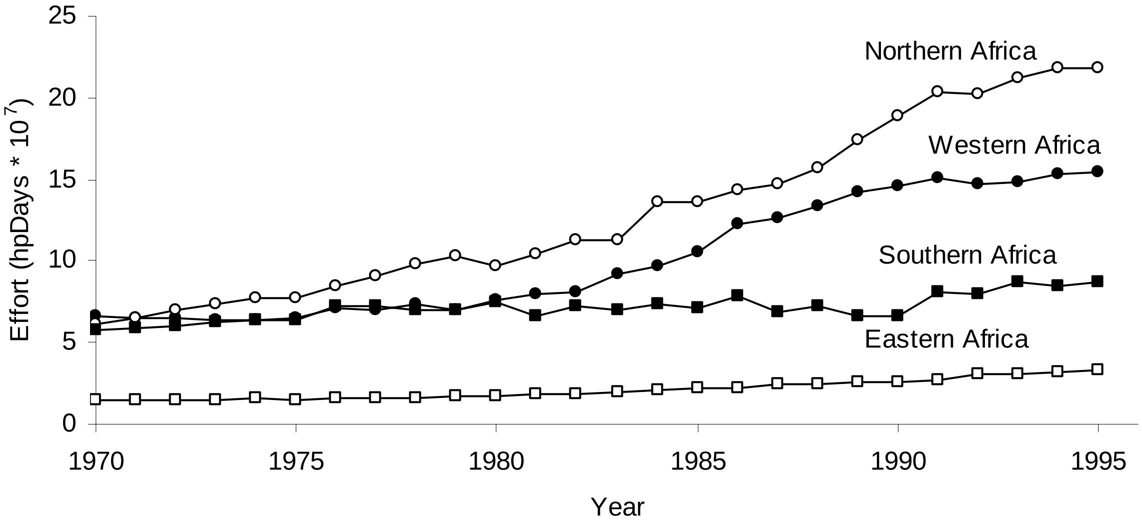

Fig. 3.15. Temporal evolution of total fishing effort in Northern (1), Western (2), Southern (3) and Eastern (4) sub-regions of Africa.

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1. Algeria, Egypt, Libya, Morocco and Tunisia.
2. Angola, Benin, Cameroon, Cape Verde, Congo Dem Rep, Congo Rep, Côte d'Ivoire, Eq. Guinea, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mauritania, Nigeria, Sao Tome Prn, Senegal, Sierra Leone, Togo and St. Helena islands;
3. South Africa, Namibia and Mozambique;
4. Tanzania, Kenya, Somalia, Djibouti, Eritrea, Sudan, Madagascar, Comoros, Seychelles, Mauritius and Réunion Island.

As can be seen from Fig. 3.15, total fishing effort in Northern and Western Africa showed tremendous increases since 1980. In these sub-regions, fishing is an important industry in both food supply and income generation, accounting for some two-thirds of animal protein consumed in countries like Ghana and Sierra Leone (Thorpe *et al*., 2004), while it is a major export product for countries, such as Morocco (Feidi, 1998). Hence, countries in these sub-regions heavily invested in fishing capacity developments (Tvedten and Hersoug, 1992). As a result, these two sub-regions have been responsible for the overall increase of total fishing effort seen in the African continent as a whole.

In the Southern sub-region, fishing effort has been declining since the 1980s, but it again showed sign of increasing in the early 1990s. The decline is mainly attributed to measures taken by South Africa and Namibia for restricting fishing effort expansion by introducing a series of effort controlling mechanisms, such as mandatory vessel licensing, catch quotas and area closures (Scott, 1951; Plessis, 1971; Goodisan, 1992; Sauer *et al*., 2003). As the result of these management measures, triggered by the diminished state of the resources, average annual landing in this sub-region has recently declined by about 41% as well (Alder and Sumaila, 2004).

On the other hand, fishing effort in the Eastern African sub-region did not show any significant change over the period considered. In this sub-region, marine fisheries, though important locally in some countries such as Tanzania, Mozambique and Madagascar, are not important internationally (FAO, 1997). The coastal fishery yield along the entire western boundary of the Indian Ocean represents less than one percent of global landings and has been stagnating since the 1990s (FAO, 1997). The stagnant trend shown in this region can be attributed to combination of resource limitation and the lack of attention given to marine fisheries in the region (Tvedten and Hersoug, 1992; FAO, 1997).

For the African continent as whole, the expansion of fishing effort has continued unabated for the period covered by this study. As a result, the stocks are overexploited, especially in the Western and Southern African sub-regions. The depletion was attributed to domestic fishing effort expansion and heavy exploitation by long distance fleets, as documented in several reports (Christensen *et al*., 2004; FAO, 1996a, FAO, 1996b, FAO, 1997; Koranteng and Pauly, 2004; Alder and Sumaila, 2004). For instance, joint pressure by several Ghanaian fleets have depleted long-lived species resulting in an outburst of short-lived, previously uncommon species, the exploitation of which contributed to overcapacity in Ghanaian fishing industry (Koranteng and Pauly, 2004). Indeed, the fish stocks in the West African sub-region have been reduced by an order of magnitude since the 1960s (Christensen *et al*., 2004).

In almost all African sub-regions the situation for all commercially important fisheries is similar. The Eastern Central Atlantic, the Southeast Atlantic and in some section of western portion of the Indian Ocean (including the Red Sea), most stocks, with the exception of some small pelagic species, are fully exploited and there are limited prospects for increasing catches from the marine environment (FAO, 1996a). In light of the chronic problem of lack of affordable employment opportunities and population migration away from inland areas, the massive population movement into fisheries sector will likely continue to fuel fishing effort expansion and what Pauly (1997) calls 'Malthusian overfishing' in the region.

Distribution of fishing effort in the African region fisheries

Groundfish fisheries

Commonly exploited groundfish assemblage in the African region include the families Sciaenidae, Lutjanidae, Sparidae, Cynoglossidae, Drepanidae, Polynemidae and Serranidae (Fager and Longhurst, 1968; Everett, 1976; Koranteng and Pauly, 2004). The results of the analyses of distribution of fishing effort targeting groundfish in the African region are shown on decadal basis from 1970 to 1990 (Fig. 3.16).

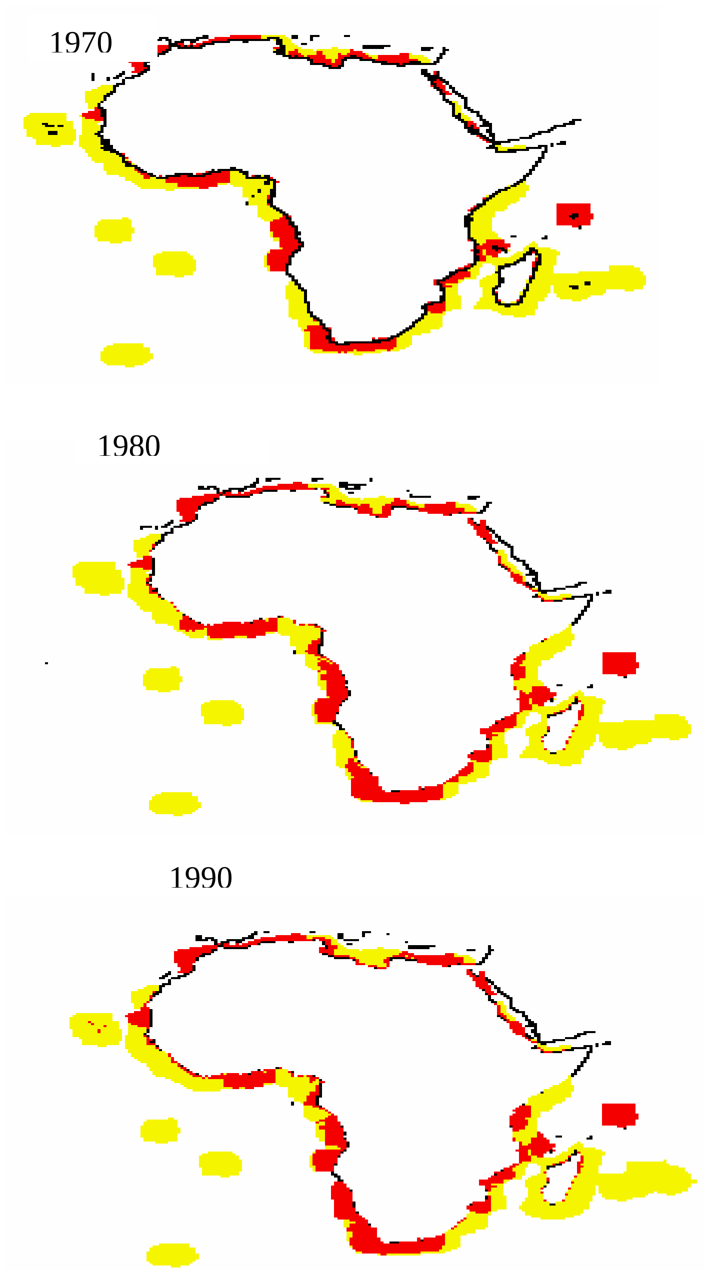

Fig. 3.16. Predicted spatial distribution of port-based fishing effort targeting groundfish fisheries in the African region. Yellow: 0.0-2.0 log hpdays*km^{-2}; red: 2.1-10.6 log hpdays*km^{-2}.

Visual inspection of Fig. 3.16 shows that fishing effort spatial distribution is concentrated in the along the coasts of major fishing nations in North, Northwest and Southern regions of continental Africa, matching the relative importance of fisheries in different regions around the continent. In the Western and Southern African sub-regions high fishing effort intensity is predicted around inshore areas of countries, notably Morocco, Ghana, Senegal, Mauritania, Angola, Namibia and South Africa (Fig, 3.16).

The continental shelf in these sub-regions is rather narrow, ranging from about 8 miles around Togo and Liberia, to 100 miles around the coasts of the two Guineas, with overall average shelf width of about 30 miles (Crutchfield and Lawson, 1974; Everett, 1976). The sub-regions are characterized by permanent or seasonal upwellings caused by the Canary, Equatorial and Benguela Currents, with high primary production and high fish catches (Gulland, 1971). In view of high inshore primary productivity, the narrowness of the shelves and the large fishing effort deployed by most countries, the predicted high fishing effort in the inshore areas of these countries makes perfect sense. Inshore trawlers of the region are based in all ports along the coasts, particularly in Casablanca, Agadir, Nouadhibou, Dakar, Freetown, Monrovia, Abidjan, Tema, Lomé, Cotonou, Lagos, Port Harcourt, Douala, Libreville, Pointe Noire and Matadi areas (Everett, 1976). Similarly, in the Southern sub-region the demersal fishing grounds are located around Southwestern Cape coast, Knysna and Stillbaai areas, Mossel Bay, Eastern Cape, around Port St. Francis, Jeffreys Bay, Port Elizabeth and off port Alfred (Sauer *et al.*, 2003). Hence, the predicted high fishing effort concentration areas largely overlap with the groundfish fishing grounds of the region.

Groundfish stocks along the Mauritania, Senegal, Angola, Namibia and South African coasts have been characterized as fully exploited or over-exploited (FAO, 1997). In the Gulf of Guinea, total demersal biomass decreased by around 50% between 1991 and 1994, while the decline of major species such as croakers (*Micropogonias* spp.*)*, threadfins (Polynemidae) and sicklefish (*Drepane* spp.), was higher than 50% (FAO, 1997). The decline in the biomass of groundfish was related to the recent increase in small-scale artisanal fisheries in most countries, and also to the increase of industrial fishing effort in some countries in the region (FAO, 1997; Koranteng and Pauly, 2004). Over time, the Northwest African sub-region has been subjected to depletion of coastal demersal stocks, followed by the offshore stocks in the sequential fashion also as reported from other parts of the world (Pauly, 2004).

In the Mediterranean and Red Sea, high fishing intensity is predicted in the inshore areas of Egypt and Algeria. The fishing grounds of Egyptian groundfish vessels are mainly located in the Mediterranean continental shelves off the Nile Delta, the Suez Canal and the Red Sea coast, while that of Algeria is concentrated on the narrow shelf on the Mediterranean coast, where the demersal stocks are heavily exploited (Anon, 1993 and Feidi, 1998). In the Southeast Africa, too ,,considerable groundfish fishing effort expansion has occured along the coasts of Mozambique and Tanzania since 1980 (Fig. 3.16).

Small pelagic fisheries

Africa has important fisheries of small pelagic fish. The species contributing to the bulk of African small pelagic catches are sardines (*Sardinella* spp.), pilchards (*Sardina* spp.), herrings (*Clupea* spp.), anchovies (*Engraulis* spp.), mackerels and jack mackerels (*Trachurus* spp.) (Everett, 1976; Sauer *et al.*, 2003). The results of the analyses of distribution of fishing effort targeting small pelagic fisheries in African region on decadal basis from 1970 to 1990 are shown in Fig. 3.17.

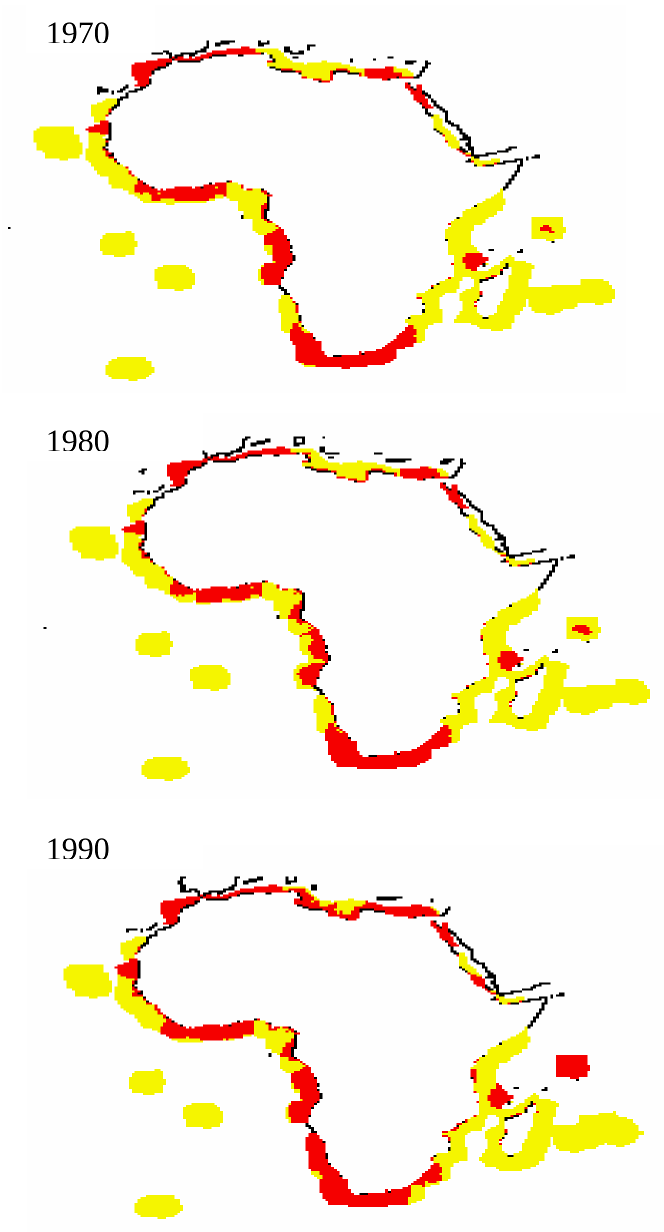

Fig. 3.17. Predicted spatial distribution of African port-based fishing effort targeting small pelagic fish. Yellow: 0.0-1.7 log hpdays*km^{-2}; red: 1.71-11.34 log hpdays* km^{-2}.

As in groundfish fisheries, small pelagic fishing effort was concentrated in the North, Northwest and Southern sub-regions of Africa (Fig. 3.17). Small pelagic fleets along the Northwest African coasts are based in port cities of Nouadhibou, Dakar, Banjul, Abidjan, Tema and Pointe Noire, where they predominantly catch sardinella (Everett, 1976). In the Southern sub-region, pelagic fishing effort is concentrated around Agulhas Bank (Sauer *et al.*, 2003). The predicted effort distribution reflect this pattern of reported fishing effort concentration (Fig. 3.17).

Overall, for both the groundfish and small pelagic fisheries, there has been modest offshore expansion since 1980 and 1990 along the coasts of some countries in the Northwest and Southern Africa. However, there was not much of an offshore expansion, despite large increases in the average size of African vessels (Gelchu, 2006). This pattern resulted due to the model rules imposed on (sub) tropical regions to limit the offshore range of vessels, thus mimicking the effect of low fish abundance in the offshore waters in tropical waters (Longhurst and Pauly, 1987; Crutchfield and Lawson, 1974). The resulting crowding of fleets of various capacities in inshore waters is believed to be one of the factors fueling conflicts among different fleet sectors in tropical regions as discussed in previous sections. The impact of intense fishing effort in African coastal waters is believed to have led to full exploitation of inshore small pelagic stocks, especially in the Northwest and Southern African sub-regions (FAO, 1997; Koranteng and Pauly, 2004).

For Africa as a whole, the overall evaluation of the status of fisheries ranges from a relatively optimistic view, characterizing African fish stocks as 'moderately exploited' or 'slightly overexploited' (FAO, 1997) to a bleaker view, which characterizes West African fish stocks as 80% depleted, i.e., as much as the North Atlantic (Worldfish, 2006).

Conclusions

With the exception of the Republic of South Africa and Namibia, African fisheries have been through two distinct expansion phases. The first phase encompasses the period from the 1950s to 1970s. During this period the newly independent African countries promoted the industrialization of their fisheries, following in the footsteps of developed Western countries. Except in a few cases, the attempts were largely unsuccessful for reasons ranging from lack of managerial skills to the competitive advantage of foreign fleets in the face of declining resources.

The second phase of African fisheries expansion began in the early 1980s. Here, the attention was shifted to modernizing small-scale fisheries, via the acquisition of modern fishing gears and motorization of canoes. To that end, numerous subsidized projects involving low interest rate loans, infrastructure development, provision of fishing gears and fishers training programs were implemented. The outcome of this phase has been largely successful. Significant canoe motorization has been achieved and the share of small-scale sector in the total catches of the region grew markedly.

As the result of fisheries expansion policies combined with natural increase in the fisher population and migration to fisheries from other economic sectors, the fishing effort of the region continued growing. This led to full exploitation of major fish stocks in the region and therefore, the fisheries of the region are increasingly characterized by conflicts between the artisanal and industrial fleets within generally narrow coastal shelves.

Global Summary: Spatio-temporal trends in global fishing effort

In the previous sections, the evolution and spatial distribution of fishing effort were discussed for each region separately. In this final section, the contribution of each region to global fisheries is presented. Also, the regional data are pooled for model validation purposes and to analyze global trends in the evolution and distribution of fishing effort in the decades from 1970 to 1995.

Relative contribution of regions in global fisheries

Driven by differences in development priorities and inherent variability in the financial/technical capacity, the countries in different regions of the world have developed their natural resources at different paces and scales. The history of global fisheries development generally reflects this regional disparity. To recap the main trends: in the Western developed region, fisheries expansion and industrialization began in the late 19th century and the early 20th century (Thomson, 1979). During the first two decades after WW II, the fisheries quickly expanded, compromised the major part of their resource bases, and then began to look for untapped resources in other parts of the world (Silvestre and Pauly, 1997; Thorpe and Bennett, 2001; Kaczynski and Fluharty, 2002; Pauly *et al*., 2002; Pauly *et al*., 2005). The success and global expansion of Western industrial fisheries sent mixed messages to the remaining parts of the world. On the one hand, it served as a role model for other regions to follow. On the other hand, the appearance of Western fleets on the doorsteps of developing countries ignited conflicts.

The Asia-Pacific region has been the largest contributor to the fishing capacity of the world since 1970. It accounted for about 50% of global capacity (GRT) in 1970, increasing to about 57% in 1995. Over the same period, the contribution of Europe-North America region declined by about 10%. The status of the South American-Caribbean and African regions did not show any significant changes over the three decades analysed, representing roughly about 7% and 2%, respectively.

Overall, the motorized global fishing fleet analyzed in this study consisted of about 1.27 million vessels in 1995, in line with the Petursdottir (2001) estimate of 1.26 million vessels in 1995. This figure represents about a third of the estimated total global fishing fleet size (motorized plus unmotorized) of about 3.8 million vessels (Petursdottir, 2001).

Evolution of fishing effort exerted by global fisheries

In this section, fishing effort data from different regions were pooled to assess the evolution of global fishing effort. On the other hand, as has been mentioned in earlier, the fishing effort data used in this study were assembled without reference or use of catch information. This allowed for comparisons with the evolution of total global marine catches. The first comparison is shown in Fig. 4.1.

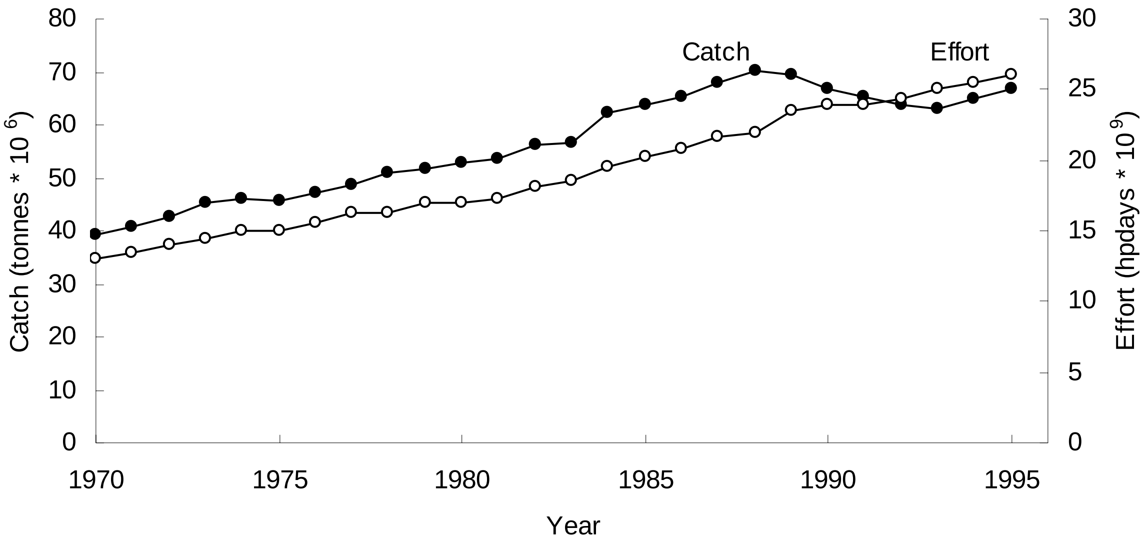

Fig. 4.1. Temporal trends in total catch and total effort in global fisheries. The catch data are from the *Sea Around Us* Project database (Watson *et al*., 2004).

Fig. 4.1 shows that total fishing effort grew from about 13 x 10^9 horsepower-days in 1970 to about 26 x 10^9 horsepower-days in 1995, representing about 100% growth, while global marine catches (excluding large pelagic catches) grew by about 52% over the same period. Or, put differently: in the decades analyzed, global fishing effort grew by a factor of 2, while catches grew by a factor of only 0.5.

The trend represented in Fig. 4.1 runs across the series of periods of fisheries expansion. The period up to the mid 1980s was marked by fishing capacity expansion worldwide (Garcia, 1992; Pauly *et al*., 2002). The expansion of fishing effort during this period resulted in a corresponding increase in total fish catches (Fig. 4.1, and Pauly *et al*., 2002), though with some years of low catches, due to early collapses, e.g., the Peruvian anchoveta (Muck, 1989; Watson and Pauly, 2001). However, since the late 1980s, global marine fish catches have been declining, and the severity of the decline has been masked by inflated catch reports from China (Watson and Pauly, 2001).

Two important features of this comparison should be highlighted:

1) Growth in fishing effort, especially since the late 1980s did not result in proportional increase in catches, leading to overcapacity;

2) Global concerns about declining catches, overcapacity and sustainability, which surfaced from the mid 1980s on, did not translate into fishing effort reduction.

The continuation of fishing effort expansion in the face of declining global catches, which led to overcapacity, has been attributed to three major reasons: (i) Open access to fish resources prevalent in most parts of the world; (ii) Expansion of fish trade/increasing fish price, and (iii) Fisheries subsidies (MacSween, 1983; Hanna *et al*., 2000; Pauly *et al*., 2002). In particular, fisheries subsidies are believed to have aggravated the problem of fishing effort expansion, by keeping unprofitable fishing fleets operational (Milazzo, 1998; Hanna *et al*., 2000; Pauly *et al*., 2002).

Impacts of fishing effort expansion on global fish resources

To put in perspective the implications of the extensive fishing effort development and the declining total catches in Fig. 4.1, an index of stock abundance, the catch per unit of effort, CPUE = C/f (Gulland, 1983) is derived, where C = total catch and f = the corresponding effort. The common assumption is that CPUE is proportional to the population biomass (B) according to a relationship, CPUE = $q \cdot B$ (Gulland 1983; Hilborn and Walter, 1992), where q is the catchability coefficient. For this relationship to hold, q must be assumed constant over time. This assumption has repeatedly been questioned, as q varies depending notably on the fish finding technology and the rigging of the vessels (Alvarez *et al.*, 1999), both of which, in most fleets, changed markedly during the period considered here.

Fishing vessels search for concentrations of fish rather than fishing randomly in the distributional area of the target species (Hilborn and Walters, 1992; Walters and Martell, 2004). In such cases, q not only varies but also becomes a function of a vessel's success in finding fish concentrations. This implies that a vessel's success is a function of onboard fish detection technology and the skipper's experience. The latter is known as 'learning effect' (Peña-Torresa *et al.*, 2004) and is not discussed further here. The applications of onboard technology are believed to have significantly boosted the average fishing power of fleets, i.e., the efficiency of vessels in catching fish has improved over time (Robins *et al.*, 1998). Efficiency improvement due to application of technology (potential changes in q over time) can be accounted for by developing a 'technology coefficient' (Fitzpatrick, 1996; Garcia and Newton, 1997).

As explained in Section 2.2.1, an annual rate of 4.4% increase in the efficiency of vessels was estimated using the data in Fitzpatrick (1996). Thus, in order to assess the effective pressure fishing effort exerts on global fish populations, the original effort data were adjusted for technology increase. The resulting corrected effort, estimated by taking into consideration temporal changes in vessel efficiency, is believed to reflect the fishing mortality exerted on the fish stocks (Garcia and Newton, 1997). Then, the corrected effort was used in conjunction with the total catches to estimate corrected CPUE, here assumed proportional to resource abundance. The results of the analyses are shown in Fig. 4.2a and b.

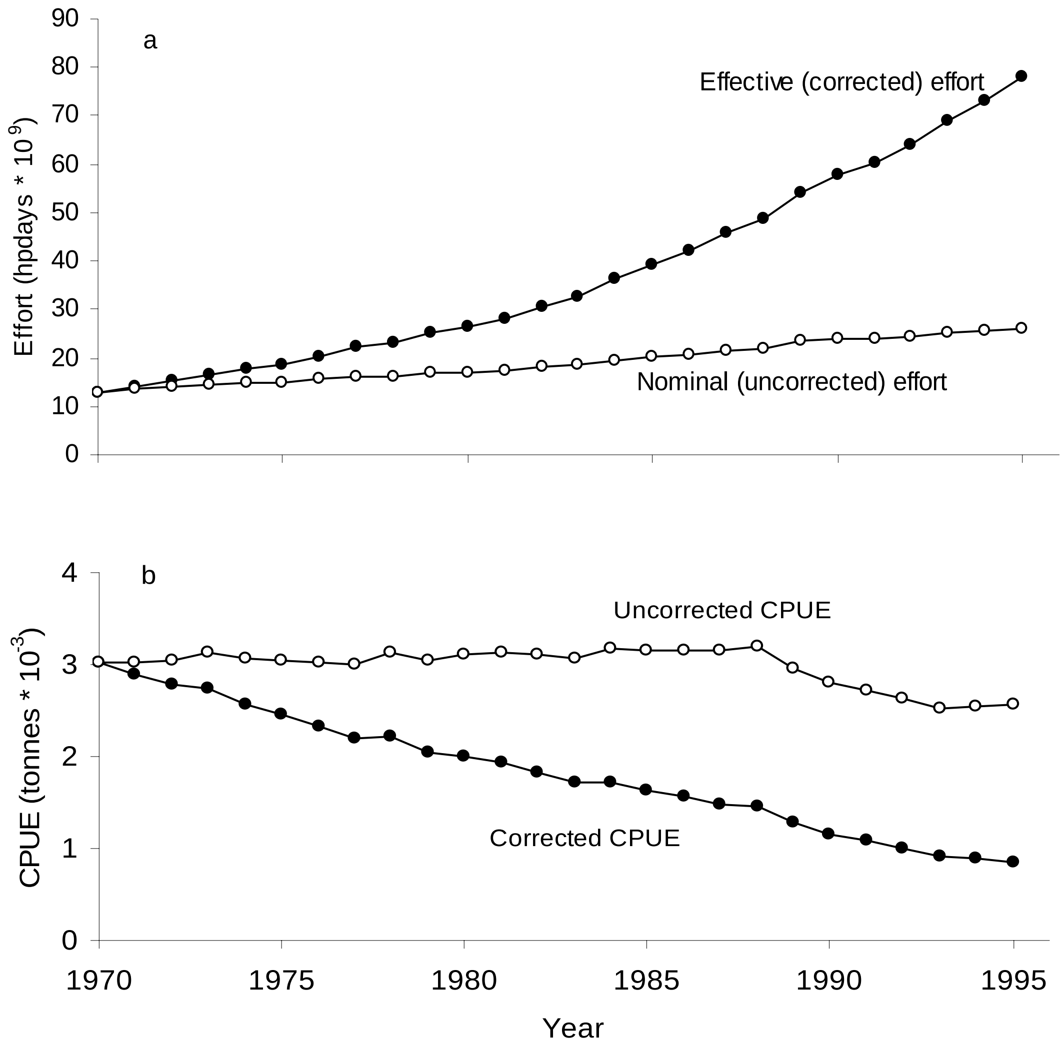

Fig. 4.2. Temporal trends in uncorrected versus corrected effort (a) and uncorrected CPUE versus corrected CPUE (b). The catch data are from the *Sea Around Us* Project database (Watson *et al.*, 2004).

The effective (corrected) fishing effort increased from 13×10^9 horsepower-days in 1970 to 78×10^9 horsepower-days in 1995, representing 502% increase; this can be compared to the increase in nominal effort, which was 'only' 100% (Fig. 4.2a). The corresponding corrected CPUE (calculated as a ratio of effective effort and total catch) decreased from 3×10^{-3} tonnes per horsepower-days in 1970 to 1×10^{-3} tonnes per horsepower-days in 1995, representing a decline of about 72%, while the uncorrected CPUE (calculated as a ratio of nominal effort to total catch) showed a decline of only about 15% (Fig. 4.2b). On the other hand, in the uncorrected CPUE trend, decline is undetectable until the mid 1980s, while it is apparent in the corrected CPUE trend since 1970.

This suggests that uncorrected fishing effort, in which temporal changes in the efficiency of vessels are not accounted for, leads to serious overestimation of CPUE (by a factor of three in this case). This type of bias carries serious consequences in fisheries where uncorrected commercial CPUE data are used as an index of fish stock abundance. The collapse of the Norwegian spring spawning herring has been blamed on stock assessment errors resulted from uncorrected commercial CPUE data being used as index of fish abundance (Ulltang, 1980). A similar error has been widely reported for the misleading stock assessments that led to the collapse of Northern cod stock off Newfoundland and Labrador (Rose and Kulka, 1999; Walters and Mcguire, 1996). Thus, a major problem with uncorrected commercial CPUE is that its trends may not reflect trends in fish abundance (Hilborn and Walter, 1992; Garcia and Newton, 1997; Salthau and Aanes, 2003).

Distribution of port-based global fishing effort

So far emphasis was given to temporal trends in global fishing effort. In the forthcoming sections, our attention turns to the analysis of the spatial patterns of global fishing effort and the validation of the results. Fishing effort targeting small pelagic fish and that targeting groundfish are pooled in order to roughly identify global hotspots of marine fisheries (Fig. 4.3).

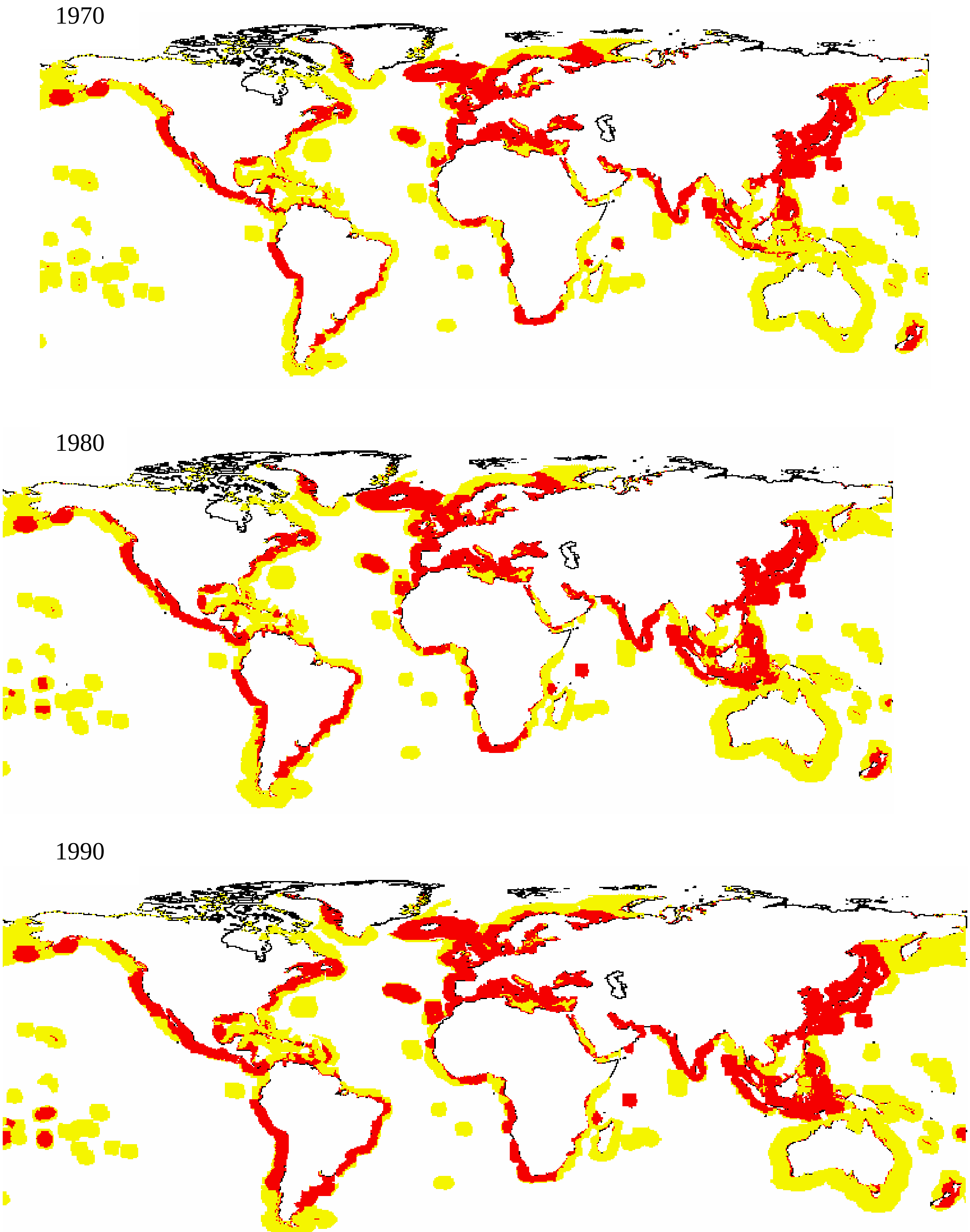

Fig. 4.3. Predicted distribution of global fishing effort in the period between 1970 and 1995; yellow: 0.0-2.6 log hpdays*km^{-2}; red: 2.61-16.2 log hpdays*km^{-2}.

In 1970 the heavily exploited fishing grounds were the North Sea, the Sea of Okhotsk, the Japan Sea, the Yellow Sea, the Northern section of the South China Sea and the coasts of India (Fig. 4.3). In the 1980s and 1990s, the emergence of Southeast Asia as major a fishing ground (i.e., the Gulf of Thailand and the Indonesian Sea, among others), the inshore areas of North America and the Southwest Atlantic (the Patagonian shelf) is evident. The impacts of such substantial effort intensity on fish stocks of these hotspot grounds have been highlighted in the regional spatial analysis in previous sections.

Fishing grounds with least fishing concentration are located around the coasts of Australia, the east coast of Africa and several oceanic islands (Fig. 4.3).

Global validation of fishing effort distribution prediction

Global-scale validation of the spatial fishing effort model was performed using an indirect technique involving a fuel consumption distribution map, independently generated by Tyedmers *et al*. (2005) using data from 2000. This map was created based on data from over 250 fisheries from around the world, combined with spatially mapped catches, following Watson *et al*. (2004). The rationale for using a fuel consumption distribution map to validate fishing effort distribution map is that spatialized fuel consumption can be assumed to be locally proportional to spatialized effort.

As the fuel consumption data pertained to the year 2000, the trends in the last five years of the effort time series (which ended in 1995) were extrapolated, by countries, to obtain estimates of the 2000 effort. The validation procedure involved: (1) visual comparison of map of fuel consumption with fishing effort distribution (Fig. 4.4); and (2) regression and correlation analysis (Fig. 4.5).

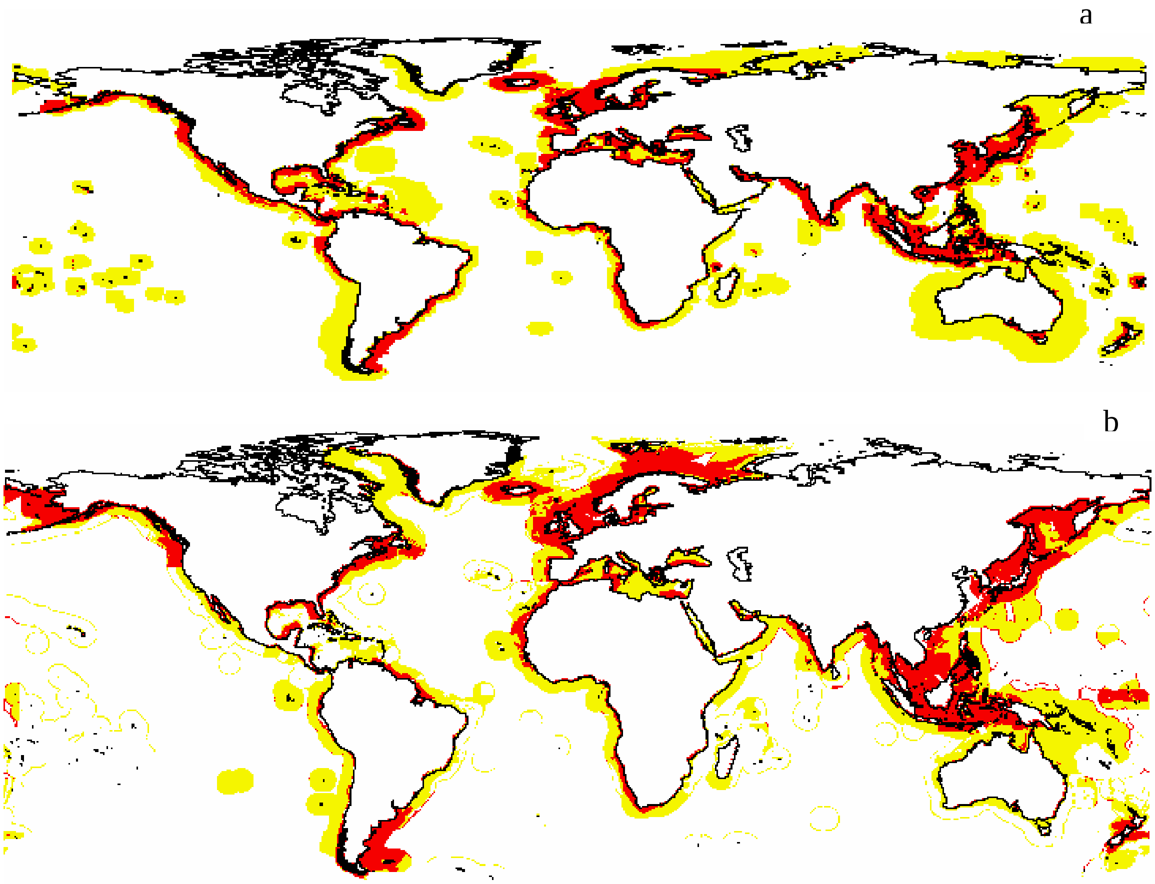

Fig. 4.4. Comparison between predicted (a) global fishing effort distribution pattern; yellow: 0.0-3.0 log hpdays km^{-2}, red: 3.1-15.7 log hpdays km^{-2}, and (b) the distribution of fuel consumption spatial pattern; yellow: 1.0-2.4 log liters*km^{-2}; red: 2.5-7.6 log liters*km $^{-2}$.

As can be seen from Fig. 4.4, the intensely-fished grounds predicted by the effort model are roughly similar with grounds of high fuel consumption intensity as shown in fuel consumption intensity map, i.e., effort and fuel spatial intensities are roughly proportional. This is confirmed by the regression analysis of Fig. 4.5.

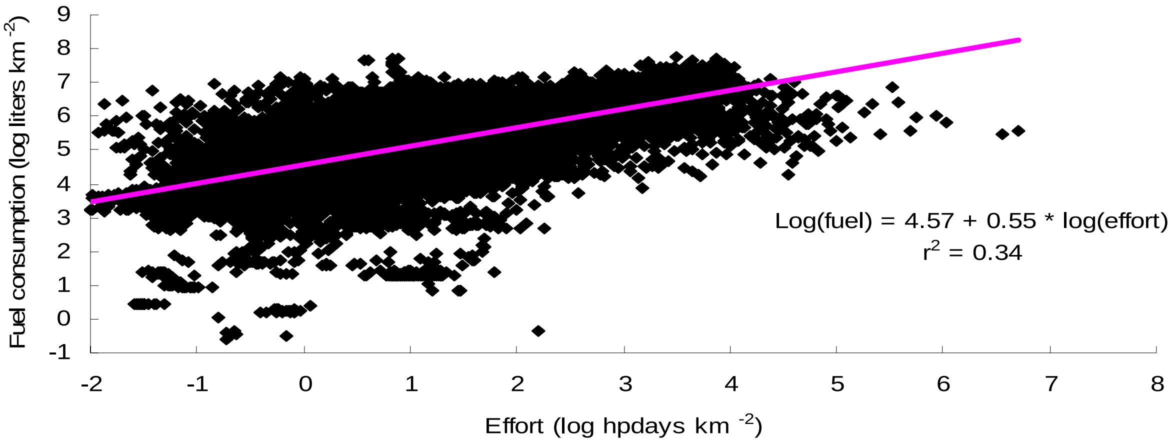

Fig. 4.5. Spatial correlation between predicted fishing effort distribution and fuel consumption intensity distribution (n>16,000).

Fig. 4.5 shows that there is an overall positive relationship between log-predicted fishing effort per cell and log global fuel consumption per cell, which validates the visual comparison of Fig. 4.4. However, the slope of this relationship (0.55) is less than the expected slope (1). This is probably due to the aggregate nature of the data in Tyedmers *et al.* (2005), which do not distinguish the fuel expended to travel to and from a given cell. This distorts the effort-fuel consumption relationship when plotted using data from a mixture of near-shore and offshore areas.

Global port-based fleets fuel consumption rate

Additional inferences can be derived by Figs. 4.4a and 4.4b, notably that a total of 37.356 billion litres of fuel were used annually (within the EEZs of maritime countries) by global fisheries in 2000. Also, the total fishing effort exerted by global port-based fleets in the same period was 15.111 billion horsepower-days.

These figures imply a fuel consumption rate of 2.47 litres per horsepower-day. Based on the assumption that, in a typical fishing trip, boat engine runs from 8 to 18 hours per fishing day, the lower limit being for boats doing day trips, and the upper for boats taking longer trips where engines run longer. Under these two running-time schedules, fuel consumption rate will be anywhere between 0.1 to 0.3 litres per horsepower-hour. Fuel consumption rate for most automotives, including small aircrafts, range between 0.17 to 0.41 litres per horsepower-hour (Wake, 2005), indicating that the fuel consumption rate figure estimated for fishing boats in this study is reasonable. However, the facts that about 20% of global port-based motorized fleets were not covered by this study (see Table 2.4) and that Tyedmers *et al.,'s* (2005) data include fuel consumption for distant water fleets fishing in the EEZs of various countries, (which were not considered in this study), suggest that the actual fuel consumption rate for global port-based fleets may be less than the estimated figure. Accounting for these distant water fleets, which contribute most of the catches taken in some regions (e. g., from West Africa) would significantly lower the estimate of fuel consumption presented here.

The fuel consumption rates estimated here were applied to global fishing fleet data in order to estimate total fuel consumption of the world's fishing fleets over the last three decades (1970-2000). The engines of small inshore vessels (<200 hp) were assumed to run for about 8 hours in any typical fishing day and that of larger boats (>200 hp), capable of longer trips, were assumed to run for about 18 hours in any typical fishing day. The result of this analysis is shown in Fig. 4.6.

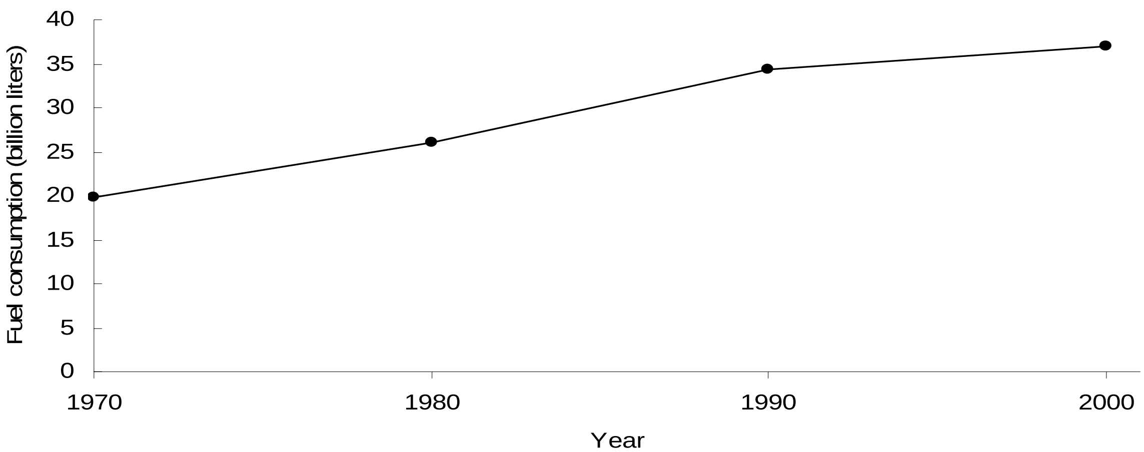

Fig. 4.6. Trends in the fuel consumption of global fishing fleets from 1970 to 2000.

Fig. 4.6 shows that global fishing fleets consumed about 20 billion liters in 1970 and this consumption grew by about 85%, reaching 37 billion liters in 2000. This translates to 2.2% annual growth rate in fuel consumption. At this rate, the fuel consumption of world fisheries would double every 31-32 years. It should be noted here that the estimations are independent of absolute fuel consumption data.

Latitudinal shift in the concentration of global fishing effort

The analyses of concentrations of fishing effort across latitudinal gradients help to assess possible latitudinal shifts in the concentration of fishing effort. Total fishing effort in bands of 10° latitude was plotted against global catches in similar bands within 200 miles of coastlines along with the total size of exploited shelves, and unexploited shelves, i.e., shelf areas that are not exploited due to sea ice (as defined in Fig. 1.1).

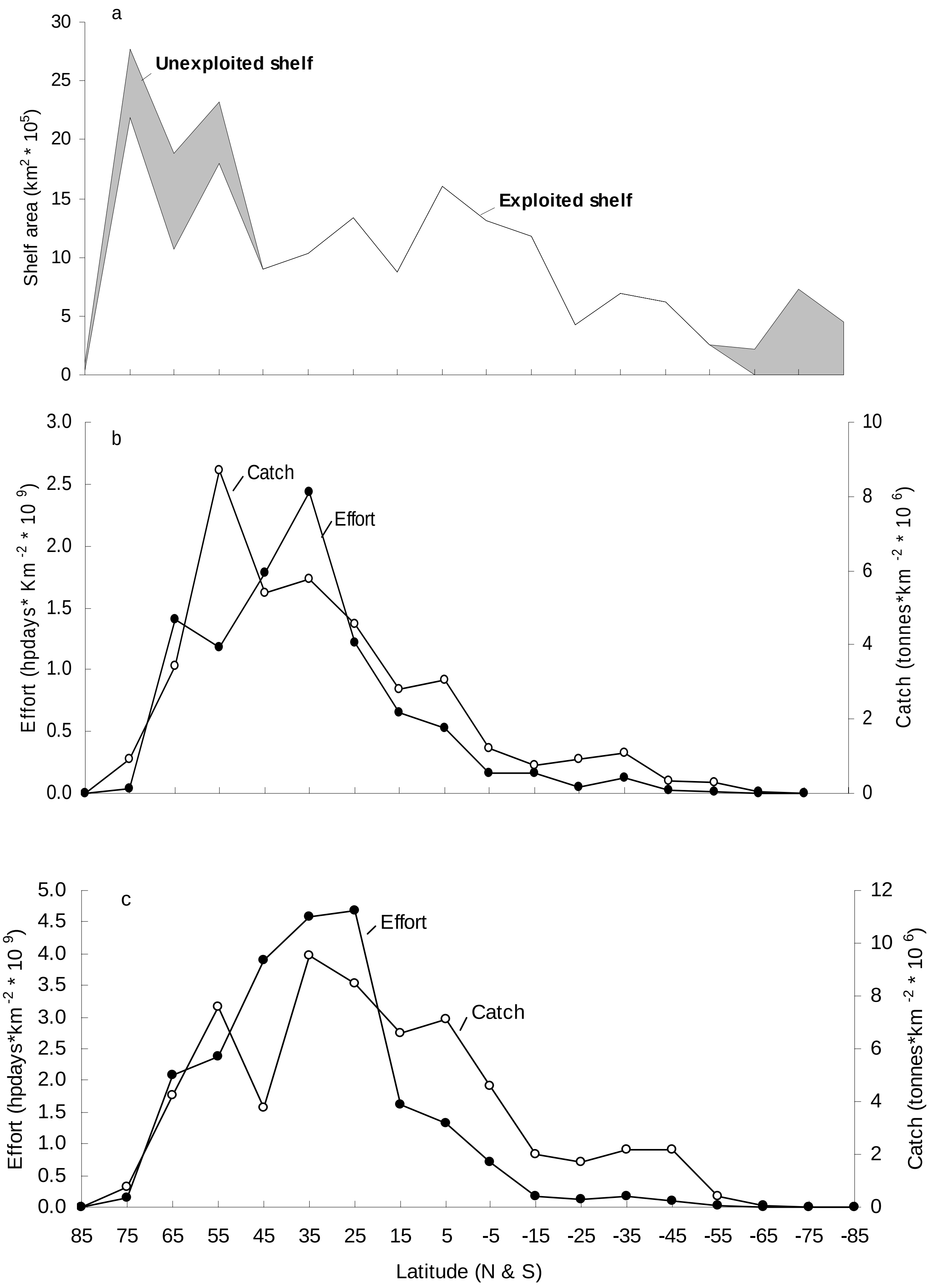

Fig. 4.7. Comparison between total size of exploited shelf areas along latitudinal gradient (a) with catch and effort concentration patterns in corresponding latitudinal gradients in 1970 (b) and 2000 (c). Spatialized catch data are from the *Sea Around Us* Project database (Watson *et al.*, 2004).

Fig. 4.10 shows that during the period between 1970 and 2000, catch and effort concentrations in the Northern hemisphere moved southward by about 20° (55°N to 35°N) and 10° (35° to 25°) respectively. The North-South shift can be explained by physical factor and the history of fisheries development.

The relevant physical factor is latitudinal differences in the sizes of fishable (exploited) shelf areas. Fishable continental shelves, though they account for a relatively small fraction of ocean area, are responsible for 80-90% of global marine catches (Pauly and Christensen, 1995; Pauly, 1996). Therefore, differences in the relative sizes of fishable continental shelves are expected to play an important role in the prospect for fisheries expansion by countries. The high catch concentration appeared in the high latitude of the Northern hemisphere in 1970, despite corresponding lower effort concentration at this latitude band for the year (Fig. 4.10b), can be associated with the vast fishable shelf area in the high latitude of the Northern hemisphere around 55°N (50°-60°N) (Fig. 4.10a). This band cut across traditionally rich fishing grounds, such as the North Sea, the Grand Banks of Northwest Atlantic, the Sea of Japan and the Gulf of Alaska. Thus, high catches were possible at lower fishing effort. In 2000, the centres of catch and effort concentrations appeared to have moved further South to 35°N (30-35°N) and 25°N (20-30°N), respectively (Fig. 4.10c). This band also provides sufficient fishable shelf areas shown by the smaller peak around 25°N (Fig. 4.10a).

The other explanatory factor for the southward shift is the history of fisheries development. Grounds in the Northern high latitudes were the first to become overexploited, particularly in the last three decades (Kaczynski and Fluharty, 2002; Pauly *et al*., 2002). The depletion led to series of effort reduction measures, by major fishing nations in the high latitudes of Northern hemisphere, involving cutbacks on their fishing capacities and exporting excess capacity to overseas (see Section 3.4.1). During the same period (1970-2000), countries in the lower latitudes of the Northern hemisphere (e.g., China and the USA) were engaged in major expansion of their fisheries. Therefore, the southward shift of the centers of catch and effort concentrations can also be attributed to the overall North-South trend in resource depletions, and the fisheries expansions in the countries of the South.

Conclusions

The total size of the global motorized fishing fleet analyzed in this study is 1.27 million vessels. This figure represents about 80% of global motorized fleets as verified through comparison with independent data sources from selected countries in different regions (Table 2.4).

On a relative basis, the Asia-Pacific region dominated the global fishing capacity in total tonnage, while, the Europe-North America declined. The contributions of the South America-Caribbean and African regions have been small (<10%) and their status remained more or less constant over the period analyzed. The nominal size of global fishing effort increased 100%, while effective fishing effort grew by more than 500% in the decades analyzed (Fig. 4.2a). This led to decline of CPUE by 72% between 1970 and 1995 (Fig. 4.2b).

Global fishing effort is now expanded on the entire continental shelves of the world's oceans, with intensely-fished areas clustered along the coasts of major fishing nations (Fig. 4.3). This geographic analysis also revealed that the centres of massive fish production and effort concentration have gradually moved southward (Fig. 4.7b and c). The estimated fuel consumption rate of port-based global fishing effort range from 0.1 to 0.3 liters per horsepower-hour. The fuel consumption of global fishing effort grew by 85% between 1970 and 2000 (Fig. 4.6).

Historically, fishing effort management began with 'input control' scheme that has been directed at limiting the size of fishing effort. Later, fishing effort management moved to schemes based on 'output control', which involved application of total allowable catch and quota systems. Both techniques were ineffective (the former due to non-random behavior of fishers in deploying their gears *vis-à-vis* target distributions and the latter due to high cost involved in providing reliable stock assessment (Walters and Martell, 2004), leading to continuous growth of fishing effort worldwide. More recently, a variant of output control system known as 'individual transferable quota' (ITQ) was proposed and implemented in countries such as Iceland, Australia and several countries in Europe and North America. The ITQ system involves assigning exclusive individual rights to harvest specific portions of the overall quota (Grafton, 1996). Theoretically, the ITQ system can curb the problem of effort expansion and overfishing as it removes fishers' incentive for competing to catch a bigger share of the total allowable quota (Memon and Cullen, 1992; Grafton, 1996). However, ITQ are also plagued with problems ranging from high discarding rate to concerns regarding their potential for large holdings controlled by a few corporations with serious implications for the survival of small-scale fisheries, leading to serious social consequences (Pálsson and Helgason, 1995; Copes and Charles, 2004). Hence, the ITQ system has yet to see a universal adoption.

Owing to these concerns, there has been a renewed interest to switch back to the old input control schemes in conjunction with some new methods to limit fishing mortality, for instance, through marine protected areas (Pauly *et al*., 2000; Walters and Martell, 2004) or combination of both. Obviously, the effectiveness of fishing effort management involving spatial closure depends on the prediction of spatial distribution of fishing effort (Walters and Martell, 2004). In light of this renewed interest in spatial management of fishing effort, the prediction of spatial distribution of fishing effort plays a crucial role. This thesis is the first of its kind in providing quantitative analyses of global patterns in the growth and distribution of fishing effort, perhaps providing a model for regional and country-based analyses.

ACKNOWLEDGEMENTS

We are grateful to Dr. Carl Walters, Fisheries Centre, for his critical contribution in providing the computer code used in spatial simulations and to Dr. Reg Watson, *Sea Around Us* Project, for providing software used for mapping the results of this study.

Thanks should go to Dr. Dirk Zeller, Mr. Chris Close and Mr. Shawn Booth, all from the *Sea Around Us* Project, for their valuable comments on the database used in this study. Last, but not least, we thank the *Sea Around Us* Project, funded by the Pew Charitable Trusts, for providing funding for the study.

REFERENCES

Abu-Talib, A. and Allas, M., 1997. Status of fisheries in Malaysia-An overview. In: Silvestre, G. and Pauly, D. (Eds.), Status and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc. 53, pp. 47-61.

Ahmad, S., 1985. Fisheries development in peninsular Malaysia (1970-1980) a country statement. In: Cleveland, B. C. (Ed.), Adjustments to changes in fisheries law and economics. FAO Fisheries Technical Paper 269. FAO. Rome, pp. 53-72.

Ahmed T., Isa, M. M., Ismail, S. P. and Yusof, S., 2003. Status of Demersal fishery Resources of Malaysia. In: Silvestre, G., Garces, L., Stobutzki, I., Ahmed, M., Valmonte-Santos, R. A., Luna, C., Lachica-Aliño, L., Munro, P., Christensen, V. and Pauly, D. (Eds.), Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries. Worldfish Center. 83-136p.

Aguilar, R., Chavez, C. and Dresdner, J., 2003. Fishery regulations and fleet employment. An application to the pelagic fishery in Southern Chile. Draft inprogress. http://www.handles.gu.se/econ/EEU/employfishey%20Regulation_Chile12aprl.doc

Alder, J. and Sumaila, R., 2004. West Africa: A fish basket of Europe past and present. Journal of Environment & Development, 13(2), pp. 156-178.

Alvarez, F., Alemany, F. and Ferrandis, F., 1999. Working document: Relationship between fishing effort and fishing mortality in the trawl fishery for hake *Merluccius merluccius* off Majorca island. Scientific advisory Committee of General Fisheries Council for Mediterranean. Rome.

Angel, J. A., Burke, D. L., O'boyle, R. N., Peacock, F. G., Sinclair, M. and Zwanenburg, K. C.T., 1994. Report of the workshop on Scotia-Fundy groundfish management from 1977 to 1993. Canadian Technical Report of Fisheries and Aquatic Science. DFO, Dartmouth, Canada.

Anon, 2003. Country Profile South Korea (sample). The Economist. Economic intelligence unit.

Anon, 2005. The global fisheries crisis. Green Peace. http://archive.greenpeace.org/comms/cbio/global.htm.

Anon, 2005a. Fishing. US Library of Congress Country Studies. http://countrystudies.us/mexico/76.htm. Accessed Dec 21, 2005.

Anon, 2005b. Peru: A Country Study: Fishing. US Library of Congress Country Studies. http://countrystudies.us/peru/76.htm. Accessed Dec 19, 2005.

Anon, 2005c. Congressional forum on the use of fisheries concessions as a tool for sustainable fisheries in Mexico. A report to Walker Foundation. The Nature Conservancy of Mexico. Mexico.

Anon, 2005d. Illegal fishing off Somalia nets $300m a year. Mail & Guardian online. http://www.mg.co.za/articlePage.aspx?articleid=249733&area=/breaking_news/breaking_news__africa/. Nairobi, Kenya. Accessed April 26, 2006

Anon, 2005e. Forestry and fishing. US Library of Congress Country Studies. http://countrystudies.us/south-korea/53.htm. Accessed March 26, 2006.

Anon, 2006. Morocco, Spain and Fishing: ICE case study number 49. American University. http://www.american.edu/ted/ice/morspain.htm. Accessed March, 2006.

http://store.eiu.com/index.asp?layout=show_sample&product_id=30000203&country_id=KR. Accessed March, 2006.

Anon, 2002a. Assessment report on fisheries and fisheries related species and habitats Issues. North Sea Conference 2002. Bergen Norway.

http://odin.dep.no/md/nsc/Intermediate_meeting/022001990240/hov004-bn.html.

Anon, 2002b. Environmental Signals 2002 - Benchmarking the millennium. European Environmental Agency reports. Copenhagen, 2002. http://reports.eea.eu.int/environmental_assessment_report_2002_9/en

Anon, 2000. Periods of peak fishery catches and declines since the peak year. World Resource Institute. http://earthtrends.wri.org/maps_spatial/maps_detail_static.php?map_select=210&theme=1. Accessed March, 2006.

Anon, 1998. Outboard Motor Maintenance and Repair in the Republic of Panama. Japan Development Cooperation. Japan.

http://www.jica.go.jp/english/evaluation/project/term/la/archives/13-3-20.html. Accessed Feb.2006.

Anon, 1997. Marine fisheries policy for South Africa: white paper. South African government information.

http://www.info.gov.za/whitepapers/1997/marine.htm Accessed Jan, 2006.

Anon, 1993. INFOSAMAK: Centre for Marketing Information & Advisory Services For Fishery Products in the Arab Region.

http://www.infosamak.org/english/pays.cfm. Accessed March, 2006

Anthony, A., 2001. Sources of crisis in the Russian Far East fishing industry. Comparative Economic Studies, 43. Winter 2001 issue.

APO (Asian Productivity Organization), 1988. Fishing Industry in Asia and Pacific. Medical International Limited. Hong Kong, China.

Arnason, R. and Felt, L., 1995. The North Atlantic Fisheries: Success, Failure and Challenges. Proceedings An Island Living Series. Volume 3. The Institute of Island Studies. Prince Edward Island. Canada.

Asada, Y., Hirasawa, Y. and Nagasaki, F., 1983. Fisheries Management in Japan. FAO Fisheries Technical Paper 238. FAO, Rome.

Atta-Mills, J., Alder, J. and Sumaila, R., 2004. The decline of a regional fishing nation: The case of Ghana and West Africa. Natural Science Forum, 28 (1), pp. 13-21.

Baisre, J., Booth, S. and Zeller, D., 2003. Cuban fisheries catches within FAO area 31 (Western Central Atlantic): 1950-1999. In: Zeller, D., Booth S., Mohammad, E. and Pauly, D. (Eds.), From Mexico to Brazil: Central Atlantic Fisheries Catch Trends and Ecosystem Models. Fisheries Centre Research Reports, 11(6). Fisheries Centre, The University of British Columbia, Vancouver, pp. 133-140.

Bakun, A., Csirke, J., Lluch-Belda, D. and Rafael, S., 1999. The Pacific Central American Coastal LME. In: Sherman, K. and Tang, Q. (Eds.), Large Marine Ecosystems of the Pacific Rim: Assessment, Sustainability, and Management. Blackwell Science, Cambridge, Pp. 268-280.

Barut, N. C., Santos, M. D. and Garces, L.R., 1997. Overview of Philippines marine fisheries. In: Silvestre, G. and Pauly, D. (Eds.), Status and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc. 53, pp. 62-71.

Basch, M., Peña-Torres, J. and Vergara, S., 1995 . Catch Efficiency in the Chilean Pelagic Fishery: Does size matter? ILADES-Georgetown University Working Papers inv140, Ilades-Georgetown University, Economics Department.

Baylon, C. C., 1997. Population characteristics and trends of fishing communities in the Philippines and their relationship of fisheries resources. In: Tietze, U. (Eds.), Reports of the workshop on population characteristics and changes in coastal fishing communities. FAO Fisheries report no.566. Madras, India, pp. 73-135

Berachi, I. G., 2003. Bioeconomic analysis of artisanal marine fisheries of Tanzania (Mainland). Msc. Thesis. Department of Economics, Norwegian College of Fishery Science University of Tromsø, Norway.

Bhathal, B., 2005. Historical reconstruction of Indian marine fisheries catches, 1950-2000, as a basis for testing the 'Marine Trophic Index'. Fisheries Centre Research Reports, 13(4). Fisheries Centre, the University of British Columbia, Vancouver.

Bian, R., 1985. Recent developments in Australian Fishing Industry. In: Cleveland, B. C. (Ed.), Adjustments to changes in fisheries law and economics. FAO Fisheries Technical Paper 269. FAO. Rome, pp. 21-26.

Bjomdal, T., 2003. Management of a straddling fish stock: the case of the Norwegian spring-spawning herring fishery. In: FAO, (Eds.), Papers presented at the Norway-FAO Expert Consultation on the Management of Shared Fish Stocks. Bergen, Norway, 7-10 October 2002. FAO Fisheries Report. No. 695, Suppl. FAO, Rome, pp. 68-85.

Bonfil, R., Munro, G., Sumaila, R., Valtysson, H., Wright, M., Pitcher, T., Preikshot, D., Haggan, N. and Pauly, D. (Eds.), 1998. Distant Water Fleets: An Ecological, Economic and Social Assessment. Fisheries Centre Research Reports, 6(6). The University of British Columbia, Vancouver.

Booth, A., 2000. Incorporating the spatial component of fisheries data into stock assessment models. ICES Journal of Marine Science, 57, pp. 858-865.

Bower, T. C., 1985. Fishing vessel optimization: a design tool. M.A.Sc. Thesis. The University of British Columbia, Vancouver.

Brandt, A. V., 1972. Fish Catching Methods of the World. Revised and enlarged. Fishing news (books) Ltd. London.

Caddy, J. F. 1975. Spatial model for an exploited shellfish population, and its application to the Georges Bank scallop fishery. J.Fish. Res. Board. Can. 32, pp. 1305–1328.

ddy J. F. and Carocci, F., 1999. The Spatial allocation of fishing intensity by port-based inshore fleets: a GIS application. ICES Journal of Marine Science, 56, pp. 388-403.

Charles, A. T., 1995. The Atlantic Canadian Groundfishery: Roots of a collapse. Dalhousie Law Journal, 18(1), pp. 65-83.

Cheung, W.-L., Watson, R. and Pitcher, T., 2002. Policy simulation of fisheries in the Hong Kong marine ecosystem. In: Pitcher, T. and Kevin, C. (Eds.), The use of ecosystem models to investigate multispecies management strategies for capture fisheries. Fisheries Center Research Reports, 10(2). The University of British Columbia, Vancouver, pp. 46-56.

Chidambaram, K., 1963. Development of mechanized fishing fleets in the Indo-Pacific council region. In: Nui, L. B. and Jan-Old Trrmg, J-O. (Eds.), Indo-Pacific fisheries council proceedings. Section II, Symposium Papers. IPFC Secretariat, FAO regional office for Asia and the Far East, Bangkok, pp. 2-27.

Christensen, V., Amorim, P., Diallo, I., Diouf, T., Guénette, S., Heymans, J. J., Mendy, A. N., Mahfoudh Sidi, T., Palomares, M. L. D., Samb, B., Stobberup, K., Vakily, J. M., Vasconcellos, M., Watson, R. and Pauly, D., 2004. Trends in fish biomass off Northwest Africa, 1960-2000. In: Palomares, M. L. D. and Pauly, D. (Eds.), West African marine ecosystems: models and fisheries impacts. Fisheries Centre Research Reports, 12(7). The University of British Columbia, Vancouver, pp. 215-220. Also available in Proceedings of the International Symposium on Marine fisheries, ecosystems, and societies in West Africa: half a century of change, Dakar, Senegal, 24 – 28 June 2002.

Christensen, V., Garces, L., Silvestre, G. and Pauly, D., 2003. Fisheries impacts on the South China Sea Large Marine Ecosystem: A Preliminary analysis using spatially-explicit methodology. In Silvestre, G., Garces, L., Stobutzki, I., Ahmed. M, Valmonte-Santos, R. A., Luna, C., Lachica-Aliño, L., Munro, P., Christensen, V. and Pauly, D. (Eds.), Assessment, Management and Future Directions for Coastal Fisheries in Asian Countries. Worldfish Center, pp. 51-62.

Christy, F. T., 1997. The development and management of marine fisheries in Latin America and the Caribbean. Policy Research Paper, Inter-American Development Bank.

Christy, F. T., 1997a. Economic waste in Fisheries: Impediments to change and conditions for improvement. In: Pikitch E. L., Huppert, D. D. and Sissenwine, M. P. (Eds.), Global trends: Fisheries management. American Fisheries Society Symposium 20. Seattle Washington, 14-16 June 1994, pp.28-39.

Chuenpagdee, R., Liguori, L., Palomares, M.L.D. and Pauly, D., 2006. Bottom-Up, Global Estimates of Small-Scale Marine Fisheries Catches. Fisheries Centre Research Reports, 14(8). The University of British Columbia, Vancouver.

Clark, C. W., Munro, G. and Sumaila, R., 2003. Subsidies, buybacks and sustainable fisheries. In: Sumaila, R. (Ed.), Three essays on the economics of fisheries. Fisheries center Research Reports, 11(3). The University of British Columbia, Vancouver, pp. 4-16.

Clark, W. G., 1976. The lesson of the Peruvian anchoveta fishery. California Cooperative Oceanic Fisheries Investigations. Reports, XIX, July 1975 to 30 June 1976.

Coffen-Smout, S., 1999. Pirates, Warlords and Rogue Fishing Vessels in Somalia's Unruly Seas. Chebucto Community Net. Halifax. Canada. http://www.chebucto.ns.ca/~ar120/somalia.html

Copes, P. and Charles, A. 2004. Socioeconomics of Individual Transferable Quotas and Community-Based Fishery Management. Agricultural and Resource Economics Review. 33: pp. 171-181.

Crutchfield, J.A. and Lawson, R., 1974. West African marine fisheries: Alternatives for management. Paper no.3 in a series prepared for the Program of International Studies of Fisheries Arrangements. Washington.

Csirke, J., 1989. Changes in the catchability coefficient in the Peruvian Anchoveta (Engraulis rigens) Fishery. In: Pauly, D., Muck, P., Mendo, J. and Tsukayama, T. (Eds.), The Peruvian upwelling ecosystem: Dynamics and interactions. ICLARM conference proceedings, 18. Manila, the Philippines, pp. 207-219.

Cushing, D. H., 1988. The Provident Ocean. Cambridge University Press. 1988. London.

Defeo, O., 2003. Misuse of Marine Protected Areas for fisheries management: The Case of Mexico. Fisheries, 28(7), pp. 35-36.

Deligiannis, T., 2000. Peru's Ingenuity Gap: Constraints of the management of natural resources and the crash of the Peruvian anchovy fishery. PhD thesis. University of Toronto. Canada.

DFO, 2000. Underwater world: Atlantic groundfish. www.dfo-mpo.gc.ca.

Diaw, M. C., 1992. Ethnogenesis, mobility and politics in the history of West African canoe fishermen. In: Tvedten, I. and Hersoug, B. (Eds.), Fishing for development: Small-scale fisheries in Africa, Nordiska Afrikainstitutet (The Scandinavian Institute of African studies). Sweden, pp. 54-69.

Die, D., 1991. Stock Assessment and population dynamics (unpubl. note). Scf, Fisheries Branch, Queensland Department of Primary Industries.

Dierks, K. 1995. Memorandum: Key points on Namibian north coast port summary of the pre-feasibility study on future port facilities in Namibia with special reference to the Möwe Bay port. Republic of Namibia, Ministry of Works, Transport and Communication. http://www.klausdierks.com/Moewe_Bay/. Accessed March, 2006.

Djohari, R., 1994. Fisheries Management: Reference material on questions used (unpubl.).

Dorn, W. 2001. Fishing behavior of factory trawlers: a hierarchical model of information processing and decision making. ICES Journal of marine science, 58(1), pp. 238-252

Doucet, W. F. and Einarsson, H., 1966. A Brief Description of Peruvian Fisheries. Reports, XI, 1 June 1963 to 30 July 1966.

Doumbia, M., 1993. Conflicts in Coastal Fisheries in the Gambia. In: Satia, B.P. and Horemans, B. (Eds.), Workshop on Conflicts in Coastal Fisheries in West Africa. IDAF Project. Cotonou, Benin, 24-26 November 1993. 64p., IDAF/WP/53, pp. 32-38.

Eales, J. and Wilen, J. E., 1986. An examination of fishing location in the Pink Shrimp fishery. Mar. Res. Econ. 2, pp. 331-351.

Eiamsa-Ard, M. and Amornchairojkul, S., 1997. The marine fisheries of Thailand with emphasis on the Gulf of Thailand trawl fishery. In: Silvestre, G., and Pauly, D. (Eds.), Status and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc. 53, pp. 85-95.

Everett, G. V., 1976. An Overview of the State of Fishery Development and Planning in the CECAF Region. CECAF/ECAF SERIES/75/4 (En). Project for Development of Fisheries in the Eastern Central Atlantic. Fisheries Committee for the Eastern Central Atlantic. FAO. Rome.

Fager, E. W. and Longhurst, A. R., 1968. Recurrent group analysis of species assemblages of demersal fish in the Gulf of Guinea. J. Fish. Res. Board Can. 25(7), pp. 1405–21.

FAO, 1989. Marine fisheries production in Asia-Pacific region. RAPA Publication:1989/6. Bangkok.

FAO, 1985. Definition and classification of fishery vessel types. FAO Fisheries Technical Paper. No. 267. FAO, Rome.

FAO, 1994. The state of food and agriculture 1994. FAO Agriculture Series, No. 27. ISSN 0081-4539. ISSN 0429-9329. FAO Rome.

FAO, 1996. Fisheries and aquaculture in Latin America and the Caribbean: Situation and outlook in 1996. FAO Fisheries Circular. No. 921. FAO, Rome.

FAO, 1996a. Fisheries and Aquaculture in Sub-Saharan Africa: Situation and Outlook in 1996. FAO Fisheries Circular No. 922 FIPP/C922. FAO, Rome.

FAO, 1996b. Fisheries and Aquaculture in the Near East and North Africa: Situation and Outlook in 1996. FAO Fisheries Circular No. 919 FIPP/C919. FAO, Rome.

FAO, 1996c. Population Dimensions of World Fishery Issues. Sustainable Development Department. http://www.fao.org/sd/wpdirect/wpan0009.html. FAO, Rome.

FAO, 1997. Review of the state of world fishery resources: marine fisheries: Northeast Atlantic: FAO statistical areas 27. FAO Fisheries Circular No. 920 FIRM/C920. FAO. Rome.

FAO, 1997a. Review of the state of world fishery resources: marine fisheries. FAO Fisheries Circular No. 920. Rome, FAO. 1997. 173 p.

FAO, 1997b. Review of the State of world Fishery Resources: Marine Fisheries: Northwest Pacific: FAO statistical areas 61. FAO Fisheries Circular No. 920 FIRM/C920. FAO. Rome.

FAO, 1998b. Modeling the spatial distribution of fishing effort. FAO COPEMED project. FAO, Rome. http://www.faocopemed.org/es/activ/research/gis/eff_network.htm. Accessed Feb, 2003.

FAO, 1999. The state of world fisheries and aquaculture 1998. ISBN 92-5-104187-3. FAO Rome.

FOA, 2004. The State of World Fisheries and Aquaculture (SOFIA) 2004. FAO, Rome,Italy. http://www.fao.org/documents/show_cdr.asp?url_file=////docrep/007/y5600e/y5600e00.htm. Accessed Dec 27, 2005.

FAO, 2005. FAO Country Profile. FAO Rome. http://www.fao.org/fi/fcp/fcp.asp

FAO, 2005a. FAO Country Profile. FAO, Rome. http://www.fao.org/fi/fcp/en/PAN/profile.htm

FAO, 2005b. FAO Major Fishing Areas Fact Sheets Search. FAO. Rome. http://www.fao.org/figis/servlet/static?dom=root&xml=geography/fao_fishing_area.xml

FAO, 2005c. CWP handbook of fishery statistical standards-section L: fishery fleet. FIGIS ontology sheet. FAO, Rome.

FAO, 2006. Global fishing fleet 1970-1995. http://www.fao.org/figis/servlet/TabLandArea?tb_ds=Fleet&tb_mode=TABLE&tb_act=SELECT&tb_grp=COUNTRY. FAO, Rome.FAO, 1998a. Bulletin of fisheries Statistics. 1970,1975,1980,1985,1989-95. FAO Rome.

Feidi, I. H., 1998. Fisheries development in the Arab world. In: Albert, J., Bernhardsson, M. and Kenna, R. (Eds.), Transformations of Middle Eastern Natural Environments: Legacies and Lessons. Yale School of Forestry & Environmental Studies: Bulletin Number 103, pp. 388-406.

Fernö, A. and Olsen, S., 1994 (eds.). Marine fish behaviour in capture and abundance estimation. Fishing News Books.

Fitzpatrick, J. and Newton, C., 2005. Assessment of world's fishing fleets. A report submitted to Greenpeace. .http://archive.greenpeace.org/oceans/globaloverfishing/assessmentfishingfleet2.html#ii

Fitzpatrick, J., 1996. Technology and Fisheries Legislation. In: FAO, (Ed.), Precautionary approach to fisheries. Part 2: Scientific Papers. Prepared for the Technical Consultation on the Precautionary Approach to Capture Fisheries (Including Species Introductions). Lysekil, Sweden, 6–13 June 1995. (A scientific meeting organized by the Government of Sweden in cooperation with FAO). FAO Fisheries Technical Paper. No. 350, Part 2. FAO, Rome, pp. 191-199.

Flewwelling, P., 2001. Fisheries Management and MCS in South Asia. FAO/FISHCODE Project, GCP/INT/648/NOR: Field Report C-6 (En),Rome, FAO, 56p.

FAO/FISHCODE Project, GCP/INT/648/NOR: Field Report C-6. FAO, Rome.

Freire, K. de M. F, 2003. A database of Landing Data on Brazilian Marine Fisheries, 1980-2000. In: Zeller, D., Booth S., Mohammad, E. and Pauly, D. (Eds.), From Mexico to Brazil: Central Atlantic Fisheries Catch Trends and Ecosystem Models. Fisheries Centre Research Reports, 11(6). The University of British Columbia, Vancouver, pp. 181-1990.

Fretwell, S. D., 1972. Population in seasonal environment. Princeton University Press, Princeton, NJ.

Fujinami, N., 1989. Perspectives of fishing nation: Japan. In: Miles, E. L. (Ed.), Management of world fisheries: Implication of extended coastal state jurisdiction. Proceedings of workshop organized by the World Fisheries Project, Institute of Marine Studies, college of Ocean and Fisheries Sciences, University of Washington, Seattle, Washington, July 8-11, 1985, pp. 184-200.

Garcia, S. M., 1992. Ocean fisheries management: The FAO programme. In: Fabbri, P. (Ed.), Ocean Management in Global Change. Proceedings of the Conference on Ocean Management in Global Change. Genoa, 22-26 June 1992, pp. 381-418.

Garcia, S. M. and Newton, C., 1997. Current Situation, Trends, and Prospects in World Capture Fisheries. In: Pikitch E. L., Huppert, D. D. and Sissenwine, M. P. (Eds.), Global trends: Fisheries management, American Fisheries Society Symposium 20. Seattle Washington, 14-16 June 1994, pp.3-27.

Gascuel, D., Fouteneau, A, and Foucher, E. 1993. Analyse de l'évolution des puissance de pêche par l'analyse des cohortes : application aux senneurs exploitant l'albacore (*Thunnus albacares*) dans l'Atlantique Est. Aquatic Living Resources 6(1): 15-30.

Gelchu, A., 2006. Growth and distribution of port-based global fishing effort within countries' EEZs. PhD thesis. The University of British Columbia. 162 p.

Gillis, D. M. and Frank, K. T., 2001. Influence of environment and fleet dynamics on catch rates of eastern Scotian Shelf cod through the early 1998s. ICES Journal of Marine Science, 58, pp. 61-69.

Gillis, D. M. and Peterman, R. M., 1998. Implication of interference among fishing vessels and the ideal free distribution to the interpretation of the CPUE. Can. J. Fish. Aquat. Sci. 55, pp. 37-46.

Gillis, D. M., Peterman, R.M. and Tyler, A.V., 1993. Movement dynamics in a fishery: application of the ideal free distribution to spatial allocation of effort. Can. J. Fish. Aquat. Sci. 50, pp. 323–333.

Goodisan, P., 1992. The Namibian fisheries experience: Analysis. In: Morales, H. L. (Ed.), The uncertain future of the earth, SAMUDRA report no. 5 & 6 - June 1992. Special edition for the United Nations Conference on Environment and Development, pp. 16-20.

Gordon, H. S., 1954. The economic theory of a common-property resource: the fishery. Journal of Political Economy, 62 (2), pp. 124-142.

Gray, R. D. and Kennedy, M., 1994. Perceptual constraints on optimal foraging: a reason for departure from the Ideal free distribution. Anim. Behav. 47, pp. 469-471.

Gréboval, D., 1999. Managing Fishing Capacity: Selected Papers on Underlying Concepts and Issues. FAO Fisheries Technical Paper 386. FAO, Rome.

Gribble, N. A. and Robertson, J. W. A., 1998. Fishing effort in the far northern section cross shelf closure area of the great barrier Reef Marine Park: the effectiveness of area-closure. Journal of Environmental Management, 52, pp. 53-67.

Grzywaczewski, Z., 1964. Modern fishing vessels. Scientific Publications, Foreign Cooperation Center of the Central Institute for Scientific, Technical and Economic Information. Warsaw, Poland.

Guénette, S., 2000. Marine Reserves for the Northern Cod. PhD thesis. The University of British Columbia. Vancouver.

Gulland, J. A., 1971. The fish resources of the ocean. Fishing News (Books) Ltd. England.

Gulland, J. A., 1974. The Management of Marine Fisheries. Scientechnica (Publishers) Ltd. Bristol.

Gulland, J. A., 1983. Fish Stock Assessment A Manual of Basic Methods. FAO/Wiley series Food and Agriculture, Volume 1. John Wiley & sons. Rome.

Haakonsen, J. M., 1992. Industrial vs. Artisanal fisheries in West Africa: The lesson to be learnt. In: Tvedten, I. and Hersoug, B. (Eds.), Fishing for development: Small-scale fisheries in Africa. Nordiska Afrikainstitutet (The Scandinavian Institute of African studies), Sweden, pp. 33-53.

Harris, L., 1996. Science and Public Policy Under Uncertainty: Learning from east Coast Fishery. In: Dobell, R. and Long, J. (Eds.), Politics, Management and conflict in the Canadian fisheries. Public forum sponsored by The Maritime Awards of Canada. University of Victoria, pp. 9-14.

Hermansen, Ø. and Flaaten, O., 2004. Government financial transfers to the fish harvesting, processing and aquaculture industries Norway 1990–2002. Norway. http://www.nfh.uit.no/dok/norut_09-2004.pdf

Hersoug, B., 1992. Limits to aid: Some considerations on fisheries development aid project. In: Tvedten, I., Hersoug, B. (Eds.), Fishing for development: Small-scale fisheries in Africa. Nordiska Afrikainstitutet (The Scandinavian Institute of African studies), Sweden, pp.135-154.

Hilborn, R., Branch, T. A., Ernst, B., Magnusson, A., Minte-Vera, C.V., Scheuerell, M. D. and Valero, J. L., 2003. State of the World's Fisheries. Annu. Rev. Resour. 28, pp. 15.1-15.40.

Hilborn, R. and Walters, C. J., 1992. Quantitative Fisheries Stock Assessment: Choice, Dynamics & Uncertainty. Chapman and Hall. USA.

Hinrichsen, D., 1995. Coasts in Crises: Coasts and the Population Bomb. AAAS. http://www.aaas.org/international/ehn/fisheries/hinrichs.htm. Accessed Dec 23, 2005.

Holland, D. S. and Sutinen, J. G, 1999. An empirical model of fleet dynamics in New England trawl fishery. Can. J. Fish. Aquat. 56, pp. 253-264.

Hongskul, V., 1999. Into the next millennium: Fishery perspective. RAP Working Paper Series 1/3. FAO Regional Office for Asia. Bangkok.

Hughes, T. P., 1994. Catastrophes, phase shifts and large scale degradation of a Caribbean coral reef. Science, 265, pp. 1547-1551.

Hutchings, A. J., 1995a. Spatial and Temporal Variation in the exploitation of Northern Cod, Gadus morhua: historical perspective from 1500 to present. In: Anon, (Ed.), Marine Resources and Human Societies in the North Atlantic since 1500. Papers presented in the conference entitled "Marine Resources and Human societies in the North Atlantic since 1500". Institute of Social and Economic Research. Paper Number 5. Memorial University of Newfoundland. Canada, pp. 45-67.

Hutchings, J. A and Myers, R. A., 1995. The biological collapse of Atlantic Cod Off Newfoundland and Labrador: An Exploration of Historical Changes in Exploitation, Harvesting Technology and Management. In: Arnason, R. and Felt. L. (Eds.), The North Atlantic Fisheries: Successes, Failures & Challenges, Volume 3. The Institute of Island Studies, Charlottetown, PEI, pp. 37-93.

ICES, 1906. Bulletin Statististique des Pěches Maritimes. Volume 1, ICES, Denmark.

ICES, 1950-1974. Bulletin Statististique des Pěches Maritimes. Volume 53 -59, ICES, Denmark.

ICES, 2001. Compilation of Submitted Inputs to the Progress Report to the Fifth North Sea Conference: Fisheries – Part II: Status of North Sea Fish Stocks. ICES, Denmark.

Isaksen, J. R., 2000. Subsidies to the Norwegian Fishing Industry: An Update. Report 13/2000. Fiskeriforskning. Norway.

http://www.fiskeriforskning.no/fiskeriforskning/publikasjoner/rapporter/subsidies_to_the_norwegian_fishing_industry_an_update.

Jia, J., and Chen, J., 2001. Sea farming and sea ranching in China. FAO Fisheries Technical Paper No. 418. FAO, Rome.

Johnson, V., 1992. Artisanal fishermen and intermediaries in Mozambique. In: Tvedten, I. and Hersoug, B. (Eds.), Fishing for development: Small-scale fisheries in Africa. Nordiska Afrikainstitutet (Scandinavian Institute of African Studies), Sweden, pp. 115-134.

Jul-Larsen, E., 1992. Attitudes towards modernization in African small-scale fisheries. In: Tvedten, I. and Hersoug B. (Eds.), Fishing for development: Small-scale fisheries in Africa. Nordiska Afrikainstitutet (Scandinavian Institute of African Studies), Sweden, pp. 70-90.

Kaczynski, V. M. and Fluharty, D. L., 2002. European Policies in West Africa: who benefits from fisheries agreements? Marine Policy, 26, pp. 75-93.

Kebe, M. and Ndiaye, M. D., 1993. Conflicts in Coastal Fisheries in Senegal. In : Satia, B.P. and Horemans, B. (Eds.), Workshop on Conflicts in Coastal Fisheries in West Africa. Cotonou, Benin, 24-26 November 1993. IDAF Project, IDAF/WP/53, pp. 6-31.

Kent, G., 1980. The Politics of Pacific Island Fisheries. Westview Replica Edition. USA.

Klaer, N. L., 2001. Steam trawler catches from South-eastern Australia from 1918 to 1957: trends in catch rates and species composition. Mar. Freshwater Res. 52, pp. 399-410.

Koranteng, K. and Pauly, D., 2004. Long-term trends in demersal fishery resources of Ghana in response to fishing pressure. In: Palomares, M. L. D and Pauly, D. (Eds.), West African marine ecosystems: models and fisheries impacts. Fisheries Centre Research Reports, 12(7). The University of British Columbia, Vancouver, pp. 75-80.

Laurec, A. and Armstrong, D., 1997. The European Common Fisheries Policy and its Evolution. In: Pikitch E. L., Huppert, D. D. and Sissenwine, M. P. (Eds.), Global trends: Fisheries management. American Fisheries Society Symposium 20. Seattle Washington, 14-16 June 1994, pp.61-72.

Lawson, R. M and Kwei, E. R., 1974. African entrepreneurship and economic growth: A case study of the fishing industry of Ghana. Ghana Universities Press. Accra.

Lear, W. H., 1998. History of Fisheries in the Northwest Atlantic: The 500-Year Perspective. J. Northw. Atl. Fish. Sci. 23, pp. 41-73.

Léon, M. N., 1993. Conflicts in Coastal Fisheries in Gabon. In: Satia, B. P. and Horemans, B. (Eds.), Workshop on Conflicts in Coastal Fisheries in West Africa. Cotonou, Benin, 24-26 November 1993. IDAF Project, IDAF/WP/53, pp. 55-59.

Le Pape, O. L. and Vigneau, J., 2001. The influence of vessel size and fishing strategy on the fishing effort for multispecies fisheries in the Northwestern France. ICES Journal of Marine Science, 58, pp. 1232-1242.

Le Ry, J-M., Tietze, U, Prado, J., 1998. Techno-economic performance of marine capture fisheries. Findings of a global study and an interregional workshop. FAO Fisheries Technical Paper no. 377. FAO, Rome.

Linbedo, E., 1999. Fishing Capacity and EU Fleet Adjustment. FAO Technical Consultation on the measurement of Fishing Capacity, Mexico City: http://www.foi.dk/cv/fisk-afd/div-conf-papirer/Mexico99.pdf

Longhurst, A. R. and Pauly, D., 1987. Ecology of Tropical Ocean. Academic Press, San Diego.

Mabawonku, A. F., 1986. The role and effect of subsidies on fisheries development in West Africa (Nigeria, Côte d'ivoire, The Gambia and Senegal). Fishery Committee for the Eastern Central Atlantic, CECAF/ECAF SERIES 90/53. FAO. Rome.

Mace, P. M. and Gabriel W. L., 1999. Evolution, Scope, and Current Applications of the Precautionary Approach in Fisheries. In: Restrepo, V. R. (Ed.), Proceedings of the Fifth National NMFS Stock Assessment Workshop: Providing Scientific Advice to Implement the Precautionary Approach Under the Magnuson-Stevens Fishery Conservation and Management Act. U.S. Dep. Commerce. NOAA Tech. Memo. NMFS-F/SPO-40, pp. 65-73.

MacSween, I. M, 1983. Markets for fish and fishery products in Eastern Europe. FAO Fisheries Technical Paper 241 FIIU/T241. FAO, Rome.

MAFF, 2005. Overview of the Japanese Fishing Industry. Ministry of Agriculture, forestry and fisheries of Japan. http://www.maff.go.jp/eindex.html . Accessed Dec, 8, 2005.

Maldeniya, R., 1997. The coastal fisheries of Sri Lanka: Resource exploitation and management. In: Silvestre, G. and Pauly, D. (Eds.), Status and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc. 53, pp. 72-84.

Manchester, L., 1970. Canada's Fisheries. Canada at work series. McGraw-Hill Company of Canada Ltd. Canada.

Marchal, P., 2001. Time changes in fishing power in the Danish cod fisheries of the Baltic Sea. ICES Journal of Marine Science, 58, pp. 298-310.

Marchal, P., Ulrich, C., Korsbrekke, K., Pastoors, M. and Rackham, B., 2002. Comaprison of Three Indices of Fishing Power on some Demersal Fisheries of the North Sea. ICES Journal of Marine Science, 5, pp. 604-623.

Marcoux, A., 1997. Population Characteristics and Change in Fishing Communities and Sustainable Exploitation of Fisheries Resources. FAO Sustainable Development Department, Interregional Workshop, Madras/Chennai, India. March 1977.

Memon, P. and Cullen, R. 1992. Fishery Policies and their Impact on the New Zealand Maori. Marine Resource Economics. VII(3). pp153-167.

Menasveta, D. 2000. APFIC: Its Changing Role. FAO Regional Office for Asia and the Pacific, Bangkok, Thailand. RAP Publication: 2000/05.

Mendoza, J., Booth, S. and Zeller, D., 2003. Venezuelan marine fisheries catches in space and time: 1950-1999. In: Zeller, D., Booth, S., Mohammad, E. and Pauly, D. (Eds.), From Mexico to Brazil: Central Atlantic Fisheries Catch Trends and Ecosystem Models. Fisheries Centre Research Reports, 11(6). The University of British Columbia, Vancouver, pp. 171-180.

Mensah, M. A. and Koranteng, K. A., 1993. Conflicts in Coastal Fisheries in Ghana. In: Satia, B.P. and Horemans, B. (Eds.), Workshop on Conflicts in Coastal Fisheries in West Africa. Cotonou, Benin, 24-26 November 1993. IDAF Project, IDAF/WP/53, pp. 39-54.

Mesinas, A. G., 1992. Fishery management in Peru. In: Loayza, E.A. (Ed.), Managing fishery resources. Proceedings of a symposium co-sponsored by the World Bank and Peruvian Ministry of Fisheries held in Lima, Peru, June 1992. World Bank Discussion Papers, Fisheries Series. No. WDP 217, pp. 79-90

Milazzo, M., 1998. Subsidies in World Fisheries: A Reexamination. World bank Technical Paper No. 406, Fisheries Series. The World Bank, Washington, D.C.

Miles, E. D., 1989. Management of world fisheries: Implication of extended coastal state jurisdiction. Proceedings of workshop organized by the World Fisheries Project, Institute of Marine Studies, college of Ocean and Fisheries Sciences, University of Washington, Seattle, Washington, July 8-11, 1985.

Mohammed, E., 2003. Reconstructing Fisheries Catches and Fishing Effort for the Southeastern Caribbean (1940-2001): General Methodology. In: Zeller, D., Booth, S., Mohammad, E. and Pauly, D. (Eds.), From Mexico to Brazil: Central Atlantic Fisheries Catch Trends and Ecosystem Models. Fisheries Centre Research Reports, 11(6). The University of British Columbia, Vancouver, pp. 11-20.

Mohammed, E. and Joseph, W., 2003. St. Lucia and Eastern Caribbean: Reconstructed Fisheries Catches and Fishing Effort, 1940-2001. In: Zeller, D., Booth, S., Mohammad, E. and Pauly, D. (Eds.), From Mexico to Brazil: Central Atlantic Fisheries Catch Trends and Ecosystem Models. Fisheries Centre Research Reports, 11(6). The University of British Columbia, Vancouver, pp. 21-43.

Mohammed, E., Parker, C. and Willoughby, S., 2003. Barbados: Reconstructed Fisheries Catches and Fishing Effort, 1940-2000. In: Zeller, D., Booth, S., Mohammad, E. and Pauly, D. (Eds.), From Mexico to Brazil: Central Atlantic Fisheries Catch Trends and Ecosystem Models. Fisheries Centre Research Reports, 11(6). The University of British Columbia, Vancouver, pp. 45-66.

Mohammed, E., Straker, L. E. and Jardine, C., 2003a. St. Vincent and Grenadines: Reconstructed Fisheries Catches and Fishing Effort, 1940-2001. In: Zeller, D., Booth, S., Mohammad, E. and Pauly, D. (Eds.), From Mexico to Brazil: Central Atlantic Fisheries Catch Trends and Ecosystem Models. Fisheries Centre Research Reports, 11(6). Fisheries Centre, The University of British Columbia, Vancouver, pp. 95-116.

Mohammed, E. and Rennie, J., 2003. St. Vincent and Grenadines: Reconstructed Fisheries Catches and Fishing Effort, 1940-2001. In: Zeller, D., Booth, S., Mohammad, E. and Pauly, D. (Eds.), From Mexico to Brazil: Central Atlantic Fisheries Catch Trends and Ecosystem Models. Fisheries Centre Research Reports, 11(6). The University of British Columbia, Vancouver, pp. 95-116.

Mohammed, E. and Shing, C. C. A., 2003. Trinidad and Tobago: Preliminary Reconstruction of Fisheries Catches and Fishing Effort, 1908-2002. In: Zeller, D., Booth, S., Mohammad, E. and Pauly, D. (Eds.), From Mexico to Brazil: Central Atlantic Fisheries Catch Trends and Ecosystem Models. Fisheries Centre Research Reports, 11(6). The University of British Columbia, Vancouver, pp. 117-132.

Moore, W. P., Walsh, D., Worden, I. and Macdonald, J. D., 1993. The Fish Processing Sector in Atlantic Canada: Industry Trends and Dynamics. Coopers & Lybrand. Prepared for the Task Force on Income and Adjustment in the Atlantic Fishery. Dept. of Fisheries and Oceans Canada.

Muck, P., 1989. Major trends in the pelagic ecosystem off Peru and their implications for management. In: Pauly, D., Muck, P., Mendo, J. and Tsukayama, I. (Eds.), The Peruvian Upwelling Ecosystem: Dynamics and Interactions, IMARPE, pp.386-403.

Munro, G. R., and Sumaila, R., 2002. Subsidies and their potential impact on the management of the ecosystems of the north Atlantic. Fish and Fisheries, 3, pp. 233-250.

Murawski, S. and Almeida, F., 2001. Status of Fisheries resources in Northeastern Unites states. NOAA. 2001. www.nefsc.noaa.gov/sos/.

Musse, G. H. and Tako, M. H., 1999. Illegal Fishing and Dumping Hazardous Wastes Threaten the Development of Somali Fisheries and the Marine Environments. In: Tropical Aquaculture and Fisheries" Conference, 99 held on 7th-9th Sept, Park Royal Hotel, Terengganu. Malaysia. (http://www.geocities.com/gabobe/illegalfishing.html).

Nanda, J. N., 1986. Development of the resources of the sea of India. Concept Pub. Co. India.

Nedelec, C. and Prado, J., (1990). Definition and Classification of Fishing Gear Categories. FAO, Rome.

Nicholson, P. T., 1996. Individual quotas in the Atlantic Fishery: retrospective and Prospective. In: Dobell, R. and Justin, L. (Eds.), Politics, Management and conflict in the Canadian fisheries. Public forum sponsored by The Maritime Awards of Canada. University of Victoria, pp. 27-35.

Doumbia, M., 1993. Conflicts in Coastal Fisheries in Côte d'Ivoire. In: Satia, B. P. and Horemans, B. (Eds.), Workshop on Conflicts in Coastal Fisheries in West Africa. Cotonou, Benin, 24-26 November 1993. IDAF Project, IDAF/WP/53, pp. 13-19.

Njifonjou, O. and Njock, J. C., 2000. African fisheries: Major trends and diagnostic of the 20th century. Oregon State University. Corvallis. USA. http:oregonstate.edu\dept\IIFET\2000\papers\njifonlou.pdf. Accessed March, 2006.

NOAA, 2004. LME 48: Yellow Sea. National Oceanic and Atmospheric Administration of the USA. NOAA Fisheries Northeast Fisheries Science Center. Narragansett Laboratory. http://na.nefsc.noaa.gov/lme/text/lme48.htm. Accessed March, 2006.

Oostenbrugge, J. A. E. V., Van Densen, W. L. T. and Machiels, M. A. M., 2001. Risk aversion in allocating fishing effort in a highly uncertain coastal fishery for pelagic fish. Mollucas, Indonesia. Can. J. Fish. Aquat. Sci. 58, pp. 1683-1691.

Pálsson, G. and Helgason, A. 1995. Figuring fish and measuring men : the individual transferable quota system in the Icelandic cod fishery. Ocean and Coastal Management. 28(1-3): pp117-146.

Panayotou, T., 1985. Small-Scale fisheries in Asia: Socioeconomic analysis and policy. IDRC, Ottawa.

Panayotou, T., 1982. Management concepts for small-scale fisheries: economic and social aspects. FAO Fisheries Technical Paper, No. 228. FAO, Rome.

Pang, L. and Pauly, D., 2001. Chinese marine capture fisheries for 1950 to the late 1990s: The hopes, the plans and the Data. In: Watson, R., Pang, L. and Pauly, D. (Eds.), The Marine Fisheries of China: Development and Reported Catches. Fisheries Centre Research Reports, 6(2). The University of British Columbia, Vancouver, pp. 1-26.

Papp, D. S, Brown, C. L., Kauffman, C. and Novac, C., 2005. Russia and the former Soviet republics in transition. Lesson 3: Economic update. Southern Center for International Studies: http://www.southerncenter.org/ru_jan05_lesson3.pdf

Pascoe, S., Coglan, L. and Mardle, S., 2001. Physical versus harvest-based measures of capacity: the case of the United Kingdom vessel capacity unit system. ICES Journal of Marine Science, 58, pp. 1232-1242.

Park, C., 1974. Fishing under troubled waters: the Northeast Asia fisheries controversy. Ocean Development and International Law Journal, 2(2), pp. 93-135.

Parraga, A. A. V, 1986. Economic cycle, migration and employment: A model of conjunctural development. The fishmeal industry in Peru, 1940-1985, unpublished PhD thesis, The University of Texas at Austin. USA.

Parsons, L. S. and Beckett, J. S., 1995. Fisheries management in Canada: The Case of Atlantic groundfish. In: Anon. (Ed.), Marine Resources and Human societies in the North Atlantic since 1500. Papers presented in the conference entitled "Marine Resources and Human societies in the North Atlantic since 1500". Institute of Social and Economic Research. Paper Number 5. Memorial University of Newfoundland, Canada, pp. 45-67.

Pauly, D., 1989. Fisheries resources management in Southeast Asia: Why bother? In: Pauly, D. (Ed.), Coastal area management in Southeast Asia: policies, management strategies and case studies. ICLARM Conference Proceedings 19, Manila, pp. 1 - 10.

Pauly, D., 1995, Anecdotes and the shifting baseline syndrome of fisheries. Trends in Ecology and Evolution, 10 (10), pp. 430-430.

Pauly, D., 1996. Biodiversity and the retrospective analysis of demeresal trawl surveys: a programmatic approach (keanekaragaman hayati dan telaah ke belakang survey trawl ikan-ikan demersal: suatu pendekatan programatik). In: Pauly, D. and Martosubroto, P. (Eds.), Baseline studies of biodiversity. The fish resources of western Indonesia. ICLARM Stud. Rev. 23, pp. 135-216.

Pauly, D., 1997. Small-Scale Fisheries in the Tropics: Marginality, marginalization, and some implications for fisheries management. In: Pikitch E. L., Huppert, D. D. and Sissenwine, M. P. (Eds.), Global trends: Fisheries management. American Fisheries Society Symposium 20. Seattle Washington, June 1994, pp. 40-49.

Pauly, D., 2004. Ecosystem-based fisheries management: the role of the SIAP project. In: Palomares, M. L. D. and Pauly, D. (Eds.), West African marine ecosystems: models and fisheries impacts. Fisheries Centre Research Reports, 12(7). The University of British Columbia, Vancouver, pp. 2-3.

Pauly, D., Alder, J., Bennett, E., Christensen, V., Tyedmers, P. and Watson, R., 2003a. The future for fisheries. Science, 302, pp. 1359-1361.

Pauly, D. and Christensen, V., 1995. Primary production required to sustain global fisheries. Nature, 374, 255-257.

Pauly, D., Christensen, V., Guénette, S., Pitcher, T. J., Sumaila, R. Walters, C. J., Watson, R. and Zeller, D., 2002: Towards sustainability in world fisheries. Nature, 418, pp. 689-695.

Pauly, D., Christensen, V., Dalsgaard, J., Froese, R. and Torres Jr. F., 1998. Fishing down marine food. Science, 279, 5352, pp. 860-863.

Pauly D. and Chuenpagdee, R., 2003. Development of fisheries in the Gulf of Thailand large marine ecosystem: Analysis of an unplanned experiment. In: Hempel, G., and Sherman, G. (Eds.), Large Marine Ecosystems of the World. Elsevier B.V., pp. 337-354.

Pauly, D. and Maclean, J., 2003. In a Perfect Ocean. The state of fisheries and ecosystem in the North Atlantic. Island Press. USA.

Pauly, D. and Pitcher, T. J., 2000. Assessment and mitigation of fisheries impacts on marine ecosystems: a multidisciplinary approach for basin-scale inferences, applied to the North Atlantic. In: Pauly, D. and Pitcher, T. J. (Eds.), Methods for Evaluating the Impacts of Fisheries on North Atlantic Ecosystems. Fisheries Centre Research Reports 8(2), The University of British Columbia, Vancouver, pp. 1-12.

Pauly, D., Tsukayama, I., 1987. The Peruvian Anchoveta and its Upwelling Ecosystem: Three Decades of Change. IMARPE. ICLARM Studies and Reviews No. 15. Callao, Peru.

Pauly, D. and Watson, R., 2003. Counting the last fish. Scientific American, 289 (1), pp. 42-47.

Pauly, D., Watson, R. and Alder, J., 2005. Global trends in world fisheries: Impacts on marine ecosystems and food security. Phil. Trans. R. Soc. 360, pp. 5-12.

Pauly, D., Watson, R. and Christensen, V., 2003b: Ecological geography as framework for a transition toward responsible fishing. In: Sinclair, M. and Valdimarson, G. (Eds.), Responsible Fisheries in the Marine Ecosystem. Food and Agriculture Organization of the United Nations and CABI Publishing, pp. 87-101.

Pauly, D. and Zeller, D., 2003. Fisheries Trends: the Global Fisheries Crises as a Rationale for Improving the FAO Database of Fisheries Statistics. In: Zeller, D., Booth, S., Mohammad, E. and Pauly, D. (Eds.), From Mexico to Brazil: Central Atlantic Fisheries Catch Trends and Ecosystem Models. Fisheries Centre Research Reports, 11(6). The University of British Columbia, Vancouver, pp. 1-9.

Pautzke, C.G., 1997. Russian Far East Fisheries Management. the North Pacific Fishery Management Council - NOAA Coop. Agreement #97-NA77FC006. http://www.shaps.hawaii.edu/fishing/country/russia/fish-rfe-all.html#Ch2

Pearse, P. H., 1996. Grasping the Nettle: Institutional Reform for Sustainable Fisheries on the Pacific Coast. In: Dobell, R. and Long, J. (Eds.), Politics, Management and conflict in the Canadian fisheries. Public forum sponsored by The Maritime Awards of Canada. University of Victoria, pp. 37-44.

Peña-Torresa, J., Vergarab, V. and Basch, M., 2004. Downward Adjustments in a Cyclical Environment: The Case of Chilean Pelagic Fisheries. JEL Classifications, Q22, C33, L7.

Petursdottir, G., Hannibalsson, O. and Turner, J., 2001. Safety at Sea as an Integral Part of Fisheries Management. FAO Fisheries Circular No. 966 FIIT/C966. FAO, Rome.

Platteau, J-P., 1992. Small-scale fisheries and the evolutionist theory of institutional development. In: Tvedten, I. and Hersoug, B. (Eds.), Fishing for development: Small-scale fisheries in Africa. Nordiska Afrikainstitutet (The Scandinavian Institute of African studies), Sweden, pp. 91-114.

Plessis, A. H. D., 2971. South West African fishing industry. South African Shipping News, 26(9), pp. 54-55.

Prado, J. and Drew, S., 1999. Research and development in fishing technology in Latin American. FAO Fisheries Circular No. 944 FIIT/x2173. FAO. Rome.

Priyono, B. E. and Sumiono, B., 1997. The Marine fisheries of Indonesia with emphasis on the coastal demersal stocks of the Sunda Shelf. In: Silvestre, G. and Pauly, D. (Eds.), Status and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc. 53, pp. 38-46.

Radovich, J., 1982. The Collapse of the California Sardine Fishery What Have We learned?. CalCOFI Rep., XXIII, pp. 56-78.

Renato, A., Chávez, C. and Dresdner, J., 2004. Regulating Fisheries: Estimating the Impact on Fleet Employment in Pelagic Fisheries in Southern Chile. European Association of Environment and Resource Economics. http://eaere2004.bkae.hu/download/paper/dresdnerpaper.doc. accessed March, 2006.

Rich, W. H., 2005. Fishing Grounds of the Gulf of Maine. Project Gutenberg. United States Bureau of Fisheries.

Rijnsdrop, A. M., Buys, A. M., Storbeck, F. and Visser, E. G., 1998. Micro-scale distribution of beam trawl effort in the southern North Sea between 1993 and 1996 in relation to the trawling frequency of the sea bed and the impact on benthic organisms. ICES Journal of marine science, 55, pp. 403-419.

Robins, C.M. , Wang, Y.-G. and Die, D. 1998. The impact of global positioning systems and plotters on fishing power in the northern prawn fishery, Australia. Can. J. Fish. Aquat. Sci. 55: p1645.1651.

Rogers, R.A., 1995. The Oceans are Empyting: Fish war and sustainability. Black Rose Books Ltd. Canada.

Rogers, S. G. and Van Den Avyle, M. J., 1983. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (South Atlantic) -- Atlantic menhaden. U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.11. U.S. Army Corps of Engineers, TR EL-82-4.

Rose, G. A. and Kulka, D. W., 1999. Hyperaggregation of fish and fisheries: how catch-per-unit-effort increased as the northern cod (*Gadus morhua*) declined. Can. J. Fish. Aquat. Sci. 56 (Suppl. 1), pp. 118–127.

Rosenberg, D., 2005. Managing the Resources of the China Seas: China's Bilateral Fisheries Agreements with Japan, South Korea, and Vietnam. http://www.zmag.org/content/showarticle.cfm?SectionID=17&ItemID=8205

Rudd, M. A, 2003. Fisheries Landing and Trade of Turks and Caicos Islands. In: Zeller, D., Booth, S., Mohammad, E. and Pauly, D. (Eds.), From Mexico to Brazil: Central Atlantic Fisheries Catch Trends and Ecosystem Models. Fisheries Centre Research Reports, Vol. 11(6). The University of British Columbia, Vancouver, pp. 149-161.

Salthaug, A. and Aanes, S., 2003. Catchability and the spatial distribution of fishing vessels. Can. J. Fish. Aquat. Sci. 60, pp. 259–268.

Sampson, D. B., 1991. Fishing tactic and fish abundance, and their influence on catch rates. ICES J. Mar. Sci. 48, pp. 291-301.

Satia, B. P. and Horemans, B., (Eds.), 1993. Workshop on Conflicts in Coastal Fisheries in West Africa. Cotonou, Benin, 24-26 November 1993. IDAF Project 64p., IDAF/WP/53.

Sauer, W. H. H, Hecht, T., Britz, P. J. and Mather, D., 2003. An Economic and Sectoral Study of the South African Fishing Industry. Volume 2, Fishery profiles. Department of Ichthyology & Fisheries Science and Department of Economics and Economic History. Rhodes University.

Schmidt, J-U., 1977. Fishing fleets of developing Countries. Lecture and contributions No.16. Institute of Shipping Economics. Bremen. Germany

Schrank, W. E., 2003. Introducing fisheries subsidies. FAO Fisheries Technical Paper No. 437. FAO, Rome.

Scott, P., 1951. Inshore fisheries of South Africa. Economic Geography, 27(2), pp. 123-147.

Silvestre, G., Garces, L., Stobutzki, I., Ahmed, M., Valmonte-Santos, R. A., Luna, C., Lachica-Alino, L., Munro, P., Christensen, V. and Pauly, D., 2003. Assessment management and future directions for coastal fisheries in Asian countries. Worldfish Center.

Silvestre, G. and Pauly, D., 1997. Management of tropical coastal fisheries in Asia: an overview of key challenges and opportunities. In: Silvestre, G. and Pauly, D. (Eds.), Status and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc. 53, pp. 8-25.

Solecki, J. J., 1966. Thee economic aspects of the fishing industry in Mainland China. Institute of animal resource ecology laboratory. The University of British Columbia. Vancouver.

Solecki, J. J., 1979. A review of U.S.S.R. fishing industry. Ocean Management, 5, pp. 97-123.

Stump, K. and Batker, D., 1996. Sinking fast-How factory trawlers are destroying U.S fisheries. Greenpeace.

Sumaila, U.R., L. Teh, Watson, R., P. Tyedmers, D. Pauly. 2006. Fuel subsidies to fisheries globally: Magnitude and impacts on resource sustainability. In Sumaila, U.R., Pauly, D. (eds.), Catching more bait: a bottom-up re-estimation of global fisheries subsidies. Fisheries Centre Research Reports 14(6), pp. 38-48. Fisheries Centre, the University of British Columbia, Vancouver, Canada.

Swartz, W. K., 2004. Global Maps of the Growth of Japanese Marine Fisheries and Fish Consumption. Msc. Thesis. The University of British Columbia, Vancouver.

Takayam, S. 1963. Mechanization of Fishing Fleets in Japan. In: Nui, L. B. and Jan-Old Trrmg, J-O. (Eds.), Indo-Pacific fisheries council proceedings. 10th session, Soul Republic of Korea: Section II, Symposium Papers. IPFC secretariat, FAO regional office for Asia and the Far East. Bangkok, pp. 1-117.

Theodore, D., 1993. Conflicts in Coastal Fisheries in Cameroon. In: Satia, B. P. and Horemans, B. (Eds.), Workshop on Conflicts in Coastal Fisheries in West Africa. Cotonou, Benin, 24-26 November 1993. IDAF Project 64p., IDAF/WP/53, pp. 6-12.

Thiele, W., 1999. Global Trends in Fishing Technology and their Effects on fishing Power and Capacity. FAO Regional Workshop on the Effects of Globalization and Deregulation of Marine Capture Fisheries in Asia. Pusan, Republic of Korea.

Thomson, D. B., 1979. South China Sea Fisheries Development and Coordinating Programme Intermediate technology and alternative energy systems for small- scale fisheries. FAO Working Paper. SCS/79/WP/87. FAO, Rome.

Thorpe A., Reid, C., Anrooy, R.V. and Brugere, C., 2004. African Poverty Reduction Strategy Programmes and the Fisheries Sector: Current Situation and Opportunities. African Development Bank. MacAthur program on multilateral governance, Institute of International Studies, UC Berkeley. Blackwell Publishing Ltd., UK.

Thorpe, A. and Bennett, E., 2001. Globalization and the sustainability of world fisheries: a view from Latin America. Mar. Resource Econ. 16, pp. 143-164.

Thorpe, A. and Reid, C., 1999. The New Economic Model and Fisheries Development in Latin America. Conf. Marine Environmental Politics in the 21st Century. The University of California, Berkeley.

Thuoc, P. and Long, N., 1997. Overview of the coastal fisheries of Vietnam, In: Silvestre, G. and Pauly, D. (Eds.), Status and management of tropical coastal fisheries in Asia. ICLARM Conf. Proc. 53, pp. 96-106.

Tietze, U., Prado, J., Le Ry, J.-M., and Lasch, R., 2001. Techno-economic performance of marine capture fisheries and the role of economic incentives, value addition and changes of fleet structure. Findings of a global study and an interregional workshop. FAO Fisheries Technical Paper no. 421. FAO, Rome.

Troadec, J-P., 1983. Practices and prospects for fisheries development and management: The case of Northwest African fisheries. In: Rothschild, B. J. (Ed.), Global fisheries: perspectives for the 1980s. Springer-Verlag New York Inc., pp. 97-122.

Tvedten, I. and Hersoug, B. (Eds.), 1992. Fishing for development: Small-scale fisheries in Africa. Nordiska Afrikainstitutet (The Scandinavian Institute of African studies). Sweden.

Tyedmers, P., Watson, R. and Pauly, D., 2005. Fuelling Global Fishing Fleets Ambio: a Journal of Human Environment, 34, pp. 59-62.

Tyedmers, P., 2001. Energy Consumed by North Atlantic Fisheries. In: Zeller, D., Watson, R. and Pauly, D. (Eds.), Fisheries Impacts on North Atlantic Ecosystems: Catch, effort and national/regional datasets. Fisheries Centre Research Reports, 9(3). The University of British Columbia, Vancouver, pp. 12-34.

Ulltang, Ø., 1980. Factors affecting the reaction of pelagic fish stocks to exploitation and requiring a new approach to assessment and management. Rapp. P.-V. Réun. Cons. Perm. Int. Explor. Mer. 177, pp. 489–504.

UN (United Nations), 2005a. United Nations Atlas of the Ocean: Biological Resources. http://www.oceanatlas.com/

UN (United Nations), 2005b. United Nations Atlas of the Ocean: overcapacity.http://www.oceansatlas.org/servlet/CDSServlet?status=ND0xMzMzNCZjdG5faW5mb192aWV3X3NpemU9Y3RuX2luZm9fdmlld19mdWxsJjY9ZW4mMzM9KiYzNz1rb3M~

UNEP, 2002. Integrated assessment of trade liberalization and trade-related policies: A country study on the fisheries sector in Argentina. United Nations, New York.

Vasconcellos, M., 2000. Ecosystem impacts of fishing forage fishes: An analysis of harvest strategies for the Brazilian sardine. PhD thesis. The University of British Columbia. Vancouver.

Walke, T., 2005. The Most Powerful Diesel Engine in the World!. The University of Bath. http://www.bath.ac.uk/~ccsshb/12cyl/. Accessed July, 6, 2006.

Walters, C. J. and Bonfil, R., 1999. Multispecies spatial Assessment models for the British Columbia groundfish trawl fishery. Can. J. Fish. Aquat. Sci. 56, pp. 601-628.

Walters, C. J. and Martell, S. J. D, 2004. Harvest Management for Aquatic Ecosystems. Princeton University press, Princeton, NJ.

Walters, C. J. and McGuire, J. J., 1996. Lessons for stock assessment from the northern cod collapse. Rev. Fish. Biol. Fisheries, 6, pp. 125-137.

Watson, R., Revenga, C. and Kura, Y. 2006a. Fishing gear associated with global marine catches. Fisheries Research, 79, pp. 97-102.

Watson, R., Revenga, C. and Kura, Y. 2006b. Fishing gear associated with global marine catches: II Trends in trawling and dredging. Fisheries Research, 79, pp. 103-111.

Watson, R., Kitchingman, A., Gelchu, A. and Pauly, D., 2004. Mapping global fisheries: Sharpening our focus. Fish and Fisheries, 5, pp. 168-177.

Watson, R. and Pauly, D. 2001. Systematic distortions in world fisheries catch trends. Nature, 414, pp. 534-536.

Watson, R., Gelchu, A. and Pauly, D., 2001a. Mapping fisheries landings with emphasis on the North Atlantic. In: Zeller, D., Watson, R. and Pauly, D. (Eds.), Fisheries Impacts on North Atlantic Ecosystem: Catch, Effort and National/Regional data sets. Fisheries Centre Research Reports. 9(3). University of British Columbia. Vancouver, pp. 1-11.

Weber, P., 1994. It Comes Down to the Coasts. World Watch, 7(2), pp.20-29.

Weidner, D. and Hall, D., 1993. World Fishing Fleet: An Analysis of Distant-Water Fleet Operations, Past-Present-Future. Vol. 4, Latin America, Silver.

Wilde, J. W., 2001. Effect of subsidies on the distant water and coastal fisheries of the Netherlands (un publ.) Fisheries Division, Agricultural Economics Research Institute LEI-DLO. The Hague, The Netherlands.

Wilen, J. E., Smith, M. D, Lockwood, D. and Botsford, L. W., 2002. Avoiding surprises: incorporating fishermen behavior into management models, Bull. Marine Sci., 70 (2), pp. 553–575.

William, J. H. and Hammer, S., 1998. The Norwegian Fisheries – an unregulated common property resource in transition by the introduction of quotas, closed access and the industry's user right perception. Royal Norwegian Ministry of Fisheries. http://odin.no/fid.engelsk/p10001873/bn.html.

Williams, J. H., 2005. Broad agreement on fisheries between Norway and the EU. http://odin.dep.no/fkd/english/news/news/047041-070091/dok-bn.html. Accessed June 2006.

Wilson, J. D. K., 1999. Fuel and financial savings for operators of small fishing vessels. FAO Fisheries Technical Paper 383. FAO, Rome.

Worldfish, 2006. Advancing international cooperation for sustainable fishing, improved livelihoods and fair trade policies. http://www.worldfishcenter.org/tjtan_1.htm

Xianshi, J., 2000. Marine Fishery Resources and Management in China. Paper presented at ICFO Seminar in, 25 – 29 October 2000. Qingdao, China. http://www.lib.noaa.gov/china/marineresource.html.

Zhong, Y. and Power, G., 1997. Fisheries in China: Progress, problems, and prospects. Can. J. Fish. Sci. 54, pp. 224-238.