ISSN 1198-6727

Information Supporting Past and Present Ecosystem Models of Northern British Columbia and the Newfoundland Shelf

Fisheries Centre Research Reports
2002 Volume 10 Number 1

ISSN 1198-6727

Fisheries Centre Research Reports

2002 Volume 10 Number 1

Information Supporting Past and Present Ecosystem Models of Northern British Columbia and the Newfoundland Shelf

Fisheries Centre, University of British Columbia, Canada

edited by

*Tony Pitcher, Marcelo Vasconcellos, Sheila Heymans,
Claire Brignall and Nigel Haggan*

116 pages © published by

The Fisheries Centre, University of British Columbia

*2204 Main Mall
Vancouver, B.C., Canada
2002*

ISSN 1198-6727

INFORMATION SUPPORTING PAST AND PRESENT ECOSYSTEM MODELS OF NORTHERN BRITISH COLUMBIA AND THE NEWFOUNDLAND SHELF

Edited by

Tony Pitcher, Marcello Vasconcellos, Sheila Heymans, Claire Brignall and Nigel Haggan

2002

Fisheries Centre Research Reports 10(1), 116 pp

CONTENTS

Canada's West Coast

Reprinted with corrections May 2002

A Research Report from

'Back to the Future: the Restoration of Past Ecosystems as Policy Goals for Fisheries'

Supported by the Coasts Under Stress 'Arm 2' Project

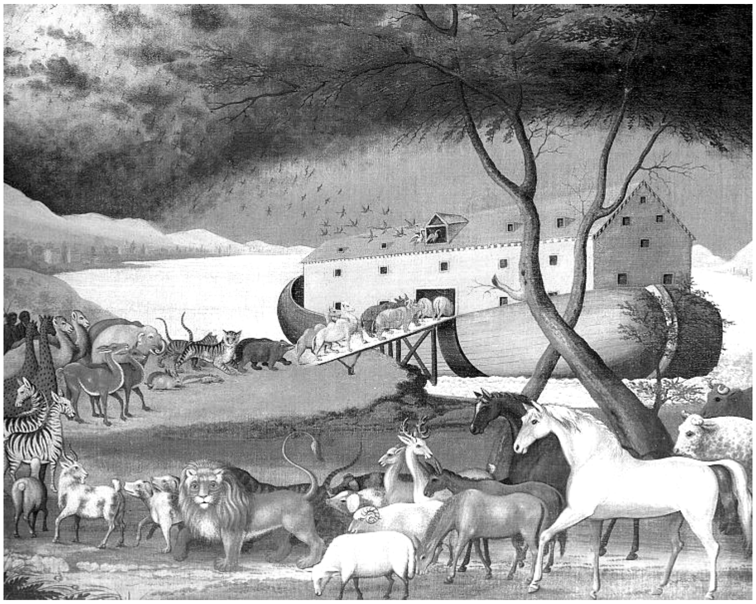
A Major Collaborative Research Initiative of the Canadian Government

FISHERIES CENTRE RESEARCH REPORTS ARE ABSTRACTED IN THE FAO AQUATIC SCIENCES AND FISHERIES ABSTRACTS (ASFA)

Director's Foreword

Back to the Future in Noah's Ark

The story of Noah's ark shows the benefits of early warning, preparedness, coordinated planning, and a concern to make sure that no species of animal is missed. The science workshops of the *Back to the Future* policy process have exactly congruent aims. This report presents material gathered in science workshops held in support of a *Back to the Future* project comparing the Newfoundland shelf with northern British Columbia, and sponsored by a Major Collaborative Research Initiative (MCRI) of the Canadian government, *Coasts under Stress*.



Noah's Ark by the American artist Edward Hicks (1780-1849). *1846, oil on canvas, Philadelphia Museum of Art.*

In short, *Back to the Future* aims to use restored past ecosystems as policy goals for future fisheries and fishing communities. Ecosystem simulations are employed for the model reconstruction of what the past was like in relation to the present. Table 1 explains the stages in the *Back to the Future* policy process. An essential element is to have Ecosystem models that are informed by the best data available, taking advantage of the knowledge and insight of experts on each kind of

Table 1. Stages in the 'Back to the Future' policy process. Modified from Pitcher *et al.* (2002) and Pitcher (1998).

Stage	Goals	Steps
1	Model construction of present and past aquatic ecosystems	Assemble present-day mass-balance model Assemble preliminary past models using compatible structure and parameters Search data archives Search historical documents Search archeological information Science workshops to receive expert comments Interviews for traditional environmental knowledge Interview for fisher's behaviour Assemble and standardize database Standardize methodology for using material Assemble and test suite of ecosystem models
2	Evaluation of economic and social benefits that could be gained from each system	Determine fisheries with which to exploit reconstructed ecosystems. ('Opening the lost valley') Ecosystem simulation scenarios.
3	Choice of system that maximises benefits to society	Identify trade-offs among economic, ecological and social criteria. Policy searches for optimal mix of fishing gears. Ecological economics evaluations. Participatory policy choice.
4	Design of instruments to achieve this policy goal	Model exploration of MPAs, effort controls, acceptable quotas, times and places for fishing.
5	Participatory choice of instruments	Evaluation of costs of these management measures. Participatory instruments choice.
6	Adaptive implementation and monitoring of management measures	On-going monitoring, validation and improvement of model forecasts using adaptive management procedures. On-going participatory guidance on instruments and policy goals.

organism.

Science workshops, and their subsequent reports, where this material is presented and discussed, are therefore an essential part of the Back to the Future process. Noah himself would likely be happy that the workshops aim to ensure that no animals are missed out in the ecosystem simulation models!

This report supports stage 1 in Table 1. Subsequent reports will document later stages in the process for Northern British Columbia and Newfoundland.

The flood myth itself probably derives from the sudden flooding of the Black Sea basin from the Mediterranean in 7600 BP (Ryan & Pitman 1999). But the well-prepared Noah himself may have been a clever Sumerian. There is archaeological evidence of a flood of the River Euphrates in about 4900 BP. The historical Noah is thought to have been the king of the riverside city of Shuruppak, who saved the city's domestic animals in a river barge and, after all this drama, set up an alter to give thanks. In fact, the invoice for the arks construction has been found and translated (Best 1999) and there are documents supporting the whole story, which eventually got rolled into the Gilgamesh epic and thence into many middle eastern religious fables, where it got mixed up with memories of the older gigantic flood.

So – I hear the sceptics ask - were there fish in Noahs' Ark? At first sight, you don't need aquarium tanks to save fish when you are surrounded by lots of new sea or a river flood. But you would need to be prepared enough to have tanks to save fish of the wrong salinity! Likewise, as set out in this report, modellers of past ecosystems have to be prepared enough to include species gone locally extinct like sea otters in northern British Columbia or walruses in Newfoundland.

The Fisheries Centre Research Reports series publishes results of research work carried out, or workshops held, at the UBC Fisheries Centre. The series focusses on multidisciplinary problems in fisheries management, and aims to provide a synoptic overview of the foundations, themes and prospects of current research.

Fisheries Centre Research Reports are distributed to appropriate workshop participants or project partners, and are recorded in the Aquatic Sciences and Fisheries Abstracts. A full list appears on the Fisheries Centre's Web site, www.fisheries.ubc.ca. Copies are available on request for a modest cost-recovery charge.

Tony J. Pitcher
Professor of Fisheries
Director, UBC Fisheries Centre

Literature Cited

Pitcher, T.J. (1998) 'Back To The Future': a Novel Methodology and Policy Goal in Fisheries. Pages 4-7 in Pauly, D., Pitcher, T.J. and Preikshot, D. (eds) Back to the Future: Reconstructing the Strait of Georgia Ecosystem. Fisheries Centre Research Reports 6(5): 99pp.

Pitcher, T.J., Heymans, S.J.J., Ainsworth, C., Buchary, E.A., Sumaila, U.R. and Christensen, V. (2002) Opening The Lost Valley: Implementing A 'Back To Future' Restoration Policy For Marine Ecosystems and Their Fisheries. (*in press*).

Ryan, W.B.F. and Pitman, W. (1999) Noah's Flood : The New Scientific Discoveries About the Event That Changed History. Simon & Schuster, New York. 319 pp.

Best, R.M. (1999) Noah's Ark and the Ziusudra Epic: Sumerian Origins of the Flood Myth. Eisenbrauns. 304 pp.

EXECUTIVE SUMMARY

This 116-page report presents information on the organisms, gathered into functional trophic groups, that form the basis of ecosystem models of the Newfoundland Shelf and Northern British Columbia. The information derives from reviews of the literature, from 12 papers submitted to the report, and from discussions at two science workshops, one on each coast, held in September 2000 and each attended by about 18 scientists, including experts on particular groups of organisms. In addition to the present day, information on what these ecosystems were like at various times in the past is also presented. For Newfoundland, work is focused on 1450, representing a time prior to contact of native peoples with European settlers, 1900, 1950 and the present day. For northern British Columbia, the equivalent time periods are 1750, 1900, 1950 and the present. Papers discuss the choice of these times in relation to major shifts in the exploitation of these marine ecosystems.

The report contains workshop notes on 24 functional groups in Newfoundland (baleen whales, porpoises, harp seals, hooded seals, seabirds, cod, Greenland halibut, American plaice, flounder, skate, redfish, capelin, arctic cod, sandlance, large and small demersals, large pelagics, small piscivororous pelagics, small planktivorous fish, shrimp, large crustaceans, benthic invertebrates, zooplankton, phyto-plankton and kelp), while 18 functional groups are covered for northern BC (baleen whales, toothed whales, sea otters, seals, sealions, seabirds, dogfish, Pacific salmon, halibut, Pacific cod, groundfish, flatfish, Pacific herring, eulachon, invertebrates, sponge reefs and macrophytes). Papers discuss data availability at DFO, the historical reconstruction of seabird populations in Newfoundland, histories of the BC whales and the BC trawl fishery and the use of traditional knowledge.

Preliminary model structures and parameters are discussed for each site and time period in relation to previous models of these areas. A web site where current versions of the ecosystem models is provided.

The material in this report will be used in the construction of ecosystem simulation models for each of the time periods past and present as part of a Back to the Future project, in which past ecosystem states are used as policy goals for future reconstruction of fisheries and marine ecosystems.

INTRODUCTION

Tony Pitcher
UBC Fisheries Centre

Structure of the Report

The Back to the Future approach relies on the use of ecosystem models and multiple sources of information from scientists and local resource users to construct mass-balance models of an ecosystem of interest at different time periods. One of the goals of BTF is to allow the explicit qualitative and quantitative comparison of ecosystem states, which in turn can be used to examine fisheries policy goals and strategies for rebuilding ecosystems. This report documents the first steps in the development of the " Back to the Future: Reconstructing past East and West Coast Ecosystems of Canada" project, an integral part of the major collaborative research initiative 'Coasts Under Stress'. The objectives of this report were: 1) to review the history of marine resource exploitation in Canada's west and east coast, which provide the basis for choosing historical reference points for reconstructing ecosystem models; 2) to compile available information and models of marine ecosystems in both coasts, and 3) from these models and with the input of marine resources scientists and experts, produce preliminary models representing ecosystem states at historical reference points. The iteration with scientists and experts was carried out in part during *science workshops* held in Vancouver, BC and in St. John's, N.F. in September 2000. Contributors have also added material gathered after the workshops.

This report is structured in two parts, one dedicated to each coast. Each part is divided in sections describing i) the boundaries of the ecosystem of interest, ii) the historical reference points of marine resources exploitation, iii) the available ecosystem models, iv) the discussions and inputs from scientists obtained during the science workshop; and v) preliminary models of present and past ecosystem states.

CANADA'S EAST COAST

SYSTEM BOUNDARIES FOR EAST COAST ECOSYSTEM MODELS

Marcelo Vasconcellos and Sheila Heymans
UBC Fisheries Centre

The 'Back to the Future' case study area for the Canada's east coast comprises the southern third of the Labrador shelf and the northeast shelf of Newfoundland, from the coast to 1,000m depth, encompassing a total area of approximately 368,000 km² (Figure 1). The study area was delimited by NAFO fisheries statistics division 2J3KL. The choice for these divisions was based on a compromise that aimed to represent areas with similar oceanic and physiographic characteristics, and areas that at the same time would delimit the boundaries of major fish stocks (Bundy *et al.*, 2000). [*Since the time of writing the East coast study area has been broadened to include the Grand Banks. Eds.*]

The study area is located within the Atlantic coastal biome, in the northern limit of Northwest Atlantic Shelves province (Longhurst, 1998). This province is defined by Longhurst (1998) as the continental shelf and slope water from Florida to the Grand Banks of Newfoundland. Water circulation on the shelf is conditioned by the Labrador Current, which transports low salinity, Arctic water south along the continental shelf and slope of Labrador. The inshore component of the Labrador Current flows along the Avalon channel off the east coast of Newfoundland and contributes to the formation of shelf waters on the Grand Banks. The region also receives influence of the discharge of the St. Laurence River, which reaches the study area by a surface flow from Cabot Strait. The oceanographic setting makes this area one of the most productive regions of the ocean, in terms of both primary production and fisheries potential.

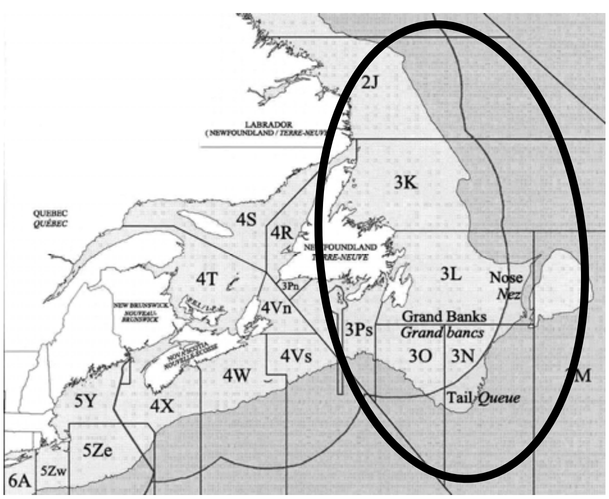


Figure 1. Canada's east coast EEZ boundary, statistical areas, the 100 metre depth contour and approximate boundary of the model area.

References

Bundy, A., Lilly, G.R., and Shelton, P.A. (2000) A mass balance model of the Newfoundland-Labrador Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 2310: xiv + 157 pp.

Longhurst, A. (1998) Ecological geography of the sea. Academic Press. 398 pp.

HISTORICAL REFERENCE POINTS FOR MODELS OF PAST ECOSYSTEMS IN NEWFOUNDLAND

Marcelo Vasconcellos, Sheila Heymans and Tony J. Pitcher
UBC Fisheries Centre

In the *Back to the Future* process, the choice of time periods at which to attempt to construct past models as 'snapshots' of a marine ecosystem aims to capture changes caused by major shifts in its embedded fisheries. Changes wrought by environmental causes can be simulated by driving such models with suitable factors. This paper briefly examines the history of the Newfoundland shelf area in order to determine suitable times for the model 'snapshots'.

This brief description of the development of fisheries in the east coast is based mainly on the review work of the cod fishery conducted by Hutchings and Myers (1995), and on Mowat's (1996) book on the history of marine resources exploitation in the North Atlantic.

16th Century

Since the voyages of John Cabot (in 1497) and Gaspar Corte-Réal (in 1500) there are records of the presence of fishers from France and England in 1504, from Portugal as early as 1506, and by Basques from 1520s. These were shore based fisheries, where cod was harvested from nearshore waters and subsequently dried split directly on pebble beaches or on shore-based, wooden stages by a combination of sun, salt and wind. England's participation in the fishery increased particularly after the mid 16th century, while the Portuguese and Spanish fisheries decreased in participation towards the end of 1500s. The number of English vessels fishing for cod off Newfoundland increased from 11 to 150 during the period of 1550 to 1600.

Whales were apparently so abundant by the time of European contact that 16th century mariners considered them the worst risk for navigation in that region. The waters of the northwest Atlantic were so abundant with whales and other marine mammals that some early Europeans referred to the region as the Sea of Whales.

The black right whale was targeted by Basque ships probably before 1500. Black right whales were so abundant during the first half of the 16th century that whaling was limited only by the processing capacity of the plants. There were approximately forty to fifty whaling stations around the Sea of Whales at the peak of the Basque fishery. The combined Basque fleet in the 16th century ranged between 40 and 120 vessels in any given year. Mowat's (1996) conservative estimate for whales killed during 1515-1560 is at least 2,500 annually.

In the late 16th century the demand for oil had become insatiable and train oil was sold at a premium price. By that time most commercial oil was made from animal fats, including seals, walrus, whales and seabirds, and oil derived from sea animals was generically known as *trayne*, or train oil. During the mid-1500s most of the train oil that was extracted was used as fuel for lamps, sources for lubricants, leather and jute processing, while cooking oil came from right whales harvested in the Newfoundland, Labrador and the Gulf of St. Laurence.

Baleen extracted from the black right whale was used to make plumes for military helmets, clothing supports, stuffing for upholstery and mattresses, bristles for brushes, knife handles, horn spoons and springs to power mechanical toys and scientific instruments. Catches were so large that by 1570 the population of black right whales had been reduced to small numbers. Between the late 1500s and early 1600s the Spanish Basque whaling in the New World subsided because of an armed conflicted with England as well as because of the discovery of better whaling grounds around Spitzbergen. Whaling subsequently gained importance in New England, where the main targets were initially both gray- and right whales.

Natives and early Europeans settlers targeted many species of seabirds along the coast of Newfoundland as sources of food, bait, oil and feathers for upholstery.

One of the species most affected was the spear-bill, spear bird or great auk. The great auk was the last flightless seabird of the northern hemisphere, and the original species name was 'penguin'. The name has many possible origins such as white [*pen*] head [*gwyn*] in Welsh, and *penquis,* which is Latin for fat (Montevecchi and Kirk, 1996). The name was much later also applied for a very similar but unrelated species in the southern hemisphere. Great auks were characterized by large body sizes (about 5 kg), diminutive wings and the ability to dive deeper than other species (Montevecchi and Kirk, 1996). The species was part of the aboriginal diet on the east coast of Canada – they provided fresh eggs, fat, and smoked meat for consumption throughout the year. Native harvest of spear-bills remained at a small scale, which was sustainable for thousands of years before European arrival. The species was distributed in a few breeding colonies, the largest one in Funk Islands, along the east coast of Newfoundland. Other smaller colonies were also found in the Gulf of St. Laurence.

The importance of seabird rockeries to seamen was enormous. Apart from fish, the most convenient food source during the fishing season was taken from the bird colonies. Spear-bills (= Great Auk) were the favorite target because of their great size and easy capture. During the 16th century Basque fishermen in Newfoundland waters probably took as much as 600 tonnes, or thousands of spear-bills. Because of their size and fat content spear-bills were the prime targets for train oil production. Seabirds were also utilized as bait during temporary shortage of other traditional bait species such as herring, capelin and mackerel. The use of seabirds for bait probably started as soon as Europeans began exploiting the area. The number of fishing boats (many of them using birds as bait) in the area rose drastically, from 300 in 1580 to more than 540 in mid-1700s, and several hundred in 1830.

The great auk was not the only seabird species targeted by Europeans. Mowat (1996) provide accounts of the exploitation of many other species, including gannets, murres, razorbills, and cormorants:

> *By 1833 the colony of Northern gannet in Bird Rock in the Gulf of St. Laurence is believed to have numbered over 100,000 individuals. Many of such rookeries apparently existed when Europeans first appeared. By the mid-1800s only nine rookeries existed in all of North America. By 1973 the six*

remaining colonies amounted to a total of 32,700 adult birds. By 1983 there had been a further decrease in the Gulf population of about 10%"

The cormorants remained very abundant until the seventeenth century probably because Europeans considered their rank and oil flesh unfit for food. The birds started declining when they became an important bait for the cod fisheries. By the beginning of the 20th century, as many fish stocks had visibly declined, fishermen concluded that cormorants were among the main culprits. This led to deliberate kills of adults, chicks and eggs in the rookeries. The campaign against the cormorants had been so successful that, by 1940, fewer than 3,000 great cormorants existed in Canadian waters. Cormorants received the protection status after WWII, so some recovery might be expected.

Terns were not directly targeted by humans until the mid-1800s when their colonies were decimated by feather hunters – terns wings, tails, and sometimes the entire skins were used to embellish women's hats. As a result, terns became comparatively rare. The decreasing abundance of terns can be also linked to human occupation and degradation of nesting sites, and toxic chemical poisoning.

Auks, guillemots, murres and puffins are among the species that have suffered most from human intervention. Razorbills in Atlantic Canada decreased from over a million birds to 15,000 pairs remaining in fifty-seven Canadian sites. Colonies of the common murre, which once numbered over 200 sites in the Gulfs of Maine and St. Laurence and along the coast of the Canadian Maritime Provinces, is now found at only 26 sites in the northern part of the Gulf of St. Laurence, Newfoundland, southern Labrador, and Bay of Fundy. Puffins once numbered several million birds. Now, ca. 70% of the total North American population are concentrated in three islands in Witless Bay in southeastern Newfoundland. Puffin colonies were destroyed by the introduction of alien animals, such as cats, dogs, sheep, hogs and cattle.

17th Century

The French and English shared control over Newfoundland cod fisheries throughout the 17th century. The English fishery expanded from 150 ships in 1600 to as many as 300 ships in 1620. English trade declined after 1624 because of wars (Spain and France) and pirates, when many vessels were lost. An important consequence of these events was the rise of permanent residents (planters) on land. Catches by planters increased from zero to 37 % of the English fishing ships between 1610 and 1675.

18th Century

Wars, and the loss of habitation rights in the south coast by the French (Treaty of Utrecht, 1713), contributed to significant changes in spatial allocation of effort by the French fleet. Prior to 1713 the shore-based fishery was larger than the bank fishery. From 1713 to 1750 the bank fishery increased in size to a level similar to the shore fishery. French fisheries were negatively impacted during the three major wars of the century: the Austrian Succession (1742-1748), the Seven Years' War (1756-1763), and the American War of Independence (1776-1783). During war years practically no French ship was involved in either shore based or bank fisheries. This century also marked the expansion of the British/Newfoundland fisheries to offshore fishing grounds and to shore areas westward and northward. This was in part due to signs of declining catch rates in the traditional fishing grounds. Although there was an expansion of the offshore fishery, shore-based fisheries still comprised the bulk of Newfoundland catches.

With the demise of gray and right whales by the early 1700s, whalers started targeting sperm whales. Spermaceti was extremely valuable and ultra-fine lubricating oil. Sperm whales were also sought after for the ambergris, a precious medicinal and chemical substance used specially as a base for perfume. By 1765 as many as 120 New England whaling vessels were fishing in the Strait of Belle Isle, the Grand Banks, and the Gulf of St. Laurence. By this time most of the whales killed were humpbacks, some were sperms and some black right whales.

By the latter part of the 18th century most of the preferred whale species (gray, black right, bowhead) were extirpated from the Northwest Atlantic. The remaining whales were not desirable, because they were faster moving and difficult to kill. They were difficult to recover after being killed because unlike the preferred species they would sink, and had low oil content. The Blue whale was considered among the least desirable.

With increased availability of guns and powder in the early 18th century, seabird kills took on a new dimension, as adult birds were shot during their migration to and from colonies. By the beginning of the 18th century the rapid growth of the population along the Atlantic coast also created an increasing commercial market for products such as seabird eggs. During the latter part of the 18th century seabird colonies started being exploited for feathers and down used in bedding and upholstery. By 1802 the last spear-bill (= Great Auk) colony in North America (in the Funk islands) had been destroyed and the species became extinct a couple of decades later.

19th Century

The 19th century saw decreased participation of British ships in the cod fishery, while the Newfoundland fishery became largely a resident fishery. Signing of the Treaty of Paris in 1814 gave back France's rights to base a shore fishery from Cape St. John to Cape Ray. The restoration of French fisheries led to an expansion of the Labrador fishery, which increased substantially between 1814 and 1829. The importance of the Labrador fisheries to the total Newfoundland catches increased from ca. 20% to 50% between 1820s to early 1900s.

By the beginning of the 19th century no more than a few thousand black right whales remained in the North Atlantic. A group of 100, which concentrated during the summer in southern Newfoundland, were discovered in the 1820s by Newfoundland and American whalers – the last one was probably killed in 1850. Not one right whale was exported from the Gulf, Newfoundland and Labrador waters for 100 years. The black right whale was practically exterminated from the North Atlantic by the early 1900s.

20th Century until 1954

During the first half of the 20th century, inshore fisheries were the dominant fisheries for northern cod. Newfoundland and France accounted for over 90% of total catches (Canada, US, Portugal and Spain were fishing offshore during most of that period). Confederation of Newfoundland with Canada occurred only in 1949.

Hutchings and Myers (1995) reconstructed temporal changes in harvest rates, based on an assumption that the harvestable biomass prior to 1960 was 3,000,000, which is the highest biomass determined by VPA. They suggested that fishing mortality did not exceed the presumed sustainable rate of 0.18 $year^{-1}$ until the late 1950s/early 1960s. From the late 1960s to the early 1990s more than 50% of the estimated harvestable biomass was landed each year.

20th Century after 1954

The introduction of diesel powered groundfish trawlers to the Newfoundland offshore fisheries had many implications for fishers, coastal communities and the ecosystem. As described by Andersen (1998),

> *.. work regimes, roles, skill and marine ecological knowledge requirements, incomes and personal lives ashore were changed. There was a quantum leap in fishing range, effectiveness, catch sale and reliability, and two-way radio transmitters enabled close coordination of their target species, and catches and landings with plant requirements. The ecological range of the fishery expanded and the industry exclusive focus on cod also expanded to include species such as haddock, redfish and flounder. Trawler skippers had to learn to fish new species and grounds, at depths they had not fished before. And the competition for fish on offshore banks increased.*

Andersen (1998) also noted the large quantities of discards in offshore fisheries, and the early days of fisheries science.

> *Groundfish trawling destroyed extraordinary quantities of undersized haddock. Government fishery science enters his (Capt. Arch Thornhill) account of the fishery for the first time. In response to Arch's concern about their future, an unidentified scientist tells him the ocean's fish stocks were inexhaustible, a view widely held by scientists then.*

Regarding changes in working conditions, Andersen (1998) noted

> *despite improved earnings and work conditions, the intensive work regime weighted heavily on the men and their families. Dragger fishing was pursued through all seasons of the year, trip after trip, with but a few hours turn-around time, and without scheduled holiday leave time. And few if any insurance or other benefits were provided despite the work's hazards.*

Hutchings and Myers (1995) found that the second half of the 20th century marked the most volatile period in the Newfoundland fishery in terms of harvests, spatial, and temporal variation in effort, technological advances in fishing equipment, and competition among fishing nations. Twenty different countries were involved in the northern cod fishery between 1954 and (1990) Canada dominated the catches from 1954 to 1960, due to the proximity to fishing grounds and the constrains on the storage capacity and harvesting ability of other nation's offshore side trawlers, pair trawlers and dory schooners. Canada dominated the catches again after the extension of EEZ jurisdiction to 200 miles in 1977.

The introduction of factory freezer stern trawlers was the single most important event in the 500-year history of the northern cod fishery according to Hutchings and Myers (1995). The first vessel (British, 8,000 GRT) appeared in 1954, and was followed by Soviet and West German trawlers.

For the first time, in 1959 offshore catches exceeded inshore catches. Between the mid-1950s and the late 1960s the total catch of northern cod tripled, reaching a historic maximum of 810,000 tonnes in 1968. Meanwhile, inshore catches declined by two thirds from 1954 to 1977, dropping from an average catch of about 156,000 tonnes to 50,334 tonnes.

A Total Allowable Catch (TAC) was first established for Northern cod by the International Commission on the Northwest Atlantic Fisheries (ICNAF) in 1973. The catch quota was based n a management strategy of fishing at MSY, i.e. F=0.35 $year^{-1}$. The harvest rate was reduced to 0.18 $year^{-1}$ in 1977. It is argued that although this reference point was sound, the means of assessing stock abundance and total fishing mortality were not. A moratorium was imposed in 1992, after the collapse of the cod fishery. As noted by Hutchings and Myers (1995), the collapse of the cod fishery represented the cumulative effect of diverse factors including temporal and spatial changes in fishing effort; increased harvesting efficiency, unachieved management objectives, errors in stock assessment, overly ambitious economic policy and industrial greed.

Hutchings and Myers (1995) also point at important changes in gear technology that increased harvest efficiency in the offshore and inshore fisheries. In terms of changes in fishing vessel characteristics they emphasize: 1) the replacement of heavy *chaloupes* (or shallops) with light dories in the bank line trawl fishery of the 1790s; 2) the gradual change in the 20th century from vessels powered by sail to vessels powered by steam and diesel; 3) the increase in vessel tonnage, from 50 to 70 GRT in the 16th century fishery to the 2,000 to 8,000 GRT of the factory freezer trawlers. In terms of fishing gear changes they noted: 1) the replacement of the single-hook hand line with multi-hooked line trawls in the bank fisheries during 1790s; 2) the introduction of side-hauled otter trawls in the 1890s; 3) stern-hauled otter trawls in 1954; and 3) nylon gill nets in 1962. Changes in technology were so remarkable that

> *.. the estimated 90 to 100 tonnes caught annually by French fishing ships in the 1500s could be harvested in two thirty-minute tows by a factory trawler of the 1960s.*

Changes in harvest technology were also observed in the inshore fisheries.

Species other than cod became commercially important and intensively harvested mainly after the mid-1900s. At first haddock was incidentally caught as bycatch in the cod fisheries. By 1952 40,000 tonnes of haddock was being caught per year, initially by Portuguese and Spanish draggers. The mesh used was so small that large quantities of juvenile individuals were discarded. In 1955 ca. 104,000 tonnes of haddock were landed from fisheries working on the Grand Banks. By 1961 the draggers were only able to catch 79,000 tonnes. The fishery subsequently collapsed and was abandoned by 1969. By 1984 haddock was still commercially extinct in Newfoundland/Grand Banks waters.

Redfish was hardly fished prior to 1953. By 1956 ca. 77,000 tonnes were being landed from fisheries in the offshore Banks. Redfish was marketed as ocean perch and multinational fisheries targeted it so heavily that up to 330,000 tonnes were landed in 1959. Subsequent to that yield steadily declined to 82,000 tonnes in 1962. The introduction of new types of mid-water trawls accelerated the rate of depletion to the point that, by the early 1970s almost all the larger and reproductively active redfish population had been depleted, the remaining population only contributed marginally to the commercial fishery.

Practically all species of flatfish have been intensively over-fished since 1962 – prior to this date they were virtually ignored by commercial fisheries. Halibut, which could measure up to 9 feet in length and weight close to 1,000 pounds, were of peripheral interest to the commercial fisheries. Earlier halibut was considered a nuisance because they would take cod bait and waste the time and break the gear of cod fishermen. Prior to 1960 few halibut were landed by inshore fishermen from Newfoundland waters and sold pickled or salted. Catches began at about 220 tonnes in 1964 and leapt to ca. 40,000 tonnes by 1970. Since then the catches declined to the point where halibut become a rarity.

The many species of smaller flatfish had no commercial value and were fished only for cod and lobster bait prior to the development of mass-freezing techniques after the WWII. By 1962 the total catch of all species was under 33,000 tonnes, most of which taken as bycatch. Plaice, yellowtail and witch flounder were the first to become exploitable species, with catches of up to 154,000 tonnes in 1966. Since then the fishery experienced a catastrophic decline.

Herring, mackerel and capelin were still very abundant until the 1960s. The depletion of these stocks began with the demand for fishmeal for animal feed and fertilizer. Herring was the species targeted for this purpose. With the collapse of the herring reduction fishery on the west coast, purse seiners were brought to the east coast. The first reduction plant in Newfoundland was built 1965. A British Columbian seiner that sailed from the west coast through the Panama Canal to Newfoundland conducted test fishing. By 1969, fifty of the biggest modern BC seiners were working year round on the south and west coast of Newfoundland and six reduction plants were operating in the region. Herring landings rapidly increased from less than 4,000 tonnes a year to 140,000 tonnes. In the early 1970s herring started disappearing and recovered the biomass once present in the area.

During the 1960s a large fishery for mackerel began operating in the east coast to produce oil, fertilizer, and animal feed. By the mid 1970s mackerel stocks faded away in Canadian and New England waters. In the 1960s Japanese seiners began exploiting capelin on the Grand Banks. Until then, capelin was only exploited by inshore fisheries, with catches of less than 10,000 tonnes a year. By the 1960s the fishery was converted into an international offshore fishery, for both human consumption and reduction. In 1976 landings reached 370,000 tonnes, and by 1978 the stock was exhausted.

The earliest records of the abundance of North American Atlantic salmon is contained in the account of Leif Ericson's voyage in 995. He observed that there was no shortage of salmon on the coast of Newfoundland and these were larger salmon than they had ever seen. At the time of the European invasion probably at least 3,000 salmon rivers provided several hundreds of thousands of spawning beds for an overall Atlantic salmon population that may have outnumbered that of several salmon species found on the Pacific coast.

The turn of the last century marked the beginning of the end for the Atlantic salmon. The causes of this decline is myriad and include the dumping of chemical, metallurgical and other industrial waste into spawning rivers, lost of rivers due to inadequate land use, and overfishing. After the discovery of wintering sites in Baffin Bay area, modern deep-sea seiners and drift net fisheries targeted salmon. Decreases of salmon abundance in the order of 87% were reported for key rivers between the mid-1960s and mid-1980s.

Sea sturgeon was abundant at time of European contact. They were initially exploited for the European market, and were also staple food for fishers, early settlers and native inhabitants. Although the slaughter of all three species had been heavy until the early 19th century, their abundance and fecundity made them among the most common fishes on the Atlantic seaboard until 1859, when it was discovered that their eggs could be converted in caviar as good as the Russian's. At the same time a major market for industrial isinglass developed, while the flesh was in increasing demand. By 1920s the species was already rare in the east coast.

Prior to 1939 only small blue-fin tuna stock were fished commercially in North American waters. The large tunas were hardly fished, only by wealthy people who could afford to charter big boats. By the 1950s canned tuna meat was popularized as food for human consumption and as pet food. Fishing effort rapidly increased. From the 1950s Japan offered the most lucrative market for tuna, and with the introduction of quick freezing and deep-sea freezer/fishing vessels, launched themselves into the fishery.

More recent impacts to seabirds include entanglement in drift-net fisheries, oils spills, oceanic pollution by poisonous chemical wastes, including pesticides, and starvation indirectly caused by overfishing. On the other hand many species of sea gulls seem to have benefited from recent human activities. They showed a remarkable comeback from the centuries-long decline during which their eggs were taken in enormous quantities for human consumption. Their recovery can be linked to the increasing availability of food in the form of wastes from fisheries activities (discards, offal) and from urban garbage.

Reference points for the reconstructed ecosystem models

Based on this review of the development of fisheries on the east coast, and on previous modeling work in the region (Bundy *et al.*, 2000), the following historical reference points are suggested for the reconstruction of ecosystem models:

a) The present day;
b) 1985-1987: Bundy *et al.* (2000) chose this period because it represented a time of relatively constant biomass for the major fisheries stocks prior to their overall decline during the late 1980s and early 1990s. Other reasons were the availability of data and climatic considerations (e.g. avoiding the very cold regime of 1983-1984);
c) The mid-1900s, when major changes occurred in Newfoundland fisheries, including the introduction of factory freezer stern trawlers;

d) The early 1900s; and
e) The mid 1400s, or prior to contact of native peoples with Europeans.

References

Andersen, R. (1998) Voyage to the Grand Banks. The saga of Captain Arch Thornhill. Creative Publishers, St. John's. 351 pp.

Bundy, A., Lilly, G.R., and Shelton, P.A. (2000) A mass balance model of the Newfoundland-Labrador Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 2310: xiv + 157 pp.

Hutchings, J. A. and R. A. Myers (1995) The biological collapse of Atlantic cod off Newfoundland and Labrador: an exploration of historical changes in exploitation, harvesting technology, and management. Pages 37 - 93 in R. Arnason and L. Felt (Eds) The North Atlantic Fisheries: Successes, Failures, and Challenges. Institute of Island Studies, Charlottetown, Canada. 317 pp.

Montevecchi, W. A.and D. A. Kirk. (1996) The Great Auk. In The Birds of North America. No. 260 (www.birdsofna.org).

Mowat, F. (1996) Sea of Slaughter. Chapters Publishing. Shelburne, Vermont, USA. 446 pp.

ADAPTATION OF A NEWFOUNDLAND-LABRADOR ECOPATH MODEL FOR 1985-1987 IN STATISTICAL AREA 2J3KLNO TO THE AREA 2J3KL

Alida Bundy
Marine Fish Division, DFO Dartmouth

This paper describes the adaptation of an Ecopath model for NAFO Divisions 2J3KL from the larger 2J3KLNO model developed in Bundy et al (2000).

The area of 2J3KL is 367 542 km², and it extends from the shore to 1000 m. The data required for the 2J3KL model were based on the data used in the final balanced 2J3KLNO model (Model 3). The details for each group are given below. In the balanced 2J3KLNO model, the model estimated the biomass of several groups since the estimated input biomass was too low. In the 2J3KL model, these biomasses were first estimated from the empirical data. During the balancing of the model, some biomass was re-estimated by the model in order to balance the model. The input parameters and model estimates for the balanced model are given in Table 24.

Whales

The biomass estimate of whales for the 2J3KLNO area was very approximate, based on estimates from various sources, years and areas. The estimate for 2J3KL is as approximate. Humpback and pilot whales were reduced by 60 % on the assumption that 60 % occurred on the southern Grand Banks in 3NO. The other whales were reduced by 40 %. The total biomass of whales was estimated as 74,704 t. The P/B ratio remained the same and the Q/B and diets were re-estimated based on the new proportions of whales in the whale group. Table 1 contrasts the parameters that have been changed. Diet information is given in Tables 25 and 26.

Table 1. Comparison of whale input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Biomass (t)	124, 421	53, 625
Biomass ($t \cdot km^{-2}$)	0.251	0.146
P/B (yr^{-1})	0.1	0.1
Q/B (yr^{-1})	11.79	11.742

Harp Seals

Harp seal, *Phoca groenlandica*, southerly distribution is approximately limited to 2J3KL. It was thus assumed that the parameters derived for the 2J3KLNO model were appropriate for the 2J3KL model (Table 2). The new biomass density is 0.248 $t \cdot km^{-2}$ (cf., 0.184 $t \cdot km^{-2}$ for the 2J3KLNO model). The diet was altered, for in the 2J3KLNO diet an unidentified Pleuronectidae group was classified as flounders. Here, it was distributed over all Pleuronectidae that occurred in the diet, that is, Greenland halibut, American plaice and flounders (see Tables 22 and 23 to contrast resulting diets).

Table 2 . Comparison of harp seal input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Biomass (t)	91, 198	91, 198
Biomass ($t \cdot km^{-2}$)	0.184	0.248
P/B (yr^{-1})	0.102	0.102
Q/B (yr^{-1})	17.4	17.4

Hooded Seals

Table 3 . Comparison of hooded seal input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Biomass (t)	16, 810	16, 810
Biomass ($t \cdot km^{-2}$)	0.034	0.046
P/B (yr^{-1})	0.109	0.109
Q/B (yr^{-1})	13.1	13.1

As with harp seals, hooded seal, *Cystophora cristata*, southerly distribution is also limited to 2J3KL. It was thus assumed that the parameters derived for the 2J3KLNO model were appropriate for the 2J3KL model (Table 3). The new biomass density is 0.046 t·km^{-2} (cf., 0.034 t·km^{-2} for the 2J3KLNO model). The diet was altered, for in the 2J3KLNO diet, an unidentified Pleuronectidae group was treated as flounders. Here, it was distributed over all Pleuronectidae that occurred in the diet, that is, Greenland halibut and flounders (see Tables 22 and 23 to contrast resulting diets).

Seabirds

It was assumed that all seabird parameters were the same as for the 2J3KLNO model (Table 4). See Bundy *et al.* (2000) and paper by Montevecchi, this volume.

Table 4. Comparison of seabird input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Biomass (t·km^{-2})	0.012	0.012
P/B (yr^{-1})	0.25	0.25
Q/B (yr^{-1})	54.75	54.75

Cod

Cod, *Gadus morhua*, are split into two size groups, fish ≤ 35 cm (0-2 years old) and fish > 35 cm (3+ year olds). In the 2J3KLNO model there were two stocks of cod, 2J3KL cod and 3NO cod, while in the 2J3KL model, only the 2J3KL stock is considered. The average total catch of cod > 35 cm in Divisions 2J3KL for the period 1985-87 was calculated from data in Shelton *et al.* (1996b) as 245, 977 t, while there was no official catch of cod ≤ 35 cm.

Table 5. A. Comparison of A. cod > 35 cm and B. cod ≤ 35 cm, input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

A.	2J3KLNO	2J3KL
Catch (t)	289, 031	245, 977
Discards (t)	9, 563	9, 563
Biomass (t)	1, 011, 907	945, 246
Biomass(tkm^{-2})	2.044	2.572
P/B (yr^{-1})	0.651	0.651
Q/B (yr^{-1})	2.2	2.2
B.		
Catch (t)	0	0
Discards (t)	1.25	1.25
Biomass (t)	46, 685	43, 397
Biomass (t·km^{-2})	0.275	0.118
P/B (yr^{-1})	1.597	0.6
Q/B (yr^{-1})	6.09	6.09

There is a by-catch of 232 t of cod > 35 cm from the shrimp fishery, and 9, 563 t of discards of cod > 35 cm and 1.25 t of cod ≤ 35 cm from the Northern cod and shrimp offshore fisheries (Kulka, 1997). The 3+ cod biomass estimate came from the ADAPT estimate, and the biomass of 0-2 cod was back-calculated from the number of 3 year olds on Jan 1 as described in Bundy et al (2000). The P/B estimates from the 2J3KLNO model for cod > 35 cm were used as these were estimated for the 2J3KL cod stock. P/B for cod ≤ 35 cm were estimated from the mortalities used in the back-calculation of numbers-at-age above. The Q/B estimates used in the 2J3KLNO model were values from the literature.

Bundy *et al.* (2000) used a value of 2.2 yr^{-1} in their Model 3 for cod > 35 cm and 6.09 yr^{-1} for cod ≤ 35 cm, and these were used here. Tables 5a and 5b list the parameters for cod > 35 cm and cod ≤ 35 cm. Diets were estimated from stomach content data from stomach collections taken during Canadian resource assessment bottom-trawl surveys in Divisions 3L during spring (1985-1987), Divisions 2J, 3K and 3L in the autumn (1985-1987), and special surveys in Division 3L in the winter (1985-1986) and summer (1985).

Greenland halibut

Greenland halibut, *Reinhardtius hippoglossoides*, are split into two size groups, fish > 40 cm (6+ years old), and fish ≤ 40 cm (0-5 years old). The stock ranges over 2J3KLMNO, but the main biomass is in 2J3KL. Thus the parameters were estimated from the same data used in the 2J3KLNO model (Tables 6a and 6b).

Table 6. Comparison of A. Greenland halibut > 40 cm and B. fish ≤ 40 cm, input parameters for balanced 2J3KLNO Model 3 and first 2J3KL .

A.	2J3KLNO	2J3KL
Catch (t)	17, 481	17, 481
Discards (t)		
Biomass (t)	172, 485	172, 485
Biomass (t·km^{-2})	0.348	0.469
P/B (yr^{-1})	0.296	0.296
Q/B (yr^{-1})	1.478	1.478
B.		
Catch (t)	0	0
Discards (t)		
Biomass (t)	81, 813	81, 813
Biomass (t·km^{-2})	0.165	0.223
P/B (yr^{-1})	0.872	0.247
Q/B (yr^{-1})	4.476	3.401

American plaice

There are two stocks of American plaice, *Hippoglossoides platessoides*, in the 2J3KL model area, the 2J3K and 3LNO stocks. Thus only part of the larger 3LNO stock is in the model. American plaice are split into two size groups, American plaice > 35 cm (7+ years old) and American plaice ≤ 35 cm (0-6 years old).

The average catch for the period 1985-87 was taken from (Morgan *et al.* 1997) and Brodie *et al.* (1993). The Campelen (*a type of research trawl, see page 24, Eds*) converted biomass estimates for 3L and 2J3K in Bundy et al (2000) were used to estimate biomass of both size groups of American plaice (Tables 7a and 7b).

The P/B and Q/B estimates from the 2J3KLNO model were used. Diets were estimated from stomach content data from stomach collections taken during Canadian resource assessment bottom-trawl surveys in Divisions 3L during spring (1985-1987), Divisions 2J, 3K and 3L in the autumn (1985-1987), and special surveys in Division 3L in the winter (1985-1986) and summer (1985) (Table 23).

Table 7. Comparison of A. American plaice > 35 cm and B. fish ≤ 35 cm input parameters for balanced 2J3KLNO Model 3 and 2J3KL.

A.	2J3KLNO	2J3KL
Catch (t)	49, 454	24, 041
Discards (t)		
Biomass (t)	481, 205	324, 306
Biomass(t·km^{-2})	0.972	0.886
P/B (yr^{-1})	0.538	0.538
Q/B (yr^{-1})	2	2
B.		
Catch (t)	12, 237	4, 904
Discards (t)	2, 081	1, 325
Biomass (t)	387, 963	272, 657
Biomass(t·km^{-2})	0.784	0.742
P/B (yr^{-1})	0.625	0.625
Q/B (yr^{-1})	3.736	3.736

Flounders

The flounder group is composed of 3 species, yellowtail, *Limanda ferruginea*, witch, *Glyptocephalus cynoglossus*, and winter *Pseudopleuronectes americanus*, flounders Yellowtail flounder are found in 3LNO, and thus only part of this stock is present in the 2J3KL model. There are two witch flounder stocks, 2J3KL and 3NO, in the 2J3KLNO model. Only the 2J3KL witch flounder stock is represented in the 2J3KL model. Winter flounder is distributed over the whole area, but is more abundant in the north (Table 8, Bundy *et al.* (2000)). The mean annual catch for the period 1985-87 was taken from the same sources as the 2J3KLNO model.

The 2J3KL witch flounder biomass estimate was taken from the 2J3KLNO model biomass estimate for 2J3KL witch flounder. For winter flounder it was assumed that all biomass occurred in 2J3KL, and thus this biomass estimate was also taken directly from the 2J3KLNO model. Only part of the yellowtail flounder stock is in the model area (3L). In 1985-1987, 10% of the yellowtail founder biomass of 5+ year olds occurred in 3L. Fish younger than this stay in 3NO (Walsh 1992). Thus the yellowtail founder biomass in 2J3KL was estimated as 10% of the 3LNO biomass estimate of 5+ fish from the 2J3KLNO model. The total flounder density is less in 2J3KL than in 2J3KLNO.

The witch flounder P/B ratio from 2J3KLNO was used to represent the flounder group. Q/B was estimated by assuming that GE=0.15. The diet was estimated from the same data used in 2J3KLNO, using the new relative abundance of each of the 3 species (Table 23). The input parameters for the flounder group are given in Table 8.

Table 8. Comparison of flounder input parameters for balanced 2J3KLNO Model 3 and first 2J3KLM.

	2J3KLNO	2J3KL
Catch (t)	39, 273	6, 510
Discards (t)	1, 071	147
Biomass (t)	429, 454	117, 996
Biomass (t·km^{-2})	0.868	0.321
P/B (yr^{-1})	0.394	0.351
Q/B (yr^{-1})	3.6	2.34

Skates

Skates of the family Rajidae occur over the whole of Divisions 2J3KLNO. However, most are found on the Grand Banks. Catch, discards, biomass and the P/B ratio were estimated from the same sources as in Bundy *et al.* 2000, while the same Q/B ratio was used since it was taken from the literature. The original biomass estimate given for 2J3KLNO in Table 9 was raised to a Campelen equivalent (see Bundy *et al.* 2000), while the biomass estimated for 2J3KL is not raised to a Campelen equivalent.

Table 9. Comparison of skate input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Catch (t)	14, 346	3, 841
Discards (t)	3, 500	1, 179
Biomass (t)	255, 979	54, 951
Biomass(t·km^{-2})	0.517	0.150
P/B (yr^{-1})	0.286	0.305
Q/B (yr^{-1})	2.878	2.878

The diet was adapted from the diet used for 2J3KLNO. The amount of sandlance in the diet was decreased and the amount of capelin increased to reflect the distributional differences of these two prey items in areas 2J3KL and 2J3KLNO.

Redfish

There are 2 stocks of redfish, *Sebastes marinus,* in the 2J3KL model area, the 2J3K stock, which is within the model area and the 3LN stock, which straddles the 3LN border.

Catch, discards, biomass and P/B were estimated from the same sources as for the 2J3KLNO model, while the same Q/B was used since it was taken from the literature (Table 10). The diet was adapted from the diet used in the 2J3KLNO model. The amount of sandlance in the diet was reduced from 0.004 to 0.001 and the difference equally attributed to capelin and piscivorous small pelagic feeders (Table 23).

Table 10. Comparison of redfish input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Catch (t)	87, 957	45, 463
Discards (t)	1, 199	1, 199
Biomass (t)	482, 379	291, 961
Biomass($t \cdot km^{-2}$)	0.975	0.795
P/B (yr^{-1})	0.33	0.303
Q/B (yr^{-1})	2	2

Large Demersal Feeders

The large demersal feeders include white hake (*Urophycis tenuis*), haddock, (*Melanogrammus aegelfinnus*), rocklings, grenadiers (*Macrouridae*), wolf fish (*Anarhichas spp.*), eelpouts (*Zoarcidae*), common lumpfish (*Cyclopterus lumpus*), monkfish (*Lophius americanus*), and Atlantic halibut (*Hippoglossus hippoglossus*).

Table 11. Comparison of large demersal feeder input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Catch (t)	21, 509	8, 746
Discards (t)	4, 285	1699
Biomass (t)	418, 173	374, 967
Biomass($t \cdot km^{-2}$)	0.052	1.020
P/B (yr^{-1})	0.262	0.235
Q/B (yr^{-1})	1.747	1.567

Wolf fish were distributed throughout 2J3KLNO in the mid-1980s, but their distribution has since contracted (Kulka and Deblois 1996). On average, 68% of the 1985-1987 2J3KLNO biomass was in 2J3KL. White hake, monkfish, haddock and Atlantic halibut occur mainly in 3NO, thus this biomass consists of wolf fish, rocklings, grenadiers, eelpouts and lumpfish.

Data for the large demersals in the 2J3KLNO model was poor, and the same is true for the 2J3KL model. Catch, discards, biomass, P/B and Q/B were estimated from the same sources as in Bundy *et al.* 2000 (Table 11). The diet was re-estimated using the relative abundance (based on ECNASAP species distribution maps) of the large demersal species in 2J3KL (Table 23).

Small demersal feeders

The small demersal feeders include gunnels, (*Pholidae*), blennies, (*Stichaeidae*), pouts (*Lycodes*) and wolfeels (*Lycenchelys spp.*), sculpins, (*Cottidae*), alligator fish (*Agonidae*), lumpfish (excluding common), *Cyclopteridae* and sea snails, *Liparidae*. None of these species were fished commercially in 1985-1987 and little is known about them. This group also includes juvenile large demersal feeders.

Catch, discard and biomass data were estimated from the same sources as in Bundy et al (2000) The P/B ratio in the 2J3KLNO model was a guess and Q/B was estimated by assuming that GE = 0.15. The same methods were used here (Table 12). The 2J3KLNO diet was based on data from Scott and Scott (1988) and this was adapted for the 2J3KL model. The proportion of sandlance in the diet was reduced from 0.01 to 0.005, and the proportion of Arctic cod increased by 0.005 (Table 23).

Table 12. Comparison of small demersal feeder input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Catch (t)	0	0
Discards (t)	44.1	44.1
Biomass (t)	112, 327	56, 497
Biomass($t \cdot km^{-2}$)	0.227	0.154
P/B (yr^{-1})	0.4	0.4
Q/B (yr^{-1})	2	2.7

Capelin

Capelin, *Mallotus villosus,* are a short-lived pelagic and are an important forage fish. In the 1980s, they were classified as 3 stocks, one in 2J3K, one in 3L and one in 3NO. Since the 1993 however, capelin in 2J3KL have been treated as one stock. Recruited of capelin is considered to be all fish 2 years old and older. Most capelin occurred in 2J3KL. Catch and biomass were estimated for 2J3KL and the 2J3KLNO values for P/B, Q/B and diet were used (Table 13). The biomass of capelin is denser in 2J3KL than in

2J3KLNO.

Table 13. Comparison of capelin input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Catch (t)	62, 362	62, 092
Discards (t)		
Biomass (t)	6, 578, 068	6, 552, 781
Biomass (t·km^{-2})	13.3	17.8
P/B (yr^{-1})	1.145	1.145
Q/B (yr^{-1})	4.3	4.3

Sandlance

In Newfoundland and Labrador waters, most sandlance, *Ammodytes dubius*, occur on the plateau of Grand Bank, thus sandlance in 2J3KL are at the northerly end of their distribution. Catch and biomass were estimated for 2J3KL from the 2J3KLNO data and the 2J3KLNO values for P/B, Q/B and diet were used. Sandlance are less dense in 2J3KL than in 2J3KLNO.

Table 14. Comparison of sandlance input parameters for balanced 2J3KLNO Model 3 and first 2J3KL.

	2J3KLNO	2J3KL
Catch (t)	0	0
Discards (t)		
Biomass (t)	1, 040, 912	306, 701
Biomass (t·km^{-2})	2.103	0.835
P/B (yr^{-1})	1.15	1.15
Q/B (yr^{-1})	7.7	7.7

Arctic Cod

Arctic cod, *Boreogadus saida,* biomass within the 2J3KLNO model is almost entirely within Divisions 2J3KL. Thus the parameters estimated for Arctic cod in the 2J3KLNO model are used in the 2J3KL model. The density of Arctic cod in 2J3KL is greater than in 2J3KLNO (Table 15).

As noted in Bundy et al (2000), there is no commercial fishery for Arctic cod and no assessment within the study area. The consequence of this is that information on the species is poor.

Table 15. Comparison of Arctic cod input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Biomass (t)	1, 350, 713	1, 350, 713
Biomass (t·km^{-2})	2.73	3.68
P/B (yr^{-1})	0.402	0.395[1]
Q/B (yr^{-1})	2.6	2.6

[1] *This was the value used in the first 2J3KLNO model*

Large Pelagic Feeders

This group includes the sharks, such as the basking shark (*Cetorhinus maximus*), the spiny dogfish (*Squalus acanthias*), tunas such as the bluefin tuna (*Thunnus thynnus*), saithe (*Pollachius virens* – also known as North American pollock), silver hake (*Merluccius bilinearis*), swordfish (*Xiphias gladius*) and Atlantic salmon, (*Salmo salar*). None are common in the study area.

Saithe, sharks, tunas and salmon are highly migratory (Scott and Scott 1988) and spend only part of the year in the study area. There is very little information for this group and as such, it is poorly defined.

Table 16. Comparison of large pelagic feeders input parameters for 2J3KLNO and 2J3KL.

	2J3KLNO	2J3KL
Catch	2, 514	1, 081
P/B (yr^{-1})	0.4	0.4
Q/B (yr^{-1})	3.3	3.3

Catch in 2J3KL was estimated from the same sources as in Bundy *et al.* (2000) and the 2J3KLNO estimates for P/B and Q/B were used. The 2J3KLNO diet was adapted to reduce the amount of sandlance in the diet and increase the amount of capelin and small pelagic feeders. In the 2J3KLNO model, biomass was estimated in the model by assuming that the ecotrophic efficiency equalled 0.95. The same approach was used here.

Piscivorous small pelagic feeders

This group includes mackerel, *Scomber scombrus*, piscivorous myctophids and other mesopelagics and the short-finned squid, *Illex illecebrosus*, and the piscivorous juveniles of large pelagics.

Table 17. Comparison of piscivorous small pelagic feeders input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Catch	7, 950	7, 572
Biomass (t)	224, 411	209, 411
Biomass (t·km^{-2})	0.453	0.570
P/B (yr^{-1})	0.6	0.6
Q/B (yr^{-1})	1.8	4

Catch and discards were estimated from the same sources as in Bundy *et al.* (2000). Mackerel biomass was estimated from catch in the 2J3KLNO model, and since all the catch occurs in 2J3KL, the 2J3KL mackerel biomass is the same as the 2J3KLNO biomass.

It was assumed that the biomass of squid and myctophids was 1/2 of the maximum biomass range in 2J3KLNO, 15,000t, giving a total of 209,411 t (Table 17). The 2J3KLNO model P/B value was used, while the Q/B value was changed to reflect the greater proportion of mackerel in the biomass. Pauly (1979) gave a Q/B estimate of 4.4 yr^{-1} for mackerel on George's Bank. A Q/B of 4 yr^{-1} was assumed for the piscivorous small pelagic feeders. The diet was adapted for differences in piscivorous small pelagic feeders group composition (more mackerel) (Table 23).

Planktivorous small pelagic feeders

This group includes herring, *Clupea harengus harengus*, planktivorous myctophids and other mesopelagics, the Atlantic saury, *Scomberesox saurus*, Arctic squid *Gonatus* sp., and the planktivorous juveniles of the large pelagics. Other than herring, little is known about the other species in this group.

Most of the herring biomass occurs in 2J3KL, and so it was assumed that the parameters used in the 2J3KLNO model were applicable for the 2J3KL model (Table 18).

Table 18. Comparison of planktivorous small pelagic feeders input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Catch	9, 322	9, 233
Biomass (t)	470, 000	470, 000
Biomass ($t \cdot km^{-2}$)	0.949	1.28
P/B (yr^{-1})	0.5	0.5
Q/B (yr^{-1})	3.3	3.3

Shrimp

Shrimp biomass, predominantly *Pandalus borealis*, within the 2J3KLNO model is almost entirely within Divisions 2J3KL. Thus the parameters estimated for shrimp in the 2J3KLNO model are applied to the 2J3KL model (Table 19).

Table 19. Comparison of planktivorous small pelagic feeders input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Biomass (t)	100,000	100, 000
Biomass ($t \cdot km^{-2}$)	0.202	0.272
P/B (yr^{-1})	1.45	1.45
Q/B (yr^{-1})	9.7	9.7

Large Crustaceans

The large crustacean group is comprised of the American lobster (*Homarus americanus*), the snow crab (queen crab), *Chionoecetes opilio*, both of which were exploited in the mid-1980s and other non-commercial species such as toad crabs (*Hyas* spp).

Catch and biomass were estimated from the same sources as in Bundy *et al.* (2000). The total catch of lobster and 84% of the snow crab catch occurred in 2J3KL. In 1997 and 1998, 80-90% of the snow crab biomass and 75% of the non-commercial species biomass was in 2J3KL. The biomass of large crustaceans in 2J3KL was thus estimated as 2J3KLNO lobster biomass plus 90% of the 2J3KLNO snow crab biomass plus 75% of the 2J3KLNO other crab biomass. Since most of the large crustacean group biomass was in 2J3KL, the Q/B and diet from the 2J3KLNO model were used. In the balanced 2J3KLNO Model 3, P/B was raised above the original range of estimates. Here the top end of that original range, 0.382, was used.

Table 20. Comparison of large crustaceans input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Catch	7, 802	6, 631
Biomass (t)	91, 462	81, 903
Biomass ($t \cdot km^{-2}$)	0.185	0.223
P/B (yr^{-1})	0.45	0.382
Q/B (yr^{-1})	4.4	4.4

Benthos

The benthic invertebrates are treated as four groups, echinoderms, molluscs, polychaetes and other benthic invertebrates (OBI). The other benthic invertebrates are considered to include of miscellaneous crustaceans, nematodes, and other meiofauna.

As for the 2J3KLNO model, the 2J3KL benthos biomass was estimated from a study carried out on the Grand Banks in 1980 (Hutcheson *et al.* 1981). Five stations were sampled from May to November 1980, and data from one station in 3L was used to estimate the 2J3KL biomass. Barrie (1979) and Barrie *et al.* (1980) conducted a coastal study of marine benthic communities off the Labrador coast in 1977 and 1979 and this study generally corroborated the results of the Grand Banks study. However, it should be stressed that benthic data is poor, and several assumptions were made in order to obtain model parameter estimates. The P/B, Q/B and diet estimates were taken from the 2J3KLNO model. As shown in Table 20, the density of benthos, and thus benthic productivity in 2J3KL is almost ½ of that in 2J3KLNO.

Table 21. Comparison of benthos input biomass densities ($t \cdot km^{-2}$) for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Echinoderms	112.3	70.6
Molluscs	42.1	16.4
Polychaetes	10.5	8.8
Other Benthic Inverts	7.8	2.7
Total Benthos Biomass	172.7	98.5

Zooplankton

Table 22. Comparison of zooplankton input biomass densities ($t \cdot km^{-2}$) for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Large zooplankton	18.3	18.4
Small zooplankton	21.7	25.3

Zooplankton is treated here as two groups. The large zooplankton group are greater than 5 mm in length and include euphausiids, chaetognaths, hyperiid amphipods, Cnidarians and Ctenophores (jellyfish), mysids, tunicates >5 mm and icthyoplankton. The small zooplankton includes zooplankton less than or equal to 5 mm in length. Copepods, mainly *Calanus finmarchicus*, and *Oithona similis* are the most numerous small plankton. Other small plankton include tunicates < 5 mm and meroplankton. *C. finmarchicus*, and *O. similis* are omnivorous.

There is no recorded catch of zooplankton. The 2J3KL biomass was estimated from the same sources used in the 2J3KLNO model, and it was assumed that the P/B, Q/B and diets were the same as in this model. Table 21 shows that there is little difference in the biomass estimates for the two areas.

Phytoplankton

Table 23. Comparison of phytoplankton input parameters for balanced 2J3KLNO Model 3 and first 2J3KL model.

	2J3KLNO	2J3KL
Biomass ($t \cdot km^{-2}$)	21.7	27.25
P/B	147.3	103.6

Primary production and biomass of phytoplankton in 2J3KL was estimated using the same data as for the 2J3KLNO model, pro-rated for the 2J3KL area. There is a greater biomass density of phytoplankton in 2J3KL, but lower productivity.

Model parameters

Table 24 lists the Ecopath model parameters. Tables 25 and 26 below show the diet matrix used for the two models, as referred to in the sections dealing with each group above.

Table 24. Input parameters and estimates from the balanced 2J3KL model.

	Group name	TL	B	PB	QB	EE	GE
1	Whales	4.1	0.146	0.100	11.742	0.000	0.009
2	Harp Seals	4.4	0.248	0.102	17.412	0.047	0.006
3	Hooded Seals	4.7	0.046	0.109	13.100	0.048	0.008
4	Seabirds	4.2	0.012	0.250	54.750	0.333	0.005
5	Cod > 35cm	4.2	2.572	0.651	2.200	0.482	0.296
6	Cod <= 35 cm	3.9	0.363	1.185	6.090	0.930	0.195
7	G.halibut>40cm	4.5	0.469	0.296	1.478	0.773	0.200
8	G.halibut<=40cm	4.2	0.811	0.972	4.743	0.915	0.205
9	Aplaice>35cm	3.7	0.883	0.538	2.000	0.146	0.269
10	Aplaice<=35cm	3.7	0.742	0.625	3.736	0.368	0.167
11	Flounders	3	0.458	0.351	2.340	0.950	0.150
12	Skates	4.1	0.150	0.305	2.878	0.325	0.106
13	Redfish	3.7	1.734	0.303	2.000	0.950	0.152
14	L.Dem.Feeders	3.3	1.020	0.235	1.567	0.173	0.150
15	S.Dem.Feeders	3.1	2.210	0.400	2.667	0.950	0.150
16	Capelin	3.3	16.097	1.145	4.300	0.950	0.266
17	Sand lance	3.2	1.722	1.150	7.667	0.950	0.150
18	Arctic cod	3.4	4.031	0.395	2.633	0.950	0.150
19	L.Pel.Feeders	4.2	0.024	0.400	3.333	0.950	0.120
20	Pisc. SPF	4.1	0.993	0.600	4.000	0.950	0.150
21	Plankt. SPF	3.3	3.418	0.500	3.333	0.950	0.150
22	Shrimp	2.5	0.998	1.450	9.667	0.950	0.150
23	Large Crustacea	2.9	1.988	0.382	4.420	0.950	0.086
24	Echinoderms	2	70.60	0.600	6.667	0.109	0.090
25	Molluscs	2	16.400	0.570	6.333	0.217	0.090
26	Polychaetes	2	8.800	2.000	22.222	0.292	0.090
27	O.Benthic Inver	2	2.700	2.500	12.500	0.871	0.200
28	L.Zooplankton	2.6	23.334	3.433	19.500	0.950	0.176
29	S.Zooplankton	2	34.646	8.400	28.000	0.950	0.300
30	Phytoplankton	1	27.250	103.600	-	0.404	-
31	Detritus	1	389.0	-	-	0.381	-

References

Bundy, A., Lilly, G. and Shelton, P.A. (2000) A mass-balance model of the Newfoundland-Labrador Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 2310. xiv + 157 pp.

Table 25. Diet Matrix used in the 2J3KL model

Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Whales	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0
2. Harp Seals	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0
3. Hooded Seals	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0
4. Seabirds	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0
5. Cod > 35cm	0	0.013	0.093	0	0	0	0	0	0	0.000	0	0	0	0
6. Cod <= 35 cm	0.007	0.034	0	0.005	0.015	0.007	0.076	0.009	0.000	0.000	0	0.050	0.002	0.008
7. G.halibut>40cm	0	0.008	0.042	0	0	0	0	0	0	0.000	0	0	0	0
8. G.halibut<=40cm	0	0.078	0.337	0	0.007	0.002	0.127	0.005	0.012	0.003	0	0.001	0	0.000
9. Aplaice>35cm	0	0.001	0	0	0	0	0	0	0	0.000	0	0	0	0
10.Aplaice<=35cm	0	0.017	0	0	0.011	0.000	0.001	0	0.001	0.004	0	0.001	0	0.015
11. Flounders	0	0.007	0.163	0	0.000	0.000	0.002	0	0.000	0.000	0	0.007	0	0.011
12. Skates	0	0	0	0	0.000	0	0.001	0	0	0.000	0	0	0	0.001
13. Redfish	0	0.005	0.049	0	0.009	0.000	0.256	0.000	0	0.001	0	0.086	0.007	0.018
14. L.Dem.Feeders	0.030	0	0	0	0	0	0	0	0	0.000	0	0	0	0
15. S.Dem.Feeders	0.030	0.047	0.120	0.016	0.039	0.024	0.086	0.008	0.010	0.009	0.021	0.111	0.001	0.031
16. Capelin	0.498	0.319	0.008	0.7	0.683	0.430	0.383	0.834	0.397	0.439	0.006	0.113	0.007	0.027
17. Sand lance	0.053	0.095	0	0.05	0.041	0.031	0	0.000	0.069	0.041	0.006	0.113	0.004	0.015
18. Arctic cod	0	0.219	0.014	0.06	0.025	0.032	0.027	0.050	0.001	0.006	0	0.001	0	0
19. L.Pel.Feeders	0	0.001	0	0.001	0	0	0.002	0	0	0.000	0	0	0	0
20. Pisc. SPF	0.164	0.051	0.028	0.016	0.002	0.005	0.006	0.010	0.000	0.000	0	0.058	0	0.001
21. Plankt. SPF	0.020	0.038	0.147	0.029	0.005	0.014	0.017	0.030	0.000	0.000	0	0.007	0.245	0.027
22. Shrimp	0	0.036	0	0.006	0.042	0.079	0.013	0.022	0.004	0.018	0.013	0.022	0.035	0.079
23. Large Crustacea	0	0.000	0	0	0.042	0.022	0.000	0	0.036	0.013	0.001	0.311	0	0.029
24. Echinoderms	0	0	0	0	0.003	0.000	0	0.000	0.307	0.144	0.037	0.004	0	0.232
25. Molluscs	0	0.000	0	0.001	0.011	0.006	0.000	0	0.041	0.012	0.051	0.015	0	0.084
26. Polychaetes	0	0.000	0	0	0.004	0.017	0.000	0.000	0.028	0.133	0.509	0.080	0	0.074
27. O.Benthic Inver	0	0.003	0	0	0.011	0.139	0.001	0.003	0.081	0.155	0.349	0.013	0	0.176
28. L.Zooplankton	0.113	0.029	0	0.111	0.048	0.193	0.003	0.029	0.013	0.022	0.007	0.004	0.538	0.160
29. S.Zooplankton	0.084	0	0	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0	0.001	0.161	0.012
30. Phytoplankton	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0
31. Detritus	0	0	0	0	0	0	0	0	0	0.000	0	0	0	0

Prey \ Predator	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1. Whales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Harp Seals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Hooded Seals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4. Seabirds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. Cod > 35cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6. Cod <= 35 cm	0	0	0	0	0.002	0.005	0	0	0	0	0	0	0	0	0
7. G.halibut>40cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8. G.halibut<=40cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9. Aplaice>35cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.Aplaice<=35cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11. Flounders	0	0	0	0	0.000	0.000	0	0	0	0	0	0	0	0	0
12. Skates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13. Redfish	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0
14. L.Dem.Feeders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15. S.Dem.Feeders	0.010	0	0	0	0.035	0.000	0	0	0	0	0	0	0	0	0
16. Capelin	0.020	0.010	0	0.038	0.145	0.758	0	0	0	0	0	0	0	0	0
17. Sand lance	0.005	0.010	0	0	0.016	0.003	0	0	0	0	0	0	0	0	0
18. Arctic cod	0.010	0	0	0.002	0	0.000	0	0	0	0	0	0	0	0	0
19. L.Pel.Feeders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20. Pisc. SPF	0.002	0	0	0	0.273	0	0	0	0	0	0	0	0	0	0
21. Plankt. SPF	0.003	0	0	0	0.188	0.044	0	0	0	0	0	0	0	0	0
22. Shrimp	0.020	0	0	0	0.012	0.005	0.005	0	0.020	0	0	0	0	0	0
23. Large Crustacea	0.010	0	0	0	0	0	0	0	0.010	0	0	0	0	0	0
24. Echinoderms	0.100	0	0	0	0	0	0	0	0.300	0	0	0	0	0	0
25. Molluscs	0.100	0	0	0	0	0	0	0	0.120	0	0	0	0	0	0
26. Polychaetes	0.200	0	0	0	0.003	0	0	0.015	0.300	0	0	0	0	0	0
27. O.Benthic Inver	0.420	0	0	0	0.019	0	0.050	0.015	0.120	0	0	0	0	0	0
28. L.Zooplankton	0.050	0.434	0.350	0.640	0.295	0.173	0.527	0.120	0.020	0	0	0	0	0.050	0
29. S.Zooplankton	0.050	0.546	0.650	0.320	0.013	0.012	0.419	0.240	0.010	0	0	0	0	0.480	0
30. Phytoplankton	0	0	0		0	0	0	0.085	0	0	0	0	0	0.370	1
31. Detritus	0	0	0		0	0	0	0.525	0.100	1	1	1	1	0.100	0

Table 26. Diet Matrix used in 2J3KLNO Model 3.

Prey \ Predator	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. Whales	0	0	0	0	0.000	0.000	0	0	0	0.000	0	0	0	0
2. Harp Seals	0	0	0	0	0.000	0.000	0	0	0	0.000	0	0	0	0
3. Hooded Seals	0	0	0	0	0.000	0.000	0	0	0	0.000	0	0	0	0
4. Seabirds	0	0	0	0	0.000	0.000	0	0	0	0.000	0	0	0	0
5. Cod > 35cm	0	0.013	0.093	0	0.000	0.000	0	0	0	0.000	0	0	0	0
6. Cod <= 35 cm	0.012	0.034	0	0.005	0.018	0.007	0.076	0.009	0.000	0.004	0	0.050	0.002	0.011
7. G.halibut>40cm	0	0.004	0.036	0	0.000	0.000	0	0	0	0.000	0	0	0	0
8.G.halibut<=40cm	0	0.045	0.290	0	0.006	0.002	0.127	0.005	0.001	0.002	0	0.001	0	0.000
9. Aplaice>35cm	0	0	0	0	0.000	0.000	0	0	0	0.000	0	0	0	0
10.Aplaice<=35cm	0	0.010	0	0	0.017	0.000	0.001	0	0.001	0.021	0	0.001	0	0.017
11. Flounders	0	0.050	0.216	0	0.001	0.000	0.002	0	0.000	0.008	0	0.007	0	0.011
12. Skates	0	0	0	0	0.000	0.000	0.001	0	0	0.000	0	0	0	0.001
13. Redfish	0	0.005	0.049	0	0.009	0.000	0.256	0.000	0	0.001	0	0.086	0.007	0.016
14. L.Dem.Feeders	0.033	0	0	0	0.000	0.000	0	0	0	0.000	0	0	0	0
15. S.Dem.Feeders	0.033	0.047	0.120	0.016	0.040	0.024	0.086	0.008	0.009	0.023	0.007	0.111	0.001	0.042
16. Capelin	0.489	0.319	0.008	0.7	0.603	0.430	0.383	0.834	0.297	0.333	0.025	0.080	0.007	0.039
17. Sand lance	0.052	0.095	0	0.05	0.105	0.031	0	0.000	0.169	0.090	0.025	0.145	0.004	0.027
18. Arctic cod	0	0.219	0.014	0.06	0.022	0.032	0.027	0.050	0.001	0.004	0	0.001	0	0
19. L.Pel.Feeders	0	0.001	0	0.001	0.000	0.000	0.002	0	0	0.000	0	0	0	0
20. Pisc. SPF	0.163	0.051	0.028	0.016	0.001	0.005	0.006	0.010	0.000	0.000	0	0.058	0	0.001
21. Plankt. SPF	0.030	0.038	0.147	0.029	0.004	0.014	0.017	0.030	0.000	0.000	0	0.007	0.245	0.034
22. Shrimp	0	0.036	0	0.006	0.037	0.079	0.013	0.022	0.003	0.013	0.007	0.022	0.035	0.090
23. Large Crustacea	0	0.000	0	0	0.048	0.022	0.000	0	0.045	0.021	0.000	0.311	0	0.026
24. Echinoderms	0	0	0	0	0.004	0.000	0	0.000	0.298	0.112	0.053	0.004	0	0.199
25. Molluscs	0	0.000	0	0.001	0.023	0.006	0.000	0	0.081	0.031	0.035	0.015	0	0.067
26. Polychaetes	0	0.000	0	0	0.006	0.017	0.000	0.000	0.017	0.111	0.470	0.080	0	0.080
27.O.Benthic Inver	0	0.003	0	0	0.010	0.139	0.001	0.003	0.058	0.134	0.351	0.013	0	0.141
28. L.Zooplankton	0.104	0.029	0	0.111	0.047	0.193	0.003	0.029	0.021	0.092	0.027	0.004	0.538	0.185
29. S.Zooplankton	0.083	0	0	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0	0.001	0.161	0.014
30. Phytoplankton	0	0	0	0	0.000	0.000	0	0	0	0.000	0	0	0	0
31. Detritus	0	0	0	0	0.000	0.000	0	0	0	0.000	0	0	0	0

Prey \ Predator	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
1. Whales	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Harp Seals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Hooded Seals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4. Seabirds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. Cod > 35cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6. Cod <= 35 cm	0	0	0	0	0.002	0.019	0	0	0	0	0	0	0	0	0
7. G.halibut>40cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8.G.halibut<=40cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9. Aplaice>35cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.Aplaice<=35cm	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11. Flounders	0	0	0	0	0.000	0.000	0	0	0	0	0	0	0	0	0
12. Skates	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13. Redfish	0	0	0	0	0.002	0	0	0	0	0	0	0	0	0	0
14. L.Dem.Feeders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15. S.Dem.Feeders	0.01	0	0	0	0.035	0.000	0	0	0.05	0	0	0	0	0	0
16. Capelin	0.02	0.010	0	0.038	0.075	0.698	0	0	0	0	0	0	0	0	0
17. Sand lance	0.01	0.010	0	0	0.086	0.011	0	0	0	0	0	0	0	0	0
18. Arctic cod	0.005	0	0	0.002	0	0.000	0	0	0	0	0	0	0	0	0
19. L.Pel.Feeders	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20. Pisc. SPF	0.002	0	0	0	0.273	0	0	0	0	0	0	0	0	0	0
21. Plankt. SPF	0.003	0	0	0	0.188	0.083	0	0	0	0	0	0	0	0	0
22. Shrimp	0.02	0	0	0	0.012	0.008	0.005	0	0.049	0	0	0	0	0	0
23.Large Crustacea	0.01	0	0	0	0	0	0	0	0.111	0	0	0	0	0	0
24. Echinoderms	0.1	0	0	0	0	0	0	0	0.2	0	0	0	0	0	0
25. Molluscs	0.1	0	0	0	0	0	0	0	0.198	0	0	0	0	0	0
26. Polychaetes	0.2	0	0	0	0.003	0	0	0.015	0.196	0	0	0	0	0	0
27.O.Benthic Inver	0.42	0	0	0	0.019	0	0.050	0.015	0.001	0	0	0	0	0	0
28. L.Zooplankton	0.05	0.434	0.35	0.64	0.295	0.168	0.527	0.12	0.049	0	0	0	0	0.05	0
29. S.Zooplankton	0.05	0.546	0.65	0.32	0.013	0.013	0.419	0.24	0.049	0	0	0	0	0.48	0
30. Phytoplankton	0	0	0	0	0	0	0	0.085	0	0	0	0	0	0.37	1
31. Detritus	0	0	0	0	0	0	0	0.525	0.097	1	1	1	1	0.1	0

ECOPATH MODELLING OF THE NEWFOUNDLAND SHELF: OBSERVATIONS ON DATA AVAILABILITY WITHIN THE CANADIAN DEPARTMENT OF FISHERIES AND OCEANS

George R. Lilly
DFO, St John's

As in other boreal marine ecosystems, the waters off southern Labrador and eastern Newfoundland (NAFO Divisions 2J, 3K and 3L) are characterized by relatively few major species that may be strongly influenced by the highly dynamic environment in which they live (Livingston and Tjelmeland 2000). In some boreal systems, such as the Norwegian/Barents Sea and the Iceland/Jan Myen area, biological interactions have been demonstrated to have important influences on recruitment, individual growth, and mortality of constituent species. Although such interactions are assumed to be important in the Labrador/Newfoundland area as well, they have not yet been as demonstrable through statistical or modeling efforts.

In the Labrador/Newfoundland area, as in the Barents Sea and the Iceland/Jan Myen area, Atlantic cod (hereafter referred to only as cod) has historically been the dominant piscivorous fish and the major target of commercial fisheries. Capelin, the major prey of cod and many other species, is the dominant planktivore in the system and itself the object of a fishery. Other important species include harp seals and northern shrimp.

The Labrador/Newfoundland area has seen dramatic changes in the abundance/biomass of many species in the past 40 years and particularly during the late 1980s and early 1990s. Cod and most other demersal fish, including species that were not targeted by commercial fishing, experienced declines to very low levels in the early 1990s (Atkinson 1994; Taggart *et al.* 1994; Gomes *et al.* 1995). In contrast, northern shrimp (DFO 2000e) and snow crab (DFO 2000d) surged during the 1980s and 1990s and now support the largest fisheries in the area. Harp seals increased in abundance from less than 2 million individuals in the early 1970s to an estimated 5.2 million in 2000 (Healey and Stenson 2000). The status of capelin has been uncertain and controversial (DFO 2000c). Biomass estimates from acoustic surveys in the offshore declined suddenly in the early 1990s, whereas various indices from the inshore showed no such decline. Modeling of year-class strength has indicated that most year-classes during the 1990s have been above average and slightly higher than year-classes in the 1980s, and yet many fishermen think that capelin abundance is lower than when they first began fishing during the 1980s (DFO 2000c). Acoustic estimates of capelin density and biomass in the offshore were low in 1998 and 1999 compared to the 1980s (O'Driscoll *et al.* 2000).

There have also been substantial changes in distributions, with cod and many other demersal species declining first from the northern and western regions of 2J3K. Some of these species, most notably cod, appeared to increase on the southeastern portion of the Northeast Newfoundland Shelf (NNS) while continuing their overall decline. Capelin was virtually absent from Division 2J for most of the 1990s. During the autumn it occurred mainly in the southeast of the NNS. Arctic cod, a cold water species, expanded its distribution from the north and west of 2J3K into the southeastern NNS (Lilly *et al.* 1994; Lilly and Simpson 2000). Many species, such as American plaice and thorny skate, became much reduced in abundance throughout 2J, 3K and 3L, but retained somewhat higher abundance on the southern Grand Bank in 3N and 3O.

The purpose of this note is to discuss briefly some of the changes that have been observed in the biota of the Newfoundland Shelf, with emphasis on Divisions 2J3KL, and to note some of the limitations in the relevant data collected by the Government of Canada, Department of Fisheries and Oceans (DFO).

Abundance/biomass data

The data available for determining trends in abundance/biomass and distribution come mainly from catches and catch rates in commercial fisheries, resource assessment bottom-trawl surveys, and acoustic surveys. There are some additional sources such as pod surveys for snow crabs, pup surveys for seals, aerial surveys for capelin, and mid-water trawl surveys for small pelagics such as capelin, Arctic squid, and 0-group groundfish. The data vary in duration, geographic coverage and quality. For some species/stocks, the commercial and fishery-independent data have been modeled in some way, such as sequential population analysis (SPA), to produce estimates of population size.

Catch data

Catch data for the 2J, 3K-3L area are compiled by both DFO and the Northwest Atlantic Fisheries Organization (NAFO). Databases are maintained by both organizations. However, it is known that there has been much misreporting, including under-reporting of catches, assignment of catches to the wrong fishery areas, and assignment of catches to the wrong species (e.g. cod reported as skate). There have been attempts to take some of this misreporting into account during assessments of stock status, so it is wise to consult assessment documents (DFO or NAFO, as appropriate) and to obtain the opinion of scientists most familiar with each species/stock.

Historic catches may not be well known. It has been suggested, for example, that catches by distant water fleets were severely under-reported during the 1960s and 1970s. There are assertions that the quantities of fish discarded during various Canadian fisheries in the 1980s are seriously underestimated (Hutchings 1996). The amount of dumping and discarding by non-Canadian fleets is very poorly known. In considering the longer timeframe, there were bait fisheries for herring, capelin, squid and even mackerel, particularly in the days of the banking schooners, and I do not know if such removals have been well estimated.

Note that catch data may be all that is available for determining relative abundance of some species, especially those that are seasonal migrants (e.g. short-finned squid).

Catch rate data

Commercial catch rate data may provide information on relative abundance of various species. For northern shrimp and snow crabs, catch rate data provide the only link between the present period of high abundance and the period of presumably lower abundance in the early to mid-1980s. A variant on the commercial catch rate is an index derived from limited fishing effort by commercial fishermen using a defined protocol. Such indices exist for herring and cod. These commercial and commercial-like indices do not in themselves provide information on absolute abundance.

Fishery independent indices

Resource assessment bottom-trawl surveys have been conducted in Divisions 2J3KL in the autumn starting in 1978 (1981 in 3L) and in Divisions 3LNO in the spring starting in the early 1970s. Since the start of these surveys, there have been several new strata added, some strata have been modified and even renamed, and the set allocation protocol changed for a while in certain strata during the early 1990s. The survey gear changed in 3L in the early 1980s, and there was a second major change for the whole of 2J3KL in autumn (1995) This latter change involved switching from an Engel 145 Hi-rise trawl with large bobbins in the footgear to the Campelen 1800 shrimp trawl with rock-hopper footgear. The Engel trawl had been towed at 3.5 knots for 30 min whereas the Campelen trawl was towed at 3.0 knots for 15 min. The selectivities of the two nets were found through comparative fishing experiments in 1995 and 1996 to be markedly different, with the Campelen being far more effective at catching small fish. Engel catches have been converted to Campelen equivalents for some stocks of commercial species, but conversions are not available for many species and in any case would be meaningless for many small species. There have been so many changes in the conduct of these surveys that investigators should be cautious about analyzing the data without collaboration with (or at least advice from) scientists at DFO.

Estimates of abundance/biomass may be calculated from the trawl survey catches, and such estimates (in Campelen equivalents) were used by Bundy *et al.* (2000) for several species. However, information on the catchability of the Campelen trawl is lacking for most species. (Note as well that catchability may vary with size/age, time of year and geographic area.) It is often assumed that the catchability coefficient will be less than 1, but for American plaice on the Grand Bank (3LNO) it appears that the catchability of the Campelen trawl (with the swept area currently used in the calculations) is greater than 1 (Morgan *et al.* 1999b). It is also highly possible that catchability may vary over time. (For example, activity of fish could vary with water temperature, and the vertical distribution of fish in the water column might vary with temperature or the abundance and distribution of prey.) The potential for annual variability in catchability is a major contributor to the uncertainty in assessing temporal trends in the abundance/ distribution of many species/stocks in the Labrador/ Newfoundland area.

The bottom-trawl surveys were initially designed to obtain relative abundance estimates of groundfish. However, with the change to the Campelen trawl in autumn 1995, the surveys became effective for assessing the distribution and relative abundance of northern shrimp and snow crab. The surveys also now provide much better information on distribution and relative abundance of small demersal fish and small planktivorous fish, such as capelin, Arctic cod and sand lance (Lilly and Simpson 2000).

Acoustic surveys

Acoustic surveys for estimation of stock size of capelin were conducted by Russia and Canada from the late 1970s to the early 1990s. Survey estimates declined very abruptly and unexpectedly in the early 1990s (DFO 2000c).

Model estimates of population size

Model estimates of population size are available for only a small portion of the species inhabiting Divisions 2J3KL.

Harp seals – The estimate of population size of harp seals in the northwest Atlantic has been updated, using the most recent estimates of pup production (Healey and Stenson 2000).

2J+3KL cod – The most recent SPA not to be rejected is found in Bishop *et al.* (1993). Various “illustrative” SPA’s have been conducted since then and the most recent is reported in Lilly *et al.* (1998). Shelton and Lilly (2000) explored possible causes of the severe residuals (between SPA model estimates and research vessel indices) and the magnitude of unreported deaths or changes in catchability required to bring the reported catches and survey indices into line.

2+3KLMNO Greenland halibut – For the first time in many years, an attempt was made during the June 2000 NAFO meeting to conduct SPA analysis on this stock (NAFO 2000). Based on the results of three sequential population approaches, it was concluded that the stock of Greenland halibut “has been increasing since the mid-1990s. … However, the overall historical trajectory of the resource, as indicated in all three analyses, suggested that the current stock size is the largest in the time period from 1975 to the present. This did not fit the trend as suggested by the longest series of research data, those for Div. 2J and 3K, nor did it fit overall perceptions of this resource over time” (NAFO 2000).

3LNO American plaice – In 1999 an SPA was provided for this stock for the first time since 1994 (Morgan *et al.* 1999a,b).

In summary, there is an updated population estimate for harp seals, but no recent model estimates for other seals or for whales. Among commercial species of groundfish, there is an SPA for American plaice, but there is no accepted estimate for the total population of 2J+3KL cod, the estimate for Greenland halibut remains uncertain, and there are no estimates for any other stocks. For harp seals, Greenland halibut and American plaice, the population estimates include individuals in areas beyond 2J3KL, and it is necessary to determine what portion of the stock resides in 2J3KL and for what portion of the year. For American plaice, the estimate that we have is for only the southern third of the 2J3KL area.

Diets

As discussed by Bundy *et al.* (2000), the quantity and quality of information on diet varies greatly among species and species groups. For demersal fish, the most extensive diet data were collected in the mid-1980s. Since that time, DFO has collected stomach content data on a much more limited basis. Diet data for cod extends to the mid-1990s and there are some data for Greenland halibut in the 1990s, but that is it. There is almost nothing for pelagic fish and invertebrates.

Diet data have been collected each year from harp seals, but not with adequate temporal and spatial resolution. Diet data for harp seals are especially weak in the offshore where most feeding is thought to occur. The most recent estimates of consumption by harp seals (Hammill and Stenson 2000) uses data averaged over several years. Diet data fore hooded seals are sparser. There is no new diet data for any of the whales.

Bundy *et al.* (2000) created diet vectors for various species or species groups for the period 1985-1987. Considerable caution must be exercised if one wishes to apply these diets to other time periods. For example, if one wished to adjust the diet of cod to a vector that would be appropriate for the middle or late 1990s, one would have to take into consideration numerous changes, including the following: a much higher proportion of the cod resided in the inshore in the 1990s than in the 1980s; cod in the offshore tended to go deeper in the winter during the early 1990s than had been the case previously; the size distribution of the cod was truncated in the 1990s, especially in the offshore; changes occurred in the distributions and relative abundances of the cod’s major prey.

The Challenge

As is usually the case when one examines changes in productivity, biomass, and yield in marine ecosystems, it is difficult to distinguish the relative importance of fishing activity and environmental change (Sherman and Duda 1999; Livingston and Tjelmeland 2000). Such questions are highly germane to modeling of the Newfoundland Shelf ecosystem, because there remains much uncertainty regarding whether the recent collapses of cod and other groundfish were due entirely to overfishing.

For example, it is now widely accepted in the scientific community (especially outside of DFO Science Branch, St. John's) that the collapse of the cod stock in NAFO Divisions 2J+3KL (the "northern cod") during the late 1980s and early 1990s was caused entirely by fishing. Indeed, the *Back to the Future*[1] website is unequivocal, stating:

> *Environmental and predator changes have been ruled out as a cause of the collapse (e.g. Myers and Cadigan 1995), and serious mistakes have been identified in stock assessment (e.g. errors in biomass estimation: Walters and Maguire 1996; failure to use spatial data: Hutchings 1996 ….*

Nevertheless, some investigators feel that there remains considerable uncertainty about the time course and causes of the collapse (see references in Lilly *et al.* 2000; Shelton and Lilly 2000). The issue is very complex, of course, and far beyond the scope of the present note. However, if one considers only the fate of those cod that were born and survived to an age when they were detected by the bottom-trawl surveys, then it is not possible to reconcile reported catches with the survey index. Either the fish were not as abundant as indicated by the standard treatment of the survey data (see critique by Hutchings 1996) or the fish were initially abundant and then rapidly disappeared. In the latter case, there are again two possibilities; these fish died of natural causes (e.g. predation, starvation) or they were caught and not reported. The latter possibility would include large quantities of fish being discarded as juveniles (Myers *et al.* 1997) and large quantities being caught and under-reported by distant water fleets on the Nose of the Grand Bank in Division 3L (Rose *et al.* 2000) (see Figure 1).

Another controversial stock is American plaice in 2+3K. Bowering *et al.* (1997) concluded that the collapse of this stock was not a result of fishing mortality, whereas Hutchings (1996) presented a scenario illustrating how substantial quantities of American plaice may have been caught and discarded in the cod fishery.

For cod in 2J+3KL and American plaice in 2+3K, there are formal exercises designed to address issues of stock size and catch, and yet factors influencing stock dynamics over the past 2 decades remain poorly understood and subject to considerable debate. How are we to understand what happened to species that are monitored even less well? It has been stated that even the declines in non-commercial species (Atkinson 1994; Gomes *et al.* 1995) were due to fishing (Haedrich and Barnes 1997), but we have not accounted for the bodies.

In this context, it is important to note that the common assumption about natural mortality (M=0.2) has been changed for SPA modeling of some groundfish stocks in Atlantic Canada. For 3LNO plaice, the SPA model "that provided the best fit to the data included a natural mortality of 0.6 on all ages from 1989 to 1996 and 0.2 otherwise" (NAFO 1999). Such an approach was not adopted for 2J+3KL cod (see Shelton and Lilly 2000), but an increase in M was adopted for SPA modeling of cod in the northern Gulf of St. Lawrence (DFO 2000b), in the southern Gulf of St. Lawrence (DFO 2000a) and on the eastern Scotian Shelf (DFO 1998). For each of these cod stocks, M was increased from 0.2 to 0.4 starting in 1986. These increases in M provide a way of accounting for various possibilities, including true natural mortality (such as deaths associated with adverse environmental conditions and predation), deaths caused by the fishery but unrecorded and changes in catchability in fishery-independent indices.

The above few paragraphs discuss problems with accounting for deaths. There have also been changes in recruitment and individual growth. For example, it appears that recruitment of most groundfish stocks has been very low during the 1990s, and many of these species/stocks experienced changes in individual growth, age/size at maturity and condition. These changes suggest a substantial decline in productivity during the 1990s compared to the 1980s, and make it clear that one should be cautious about one's application of P/B and Q/B ratios.

In contrast to the declines seen in groundfish, there has been an intriguing surge in northern shrimp and snow crab. The rise of these crustaceans and the decline in their finfish predators has lead to the obvious supposition (and for many observers, the obvious conclusion) that the crustaceans increased because of a reduction in predation pressure. Nevertheless, it appears that the rise in shrimp may have started before the collapse of the cod, their major predator, and may be related, at least in part, to the cooling during the early 1980s (Lilly *et al.* in press).

[1] www.fisheries.ubc.ca/Projects/BTF/

One of the challenges for any group wishing to model the ecosystem of the 2J3KL portion of the Newfoundland Shelf is to obtain a better understanding of the changes in recruitment, individual growth and mortality of constituent species. With respect to mortality, it will be essential to achieve a better understanding of the contribution of fisheries. Documented landings and discards are insufficient to account for the declines that have been observed in 2J+3KL cod and 2+3K American plaice, and it is likely that this will be the case for all groundfish stocks. The challenge for the Back to the Future exercise is to demonstrate that misreporting and poor fishing practices can account for the differences. (That is, it will be necessary to demonstrate that the declines can be accounted for without invoking increases in natural mortality.) I suspect that it will be necessary to document all fisheries, where a fishery is defined by gear, time of year, and location. For each fishery, it will be necessary to compile reported landings and documented discards, and then attempt to gather information on unreported landings, misreported landings and undocumented discards (see, for example, Hutchings and Ferguson 2000). It will also be necessary to estimate how much fish are killed but not even seen (e.g. fish that fall out of gillnets before or during hauling and fish that are killed in gillnets that are never retrieved – 'ghost' nets).

References

Atkinson, D.B. (1994) Some observations on the biomass and abundance of fish captured during stratified-random bottom trawl surveys in NAFO Divisions 2J and 3KL, autumn 1981-1991. NAFO Sci. Coun. Studies 21: 43-66.

Bishop, C.A., Murphy, E.F., Davis, M.B., Baird, J.W., and Rose, G.A. (1993) An assessment of the cod stock in NAFO Divisions 2J+3KL. NAFO SCR Doc. 93/86. Serial No. N2271. 51 p.

Bowering, W.R., Morgan, M.J., and Brodie, W.B. (1997) Changes in the population of American plaice (*Hippoglossoides platessoides*) off Labrador and northeastern Newfoundland: a collapsing stock with low exploitation. Fisheries Research 30: 199-216.

Bundy, A., Lilly, G.R., and Shelton, P.A. (2000) A mass balance model of the Newfoundland-Labrador Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 2310: xiv + 157 p.

DFO (1998) Eastern Scotian Shelf cod. DFO Science Stock Status Report A3-03 , 1998.

DFO (2000a) Cod in the southern Gulf of St. Lawrence. DFO Science Stock Status Report A3-01, 2000.

DFO (2000b) Northern Gulf of St. Lawrence Cod (3Pn,4RS). DFO Science Stock Status Report A4-01, 2000.

DFO (2000c) Capelin in Subarea 2 + Div. 3KL. DFO Science Stock Status Report B2-02, 2000.

DFO (2000d) Newfoundland and Labrador snow crab. DFO Science Stock Status Report C2-01, 2000.

DFO (2000e) Northern shrimp (*Pandalus borealis*) – Div. 0B to 3K. DFO Science Stock Status Report C2-05.

Gomes, M.C., Haedrich, R.L., and Villagarcia, M.G. (1995) Spatial and temporal changes in the groundfish assemblages on the north-east Newfoundland/Labrador Shelf, north-west Atlantic, 1978- 1991. Fish. Oceanogr. 4: 85-101.

Haedrich, R.L., and Barnes, S.M. (1997) Changes over time of the size structure in an exploited shelf fish community. Fisheries Research 31: 229-239.

Hammill, M.O., and Stenson, G.B. (2000) Estimated prey consumption by harp seals (*Phoca groenlandica*), hooded seals (*Cystophora cristata*), grey seals (*Halichoerus grypus*) and harbour seals (*Phoca vitulina*) in Atlantic Canada. J. Northw. Atl. Fish. Sci. 26: 1-23.

Healey, B.P., and Stenson, G.B. (2000) Estimating pup production and population size of the northwest Atlantic harp seal (*Phoca groenlandica*). DFO Can. Stock Assess. Sec. Res. Doc. 2000/081.

Hutchings, J.A. (1996) Spatial and temporal variation in the density of northern cod and a review of hypotheses for the stock's collapse. Can J. Fish. Aquat. Sci. 53: 943-962.

Hutchings, J.A., and Ferguson, M. (2000) Temporal changes in harvesting dynamics of Canadian inshore fisheries for northern Atlantic cod, *Gadus morhua*. Can. J. Fish. Aquat. Sci. 57: 805-814.

Lilly, G.R., Hop, H., Stansbury, D.E., and Bishop, C.A. (1994) Distribution and abundance of polar cod (*Boreogadus saida*) off southern Labrador and eastern Newfoundland. ICES C.M. 1994/O:6. 21 pp.

Lilly, G.R., Parsons, D.G., and Kulka, D.W. in press. Was the increase in shrimp biomass on the Northeast Newfoundland Shelf a consequence of a release in predation pressure from cod? J. Northw. Atl. Fish. Sci.

Lilly, G.R., Shelton, P.A., Brattey, J., Cadigan, N.G., Murphy, E.F., and Stansbury, D.E. (2000) An assessment of the cod stock in NAFO Divisions 2J+3KL. DFO Can. Stock Assess. Sec. Res. Doc. 2000/063. 123 p. (also NAFO SCR Doc. 00/33)

Lilly, G.R., Shelton, P.A., Brattey, J., Cadigan, N., Murphy, E.F., Stansbury, D.E., Davis, M.B., and Morgan, M.J. (1998) An assessment of the cod stock in NAFO Divisions 2J+3KL. DFO Can. Stock Assess. Sec. Res. Doc. 98/15. 102 p.

Lilly, G.R., and Simpson, M.R (2000) Distribution and abundance of capelin, Arctic cod and sand lance on the Northeast Newfoundland Shelf and Grand Bank as deduced from bottom-trawl surveys. DFO Can. Stock Assess. Sec. Res. Doc. 2000/091.

Livingston, P.A., and Tjelmeland, S. (2000) Fisheries in boreal ecosystems. ICES J. mar. Sci. 57: 619-627.

Morgan, M.J., Brodie, W.B., and Bowering, W.R. 1999a. An assessment of American plaice in NAFO Divisions 3LNO. NAFO SCR Doc. 99/40, Serial No. N4099.

Morgan, M.J., Brodie, W.B. and Maddock Parsons, D. (1999b) Virtual population analyses of the American plaice stock in Divisions 3LNO from 1975 to 1997. NAFO SCR Doc. 99/58, Serial No. N4117.

Myers, R.A., and Cadigan, N.G. (1995) Was an increase in natural mortality responsible for the collapse of northern cod? Can. J. Fish. Aquat. Sci. 52: 1274-1285.

Myers, R.A., Hutchings, J.A., and Barrowman, N.J. (1997) Why do fish stocks collapse? The example of cod in Atlantic Canada. Ecological Applications 7: 91-106.

NAFO (1999) Report of ScientificCouncil Meeting, 3-16 June 1999. NAFO Redbook (1999) Part B.

NAFO (2000) Report of the Scientific Council Meeting. June 2000. NAFO SCS Doc. 00/24, Serial No. N4283.

O'Driscoll, R.L., Rose, G.A., Anderson, J.T., and Mowbray, F. (2000) Spatial association between cod and capelin: a perspective on the inshore-offshore dichotomy. DFO Can. Stock Assess. Sec. Res. Doc. 2000/083. 23 p.

Rose, G.A., deYoung, B., Kulka, D.W., Goddard, S.V., and Fletcher, G.L. (2000) Distribution shifts and overfishing the northern cod (*Gadus morhua*): a view from the ocean. Can. J. Fish. Aquat. Sci. 57: 644-663.

Shelton, P.A., and Lilly, G.R. (2000) Interpreting the collapse of the northern cod stock from survey and catch data. Can. J. Fish. Aquat. Sci. (in press).

Sherman, K., and Duda, A.M. (1999) An ecosystem approach to global assessment and management of coastal waters. Mar. Ecol. Prog. Ser. 190: 271-287.

Taggart, C.T., Anderson, J., Bishop, C., Colbourne, E., Hutchings, J., Lilly, G., Morgan, J., Murphy, E., Myers, R., Rose, G., and Shelton, P. (1994) Overview of cod stocks, biology, and environment in the Northwest Atlantic region of Newfoundland, with emphasis on northern cod. ICES mar. Sci. Symp. 198: 140-157.

Walters, C., and Maguire, J.-J. (1996) Lessons for stock assessment from the northern cod collapse. Reviews in Fish Biology and Fisheries 6: 125-137.

WINGING BACK TO THE FUTURE: AN HISTORIC RECONSTRUCTION OF SEABIRD DIVERSITY, DISTRIBUTION AND ABUNDANCE IN THE NORTHWEST ATLANTIC, 1500-2000

(work in progress)

C. Burke , G.K. Davoren,
W.A. Montevecchi and I.J. Stenhouse
Biopsychology Programme, MUN

Introduction

Access to resources has always been a critical determinant of human movement and settlement patterns (e.g. Freuchen & Salomonsen 1958, Kurlansky 1997). The distributions and abundance of natural resources, primarily fish, large mammals, water, and trees, determined the distributions of aboriginal and later-arriving European peoples in northeastern North America (e.g. Prowse 1895, Tuck 1975). The European exploration and colonization of North America was driven by a quest for exploitable resources. In the Northwest Atlantic, natural and human-induced environmental perturbation and change have been increasingly and inextricably interactive for five centuries, 1500-2000 (e.g. Harris 1990).

Changes in community establishment, growth and devolution have had profound effects on local and regional environments, with the ultimate consequence of a restructuring in the ecosystem (e.g. Pitcher 2001). The economic and social structuring of communities have determined local and regional patterns of resource use, over-exploitation and conservation. These human-induced changes in the ecosystem, in turn, feedback and influence change in the economic climate and social structure of communities. Clearly, social and ecosystem restructuring are interactive processes.

Seabirds were important in the lives and economies of many aboriginal peoples and played important roles in the exploration and settlement of North America (Montevecchi and Tuck 1987). Seabirds are the most conspicuous marine animals, and owning to their associations with marine productivity, many species, including Great Auks (Penguinis impennis), were exploited as navigational markers of the Grand Banks and other coastal sites and as bio-indicators of fish conditions (Montevecchi & Tuck 1987, Montevecchi 1993).

Most species were killed for food as well as for bait (Collins 1882), and the largest known Great Auk colony, on Funk Island off the northeast coast of Newfoundland, essentially served as North America's first "fast-food take-out" for trans-Atlantic sailing vessels through the 16th, 17th and 18th centuries. Because seabirds provided important, often essential, sources of protein for humans, knowledge of their diversity, distribution, abundance and ecology was well-developed among aboriginal peoples and early European explorers and settlers (Montevecchi & Tuck 1987).

Table 1: Approximate annual occupation periods, estimated population numbers, body masses and average annual biomass for each seabird species (A) breeding and (B) wintering in the study area (2J3KLNO). (Most species also include information from Brown *et al*. 1975, Cairns *et al*. 1989, Montevecchi & Tuck 1987)

(A) Species breeding	Occupation period	Population (number)	Individual mass (kg)	Average biomass over year (t)	References
Northern Fulmar	Jan-Dec	181	0.80	0.14	Nettleship & Montgomerie 1974, Montevecchi *et al*. 1978, Stenhouse & Montevecchi 1999a
Manx Shearwater	Mar-Nov	340	0.48	0.12	Storey & Lien 1985
Leach's Storm-Petrel	Apr-Oct	15,340,636	0.05	447.44	Sklepkovych & Montevecchi 1989, Montevecchi *et al*. 1992, Huntington *et al*. 1996, Stenhouse & Montevecchi 1999b, 2000, Stenhouse *et al*. 2000
Northern Gannet	Apr-Oct	48,806	3.20	91.10	Montevecchi *et al*. 1988, Montevecchi & Myers 1995, 1997
Great Cormorant	Mar-Nov	601	2.25	1.01	
Double-crested Cormorant	Mar-Oct	1,048	2.33	1.63	
Common Eider	Jan-Dec	2,344	2.23	5.23	
Black-headed Gull	Jan-Dec	25	0.28	0.01	Montevecchi *et al*. 1987
Ring-billed Gull	Apr-Oct	23,062	0.50	6.73	
Herring Gull	Jan-Dec	151,787	1.12	170.00	
Great Black-backed Gull	Jan-Dec	12,460	1.68	20.93	
Black-legged Kittiwake	Jan-Dec	293,822	0.44	129.28	Maunder & Threlfall 1972, Regehr & Montevecchi 1997, Massaro *et al*. 2000
Caspian Tern	May-Oct	108	0.61	0.03	Lock 1983, Howes & Montevecchi 1993
Common Tern	May-Oct	11,128	0.12	0.67	Howes & Montevecchi 1993
Arctic Tern	May-Oct	16,358	0.11	0.90	
Common Murre	Jan-Dec	1,912,857	0.99	1893.73	Bryant & Jones 1999, Bryant *et al*. 1999, Davoren ????
Thick-billed Murre	Jan-Dec	40,800	0.93	37.94	Bryant & Jones 1999, Bryant *et al*. 1999
Razorbill	Jan-Dec	37,305	0.69	25.74	Hipfner ????
Black Guillemot	Jan-Dec	54,000	0.40	21.60	
Atlantic Puffin	Jan-Dec	[1,032,855]	0.46	[475.11]	Nettleship 1972, 1991, Rodway & Montevecchi 1996, Russell & Montevecchi 1996, Montevecchi unpubl.
(A) TOTALS	-	[18,970,651]	-	[3329.35]	
(B) Species overwintering					
Wilson's Storm-Petrel	May-Oct	50,000	0.04	1.00	
Northern Fulmar	Jan-Dec	300,000	0.80	240.00	
Greater Shearwater	May-Oct	1,500,000	0.89	667.50	
Sooty Shearwater	May-Oct	300,000	0.79	118.50	
Oldsquaw	Nov-Apr	15,000	0.76	5.70	
Scoter spp.	Oct-Apr	40,000	1.11	25.90	
Common Eider	Nov-Mar	50,000	2.23	46.46	
Iceland Gull	Oct-Apr	100,000	0.86	50.17	
Glaucous Gull	Oct-Apr	50,000	1.70	49.58	Gilchrist (unpubl.)
Black-legged Kittiwake	Oct-Apr	500,000	0.44	128.33	
Thick-billed Murre	Oct-Apr	1,500,000	0.93	813.75	Elliot *et al*. 1990, Rowe *et al*. 2000
Dovekie	Nov-Mar	14,475,000	0.15	625.00	Stenhouse & Montevecchi 1996
(B) TOTALS	-	14,475,000	-	2771.89	
GRAND TOTALS	-	[33,445,651]	-	[6101.2]	

Efforts to reconstruct marine species diversity, distributions, ecology and population patterns in the historic and pre-historic past challenge our concepts of ecosystem change and resiliency (e.g. Pitcher 2001). Such efforts require researchers working across the range of biotic levels to integrate their knowledge through biophysical ecosystem approaches. Within an historic context, it can be highly informative to integrate archaeological information and changing patterns of human-settlement, population patterns and resource use to better understand changes in marine ecosystems and species' extinctions, range

Table 2. Trophic level, approximate occupation periods, estimated population numbers, body masses and average annual biomass for each seabird species (A) breeding and (B) wintering in the study area (2J3KL). (Most species also include information from Brown *et al.* 1975, Cairns *et al.* 1989, Montevecchi & Tuck 1987). Planktivores = species foraging primarily on a range of plankton and nekton (zooplankton, crustacea, squid, larval & small fishes). Piscivores - forage fish = species foraging primarily on small mid-water fishes (capelin, sandlance). Piscivores - large pelagics = species foraging primarily on large deep-water fishes (mackerel, herring, salmon, squid). Benthic = species foraging primarily on invertebrates and bottom-dwelling fishes (bivalves, echinoderms, flatfish, blennies).

(A) Trophic level: breeding birds	Species	Occupation period	Population (number)	Individual mass (kg)	Average biomass over year (t)
Planktivores	Leach's Storm-Petrel	Apr-Oct	15,340,636	0.05	447.44
	Northern Fulmar	Jan-Dec	181	0.80	0.14
	Manx Shearwater	Mar-Nov	340	0.48	0.12
Piscivores - forage fish	Black-headed Gull	Jan-Dec	25	0.28	0.01
	Ring-billed Gull	Apr-Oct	23,062	0.50	6.73
	Herring Gull	Jan-Dec	151,787	1.12	170.00
	Great Black-backed Gull	Jan-Dec	12,460	1.68	20.93
	Black-legged Kittiwake	Jan-Dec	293,822	0.44	129.28
	Caspian Tern	May-Oct	108	0.61	0.03
	Common Tern	May-Oct	11,128	0.12	0.67
	Arctic Tern	May-Oct	16,358	0.11	0.90
	Common Murre	Jan-Dec	1,912,857	0.99	1893.73
	Thick-billed Murre	Jan-Dec	40,800	0.93	37.94
	Razorbill	Jan-Dec	37,305	0.69	25.74
	Black Guillemot	Jan-Dec	54,000	0.40	21.60
	Atlantic Puffin	Jan-Dec	[1,032,855]	0.46	[475.11]
Piscivores - large pelagics	Northern Gannet	Apr-Oct	48,806	3.20	91.10
Benthic	Great Cormorant	Mar-Nov	601	2.25	1.01
	Double-crested Cormorant	Mar-Oct	1,048	2.33	1.63
	Common Eider	Jan-Dec	2,344	2.23	5.23
(A) TOTALS	-	-	[18,970,651]	-	329.35]
(B) Trophic level: wintering birds					
Planktivores	Wilson's Storm-Petrel	May-Oct	50,000	0.04	1.00
	Northern Fulmar	Jan-Dec	300,000	0.80	240.00
	Greater Shearwater	May-Oct	1,500,000	0.89	667.50
	Sooty Shearwater	May-Oct	300,000	0.79	118.50
	Dovekie	Nov-Mar	14,475,000	0.15	625.00
Piscivores - forage fish	Iceland Gull	Oct-Apr	100,000	0.86	50.17
	Glaucous Gull	Oct-Apr	50,000	1.70	49.58
	Black-legged Kittiwake	Oct-Apr	500,000	0.44	128.33
	Thick-billed Murre	Oct-Apr	1,500,000	0.93	813.75
Benthic	Oldsquaw	Nov-Apr	15,000	0.76	5.70
	Scoter spp.	Oct-Apr	40,000	1.11	25.90
	Common Eider	Nov-Mar	50,000	2.23	46.46
(B) TOTALS	-	-	14,475,000	-	2771.89
GRAND TOTALS	-	-	[33,445,651]	-	[6101.24]

Expansions, contractions and population trends (e.g. Montevecchi and Hufthammer 1990, Starkney *et al.* 2000).

In biological reconstruction exercises, marine ornithology offers promising and complimentary inputs that are indicative of the state of oceanic and trophic conditions (e.g. Aebisher *et al.* 1990). Birds are the most highly visible, the most wide-ranging and among the most easily studied components of marine ecosystems. As top and multi-level trophic consumers, they are key elements for studying ecosystem changes (see May *et al.* 1979). In as much as they have been exploited by humans for millennia for food as well as for spiritual (Tuck 1975) and navigational purposes, the breeding populations and ranges of marine birds are well known historically (Tuck 1961) and, through zooarchaelogical investigations, pre-historically as well (Montevecchi & Tuck 1987; Montevecchi & Hufthammer 1990).

Owing to social constraints related to predation, food procurement and mating, seabird colonies have considerable inertia and are often very persistent through time (Montevecchi & Tuck 1987). Changes in the distributions, populations and trophic relationships of seabirds reflect current conditions (Stenhouse & Montevecchi 2000) as well as decadal, centurial and millennial climatic changes (Montevecchi & Hufthammer 1990, Montevecchi & Myers 1996, 1997).

Table 3. Habitat type, approximate occupation periods, estimated population numbers, body masses and average annual biomass for each seabird species (A) breeding and (B) wintering in study area (2J3KL). (Most species also include information from Brown *et al.* 1975, Cairns *et al.* 1989, Montevecchi & Tuck 1987). Surface = species restricted to foraging at the surface or in the upper 5 meters of water. Water column = species foraging in water column to depths of approximately 20 - 140 meters. Benthic = species foraging at the seabed, up to a depth of 20 meters

(A) Breeding; Habitat type	Species	Occupation period	Population (number)	Individual mass (kg)	Average biomass over year (t)
Surface	Leach's Storm-Petrel	Apr-Oct	15,340,636	0.05	447.44
	Northern Fulmar	Jan-Dec	181	0.80	0.14
	Manx Shearwater	Mar-Nov	340	0.48	0.12
	Black-headed Gull	Jan-Dec	25	0.28	0.01
	Ring-billed Gull	Apr-Oct	23,062	0.50	6.73
	Herring Gull	Jan-Dec	151,787	1.12	170.00
	Great Black-backed Gull	Jan-Dec	12,460	1.68	20.93
	Black-legged Kittiwake	Jan-Dec	293,822	0.44	129.28
	Caspian Tern	May-Oct	108	0.61	0.03
	Common Tern	May-Oct	11,128	0.12	0.67
	Arctic Tern	May-Oct	16,358	0.11	0.90
Water column	Northern Gannet	Apr-Oct	48,806	3.20	91.10
	Common Murre	Jan-Dec	1,912,857	0.99	1893.73
	Thick-billed Murre	Jan-Dec	40,800	0.93	37.94
	Razorbill	Jan-Dec	37,305	0.69	25.74
	Black Guillemot	Jan-Dec	54,000	0.40	21.60
	Atlantic Puffin	Jan-Dec	[1,032,855]	0.46	[475.11]
Benthic	Great Cormorant	Mar-Nov	601	2.25	1.01
	Double-crested Cormorant	Mar-Oct	1,048	2.33	1.63
	Common Eider	Jan-Dec	2,344	2.23	5.23
(A) TOTALS	-	-	[18,970,651]	-	[3329.35]
(B)Wintering; Habitat type					
Surface	Wilson's Storm-Petrel	May-Oct	50,000	0.04	1.00
	Northern Fulmar	Jan-Dec	300,000	0.80	240.00
	Greater Shearwater	May-Oct	1,500,000	0.89	667.50
	Sooty Shearwater	May-Oct	300,000	0.79	118.50
	Dovekie	Nov-Mar	14,475,000	0.15	625.00
	Iceland Gull	Oct-Apr	100,000	0.86	50.17
	Glaucous Gull	Oct-Apr	50,000	1.70	49.58
	Black-legged Kittiwake	Oct-Apr	500,000	0.44	128.33
Water column	Thick-billed Murre	Oct-Apr	1,500,000	0.93	813.75
Benthic	Oldsquaw	Nov-Apr	15,000	0.76	5.70
	Scoter spp.	Oct-Apr	40,000	1.11	25.90
	Common Eider	Nov-Mar	50,000	2.23	46.46
(B) TOTALS			14,475,000		2771.89
GRAND TOTALS			[33,445,651]		[6101.24]

There is extensive long-term information and knowledge about marine birds in the North Atlantic. Specifically, in the Northwest Atlantic, we are fortunate in having extensive archaeological information relating to aboriginal knowledge as well as the longest historical records of seabirds in North America. Written historical accounts span 500 to 1000 years BP beginning with the earliest known European incursions (Montevecchi & Tuck 1987). Archaeological information accesses the utilitarian interactions and knowledge of aborigional peoples over millennial scales (Tuck 1976, Montevecchi and Tuck 1987). Birds are also included in current ecopath models (Bundy *et al.* 2000), though they have much greater potential as indicators of ecosystem conditions and change than their estimated biomass and production indicate (Furness & Greenwood 1993; Montevecchi 2001 a, b). There is also a well developed methodology to access and assess biological and ecological information from resource users (Hutchings *et al.* 1997; Neis *et al.* 199a, b) that can also be applied to both hunters and fishers (non-exclusive overlapping groups) to obtain both local and traditional ecological knowledge (LEK and TEK) about marine birds and waterfowl (e.g. Chaffey *et al.* submitted).

Objectives

The objective of this paper is to describe the changes in seabird species diversity, distributions and populations and to relate these to shifting human activities on the Northeast Newfoundland Shelf. (North Atlantic Fisheries Organization [NAFO] Areas 2J3KLNO). Specifically, we examine how changing direct and indirect

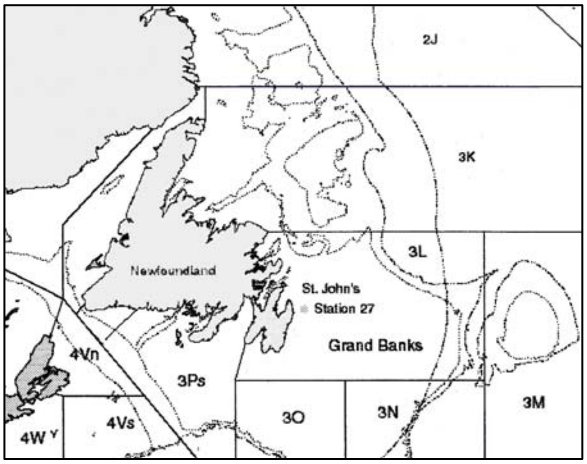


Figure 1. Study area: the Northeast Newfoundland Shelf, NAFO area 2J3KLNO

seabird-human interactions influence seabird populations (see Tasker *et al.* 2000, Montevecchi 2001a). We examine three human activities in the Northwest Atlantic that impact seabird populations: (1) hunting, (2) fishing: a) direct mortality (i.e. using bird for bait, by-catch), b) indirect mortality (i.e. competition for food resources), c) direct food enhancement (i.e. discards and offal) and d) indirect food enhancement (i.e. over-harvesting large predatory fishes, and (3) oil pollution: a) direct mortality (oiling of feathers) and b) indirect mortality (oil pollution of food). We also examine changing oceanographic conditions that occurred during the past 500 years. We assess these human and environmental interactions with seabirds at three times: present (2001), 100 years BP (1900) and 500 years BP (1500). These periods were chosen because they mark eras of pre-European contact (1500) and of significant technological changes in the exploitation of the marine ecosystem (1900) of the Northwest Atlantic shelf. With respect to aboriginal occupations and populations, we also map Beothuk occupations of insular Newfoundland and the Strait of Belle Isle (500 BP) and occupations by Palaeo-Eskimos and Maritime Archaic Peoples (1000-9000 BP). The ultimate goal of this exercise is to use seabird species diversity, distributions and populations as bio-indicators to understand the underlying social and ecological mechanisms driving long-term ecosystem change and the extinction, resilience and persistence of populations in the marine environment.

Methods

Our study area covers five of Northwest Atlantic Fisheries Organization (NAFO) Divisions (2J3KLNO) on the Northeast Newfoundland Shelf (Figure 1). First, we assess current species diversity, distributions and populations, then we reconstruct historical data (1950, 1900) and accounts and archaeological information (1900, 1500). We then back-projected (hind-cast) quantitative and qualitative assessments of seabird species, diversity, distributions and population levels from current ones and assessed concordance among current and previous scientific information, LEK and TEK. Next, we assess findings to gain long-term perspectives on baseline conditions (Pitcher 2000) and to identify key periods of species loss or gain, shifts in species distributions, and of population changes. Finally, we overlay oceanographic conditions and intensifying and human-seabird interactions and advances in human technology in an attempt to understand the mechanisms and interactions underlying observed changes.

To describe the seabird communities and trophic interactions, we gleaned the following five types of data from the literature, LEK, TEK and archaeological information for each time period under examination: (1) species diversity of the seabird community in the study area throughout the year including both breeding and wintering populations, (2) estimates of the population size of each species (total numbers and total biomass estimates), (3) consumption levels, (4) prey types consumed (diet diversity within and among seasons) and (5) interactions with other marine organisms as well as humans (e.g. large gull activity during the 1990s eastern Canadian ground-fishery closure).

Consumption rates were based on allometric equations in Friesen *et al.* (1989) and in Diamond *et al.* (1993). Prey types were generalized into four categories: plankton and nekton (zooplankton, crustacea, squid, larval and small fishes), forage fishes (small midwater fishes), large pelagic fishes, and benthic organisms and (bottom-dwelling fishes and invertebrates). We also generalized the foraging habitat of each seabird species: surface (upper 5 meters of the ocean), water column (to depths of 20 + 140 m), and benthic (at or near the seabed in depths of up to 50 m).

We also characterize human activities in the four periods of interest. First, we map the major aborigional settlements, then those of nonaboriginal people in Newfoundland and southern Labrador and explore the changing capabilities of both aboriginal and nonaboriginal people in exploiting the marine environment. We also describe the location of local communities, in relation to the location of seabird breeding colonies and wintering areas.

Results

The approximate population numbers, occupation dates and average annual biomasses of seabird species in the Northwest Atlantic during 2000 are given in Table 1. The approximate population numbers, occupation dates and average annual biomasses of seabird species classified by trophic level categories in the Northwest Atlantic during 2000 are presented in Table 2. Table 3 gives the approximate population numbers, occupation dates and average annual biomasses of seabird species during 2000 classified by marine habitat categories.

Seabird Colony Distributions

Descriptions of recent seabird colony distributions in Newfoundland are in Cairns *et al.* (1989). We are currently in the process of mapping these.

Seabird Diversity and Populations

The diversity of the seabird community in the study area changes considerably over the year. A total of 20 species currently breed in the area and a further three species are present in the area during the summer months (approx. May-Sept). Nine of the breeding species and all three of the non-breeding species present in summer leave the area entirely in the winter months (approx. Oct-Apr). The populations of five of the 11 species remaining in the area grow substantially over the winter months, due to influxes of large numbers of wintering birds. In addition, the 11 breeding species that remain in winter are joined by a further 8 species, for a total of 19 species in the area during the winter months. Despite these changes in the species composition from summer to winter, however, the overall seabird population in the area remains high, with somewhere in the region of 20 million individuals present throughout the year.

Trophic level

Most (14) of the 20 species breeding in the area are piscivorous, with 13 of these species typically preying on small forage fishes. The Northern Gannet is the only breeding species that preys on large pelagic fishes. Three benthic feeding species breed in the area in fairly small numbers. Three planktivorous species breed in the area (Manx Shearwaters and Northern Fulmars in small numbers, and Leach's Storm-Petrels in vast numbers) and three planktivorous species that breed in the Southern Hemisphere are present in summer (Greater and Sooty Shearwaters and Wilson's Storm-Petrels).

With the departure of Northen Gannets in October, there are no large pelagic piscivores in the area through the winter. The nine breeding species preying on small forage fishes that remain in the area are joined by two wintering species, Glaucous and Iceland gulls. Of the benthic feeders, only Common Eiders remain in winter, being joined by large populations of wintering eider and other seaducks. Of the three breeding planktivorous species, two leave the area entirely in winter. There is a large influx of planktivores, however; the small breeding population of Northern Fulmar remains and is joined by a large population of wintering fulmars, and Dovekies (breeding in Greenland) move south to winter in the study area in the tens of millions.

Habitat

Species exploiting resources within the upper few metres of the ocean surface predominate throughout the year. Of the 20 breeding and three non-breeding species present in the area in the summer months, 14 are surface feeders, six feed deeper in the water column (up to 140 m), and three are benthic feeders. Four of the surface feeding species remain in the area, joined by three wintering surface feeders. Five of the species feeding in the water column remain in the study area throughout the winter months, joined by large numbers of Thick-billed Murres (breeding in Greenland and the Canadian Arctic). Both surface and water column feeders move from inshore areas near colonies in summer to offshore areas in winter. Of the benthic feeders, Common Eiders remain in the area and the cormorants are replaced by seaducks (Long-tailed Duck, Scoters spp.). Benthic feeders are restricted to shallow bays and, thus, remain inshore throughout the year.

Biomass

Based on an average biomass for individuals of each species, together the 20 breeding and three non-breeding species present in summer approach an average biomass of 3,500 tonnes over the year. With the large influx of wintering birds, however, the average biomass in the study area increase to approximately 6,000 tonnes.

Most of this biomass consists of piscivores concentrating on forage fishes, but the study area supports a large breeding population of Leach's Storm-Petrels and a large wintering population of

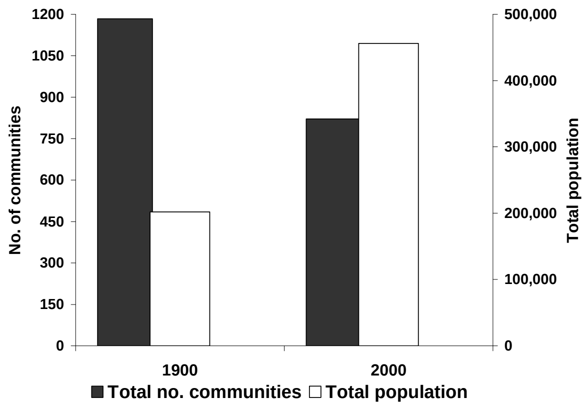


Figure 2. Comparison of the distribution and size of coastal communities in Newfoundland and Labrador, 1900-2000.

Dovekies. Together, due to their enormous numbers, these small planktivores represent a considerable portion of the overall seabird biomass throughout the year.

Human Settlements and Populations 1900 and 2000

Census records from 1891 and 1996, representing 1900 and 2000 respectively, illustrate a dramatic shift in the number of coastal communities and human population size in Newfoundland and Labrador over the last 100 years (Figure 2). At the time of the first official census in 1891, the population of Newfoundland and Labrador was recorded at 202,040 individuals dispersed over 1183 communities in coastal regions (Figure 3). Nineteen percent (234) of these communities had a recorded population of less than 20 people. Forty percent (24) of the coastal communities in Labrador and thirty-two percent (48) of those in the District of St. Barbe had a population of fewer than 20 people. These sparsely populated communities tended to consist of a number of families living a traditional lifestyle in which the fishery was the central component.

From 1900 to 2000, the number of coastal settlements in Newfoundland and Labrador declined by 31 % from 1183 to 821 while the population increased by 44%. The specifics of this change are illustrated by Figures 4 (2000) and 5 (1900). Many of these coastal communities were abandoned or resettled in the 1950s and 60s during a period of economic restructuring. The government of the time proposed to develop resources and industries outside of the fishery that up to that time had dominated the economic and social landscape of Newfoundland and Labrador. Residents of coastal communities situated in isolated bays and remote islands were encouraged to relocate to larger growth centers with centralized services. Economic development related to forestry, mining and hydro-electric development led to the establishment of new communities in the interior of Newfoundland and Labrador (Mannion 1977). Prior to these developments, the entire population of Newfoundland and Labrador was settled in coastal areas. In 2000, communities located on the interior represented fifteen of the total population of Newfoundland and Labrador. As Newfoundland and Labrador emerged into a modern era with new industry and technological advances the traditional inshore fishery experienced a downturn and the lifestyle associated with it began to change. One of the most significant of these changes

Coastal regions from 1891 Census records

- St. Barbe
- Twillingate
- Fogo
- Bonavista
- Trinity
- Conception Bay (see insert)
- Ferryland
- Placentia-St. Mary's
- Burin
- Fortune
- Burgeo-La Poile
- St. George

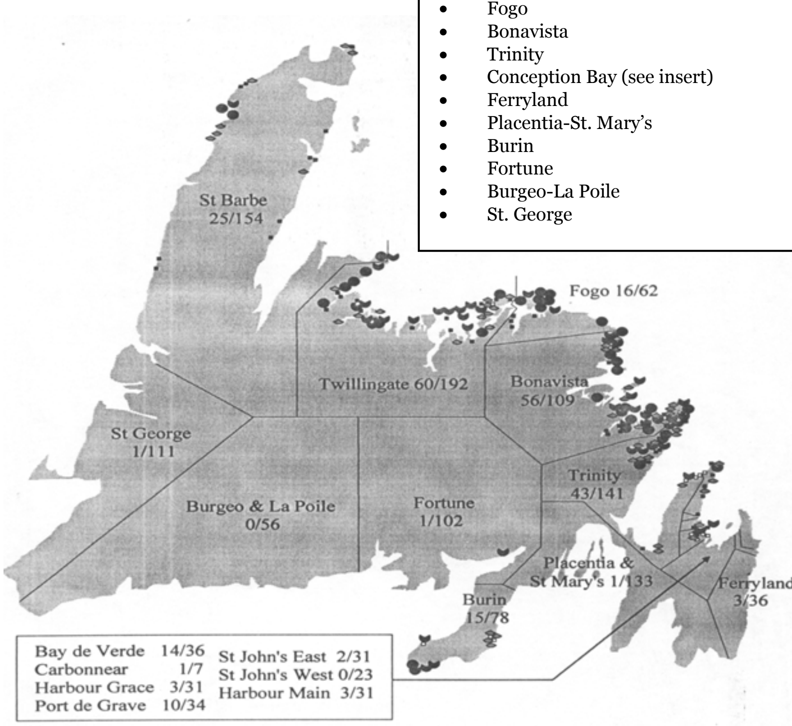


Figure 3. Coastal regions of insular Newfoundland and Labrador, as defined in the 1891 census.

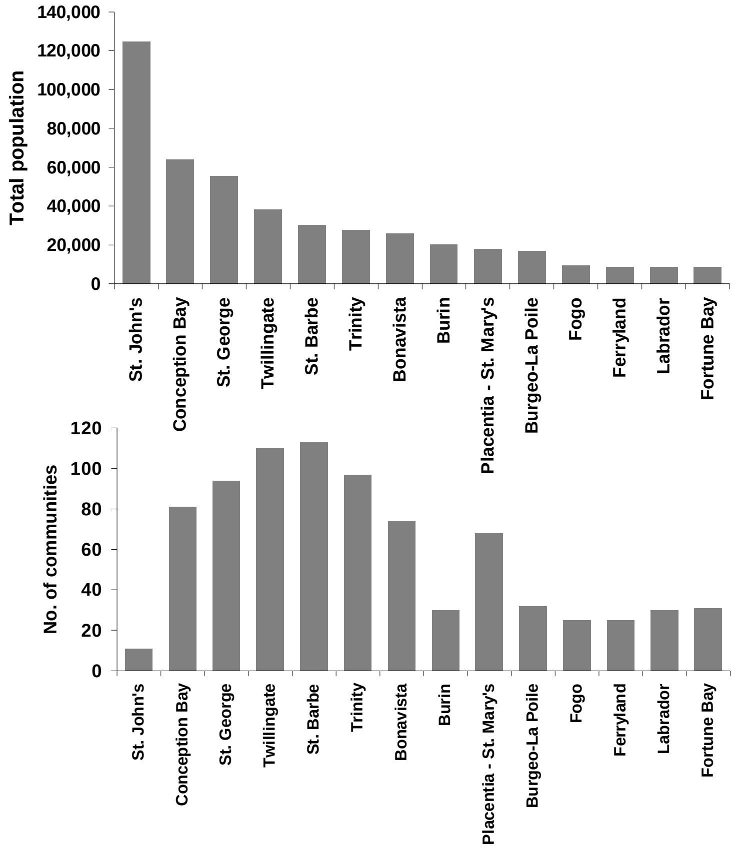


Figure 4. Distribution (lower panel) and size (top panel) of coastal communities in Newfoundland and Labrador, 2000.

was the movement of people out of isolated communities.

European Exploration and Settlement
+ 1500-1900

European fisherman from England, France, Ireland, Spain and Portugal arrived in spring at coastal areas in Newfoundland and established temporary settlements to fish the adjacent waters for cod (Kurlansky 1997). Basque fisherman from Spain and France established seasonal settlements in southern Labrador as early as 1470 to fish for cod and harvest whales that migrated through the Strait of Belle Isle each spring through late summer (Barkham 1982). Seasonal and temporary settlements defined the first 300 years of settlement in southern Labrador and Newfoundland. Seasonal settlements were abandoned during the winter as the fisherman returned to Europe to trade their salted cod and whale oil (Kurlansky 1997). The resident population of Newfoundland and southern Labrador grew significantly during the 19th century as economic and political events in Europe contributed to immigration (Mannion, 1977). Permanent settlements were established in areas such as Trepassy, Trinity and St. John's where the cod fishery was managed by merchants from Europe on a year-round basis. The earliest permanent settlements established on the Northeast Avalon by the English developed into some of the major growth centers of the 19th century from which the commercial inshore cod fishery was managed (Mannion 1977). The seasonal abundance of migratory harp seals from December to March in Bonavista Bay and Notre Dame Bay extended the pattern of permanent settlements beyond the northeast Avalon (Mannion 1977). By 1810, ninety percent of the families in Newfoundland and southern Labrador were permanent residents reliant on commercial activity related to the cod fishery and the seal harvest (Mannion 1977). Small plots of cultivated land supplemented the year round survival of the early permanent settlers. At the time of the first official census in 1891, the resident population of Newfoundland and Labrador was at 202,040 individuals dispersed over 1183 coastal communities (Figure 5). Most of the population at this time was dispersed around the coastline in small outport settlements located a long distance from larger settlements.

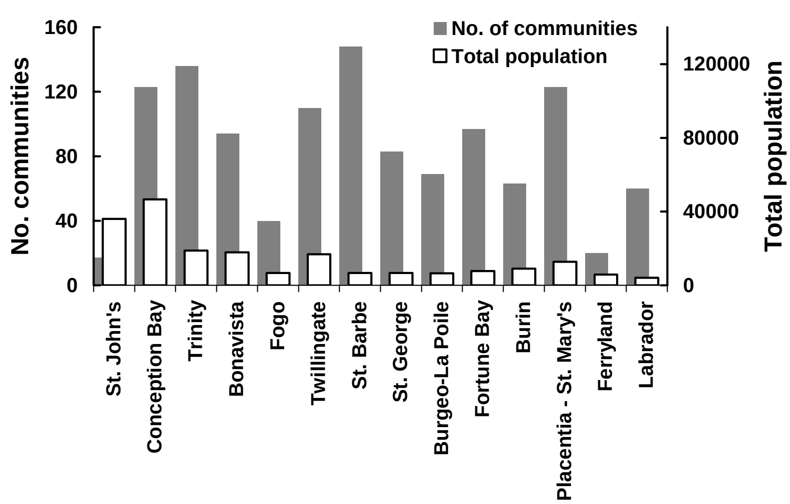


Figure 5. Distribution and size of coastal communities in Newfoundland and Labrador, 1900.

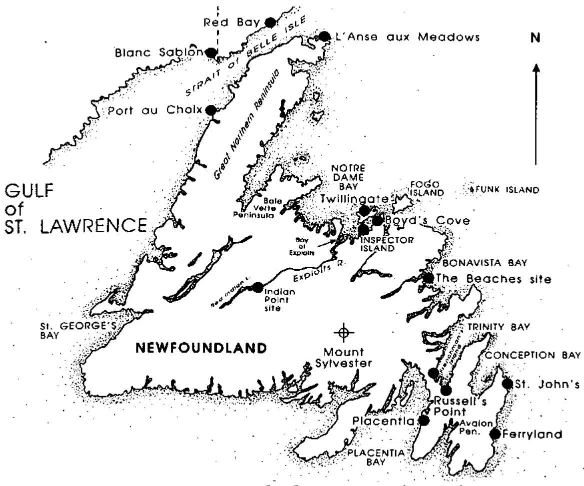


Figure 6. Known Beothuk occupation sites, 500BP (from Pastore 1992).

Beothuk occupation sites - 500 years BP

Aboriginal cultures occupied the coast of Newfoundland and Labrador up until the 1800s when the last Beothuk Indian died in 1829 (Howley 1915). During the early 1600's, shortly before European exploration of the Northwest Atlantic, the estimated number of Beothuks was between 500-700 divided into bands of 35-55 members (Howley 1915). The Beothuk Indians and earlier Recent Indians occupied coastal areas from Placentia Bay in the south to Port au Choix on the northwest tip of Newfoundland and interior sites along the Exploits River in central Newfoundland (Figure 6). The Beothuks did not occupy any coastal regions in Labrador beyond the Strait of Belle Isle. As the European presence became more frequent along coastal areas the Beothuks were forced to retreat inland (Howley 1915; Marshall 1992). This retreat would have limited their supply of fresh seal meat, seabirds, salmon and other seafood and threatened their survival during periods when terrestrial species such as caribou and beaver were not plentiful (Pastore 1992). The European settlements along productive coastal areas in Newfoundland interfered with the traditional hunting and gathering way of life and contributed in part to the extinction of the Beothuks (Marshall 1989).

Ancient Aboriginal Occupation Sites
+ 9000 - 1000 BP

For thousands of years prior to the European exploration and colonization of northeastern North America ancient aboriginal cultures inhabited coastal areas in southern Labrador and Newfoundland (Figure 7). Evidence of aboriginal occupation date back to 9000 BP with the Maritime Archaic People at L'Anse Amour in southern Labrador (Tuck 1975). Around 4000 BP Palaeoeskimos migrated into southern Labrador from the eastern Canadian Artic. 2000 years later another Palaeoeskimo culture known as the Dorset Eskimo (2100 BP) continued to occupy southern Labrador and establish more southerly sites in Newfoundland.

These ancient cultures were marine specialists whose survival was inextricably linked to the seasonal migration of mammals, fish and seabirds (Tuck 1976). Occupation sites along the Straits of Belle Ilse at L'Anse Amour and Port au Choix persisted for thousands of years due to their proximity to an abundance of migratory marine species such as harp seals. Ivory harpoons and stone jewelry uncovered at Maritime Archaic sites

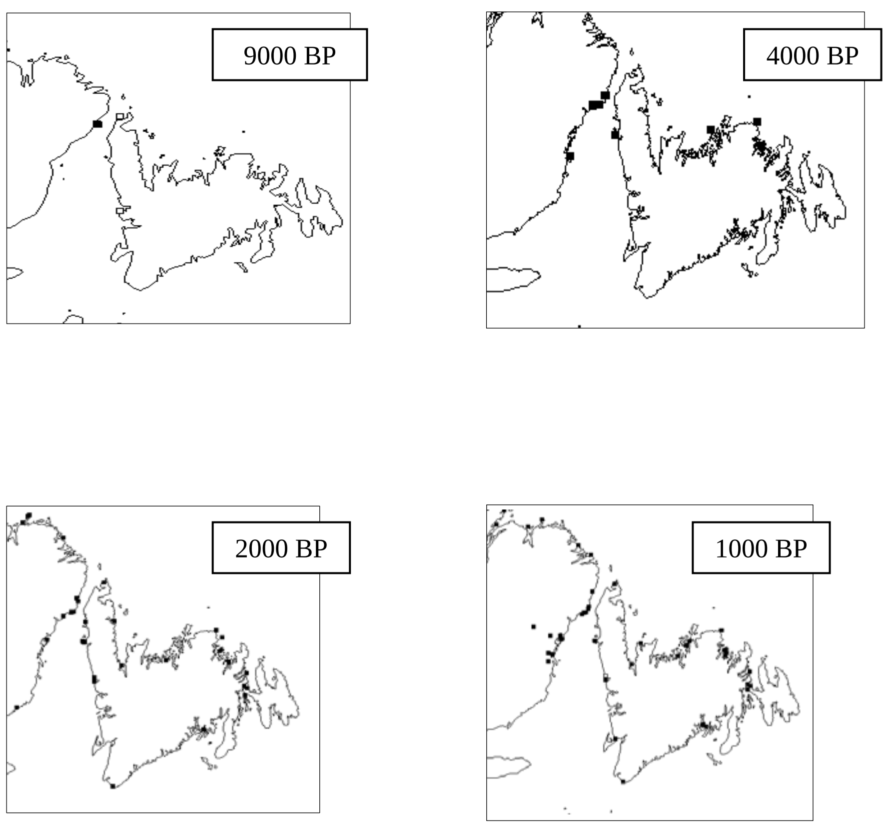


Figure 7. Known aboriginal occupation sites in Newfoundland and Labrador 9000 to 1000 BP from www.canadianarchaeology.ca.

in Port aux Choix depicting whales, seals and the now extinct Great Auk illustrate the strong connection of these ancient cultures to the resources of the sea (Montevecchi and Tuck 1987).

Discussion

During the 1500s-1700s, there were very few, very small, seasonal settlements along the coastline of Newfoundland and Labrador. At the turn of the 20th century, there were many small, widely-dispersed communities and seasonal camps. Small, inshore fisheries had low intensity DIRECT effects on seabirds [disturbance (-), harvest (-), competition (-)]. In contrast, at the turn of the 21st century, there are fewer larger, aggregated communities, probably with lessened contact with seabirds. Large, highly mechanised, offshore fisheries have more INDIRECT effects on seabirds [by-catch (-), oil pollution, (-), offal (+/-)] and are more difficult to quantify. Many of these are likely to have effects of high intensity (see Montevecchi 2001a).

References

Aebisher, N.J., Coulson, J.C. & Colebrook, J.M. (1990) Parallel long term trends across four marine trophic levels and weather. Nature 347: 753-755.

Barkham, S. (1982) Documentary evidence for sixteenth century Basque whaling ships in the Strait of Belle Isle. In G.M. Story (Ed.) Early Settlement and Exploitation in Atlantic Canada. Memorial University of Newfoundland, St. John's.

Brown, R.G.B., Nettleship, D.N., Tull, C.E. & Davis, T. (1975) Atlas of Eastern Canadian seabirds. Canadian Wildlife Service, Ottawa.

Bryant, R. & Jones, I.L. (1999) Food resource use and diet overlap of Common and Thick-billed Murres at the Gannet Islands, Labrador. Waterbirds 22: 392-400.

Bryant, R., Jones, I.L. & Hipfner, J.M. (1999) Responses to changes in prey availability by Common Murres and Thick-billed Murres at the Gannet Islands, Labrador. Can. J. Zool. 77: 1278-1287.

Bundy, A., Lilly, G.R. & Shelton, P.A. (Eds.) (2000) A mass balance model of the Newfoundland-Labrafor Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 2310.

Cairns, D.K., Montevecchi, W.A. & Threlfall, W. (1989) Researcher's Guide to Newfoundland Seabird Colonies (2nd edn.). Occas. Pap. Biol., Memorial U. of Nfld. No. 14.

Chaffey, H., Montevecchi, W.A. & Neis, B. (*in press*) Integrating science and local ecological knowledge (LEK) in studies of eider ecology in southern Labrador. In N. Haggan, B. Neis and T. Pitcher (Eds.) Putting Fishers Knowledge to Work. UBC Fisheries Centre, Vancouver (*in press*).

Chardine, J. (2000) Census of Northern Gannet colonies in the Atlantic region. Can. Wildl. Serv. Tech. Rep Atlan. Reg. No. 361.

Collins, J.W. (1882) Notes on the habits and methods of capture of various species of seabirds that occur on the fishing banks off the eastern coast of North America, and which are used as bait for catching codfish by New England fishermen. Smithson. Misc. Coll. 46: 311-338.

Elliot, R.D., Ryan, P.C., & Lidster, W.W. (1990) The winter diet of Thick-billed Murres in coastal Newfoundland waters. Stud. Avian Biol. 14: 125-138.

Freuchem, P. & Salomonsen, F. 1958. The arctic year. Putnam & Some, New York.

Furness, R.W. & Greenwood, J.J.D. (Eds.) (1993). Birds are monitors of environmental change. Chapman & Hall, London.

Harris, L. (1990) Independent Review of the State of Northern Cod Stock. Supply and Services Canada, Ottawa.

Howes, L.-A. & Montevecchi, W.A. (1993) Population trends and interactions among terns and gulls in Gros Morne National Park, Newfoundland. Can. J. Zool. 71: 1516-1520.

Howley, J.P. 1915. The Beothucks or Red Indians: The Aboriginal Inhabitants of Newfoundland. Coles, Toronto.

Huntington, C.E., Butler, R.G. & Mauk, R.A. (1996) Leach's Storm-Petrel (*Oceanodroma leucorhoa*). In A. Poole & F. Gill (Eds.) The Birds of North America, No. 233. Academy of Natural Sciences, Philadelphia, PA, and American Ornithologists' Union, Washington DC.

Hutchings, J.A., Neis, B. & Ripley, P. (1997) The "nature of cod": perceptions of stock structure and cod behaviour by fishermen, "experts" and scientists from the nineteenth century to the present. In D. Vickers (Ed.) Marine resources and human societies in the North Atlantic since 1500. Conf. Pap. 5 ISER, St. John's, Newfoundland.

Kurlansky, M. 1997. Cod: A Biography of a Fish that Changed the World. Knopf, Toronto. 294 pp.

Lock, A.R. (1983) Caspian Terns (*Sterna caspia*) breeding in Labrador. Can. Field-Nat. 97: 448.

Mannion, J.J. (Ed.) (1977) The Peopling of Newfoundland: Essays in Historical Geography. Institute of Social and Economic Research, Memorial University of Newfoundland, St. John's.

Marshall, I.C.L. (1989) Reports and Letters by George Christopher Pulling: Relating to the Beothuck Indians of Newfoundland. Breakwater, St. John's, Newfoundland.

May, R.M., Beddington, J.R., Clark, C.W., Holt, S.J., & Laws, R.M. (1979) Management of multispecies fisheries. Science 205: 267-277.

Massaro, M., Chardine, J.W., Jones, I.L. & Robertson, G.J. (2000) Delayed capelin (*Mallotus villosus*) availability influences predatory behaviour of large gulls on Black-legged Kittiwakes (*Rissa tridactyla*), causing a reduction in kittiwake breeding success. Can. J. Zool. 78: 1588-1596.

Maunder, J.E. & Threlfall, W. (1972) The breeding biology of the Black-legged Kittiwake in Newfoundland. Auk 89: 789-816.

Montevecchi, W.A. (1993). Birds as indiators of change in marine prey stocks. In R.W. Farness & J.J.D. Greenwood (Eds) Birds as monitors of environmental change. Chapman & Hall, London.

Montevecchi, W.A. (2001a). Interactions between fisheries and seabirds. In E.A. Schreiber & J. Burger (Eds.) The biology of marine birds. CRC Press, Boca Raton, Florida.

Montevecchi, W.A. (2001b). Seabirds as indicators of ocean pollution. In J. Steele, S. Thorpe and K.T. Turekian (Eds.). Encyclopedia of ocean sciences. Academic Press, New York.

Montevecchi, W.A. & Hufthammer, A.K. (1990) Zooachaeological implications for prehistoric distributions of seabirds along the Norwegian coast. Arctic 43: 110-114.

Montevecchi, W.A. & Myers, R.A. (1995) Prey harvests of seabirds reflect pelagic fish and squid abundance on multiple spatial and temporal scales. Mar. Ecol. Prog. Ser. 117: 1-9.

Montevecchi, W.A. & Myers, R.A. (1996) Dietary changes of seabirds reflect shifts in pelagic food webs. Sarsia 80: 313-322.

Montevecchi, W.A., Myers, R.A. (1997) Centurial and decadal oceanographic influences on changes in Northern Gannet populations and diets: implications for climate change. ICES J. Mar. Sci. 54: 608-614.

Montevecchi. W.A. & Tuck, L.M. (1987) Newfoundland birds: exploitation, study, conservation. Nuttall, Cambridge, USA.

Montevecchi, W.A., Birt, V.L. & Cairns, D.K. (1988) Dietary changes of seabirds associated with local fisheries failures. Biol. Oceanog. 5: 153-161.

Montevecchi, W.A., Birt-Friesen, V.L. & Cairns, D.K. (1992) Reproductive energetics and prey harvest of Leach's Storm-Petrels in the Northwest Atlantic. Ecology 73: 823-832.

Montevecchi, W.A., Blunden, E., Coombes, G., Porter, J. & Rice, P. (1978) Northern Fulmar breeding range extended to Baccalieu Island, Newfoundland. Can. Field-Nat. 92: 80-82.

Montevecchi, W.A., Cairns, D.K., Burger, A.E., Elliot, R.D. & Wells, J. (1987) The status of the Common Black-headed Gull in Newfoundland and Labrador. Am. Birds 41: 197-203

Neis, B., Felt, L., Haedrich, R.L. & Schneider, D.C. (1999a) An interdisciplinary methodology for collecting and integrating fishers' ecological knowledge into resource management. In D. Newell & R. Ommer (Eds.) Fishing Places, Fishing People: Issues and Traditions in Canadian Small-scale Fisheries. University of Toronto Press, Toronto.

Neis, B., Schneider, D.C., Felt, L., Haedrich, R.L., Fischer, J. & Hutchings, J.A. (1999b) Fisheries assessment: what can be learned from interviewing resource users? Can J. Aquat. Fish. Sci. 56: 1949-1963.

Nettleship, D.N. (1972) Breeding success of the Common Puffin (*Fratercula arctica*) on different habitats at Great Island, Newfoundland. Ecol. Monogr. 42: 239-268.

Nettleship, D.N. (1991) The diet of Atlantic Puffin chicks in Newfoundland before and after an international capelin fishery, 1967-1984. Proc. Int. Orn. Cong. 20: 2263-2271.

Nettleship, D.N. & Montgomerie, R.D. (1974) The Northern Fulmar (*Fulmarus glacialis*) breeding in Newfoundland. Am. Birds 28: 16.

Pastore, R.T. (1992) Shanawdithit's People: The Archaeology of Beothuks. Atlantic Archaeology.

Pitcher, T.J. (2001) Fisheries managed to rebuild ecosystems? Reconstucting the past to salvage the future. Ecol. Appl. 11: 601-617.

Prowse, D.W. 1895. A history of Newfoundland from the English, colonial and foreign record. MacMillan, London.

Regehr, H.M. & Montevecchi, W.A. (1997) Interactive effects of food shortage and predation on breeding failure of Black-legged Kittiwakes: indirect effects of fisheries activities and implications for indicator species. Mar. Ecol. Prog. Ser. 155: 249-260.

Rodway, M.S. & Montevecchi, W.A. (1996) Sampling methods for assessing the diets of Atlantic puffin chicks. Mar. Ecol. Prog. Ser. 144: 41-55.

Rowe, S., Jones, I.L., Chardine, J.W., Elliot, R. & Veitch, B.G. (2000) Recent changes in the winter diet of murres (*Uria* spp.) in coastal Newfoundland waters. Can. J. Zool. 78: 495-500.

Russell, J. & Montevecchi, W.A. (1996) Predation on adult Puffins (*Fratercula arctica*) by Great Black-backed Gulls (*Larus marinus*) at a Newfoundland colony. Ibis 138: 791-794.

Sklepkovych, B.O. & Montevecchi, W.A. 1989. The world's largest known nesting colony of Leach's Storm-Petrels on Baccalieu Island, Newfoundland. Am. Birds 43: 38-42.

Starney, D.J., Holm, P., Smith, T., Francis, R. & Rozwadowski. 2000. H-OBIS: A historical dimension to the ocean biogeographical information system. Oceanography 13: 39-40.

Stenhouse, I.J. & Montevecchi, W.A. (2000) Habitat utilization and breeding success in Leach's Storm-Petrel: the importance of sociality. Can. J. Zool. 78: 1267-1274.

Stenhouse, I.J., Robertson, G.J. & Montevecchi, W.A. (2000) Herring Gull (*Larus argentatus*) predation on Leach's Storm-Petrels (*Oceanodroma leucorhoa*) breeding on Great Island, Newfoundland. Atlan. Seabirds 2: 35-44.

Stenhouse, I.J. & Montevecchi, W.A. (1999a) Increasing and expanding populations of breeding Northern Fulmars in Atlantic Canada. Waterbirds 22: 382-391.

Stenhouse, I.J. & Montevecchi, W.A. (1999b) Indirect effects of the availability of capelin and fishery discards: gull predation on breeding storm-petrels. Mar. Ecol. Prog. Ser. 184: 303-307.

Stenhouse, I.J. & Montevecchi, W.A. (1996) Winter distribution and wrecks of Little Auks (Dovekies) Alle a. alle in the northwest Atlantic. Sula 10: 219-228.

Storey, A.E. & Lien, J. (1985) Development of the first North American colony of Manx Shearwaters. Auk 102: 395-401.

Tasker, M.L., Camphuysen, K., Cooper, J., Garthe, S., Leopold, M., Montevecchi, W.A. & Blaber, S. 2000. The impacts of fisheries on marine birds. ICES J. Mar. Sci. 57: 531-547.

Tuck, J.A. (1975) Ancient people of Port au Choix. ISER Memorial University of Newfoundland, St. John's.

Tuck, J.A. (1976) Newfoundland and Labrador Prehistory. Van Nöstrand Rheinhold, Toronto.

Tuck, L.M. (1961) The murres. Queen's Printer, Ottawa.

RECONSTRUCTING PAST ECOSYSTEM MODELS OF THE NEWFOUNDLAND SHELF: WORKSHOP NOTES AND SOURCES ON THE ECOSYSTEM GROUPS

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

The East coast science workshop was held at Memorial University of Newfoundland, St. John's, Newfoundland, between 29th and 30th September (2000) The workshop started with introductions, which was followed by a presentation of the objectives of the MCRI Coasts under Stress program, and the Back to the Future project by Tony Pitcher. Questions were raised concerning the boundaries of the study area and of the ecosystem being modeled on various occasions during the workshop. From the Traditional Ecological Knowledge (TEK) perspective the choice of the modeled area should consider the fact that most community TEK is related to smaller spatial scales (bays, regions). Conversely, DFO scientists mainly prefer to use a combination of NAFO statistical areas (2J3KL or 2J3KLNO), given current assumptions about fish stock structure.

Barb Neis raised the point that the relevance of reconstructing the past is not on the exercise to deciding the future, but to make fishers realize where they are in the history of the fishery. In this regard Tony Pitcher commented that the BTF approach is proactive in the sense that communities will be presented with different scenarios/options for the future – compromise and tradeoffs will be there from the beginning.

Subsequent to these introductions, Marcelo Vasconcellos presented an overview of Ecopath with Ecosim.

Alida Bundy presented a model of the 1985-1987 2J3KL model adapted from the previous model (Bundy *et al.* 2000) for the same time period for 2J3KLNO. Alida Bundy emphasized that 2J3KL would be a more appropriate system definition given the accepted boundaries of fish stocks. The model has a total area of 367,542 km^2 and extends up to the 1,000 metre isobath.

Some suggestions were made to improve the model structure, including splitting both Demersal Feeders and Large Crustaceans into two pools each, to alleviate cannibalism in the model. Alida also raised the point that biomasses estimated by Ecopath are usually higher that biomass from surveys. The reasons for this were discussed, and included the catchability assumptions for Redfish in bottom surveys, and assumptions about natural mortality for cod. Cannibalism was also problematic for zooplankton – changing assumptions about zooplankton cannibalism rates cause considerable changes in biomass estimates. Another potential problem in the model is that Benthic Invertebrate groups are not consumed much in the system. Related to this observation, George Lilly commented that the study area is more pelagic-based than benthic.

George Lilly acknowledged that there are many unknowns and uncertainties in the current understanding of the system. The 1985-1987 period is the best time in terms of data for many groups, with the exception of crustaceans.

Barb Neis commented on the need to represent in the model cases of population with known or suspected multiple stocks (e.g. cod).

Paul Fanning then presented an overview of the CDEENA project, (*Comparative Dynamics of Exploited Ecosystems)* in the Northwest Atlantic. According to him diet information is the biggest knowledge gap for the region and how to convert survey data into biomass of individual species is one of the major problems.

There are several Emerging fisheries in the region. Sea urchins are being targeted for roe by diving. Two species of grenadier are commercially exploited, and an assessment has been completed. They are common in trawl fisheries in deep waters. There is also an emerging fishery for rock crab.

Dave Schneider indicated that it would be interesting to add a conceptual basis to the model, i.e. to use power laws to calculate expected P/B ratios. He said that there is a recent article in Science (J.H. Brown and Enquist) that revised old literature and redefined ratios conceptually and we should try and incorporate that into this model.

After these discussions Marcelo Vasconcellos presented the choices of reference points for rebuilding and results of preliminary analysis of changes in biomasses between time periods and a comparison of ecosystem indices. Discussions were then focused on each functional group. Tony Pitcher suggested that discussions on each functional group should try to answer the following set of questions:

1) What are the sources of information for the group?
2) Who would author sections for the report?
3) Values for parameters B, P/B, Q/B and Diets?
4) Biomass relative to 1985: now, 1900, 1400?
5) Should group be split (based on ecological, policy constrain)?
6) Fisheries (section/gear/bycatch)

The following sections are based on notes taken during the workshop and later revised and complemented by individual authors. Experts that could not attend the workshop agreed to prepare contributions addressing the issues raised at the workshop. Separate papers (published above in this volume) were submitted by Alida Bundy, George Liley and Bill Montevecchi. Finally, sections authored by the UBC team reflect material from a review of primary and secondary literature along with information from discussions during the workshop. Additionally, reports of discussions on each particular functional group are added to each section. In these notes, participants are identified by their initials.

WHALES AND PORPOISES

Garry Stenson, Becky Sjare and Mike Hammill
DFO, St John's

For most species of small toothed whales and larger baleen whales there are no current population estimates available. The exceptions being humpbacks in the north Atlantic and harbour porpoise white-sided and white-beaked dolphins in the Gulf of St. Lawrence. Humpback numbers for the 1985 Ecopath model were back calculated based on the most current population estimates and assuming a 3% rate of increase. It is likely that whale biomass and abundance has probably not changed much between the mid 1980s and the present. Given pending endangered species legislation (SARA) large-scale cetacean surveys are being proposed for in Atlantic Canada and new estimates will be available for many species sometime within the next five years.

Regarding biomass in the past, for many species whaling data is available going back to the early 1900s; and for some species much longer – probably the 1600s. Comprehensive historical information from whaling records will be available only for key baleen species – humpback, right whales, fin, blue and some bowhead and sperm whales in certain locations. Much of the information pertains to eastern Canadian Arctic waters but there is also significant information available for the Atlantic region as well. Dr. Edward Mitchell reconstructed the historical population size of several species of baleen whales from whaling records in the mid 1970s and Randal Reeves is presently continuing this work. This body of literature will be a useful start for the historical studies. For toothed whales (other than sperm) historic estimates will be guesswork; unfortunately the whaling database is very spotty with regard to these smaller whales. Even collecting information on current population trends and distribution for dolphin species is difficult in some areas of the Atlantic region because the fishermen only know them "jumpers" rather than by species.

With regard to diet information, in most cases there are no current data other than what was included in the 1985 model (Bundy *et al.*, 2000). However, there have been some recent diet studies on minke whales in Norwegian and Icelandic waters; some of this new information may be of interest from a comparative perspective. Separating baleen and toothed whales in the Eco-path model would be desirable, but probably not necessary considering that dolphins were not included in the current model structure.

If a decision was made to include small toothed whales, there is some information on the abundance and diet for harbour porpoises (Gulf of St. Lawrence and Newfoundland), and for white-sided and white-beaked dolphins (Gulf of St. Lawrence). Hal Whitehead (from Dalhousie University) has research on northern bottlenose research off the Scotian Shelf. John Lien has a paper out on the present estimates for the early 1990s. It is also suggested that we deal with seasonality in the estimation of abundance by using the average annual biomass, and the consumption for the time period of residence.

Model parameters

Biomass of whales in the present time model was assumed to be the same as the biomass for the 1985-1987 model. Biomass in the early 1900s can probably be estimated from reconstructed populations size carried by Dr. Edward Mitchell and Randal Reeves. If this information is lacking, in the preliminary early 1900s model it might be assumed that biomass was twice the present time value.

HARP SEALS

Garry Stenson and Mike Hammill
DFO, St John's

The northwest Atlantic harp seal population was assessed in April 2000 based on results from a new survey conducted in (1999) Current information on abundance, population trends, reproductive productivity and catch statistics are available. Estimating harp seal abundance for the early 1900s would be difficult; however, there a number of published 'guesses' ranging from 6 to 12 million animals. There are good historic data on the commercial white-coat seal hunt dating back to at least the mid 1800s (contact Shannon Ryan, historian; Memorial University). In addition to providing insight into catch statistics it may be possible to reconstruct the historical population for some time periods. Information for the pre-1850 period is either non-existent or very sketchy. Seals were harvested by aboriginal people and there are some Hudson Bay and Moravian records that may be useful for the coast of Labrador (Center for Newfoundland Studies, Memorial University). For the pre-Cabot model, climatic conditions (particularly ice extent and distribution) might provide some insights on the general distribution and relative abundance of seals. Also Newfoundland archeology records from ancient dorset and maritime archaic Indian camp sites may be useful for this purpose as well (contact: Dr. Pricilla Renouf, Memorial University).

Since the 1985 Ecopath model there has been a significant amount of work done on improving the harp seal prey consumption model and new estimates are now available (Hammill and Stenson, 2000). The current model includes diet information up to 1996; however, stomach content analyses are ongoing and the 1999 samples will be completed early in the (2000) Hammill and Stenson (2000) the estimated consumption of cod by harp seals is lower than the estimates used in the 1985 Ecopath model. This difference occurs primarily because we now have new satellite telemetry data on the proportion of seals frequenting inshore and offshore waters (i.e. habitat significantly influences the amount of cod in the diet).

Model parameters

Stenson *et al.*.(1999; 2000) provide catch and biomass values for the Gulf and Front herds. Both herds spend time in the model area during a period of the year, but the Front herd is perhaps the most important. Bundy used information on seasonal distribution of harp seals in 2J3KLNO to estimate the total numbers and biomass in the area. A ratio of the reported catches and biomass of the Front herd between 1995-99 and 1985-87 (Stenson *et al.*, 1999; 2000) was used to calculate the current catches and biomass in the model area. The average removal from the front and gulf herds in 1995-1999 was 220,011 animals, compared to 30,588 in 1985-1987. That represents an increase of 7.2 times between the two periods The average population numbers in 1995-1998 was 5,206,338 animals, compared to 3,440,664 animals in 1985-87. That represents an increase of 1.51 times between the two periods.

Biomass in the early 1900s was considered the median of the published guesses reported by Becky Sjare (6 to 12 million animals), and therefore represents about 3 times the estimated biomass in the mid-1980s. No changes in diet were included in the preliminary models, although they should be considered in the next iteration

References

Hammill, M. O., and G. B. Stenson (2000) Estimated prey consumption by Harp seals (*Phoca groenlandica*), Hooded seals (*Cystophora cristata*), Grey seals (*Halichoerus grypus*) and Harbour seals (*Phoca vitulina*) in Atlantic Canada. J. Northw. Atl. Fish. Sci. 26: 1-23.

Stenson, G. B., Healey, B., Shelton, P. A. and B. Sjare (1999) Recent Trends in the Population of Northwest Atlantic Harp Seals, Phoca groenlandica. Canadian Stock Assessment Secretariat Research Document 99/107.

Stenson, G. B., Healey, B.P., Sjare, B. and D. Wakeham. 2000 Catch at age of the Northwest Atlantic Harp seals, 1952-1999. CSAS Research Documents 2000/079.

HOODED SEALS

Garry Stenson and Mike Hammill
DFO, St John's

Since the 1985 model there is new information on the abundance, reproductive productivity, catch statistics and diets of hooded seals. There have been no new surveys but an improved population model has been formulated and it incorporates new reproductive information. There are tentative plans for a new pup production survey in the near future. As in the case of harp seals, diets are available up to 1996 with analyses ongoing. The hooded seal diet database will still not be as extensive as the harp seal database given the difficulty in obtaining samples in offshore waters. Gaps (and in some cases low sample sizes) will continue to be a problem for any future Ecopath modeling initiatives. The catch statistics for hooded seals have been comprehensive since the 1950s. However, historic data from 1900 to 1950 is not as good as for harp seals, the information available is summarized with harp seal data by Shannon Ryan. The main problem being that for these early time periods hooded seals were not separated from harps in the statistics. There is less traditional knowledge available for hooded seals as compared to harps because hooded seals are distributed more offshore and are not seen as much by coastal fishermen.

During the workshop, Becky Sjare confirmed that blubber samples are planned for fatty acid research.

Model parameters

Hooded seals are generally less abundant in the area, occurring mostly off northeast Newfoundland, the Davis Strait and the Gulf of St. Laurence. The information available on pulp production (DFO, website) indicates an increase in population size from 62,000 in 1984 to 83,000 in (1990) Based on this information it was therefore assumed that the biomass of hooded seals must have increased by at least 1.4 times between the mid-1980s and the 1990s. As for harp seals, biomass in the early 1900s was assumed 3 times the mid-1980s value.

SEABIRDS[2]

G. K. Davoren, W. A. Montevecchi and I. J. Stenhouse
Biopsychology Programme, MUN

Efforts to reconstruct marine species diversity, community ecology and population patterns in the historic and pre-historic past challenge our concepts of ecosystem structure and resiliency. Such efforts require researchers working across the range of biotic levels to integrate their knowledge through biophysical ecosystem approaches.

In such exercises, marine ornithology offers promising and complimentary inputs that are indicative of the state of oceanic and trophic conditions (e.g. Aebisher *et al.* 1990). Birds are the most highly visible, the most wide-ranging and among the most easily studied components of marine ecosystems. As top and multi-level trophic consumers, they are key elements for studying ecosystem changes (May *et al.* 1979). In as much as they have been exploited by humans for millennia for food as well as for spiritual (Tuck 1976) and navigational purposes, the breeding populations and ranges of marine birds are well known historically and, through zooarchaelogical investigations, pre-historically as well (Montevecchi and Tuck 1987). Owing to social constraints related to predation, food procurement and mating, seabird colonies have a considerable inertia and are often very persistent through time. Changes in the distributions, trophic relationships and populations of seabirds reflect current conditions (Stenhouse and Montevecchi 2000) as well as decadal and centurial climatic changes (Montevecchi and Myers 1996, 1997) and likely millennial ones as well (Montevecchi and Hufthammer 1990).

In the North Atlantic there are numerous relevant studies of marine birds, and specifically in the NW Atlantic the longest historic records of seabirds in North America, spanning 500 to 1000 years BP from the earliest known European incursions (Montevecchi and Tuck 1987) are known. Birds are included in current Ecopath models (Bundy *et al.* 2000), though they have much greater potential as indicators of ecosystem conditions and change than their biomass and production indicate. There is also a well-developed methodology to access and assess biological and ecological information from fishers (Hutchings *et al.* 1997, Neis *et al.* 1999a, b) than can be applied to both hunters and fishers (non-exclusive overlapping groups) to obtain both local and traditional ecological knowledge about marine birds and waterfowl.

References

Aebisher NJ, Coulson JC, Colebrook JM (1990) Parallel long term trends across four marine trophic levels and weather. *Nature* 347: 753-755.

Bundy A, Lilly GR, Shelton PA (2000) A mass balance model of the Newfoundland-Labrafor Shelf. *Can Tech Rep Fish Aquat Sci:* 2310.

Hutchings JA, Neis B, Ripley, P. (1997) The "nature of cod": perceptions of stock structure and cod behaviour by fishermen, "experts" and scientists from the nineteenth century to the present. *In* D Vickers (Editor) Marine resources and human societies in the North Atlantic since 1500. *Conf Pap 5 ISER*, St. John's, Newfoundland.

May R M, Beddington JR, Clark CW, Holt SJ and Laws RM (1979) Management of multispecies fisheries. *Science* 205: 267-277.

---

[2] See also Burke *et al.*, this volume.

Montevecchi WA, Hufthammer AK (1990) Zooachaeological implications for prehistoric distributions of seabirds along the Norwegian coast. *Arctic* 43: 110-114.
Montevecchi WA, Myers RA (1996) Dietary changes of seabirds reflect with shifts in pelagic food webs. *Sarsia* 80: 313-322
Montevecchi WA and Myers RA (1997) Centurial and decadal oceanographic influences on changes in northern gannet populations and diets: implications for climmate change. *ICES J Mar Sci* 54: 608-61
Neis B, Felt L, Haedrich RL, Schneider DC (1999a) An interdisciplinary methodology for collecting and integrating fishers' ecological knowledge into resource management. *In* D Newell, R Ommer (Editors) *Fishing places, fishing people: issues and traditions in Canadian small-scale fisheries*. University of Toronto Press, Toronto
Neis B, Schneider DC, Felt L, Haedrich RL, Fischer J, Hutchings JA (1999b) Fisheries assessment: what can be learned from interviewing resource users? *Can J Aquat Fish Sci* 56: 1949-1963.
Stenhouse IJ, Montevecchi WA (2000) Increasing and expanding populations of Northern Fulmars in Atlantic Canada. *Col. Waterbirds* 22: 382-391.
Tuck JA (1975) *Ancient people of Port au Choix*. ISER Press, St. John's.

WORKSHOP NOTES ON SEABIRDS[3]

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

Ian Stenhouse suggested that seabirds should have a more important role of sustaining local communities in models from earlier time periods. Seabirds have been suggested as visible indicators of health of coastal ecosystems. The study area includes some of world's largest seabirds colonies, the Grand Banks being an important over-wintering site. It is possible to establish good biomass estimates because adult size is fairly consistent. There was an increase in generalist species at expense of specialist over last 100 years due to anthropogenic influences. There is also evidence of one species extinction in the area: the great auk. Since the mid-1980s there was a relative balance in species composition and biomass, the information can be updated with more recent data. There is good information on particularly diets from the 1960s. Ian suggested that if any split has to be done, the best strategy would be to separate piscivores and planktivores birds.

Dave Schneider remarked that there is a time series of data available from 1930s for breeding populations (updated since 1985), and that sea counts were done in the 1970s and 1980s only (a good contact is Dick Brown).

Dave Schneider also observed that there are probably more fulmars in the area (perhaps an order of magnitude more) than what is reported by Montevecchi in Bundy's report. Good diet information is available for inshore breeding colonies compared to offshore. For the offshore zone one could use literature from George's Bank to make diet estimates for the area. Consumption rates are available from other locations and can be used as well for estimations and comparison. Consumptions will vary from roughly 50%/day for little birds to 10%/day for bigger birds. Seabirds rarely account for large consumption relative to the total prey biomass - examples of calculated seabird biomass to fish and primary production were published in Limnology and Oceanography and two publications claim that birds eat 30% of fish, but they can be proven wrong.

On a question about the great auk, Dave Schneider answered that the diet of great auk, for the 1400s model, could be predicted using the diet of similar size class birds of today. Seabird diets are predictable by size-classes, not by species. The Great Auks were like murres in that they did not fly. It is probably possible to estimate the number of Great Auks in the past by measuring the available habitat in areas they were known to populate, such as the Funk Island. The Great Auks were used as landmarks for fishers. It was suggested that Great Auks be split from seabirds group in the pre-Cabot model.

Barb Neis then suggested that predation on mussel farms by eider ducks is a concern and that they can have a strong local impact. She wanted to know if they should be split out of the seabirds group?

George Lilly said that there are no information at DFO about birds bycatch, but Dave Schneider suggested that the Canadian Wildlife Service (John Lien, John Chardine, Bruce Turner, Greg Robertson and Scott Gilliland) will have some information on bird bycatch.

Model Parameters

For the preliminary models it was assumed that biomass in the present time is the same as in the mid-1980s and half of the biomass in the early 1900s.

[3] See also Burke *et al.*, this volume.

Workshop Notes on Northern Cod

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

The best sources of information for cod are DFO and NAFO Research Documents, and also the references cited in those documents. There is also good documentation of the fisheries. George Lilly at DFO can assist in locating specific types of information. Other sources of information include acoustic surveys (George Rose) conducted in inshore and offshore areas during the winter and late spring; biomass estimates from mark-recapture experiments (inshore areas); and also a recent Honours thesis on diet of juvenile cod in inshore areas (Daneen Cull, MUN). There were marked changes in stock productivity during the 1980s and 1990s, evident from the decrease in size at age, maturity at age, fish condition and the decrease in recruitment.

At the workshop Paul Fanning suggested that changes in productivity are crucial, and George Lilly said that the P/B ratio would have been higher in the mid-1980s than in the 1990s. So the P/B will have to be specified for each time period in order to capture the fact that recruitment was low, fish condition was poor and growth was down, with fish smaller at age.

Dave Schneider asked that if the P/B ratio is for whole stock, how do we deal with P/B in relation to body size? Tony Pitcher explained that in the model Juvenile cod was split out and model simulations show cod coming back 8 or 9 years after the moratorium, although it is not seen in real life, so the changes haven't been captured properly in the model. He suggested that the P/B ratio needed to be changed for the recent period. George Lilly suggested that juvenile natural mortality, as deduced from total mortality calculated from survey catches, has been high in the offshore in the 1990s.

Dave Schneider then asked about the P/B being transferred to something else – being eaten, but by what? Consumption by seals? George Lilly suggested that harp seals eat cod, but cod is a minor prey in its diet. Based on diet reconstruction from otoliths found in seal stomachs, seals eat mainly 1 and 2 year olds, but older cod are also taken. Harp seals also consume cod by "belly-biting". Cod killed in this manner tend to be larger than those ingested whole. Belly-biting has been observed from shore, but in limited areas. Fishermen (or fish harvesters) say this has always happened, but has become more frequent in inshore waters in recent years. The frequency of cod otoliths in seal stomachs increased as cod declined.

Tony Pitcher then suggested that the current model (presented in the workshop) predicts a decrease in seals biomass when it should in fact be increasing, and that some processes are not been captured in the model.

Nigel Haggan wanted to know how the condition of cod has changed? George Lilly replied that during the late 1980s and early 1990s the condition of cod changed dramatically, declining in 2J3K and increasing in 3L. There is much information on abundance and distribution of juveniles in 90s from a variety of sources. Cod of age 0 and 1 are found inshore. They expand across shelf by age 3, and reach adult distribution by age 4. In recent years the abundance of each cohort has declined rapidly in catches from offshore trawl surveys, and very few cod older than age 5 or 6 have been caught.

Tony Pitcher wanted to know if total mortality had increased in these groups? George Lilly replied that they don't have comparable information from other periods.

He also wanted to know if the P/B ratio needs to be adjusted, and Paul Fanning suggested that there is no indication that Z (total mortality) has stabilized and that P/B does not equal to Z in non-stable situation.

George Lilly also proposed that whatever happens offshore is very different from what is happening inshore. Inshore fish are surviving and healthy. The dynamics appear to have been different between inshore and offshore during much of the 1990s. Barb Neis then asked if the juveniles stay inshore, and George replied that it appears that the inshore is the nursery area both for fish that will remain inshore throughout their lives and for fish that will move offshore as they age.

Dave Schneider advised that these issues will be important for community consultation – in order to make the connection between coast and offshore. Barb said that the vertical aspect must also be considered, and reminded the workshop that it can become very deep just off coast in Trinity Bay but shallow on banks.

Paul Fanning then suggested that it would be better to built two models: a coastal and offshore Ecopath model. Since the areas are very different (size, scale) it may not be compatible to combine coast and offshore components into one single model. However, Tony Pitcher replied that that would increase the time in the project dedicated to modeling.

George Lilly found that another problem of splitting the models would be how to represent energy flows between inshore and offshore: for instance, capelin carry energy from offshore feeding areas to the inshore where they spawn. The eggs are fed on by numerous species, and many of the adult capelin are consumed either before or after spawning. Many capelin die of natural causes during the spawning process and are then consumed by a variety of species, and it becomes tricky to decide from stomach content examinations if this represents predation mortality or carrion feeding. Alida Bundy replied that capelin is also prey for offshore predators that move inshore (e.g. harp seals). Tony Pitcher concluded that it was agreed that the model has to somehow capture inshore and offshore variations, but we have not decided yet how to do so. However, Dave Schneider suggested that the coastal zone is where cod and capelin are, where most people fish, and where TEK is found.

Model Parameters

The abundance and distribution of 2J3KL cod changed dramatically during the late 1980s and early 1990s. This was a period of rapid decline in biomass and high fishing mortality. With the stock collapse, a moratorium on directed commercial fishing was implemented in (1992) From the mid-1990s the stock biomass has remained at the lowest historical levels. The following sections present biomass estimates for juvenile and adult cod in the models.

Cod > 35 cm

Reported catches in the period 1993 to 1998 came from bycatch and sentinel surveys (1995-1998) and estimates of catches during food fisheries in 1994, 1996 and 1998. In 1999 the commercial fishery was reopened with a TAC of 9,000 tonnes but only 8,500 tonnes were reported caught. In 1999 catches mainly comprised fish 4 to 9 years old. The average catch from 1995 to 1999 was 3,400 tonnes.

There are large uncertainties in the estimation of cod biomass. Two sources were used here: DFO (2000) and biomass at age from sequential population analysis from the DFO website (Shelton *et al.*, 1996). The first reference provides biomass indices from spring and autumn offshore bottom-trawl surveys for 1995 - (1999) Data shows very low stock biomass throughout the area and years. The biomass index in 1999 was ca. 2.5% of the average biomass index estimated for the period 1983 to 1988. Biomass estimates were below 30,000 tonnes.

In the inshore areas of 3KL (there are genetic differences between inshore and offshore fish), tag recapture data were used to estimate exploitation rates and consequently stock biomass. Exploitation rate values ranged from 13 to 19% in 3K and from 2.3 to 3.8 in northern 3L. Biomass values ranged from 8,900 to 11,000 in 3K and from 49,000 to 42,000 in northern 3L in (1999) The sequential population analysis estimates a biomass of 3+ at 28,072 tonnes in 1995 (Shelton *et al.*, 1996).

Cod< 35 cm

Catches of juvenile fish were assumed equal to the estimated mean annual discarded catch of 1.25 tonnes as in Bundy *et al.* (2000). The recruitment index, comprised of catch rates of 0 to 3 years old cod, points to an increase in year class strength from 1996 to 1999 (DFO, 2000). No biomass values could be calculated from the data available. A sequential population analysis carried by Shelton *et al.* (1996) estimates the biomass of 3 years old cod at 5,951 tonnes in (1995) Using the number of 3 years old cod in 1995 (20,961 x 10^3 fish) as representative of the average number of 3 years old in the following years, which is equivalent to assume stable recruitment rates, it was back-calculated the number and biomass of 0, 1 and 2 years old fish as in Bundy *et al.* (2000). That is, numbers at age were reconstructed using M of 0.6 and assuming no fishing mortality. With a mean weight of 0.003, 0.025 and 0.100 kg, the total biomass of juvenile cod is estimated at 5,939 tonnes.

Juvenile and adult cod biomass in the early 1900s was taken from Hutchings and Myers (1994). The assumption made by the authors is that the total harvestable biomass (3+ fish) of cod was 3,000,000 tonnes prior to the industrial fisheries. Catches at that period are estimated at 211,800 tonnes. To calculate the biomass of juvenile cod in the past model we assumed that the same rate of change of adult biomass applies to juveniles, i.e. biomass in the early 1900s is 3.2 times the biomass in the mid 1980s.

References

DFO (2000) Northern (2J3KL) cod. DFO Science Stock Status Report A2-01, 2000. 13 pp.
Bundy, A., Lilly, G.R., and Shelton, P.A. (2000) A mass balance model of the Newfoundland-Labrador

Shelf. Can. Tech. Rep. Fish. Aquat. Sci. 2310: xiv + 157 pp.
Hutchings, J. A. and R. A. Myers (1995) The biological collapse of Atlantic cod off Newfoundland and Labrador: an exploration of historical changes in exploitation, harvesting technology, and management. Pages 37 - 93 in R. Arnason and L. Felt (Eds) The North Atlantic Fisheries: Successes, Failures, and Challenges. Institute of Island Studies, Charlottetown, Canada. 317 pp.
Shelton, P. A., Stansbury, D. A., Murphy, E. F., Lilly, G.R. and J. Brattey (1996) An assessment of the cod stock in NAFO divisions 2J + 3KL. DFO Atlantic Fisheries Research Document 96/80. 11 pp.

WORKSHOP NOTES ON GREENLAND HALIBUT

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

The DFO contact person for Greenland halibut is Ray Bowering. It is considered that Greenland halibut comprises a single stock from Davis Strait to the Tail of the Grand Bank. There is a shallow-deep water gradient in fish size, where young are usually on the shelf and older fish in deeper waters. In the 1990s a fishery in the Flemish Pass started with Spanish vessels. It is not known if fish migrated into the Flemish Pass area in the late 1980s and early 1990s or if the concentrations found by the new fishery were always there. Surveys conducted prior to the 1990s didn't go deep enough to resolve the issue. It is possible that there were changes in distribution.

Barb Neis suggested that Greenland halibut is actually being caught as bycatch in the cod fishery, but George Lilly said that as far as he knows, the Greenland halibut fishery in the Flemish Pass was targeted primarily on that species. Barb then replied that in shallower water, younger fish do mix with cod.

According to Barb Neis a fishery for Greenland halibut begin in Trinity Bay during the 1960s, but the area was fished out within a year and then the fishery moved offshore. There are now some stronger year classes in Trinity Bay area, which are again being fished before fish grow large. However, the largest fishery for Greenland halibut is in Labrador.

To a question on the situation outside Canada's EEZ by Tony Pitcher, Barb Neis replied that a study of the TEK on Greenland halibut in Greenland has challenged the theory that fish, apparently advected from the Davis Strait into the area is all one single stock.

George Lilly suggested that historical biomass levels are unknown, because there were no substantial fisheries for them. However, Barb Neis said that there has been a historical fishery for food in late fall, and they set trawls in the deep water in the Melrose area, with presumably bycatch and discarding. George Lilly also mentioned that there are German and Russian survey data from the 1960s and 1970s, and that observer data is also available.

Barb Neis reminded that data for the period pre-1950s would be needed to get information about un-fished biomass and that the fishery for Greenland halibut was largely offshore line trawl until WWII. George Lilly indicated that between 1950 and 1953 there were exploratory surveys with longlines off the east and northeast coasts of Newfoundland. Gillnets were used as the main gear of inshore fleets after approximately the mid-1960s. Barb Neis also suggested that there are many papers on Bonavista longliner experiments, which will at least give indications of the transition from inshore to offshore.

George Lilly indicated that there is probably more recent data on the diet of Greenland halibut from stomach analysis, and on a question about how deep they fish for G. halibut by Alida Bundy, George replied that they fish to about 1000m in the Flemish Pass and Flemish Cap area. He also suggested that it is fair to assume that everything reported in 3L will be in study area.

Model Parameters

Survey indices shows an increase in stock size from 1996 to 1998, and probably continuing up to (2000) Research surveys conducted in 2J3KL from 1977 to 1999 (Bowering, 2000) indicate that biomass of fish > 35 cm in the period 1995-1998 is ca. 43% of the biomass observed in the mid-1980s.

On the other hand fish <35 cm is 2.6 times more abundant now than during the mid-1980s, probably reflecting good recruitment in recent years. It was assumed that Bowering length intervals (< 35 cm >) are representative of the interval of 40 cm used by Bundy *et al.* (2000) in the model of the mid-1980s. Biomass in the early 1900s is not known. Using 1978, the first year of the survey time series, as a reference, biomass of fish >35cm was ca. 1.3 higher than in the mid-1980s, while the biomass of fish < 35 cm was 1.4 higher. These values are used in this study as minimum estimates of the biomass of Greenland halibut in the early 1900s.

References

Bowering, W. R. (2000) Trends in distribution, biomass and abundance of Greenland halibut (*Reinhardtius hippoplossoides*) in NAFO Subarea 2 and Divisions 3KLMNO from Canadian Research vessel survey during 1978-1999. NAFO SCR Doc. 00/12, June 2000.

WORKSHOP NOTES ON AMERICAN PLAICE

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

Joanne Morgan and Bill Brodie are the DFO representatives on American Plaice. There are two stocks of American plaice in the area. The 2+3K stock is being assessed within the Newfoundland Region of DFO in October. The 3LNO stock is assessed by NAFO. There was a long-term decline in the overall abundance of both stocks, starting in the early 1980s that cannot be accounted for by direct fishery removals only. Discards from cod fishery may be in part responsible for the decline. Fish is disappearing from north and central area, and some left on the southern Banks. Either the natural mortality is high or there is a tremendous amount of discarding. American plaice is a valuable fish for market. Canada mostly catches American Plaice on the Grand Banks, but foreign fleets target it as a bycatch to catch as much as they can.

The predators of American Plaice are primarily harp and hood seals, although Becky Sjare indicated that American plaice occasionally shows up in the diet of seals, but they are not significant. Dave Schneider advised that American Plaice are one of the most heavily parasitised fishes.

George Lilly indicated that modeling exercises carried out in 1999 for the 3LNO stock showed that the best fit to the data occurs when natural mortality is increased from 0.2 to 0.6 year^{-1}. He also suggested that stock catchability could be a problem: it probably changed over time and may be related to temperature change. For instance, biomass estimates for yellowtail are increasing more quickly than fish can grow, possibly reflecting a change in catchability.

Barb Neis asked if there is a connection in the literature between American plaice and yellowtail flounder, as fishers suggest that there is one. George replied that a connection has been suggested between yellowtail flounder and haddock on Grand Bank. The yellowtail stock increased considerably decades ago after the decline in haddock. Yellowtail flounder and small American plaice feed on the same diet: mainly on benthos.

Model Parameters

The American plaice stock size peaked in the early 1980s, then declined by more than 90% during the early 1990s, and have remained low through the 1990s although catches are insignificant (DFO, 1996). Catches from 1992 to 1995 averaged less than 70 tonnes, with only 23 tonnes caught in 1995. From 1995 to 1997 the fishery was under moratorium. Plaice catches in 3LNO were the by-catch of other fisheries only. The average by-catch in that period was 986 tonnes. Meanwhile, the NAFO database reported an average catch of 49 tonnes of plaice for 2J3KL. Considering that about 94% of Canadian catches are fish >35 cm (Bundy *et al.*, 2000), the total catch was split between the two size categories as 46 tonnes for fish >35 cm and 3 tonnes for fish <35 cm. The overall survey biomass index in 1995 was only approx. 10% of the peak values observed during 1982-1983, but the average biomass in 1995-97 is approx 26% of the average biomass in 1985-87 (DFO, 1998). The latter proportion was applied to juvenile and adult biomass in the mid-1980s model to obtain a biomass for the present time. As for Greenland halibut, the ratio between survey index biomass between 1978 (the first year of the series) and 1985-1987 (ratio = 1.8) was used as minimum estimate for the 1900s biomass.

References

DFO (1996) Subarea 2+ 3K American plaice. DFO Stock Status Report 96/48. 5 pp.
DFO (1998) Newfoundland Region Groundfish Overview. DFO Science Stock Status Report A2-19, 1998. 15 pp.

WORKSHOP NOTES ON FLOUNDERS

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

Dave Kulka, Steve Walsh, Bill Brodie, Ray

Bowering and Joanne Morgan are the DFO representatives for these species.

The three main species that are grouped under 'flounders' in the area are yellowtail, witch and winter flounder. There is not much overlap in the species distribution, but all three occupy the model area. Yellowtails are mostly found on Grand Banks, witch flounder is a deep-water species, while winter flounder is found mostly in shallow inshore water. There is considerable information on yellowtail and witch flounder, but winter flounder has not been well studied in the model area. Winter flounders were largely considered trash fish until the collapse of the cod fishery, after which they were upgraded to "underutilized".

If any split has to be done it would be based on distribution, not on diets, in which case winter flounder should be separated into an inshore model.

According to George Lilly, yellowtail and witch flounder have been fished commercially for years and are caught and sampled during research vessel surveys, so there is considerable information on these species. Winter flounder has not until recently been the object of a directed fishery, and it occurs closer inshore than their surveys, so much less is known about them. There is much more information in Bundy *et al.* (2000) and in DFO research documents.

Model Parameters

The flounders compartment consists of yellowtail flounder, *Limanda ferruginea*, witch flounder, *Glyptocephalus cynoglossus*, and winter flounder, *Psedopleuronectes americanus*. Yellowtail dominates the biomass of the group. The yellowtail flounder stock in NAFO division 3LNO occurs in the study area. The stock has been severely reduced and there was a moratorium on the yellowtail flounder fishery from 1994 to 1997.

Biomass in division 3L declined since 1985, reached a level of 2,000 tonnes in 1990 and practically zero in 1994 (Walsh *et al.*, 2000). From 1995 to 1997 the stock fluctuated around 1,700 tonnes and increased ca. 4 times, reaching a level of 5,000 tonnes in 1999. The current stock biomass is believed to be the same as observed during the mid-1980s (Walsh *et al.*, 2000). Although the stock has been increasing in recent years, the average biomass in the period from 1995 to1999 represents only ca. 38% of the average biomass during 1985-1987.

A single stock of witch flounder occurs in 2J3KL. The fishery for witch flounder started in the early 1960s. Peak catches of 24,000 tonnes were obtained in 1973; and catches oscillated between 3,000 and 4,500 tonnes until 1991 after which it declining to only 12 and 0.5 tonnes in 1994 and 1995, respectively (DFO, 1996a). Current catches are probably still low. Survey data suggests that the stock of witch flounder have declined by as much as 40 times since the early 1980s - biomass of witch flounder in 1995 is ca. 4% of the average in 1985-1987 (Bowering, 2000). The fishery is also under a moratorium since 1995.

Little is known about the winter flounder, as their shallow and coastal distribution make them rarely seem in research surveys. Catches in areas 3KL in 1995 was approximately 800 tonnes (DFO, 1996b).

Given the above information, it is expected that the biomass of flounders in the recent period be lower compared to the mid-1980s. The combined average biomass of witch and yellowtail flounder in 2J3KL in 1995-1999 is 7,569 tonnes, which represents ca. 6% of the biomass of 117,996 tonnes reported by Bundy (this volume) for 1985-1987. The average catch from 1995-1999 was 1,156 tonnes. Biomass in the early 1900s estimated by the model.

References

Bowering, W. R. (2000) Stock Status Update of Witch Flounder in Divisions 2J, 3K and 3L. NAFO SCR Doc. 00/13. June 2000.

DFO (1996a) Divisions 2J3KL Witch Flounder. DFO Stock Status Report 96/49. 5 pp.

DFO (1996b) Blackback (Winter) flounder in divisions 3K, 3L and 3Ps. DFO Stock Status Report 96/92. 4 pp.

Walsh, S. J. Veitch, M. J., Morgan, M. J., Bowering, W. R. and B. Brodie (2000) Distribution and abundance of Yellowtail Flounder (*Limanda ferruginea*) on the Grand Bank, NAFO Divisions 3LNO, as Derived from Annual Canadian Bottom Trawl Surveys. NAFO SCR Doc. 00/35, June 2000.

Workshop Notes on Skates

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

The DFO representative for skates is Dave Kulka. The overall abundance of skates has declined dramatically. Skates largely disappeared from northern areas but are still found on the southern

Grand Banks. Large quantities of skates were caught as bycatch and discarded in the past. Diet data for the preliminary 1980s model was based on scattered information from a wide area. Thorny skates are the dominant and abundant species in the area and therefore their diet was used as reference diet for the group in the mid-1980s model. However, Alida Bundy indicated that barn door skates are also present in the study area, and George Lilly said that although some references say barn door skates have largely disappeared, they are still caught in commercial fisheries. Paul Fanning then suggested that they might never been very abundant compared with other skates. To a question on if we should split out barn door skates due to the public attention they received, George Lilly replied that they were never very abundant, so it would not be worth splitting into a separate compartment.

Model Parameters

There are about 10 species of skates inhabiting Newfoundland waters, but the thorny skate, *Raja radiata*, is by far the most common in surveys and catches (DFO, 1996). Skate catches in the mid-1980s weren't as important as during the 1990s due to the moratorium on traditional stocks. Skates were usually discarded and constituted the most important non-commercial bycatch species in offshore trawlers catches. Most of these catches remained unreported. Most of the catches of skates in 1996 were taken in NAFO divisions 3O and 3P. The TAC in 1996 was set to 2,000 tonnes, with the TAC for area 3L of 200 tonnes (DFO, 1996). For lack of better information from NAFO, this is considered the approximate catches of skates at the present time.

Survey indices of biomass declined steadily in division 3L from 1986 to 1995, with the biomass in 1995 being only ca. 3% of the average in 1986-1987 (DFO, 1996). It is suspected that the decline of skates is a result of high catch rates outside the 200-mile EEZ during the second half of 1980s. It is assumed that biomass in the present time model is 3% of the biomass in the mid-1980s. Biomass in the early 1900s was probably higher than what is estimated for the mid-1980s considering that large quantities of skates were discarded since the beginning of trawling. Biomass of skates in the preliminary model of the early 1900s was assumed to be twice the number estimated for the mid-1980s.

References

DFO (1996) Divisions 3L, 3N, 3O and 3Ps Skates. DFO Stock Status Report 96/86. 7pp.

Workshop Notes on Redfish

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

Don Power and Bruce Atkinson are the DFO representatives for this group.

Aging of redfish is a significant problem. The data available show a long steady decline in 2J3K with poor recruitment for many years. The fishery occurs on the eastern and southern Grand Banks. Redfish is assessed as a group, but there are actually three species. Some efforts have been made at distinguishing between the species, but their diets are similar, based primarily on Euphausiids and small fish. They need to be dissected to tell the species apart, according to Paul Fanning, and George Rose suggested that their behaviour is distinguished by size, age and gender, and not by species. Thus Paul Fanning concluded that the species are functionally similar.

Tony Pitcher suggested that if the species live in different areas, something in the life history must distinguish them and Barb Neis indicated that fishers describe them in different areas, with different behavior, so that they must use different fishing strategies. George Rose also indicated that redfish are closely associated with Euphausiids.

According to George Rose the fishery for redfish started with the Russians in the 1950s – after sequential overfishing of redfish, the fleet started targeting cod. The virgin abundance is unknown, but catch rates show a significant decline since the 1950s.

Model parameters

Since 1979 redfish catches were mainly taken in division 3K. Landings of redfish stock from Sub-area 2 and division 3K have been in the order of 15 tonnes from 1992 to (1997) Discard as shrimp bycatch declined from 386 tonnes in 1992 to 110 tonnes in (1994) But no updated information has been compiled yet (DFO, 1999). It is assumed that the average catch of redfish in division 2J3K is 125 tonnes at present. Power (1999) provided provisional catch data in division 3L of ca. 313 tonnes per year from 1995- (1999) Therefore the total catch in 2J3KL is estimated at 438 tonnes. Research vessel surveys conducted in the area show that the 1995-1997 biomass is still very low, less than 10% of the 1978-1988 average (DFO, 1999). The average biomass in period 1995 to

1997 was ca. 15,000 tonnes. There have been about 25 years of continuous recruitment failure since strong year classes entered the population on the early 1970s (Power, 1995). The ratio between biomass in 1978 and the average biomass in 1985-1987 (5.17 times) was used as minimum reference point for biomass in 1900s.

References

DFO (1999) Status of redfish stocks in the North Atlantic: Redfish in units 1, 2 and 3 and in Division 3O. DFO Science Stock Status Report A1-01, 1999. 24 pp.

Power, D. (1995) Status of redfish in Subarea 2+Division 3K. DFO Atl. Fish. Res. Doc. 95/25.

Power, D. (1999) A Stock Status Update of Redfish in NAFO Divisions 3LN. NAFO SCR Doc. 00/52.

WORKSHOP NOTES ON LARGE DEMERSAL FISH

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

Haddock is primarily distributed on the Grand Banks and should therefore be removed from Large Demersal Feeders in the 2J3KL model.

Regarding lumpfish, DFO requests annual assessments but no support is provided and hence little assessment work is done for the species. There are catch information available and some studies on lumpfish biology (a tagging study by private industry is currently underway). Lumpfish spawn on the coast in shallow water. Don Stansbury at DFO may be able to build a catch scenario for 1989-1998 period using records of roe landings. This information will be available within the next 18 months. But there is no fishing effort data because it is a small boat fishery, and it is difficult to track days at sea, number of participants, etc. Lumpfish diet is mainly jellies and small benthos.

Becky Sjare told of a Masters student (Darryl Walsh) looking at seal bycatch in lumpfish fisheries, which can indicate some roe catch data. Barb Neis also suggested that relevant information could be obtained from the interviews carried in Trinity Bay, the last of which was in 1998.

The lumpfish fishery began in 1960s in Bonavista/Trinity bay area. There was a massive shift in effort as cod declined. The fishery remained uncontrolled until the early 1990s. Becky Sjare then indicated that the first commercial fishery began in 1969, and remained a small fishery until mid-1980s. Barb Neis said that the price of roe increased in that period, and Dave Schneider suggested that that was a major drive to develop the fishery.

According to Becky Sjare, lumpfish is considered an underutilized fishery. George Rose said that the species is widely dispersed offshore, but only fished inshore. Barb Neis suggested that studies have shown that lumpfish will home to wherever area they were spawned. George Lilly said that tagging studies will give some ideas on fish movement.

According to George Lilly there are only a few other Large Demersal feeders in 2J3KL. Many of the species included in the 2J3KLNO Ecopath model of Bundy *et al*. (2000) will have even less importance in a 2J3KL model because they live in relatively warm water and are not abundant north of 3NO. These species include haddock, monkfish, white hake, silver hake and Atlantic halibut.

Tony Pitcher asked if there is any historical information on Atlantic halibut, and George Rose said that there might be that that halibut was never very abundant in 2J3KL – any halibut found are probably from the Gulf. Barb Neis indicated that there were halibut in the Bonavista longliner experiments. George Rose suggested that there were lots of halibut on the south coast. Some information can be found in Raoul Anderson's (MUN anthropologist) new book '*Voyage to the Grand Banks*' about early dragger skipper/Grand Bank schooner captain Capt. Arch Thornhill, and also in a paper titled *Millions of Fish*.

George Lilly suggested that wolf fish is probably not targeted directly, but it is caught, and that the species showed dramatic declines. Becky Sjare agreed and said that Bruce Atkinson was worried that wolffish will be put on the endangered species list. Paul Fanning indicated that a report was submitted to COSEWIC. George Lilly suggested that wolffish population is down to about 2-10% of what it was in the 1980s, and that diet information is very poor.

Paul Fanning said that one of the species feed on mollusks and George Lilly suggested that we should separate out lumpfish and wolf fish, and keep the rest of the species in the Large demersal feeders group. Monkfish are mainly on Banks, but should be left in the group. Alida Bundy reminded us that adult and juvenile large demersal feeders have different diets, so it may be needed to separate out juveniles.

Model Parameters

Large demersal feeders include the white hake, *Urophycis tenuis*, haddock, *Melanogrammus aegelfinnus*, rocklings, grenadiers (Macrouridae), wolfish, *Anarhichas* spp., eelpouts (Zoarcidae), common lumpfish, *Cyclopterus lumpus*, monkfish, *Lophius americanus*, and Atlantic halibut, *Hippoglossus hippoglossus*.

Until recently, white hake was mainly taken as by-catch in other fisheries; with the decline of traditional groundfish stocks interest in hake has increased (DFO, 1996). There is no catch limit, but fishing is controlled by the by-catch of cod and haddock. Catches are mainly taken in areas 3P, 3O, and catches in 3L in 1995 were insignificant. Similarly, research survey indices indicate that most white hake are found in 3O and 3P (DFO, 1996a).

Two species of wolf fish (or catfish) occur in the Newfoundland area: the striped catfish, *Anarhichas lupus*, and the spotted catfish, *A. minor*. Both species are taken as by-catch in trawler fisheries, and the current catches are unregulated. The two species together comprised the second most abundant by-catch in trawler catches after skates. The species are also by-catch in gillnets and longlines. From 1977 to 1995 most of the catches were reported from 3L. Catches in 1985-87 have been in the order of 1,000 tonnes, but in 1995 it was less than 20 tonnes (DFO, 1996b). Survey indices for spotted wolf fish shows a decline in biomass from 1989 to 1995, primarily in division 2J and 3L. The stripped wolfish is most abundant in division 3N and 3O. According to biomass surveys the biomass of spotted wolfish present in 1995 is only about 19% of the average in 1986-1987 (DFO, 1996b).

The study area comprises the northern range of the haddock distribution. Historical landings of haddock by the Canadian fleet were highest in the Grand Bank division 3NO. Research surveys have been conducted since the early 1970s, and since early periods very few haddock were ever found in Division 3L during spring. Overall the stock shows trends in abundance in accordance to the strength of year-classes (DFO, 1996c): low during the 1970s, highest in 1984, declined in 1985 and showed a gradual increase to 1988. The stock was very low since then, with the1994 and 1995 estimates close to those of the 1970s. The most recent surveys also show weak year-classes. There is evidence that haddock were abundant in the earlier period of the fishery (1950's) when up to 75,000 were landed (DFO, 1996c). The provisional catches for 1994 and 1995 were 8 and 2 tonnes respectively, the lowest on record.

Commercial fishing for lumpfish in Newfoundland started in 1969. The fishery was mostly for roe. Average catches in 3KL during 1985-87 was ca. 1,100 tonnes, while in 1995-96 it was ca. 500 tonnes (DFO, 1996d). There was an apparent change in distribution of catches since the late 1980s, with most of landings coming from division 3P. Results of fall trawl surveys in 3KL indicate that the resource have fluctuated between years with no trend over time (DFO, 1996d). In subdivision 3P biomass estimates have declines an order of magnitude from 1985 to 1995 (DFO, 1996d). Other auxiliary information from fishers in Trinity bay and marine study sites in Conception bay also indicate a dramatic decrease in the abundance of lumpfish (DFO, 1996d). The more cautious approach here should be that biomass now is lower than in the mid-1980s.

Until recently, monkfish were taken only as by-catch, but with the depletion of traditional stocks, the directed fishery (with fixed gear) has increased. Canadian catches (from by-catch) remained under 200 tonnes until 1991 (DFO, 1996e). Catches increased with directed trawl fisheries reaching 1,000 tonnes in 1994, decreasing subsequently to 165 tonnes in 1995 and 200 tonnes (TAC) in (1996) Catches were predominantly from 3O and 3P. Non-Canadian catches have generally been less than 1,000 tonnes (with the exception of 1977 and 1987 when ca. 3,500 tonnes were reported). Most non-Canadian catches are from 3N. Landings in 3L in 1985-87 were below 100 tonnes, and in 1995 below 20 tonnes. Although this low catch rates in 3L, research surveys from 1986 to present have nor been able to find any monkfish in 3L. In the other areas there are some indication of a decline in biomass from the 1980s to the 1990s (DFO, 1996e).

There is no directed fishery for rough-head grenadiers *Macrourus berglax* (DFO, 1998). Most of the catches came from by-catch in the Greenland halibut fisheries of 3LMN. The catch of rough-head grenadiers remains uncertain due to mis-reporting. The total reported catches for subdivision 2 and 3 was less than 8 tonnes from 1997 to 1999, and the state of the stock is unknown.

Prior to 1990, Russian and German boats operating in division 2GH and 3K caught most of the round-nose Grenadier (*Coryphaenoides rupestris*, DFO, 1998). Since 1991 the species have been caught mostly as bycatch of Greenland halibut in divisions 3LMN. The total reported catches in this areas in 1997 –1998 was 50 tonnes, and the fishery has been under a moratorium since (1997) The state of the stock is unknown.

According to Bundy *et al.* (2000), haddock, round-nose grenadier and white hake make up 80% of the total catches of large demersal feeders in 2J3KLNO in 1985-87. Using the same proportion for the present time it is estimated that catches in 1995 were ca. 540 tonnes. Better estimates of catches are available from NAFO. Overall the biomass of the group has declined significantly from the mid-1980s. Taking wolffish as an example, the biomass in 1995 is ca. 19% of the average in 1985-87. We applied this proportion to estimate the biomass in the present time from Bundy's (this volume) estimate for the mid-1980s. Biomass in the early 1900s was assumed the same as in the mid-1980s.

References

DFO (1996a) White hake in divisions 3L, 3N, 3O and 3Ps. DFO Stock Status Report 96/04. 5 pp.

DFO (1996b) Catfish (wolfish) in divisions 2J, 3K, 3L, 3N, 3O and 3Ps. DFO Stock Status Report 96/91. 6pp.

DFO (1996c) Divisions 3LNO haddock. DFO Stock Status Report 96/46. 4 pp.

DFO (1996d) Lumpfish in divisions 3K, 3L and 3Ps. DFO Stock Status Report 96/87. 4pp.

DFO (1996e) Monkfish in divisions 3L, 3N, 3O and 3Ps. DFO Stock Status Report 96/89. 4pp.

DFO (1998) Newfoundland region groundfish over-view, DFO Science Stock Status Report A2-19, 1998. 15pp.

Workshop Notes on Small Demersal Fish

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

None of the species in this group is commercially exploited, and there is little information available. Dave Schneider suggested that Daneen Cull's honours thesis would be useful as it compares biomass of small demersal feeders between 1960s and 1990s. Her work shows an increase in biomass between time periods.

Model Parameters

The group includes gunnels (Pholidae), blennies (Stichaeidae), pouts, *Lycodes* spp., wolfeels, *Lycenchelys* spp., sculpins (Cottidae), alligatorfish (Agonidae) and lumpfish (excluding the common lumpfish which is part of Large demersal Feeders). Biomass of Small demersal feeders in the present time and in the early 1900s was left to be estimated by the model assuming an Ecotrophic Efficiency of 0.95.

Workshop Notes on Capelin

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

Research surveys carried out by DFO ended in 1992/ (1993) Sources of survey data subsequent to these surveys include studies done by George Rose and pelagic surveys by John Anderson and Edgar Dalley. There are considerable uncertainties about whether there was a collapse in capelin. It is thought that the biomass in the 1980s was higher than during the 1990s. The problem is that there is no single reliable biomass index spanning the 1980s and 1990s, the available indices from the 1980s and the 1990s do not overlap as much as one would wish and modelling of the available data has produced a time series of relative year-class strength but not biomass.

Becky Sjare suggested that there were changes in capelin biomass and dynamics in the late 1980s, which influenced the dynamics of seals. Changes in seal distribution (around 1987-1993) seem correlated to changes in capelin spawning/ migration – you could not find capelin offshore in that period. George Lilly suggested that we check the annual assessments and Research Documents. References can be obtained with Jim Carscadden and Brian Nakashima. He suggested that estimates of catches in the past would have to be based on what was taken for personal use, agriculture, etc. Capelin and herring were used as fertilizers, dog food, and bait, and George also indicated that there was a reduction fishery for capelin in the 1970s.

Barb Neis said that Sean Caddigan has access to merchant data that could help reconstruct catches, and that in the 1980s there was the question of discards and dumping in the roe fishery. George Rose indicated that the data doesn't agree across different techniques, so there are many disagreements on the historical trends.

He told of a beach in the Strait of Belle Isle where spawning was predictable on exact days (St. Jean Baptiste day) in the past, but this is not possible anymore. Paul Fanning then pointed out that that is a coastal observation and that perhaps small changes on a macro level lead to large variation on a micro level. He suggested that there is an old theory that explains that capelin spawned on the beach because they were pushed onto the beach by the competition for spawning areas.

Barb Neis pointed to a paper by Melanie Morris relates fish density with beach spawning and George Rose said that there are similar high concentrations of capelin in Trinity and Conception bays. He asked if the species is distributed in pockets of areas with high density? How extensive they are? Is it a coincidence that cod are also in the same areas? Tony Pitcher suggested that it sounded like range collapse and that we should have a range of scenarios based on the different hypotheses.

Alida Bundy then asked if there was an agreement on biomass estimates for the 1980s? George Rose said that he would challenge some estimates that were published. Acoustic studies show conflicting results, notably after 1990, and he suggested that despite uncertainties, relative densities could be re-scaled. George Lilly said that at same time that capelin are disappearing from some areas, they were showing up in increasing numbers in other areas (e.g. Flemish Cap and Scotian Shelf), and Paul Fanning indicated that capelin were absent in the Scotian Shelf surveys for 10 years to 1988, and then there were signs of colonization in 4Ps. Barb Neis suggested that capelin abundance may still be high, and Becky Sjare said that at the same time, more harps and hood seals are found in southern areas. Dave Schneider indicated that if capelin were not abundant on the coast, there would be major changes in seabird populations.

Barb Neis asked what about the diet shifts to gunnels? Do we know anything about them? There is a thesis by Rachel Bryant, and George Rose said that gunnels were a “last resort” food. Paul Fanning also indicated that gunnels are not found in the densities that capelin are found in – capelin is a survival food for adults but does not give enough energy for them to reproduce.

Model parameters

Capelin in 2J3KL is considered as a single stock. The average catch in the period of 1995 to 1999 was 17,580 tonnes (DFO, 2000). There are large discrepancies between biomass estimates (from stock assessments), which indicate that most year class strengths during the 1990s was higher than those observed during the 1980s, and capelin fixed gear fishers whom felt that the capelin abundance in 1990s and especially in 1999 was below average and even lower than when they started fishing in the 1980s (DFO, 2000). The assessment of the stock has been difficult because of divergences between inshore abundance indices and offshore acoustic surveys. In general the uncertainties around estimates are so large that the biomass may be totally indistinguishable between the mid-1980s and the late 1990s. Ecopath was used to estimate biomass in both the present time and the early 1900s periods assuming an Ecotrophic efficiency of 0.95.

References

DFO (2000) Capelin in Subarea 2 + Divisions 3KL. DFO Science Stock Status Report B2-02, 2000. 6 pp.

Workshp Notes on Sandlance

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

Most sandlance occur on the plateau of the Grand Banks, but some are also found in inshore areas. A DFO research document with sandlance biomass and distribution estimated from trawl surveys will be available by the end of (2000) Sand lance is a major food item for many species on Grand Banks, including cod, American plaice, whales and seabirds. They are primarily planktivorous. Sandlance was never commercially exploited and there is strong resistance to reduction fisheries in Newfoundland region.

Model parameters

Sandlance, *Ammodytes dubius*, occur in inshore waters of Newfoundland and Labrador, but most of the population is on the Grand Bank area. Bundy *et al.* (2000; this volume) calculated the biomass of sandlance in the area from survey data carried in 1996-1997 - the assumption made was that there was no change in biomass between the two periods. This assumption is supported by the fact that the species is not commercially fished in the area. Biomass in the 1995-1999 model was therefore assumed to be the same as in the mid-1980s model. The model was used to estimate biomass in the early 1900s by assuming an Ecotrophic efficiency of 0.95.

WORKSHP NOTES ON ARCTIC COD

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

Various DFO Research documents report biomasses and distribution from surveys. Arctic cod is a cold-water species that occur in the Labrador shelf, in northeast Newfoundland and on the northern Banks. In the late 1970s older fish was found further north and younger fish (0, 1, and 2 year olds) were mostly found in the study area. With the change in cold-water distribution in the early 1990s, the Arctic cod expanded over the southeast and northeast Newfoundland shelf and onto the Grand Banks to a greater degree than in the 1980s. It subsequently moved back to the 'normal' range for the species. There is no direct fishery for Arctic cod but small amounts appear as bycatch in the capelin fishery. They were very abundant in the early 1990s as distribution expanded to the south. At that time there was some interest in the fishery, but then they disappeared again.

Arctic cod feeds mostly on copepods and Hyperiid amphipods. It has also been noted to eat small capelin, the diet changing with size. Becky Sjare indicated that there was an increase in the importance of Arctic cod in harp seal diets in coastal samples during the winter, starting in 1986 though to at least 1993 and 1994, but the diets in recent years reflect changes in cod and capelin distribution.

Model parameters

Biomass values reported in Bundy *et al.* (2000) for RV trawl-surveys in 1985-1987 (2,819 tonnes) and 1992-1994 (4,015 tonnes) were used to calculate the proportional change in biomass between the mid-1980s and the 1990s. Accordingly, Arctic cod is 1.42 times more abundant in the present time model than the mid-1980s. The model estimated biomass in the early 1900s assuming an Ecotrophic efficiency of 0.95.

WORKSHOP NOTES ON LARGE PELAGIC FISH

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

Large Pelagic Feeders include tuna, pollock, sharks, salmon, dogfish and swordfish.

Around 200 or more **blue-fin tuna** were caught each year in Conception Bay during the 1960s, then they disappeared for decades, and are now they re-appearing again. There was never a substantial biomass of blue-fin tuna, but they are present in the study area.

Pollock (=saithe) is outside the study area (2J3KL) and is present mostly in 3NO.

Alida Bundy suggested that **basking sharks** could have become more abundant lately, and Becky Sjare suggested that we speak to John Lien about sharks in general. Barb Neis indicated that drag fishers described encountering basking sharks in deep water, and both George Lilly and George Rose thought that they were probably **Greenland sharks**, not basking sharks.

Tony Pitcher asked if **salmon** should be split from this group, and Dave Schneider indicated that historically there was a change in the exploitation regime, from gillnets. Tony Pitcher reminded us that salmon is a difficult group because they are so transitory, and Alida Bundy asked if they actually feed on the shelf? George Lilly indicated that they do, as they only stop feeding when they are in fresh water. Barb Neis wanted to know if there is any char in area 2J, and Becky Sjare replied in the negative. Tony Pitcher asked if there are any sea-run **trout** and suggested that we split out salmon from the Large Pelagic Feeders, and include other salmonids in this box.

Tony Pitcher asked if **dogfish** really feed in the pelagic zone, and Becky Sjare suggested that we contact John Lien to find out. Barb Neis also indicated that there are papers by Templeman that document the Bonavista longline fishery that would also have information on dogfish. Tony then asked if we should separate dogfish from the large pelagics, and Alida Bundy suggested that their diet information shows that dogfish are basically generalists, that feed on small pelagics, squid, etc. Paul Fanning confirmed that dogfish are opportunistic feeders and George Lilly said that we have no biomass information for dogfish.

Barb Neis found that fishers describe the disappearance of dogfish, and Nigel Haggan asked if dogfish was fished for oil in the past? Barb Neis indicated that they were fished for pet food when they migrated into this area.

Swordfish occur mainly on the Grand Banks and to the south of Flemish Cap and can therefore be considered out of the study area.

Model Parameters

There are no biomass estimates for the group, and the model therefore estimated biomass by using an Ecotrophic efficiency of 0.95. The recent and mid-1980s catches are given in the NAFO database.

Workshop Notes on Small Piscivorous Pelagic Fish

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

There is a paucity of good information for several members of this group, which includes mackerel, short-fin squid, and mesopelagics.

Mackerel comprises a single stock in the study area and in some years they are present in large quantities, while in other years mackerel is virtually absent. Thus, the stock is highly variable. Mackerel are fished with purse seines, and perhaps bar seine.

There is a single stock of **short-fin squid** in the area, which migrates from the south. There are no catch and effort information and catches are basically market-driven. Large quantities of squid were last seen 20 years ago, but the biomass appears to be high. Paul Fanning suggested that the squid used for bait is probably more expensive than the groundfish it is used for as bait. The Russians used to trawl for squids on the edge of the Scotian shelf and an estimated 30,000 to 50,000 tonnes were taken annually. Paul also suggested that squid jigging was an old traditional Newfoundland fishery in inshore bays. Becky Sjare indicated that short-fin squid are important prey for pilot whales, but they disappeared off Newfoundland for 15-20 years and are now starting to reappear.

Tony Pitcher suggested that squid should be split out from the group small pelagics group into a group of their own, as they are very different from mackerel and hold a strong community interest. The other squid (Arctic squid) is a planktivorous small pelagic feeder, and should be added to the squid compartment.

Alida Bundy indicated that **mesopelagics** were originally separated from the group, but were put back together because of lack of information. George Rose suggested that in acoustic surveys they show up as a ‘big cloud’ on the shelf break that could go all the way to Greenland. However, the “cloud” also includes planktonic organisms such as euphausiids. Chris Stevens in the hydro-acoustic section of DFO suggested that the cloud was much smaller before, and it is now greatly extended. This could be related to the decline in redfish? George Rose suggested that it would be possible to use the acoustic data to estimate mesopelagics biomass, and it might be the biggest biomass in 2J3K. Paul Fanning indicated that mesopelagics include both piscivores and planktivores, and asked if both piscivores and planktivores be joined in a same pool with a mixed diet?

Model Parameters

The group includes mackerel, *Scomber scombrus*, piscivorous myctophids and other mesopelagics and the short-finned squid, *Illex illecebrosus*. The group also includes piscivorous juveniles of the large pelagics. Only mackerel and the short-finned squid are commercially fished. Both species are highly migratory and spend only part of the year in the Newfoundland area. Biomass of Mackerel in 2J3KL in the present time period was estimated from an exploitation rate of 4% (assumed the same as in 1985-1987 period (Bundy *et al.*, 2000)) and catch data. Catch of mackerel in 2J3KL in 1995-1996 was 12.5 tonnes, which leads to an estimated biomass of 312.5 tonnes, and newer catches are available from NAFO.

Catches of *Illex* in Subdivision 3 and 4 from 1997 to 1999 averaged 5,760 tonnes. Relative fishing mortality of *Illex* sp. increased in the mid-1970s and reached a peak during 1977-82. During 1983-99 the fishing rate have been around 10% of the peak period. Since 1982 the stock has remained at low size, indicating low productivity (Dawe *et al.*, 2000). Based on the above, the relative abundance of *Illex sp.* was assumed the same between 1985-1987 and 1995-(2000) Bundy (this vol.) estimated the combined biomass of *Illex* sp. and myctophids in the order of 15,000 tonnes. The total biomass of piscivorous small pelagic feeders is therefore estimated at 15,312.5 tonnes, which represents approximately 7% of the 1985-1987 biomass. Biomass in the early 1900s model was estimated by the model.

References

Dawe, E. G., Hendrickson, L.C. & M. A. Showell (2000) An update to commercial catch and survey indices for short-finned squid (*Illex illecebrosus*) in the Northwest Atlantic for 1999. NAFO SCR Doc. 00/37.

WORKSHOP NOTES ON SMALL PLANKIVOROUS PELAGIC FISH

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

Herring probably is not an important player in the area. It was suggested that the species be split from the planktivorous small pelagic fish group.

GL - The abundance of herring is currently low, but it was probably far higher in the past. It may be the case to place herring in a group of its own because of its interest to residents of the communities in the study area.

Model parameters

This model group originally included herring, planktivorous myctophids and other mesopelagics, Atlantic saury, *Scomberesox saurus*, the Arctic squid *Gonatus* sp., and planktivorous juveniles of the large pelagics.

Herring is the only species commercially fished. Of the five herring stocks found along the coast of Newfoundland, three occur in the study area: White Bay-Notre Dame Bay, Bonavista Bay-Trinity Bay, and Conception Bay-Southern shore (DFO, 1998). There are no reports of the status of the Conception Bay-Southern shore stock due to the lack of commercial fishing in the area in recent years.

The average catch of herring in the study area between 1995 and 1998 was 2,475 tonnes. The White Bay-Notre stock is at low level compared to the 1970s with poor recruitment through the 1980s and 1990s. The 1998 mature biomass (age 5+) was estimated at 30,800 tonnes (DFO, 1998). The Bonavista Bay – Trinity Bay adult stock biomass in the period was estimated at ca. 20,000 tonnes, thus the total adult biomass sums to 50,800 tonnes. Assuming a similar biomass of juveniles, the biomass of the two stocks in the area is estimated at 101,600 tonnes. As noted in Bundy *et al.* (2000), the Conception Bay-Southern shore stock has historically been a very small stock, amounting for no more than 10% of the biomass of the northern stock. The total biomass of herring in the area is therefore estimated at 111,760 tonnes.

For biomass of other groups Bundy et al (2000) considered that they can make up to 60% of the total group biomass. Therefore the total biomass is estimated at ca. 279,400 tonnes, which represents 59% of the mid-1980s biomass. The input biomass in the present time model was calculated by multiplying this percentage by the estimated biomass of small planktivorous fish for the mid-1980s, and the model was used to estimate biomass in the early 1900s.

References

DFO (1998) East and Southeast herring. DFO Science Stock Status Report B2-0.1. 8pp.

SHRIMP

Earl Dawe and Dave Orr
DFO, St John's

Information on shrimp biomass will be found in the annual assessments conducted until 1999-(2000) There are better biomass data available for 1995-2000 (from Campelen trawl surveys) than for the past, but these are minimum biomass estimates. There is no information available for the 1900 and 1400 models. The distribution of shrimps goes further north than the northern boundary of 2J, but northern shrimp, *P. borealis*, is more abundant in 3K than to the south. There is also a new fishery within 3L, which is limited to 200 – 500 m depths, but there is not much to gain by including 3NO in the study area.

The northern shrimp is the species that is assessed, but striped shrimp (*P. montagui*) is also present in the inshore areas. It would be a good idea to split northern shrimp from other species of shrimp. The recent increase in biomass, especially in 3K, led to development of a new fishery by a small vessel fleet. Bycatch of Greenland halibut (*Reinhardtius hippoglossoides*) in shrimp trawls is a concern, but a recent study found that bycatch of Greenland halibut was not a major problem in the offshore portion of shrimp fishery.

Observer data are mostly obtained from large vessels and not much information is available for the smaller vessels in the new Div. 3K fishery. Data from observers has been challenged as it may grossly underestimate bycatch. As of 2000, there has been an observer allocation plan, which will hopefully allow for the provision of useful information pertaining to the inshore fleet. Bycatch of various groundfish species will continue to be monitored.

Model parameters

Information on catches and biomass of northern shrimp is available in DFO (2000). The fishery for shrimp on the east coast started in the mid-1960s in the Gulf of St. Laurence, and it was not until the mid-1970s that the fishery expanded into the Labrador coast, mainly for *Pandalus borealis*. Catches in Hawke Channel and division 3K increased from ca. 10,000 tonnes in 1995 to 50,000 in 1999, with an average catch of approximately 27,000 tonnes. In Sub-area 5 (Hopedale + Cartwright) catches were 7,650 tonnes in 1995 and 1996, and increased to 15,300 tonnes in 1997, 1998 and 1999. The average catches in the period was 12,240 tonnes. The total catches in both areas for the present time model is estimated at 39,240 tonnes.

Resource survey biomass indices in Hawke Channel and 3K increased from 1989 to 1995 and remained stable from 1996 to 1999. Catch to survey biomass ratio remained at ca. 11% in recent years. Using this exploitation rate with the average catch in the period, biomass is estimated in 245,454 tonnes. Catch rates in Hopedale and Cartwright (SFA5) increased through the 1990s and remained stable from 1997 to (1999) Catch to survey biomass ratio ranged from 16 to 26% in the last three years. Assuming the mid-range value of 21% and using the average catch in the period the biomass of shrimp in the area is estimated at 58,285 tonnes. The total biomass of shrimp in the 1995-1999 model is estimated at 303,739 tonnes, or 0.825 tonnes/km². The biomass in this model is ca. 3 times the value estimated by Bundy (this vol.) for the mid-1980s model, which is consistent with the reported increase in shrimp biomass between the two time periods. The 1995-1999 biomass is however smaller than the biomass in the balanced model of the mid-1980s, which was estimated assuming an Ecotrophic efficiency of 0.95 (see Bundy, this vol.). To be consistent with the ratio of biomass increase between the two time periods, the 1995-1999 biomass was assumed to be three times the balanced biomass of the mid-1980s, i.e. 2.994 tonnes/km². Ecopath estimates the biomass in the early 1900s assuming an Ecotrophic efficiency of 0.95.

References

DFO (2000) Northern shrimp (*Pandalus borealis*): Div 0B to 3K. DFO Stock Status Report C2-05, 2000. 15 pp.

LARGE CRUSTACEANS

Earl Dawe
DFO, St John's

It is necessary to reconsider the group for all periods, especially with regards to the inclusion of lobsters (which occur mostly inshore) and deep-water crabs (that is not yet included). It is possible to obtain better information for toad crabs than was originally included in the preliminary model because exploratory fisheries have recently been initiated on these two species. Snow crab, particularly for the 1995-2000 model, drives the group. NAFO Divisions 2J3KL jointly represent an appropriate study area for snow crab between 1995-1999, because the resource has been broadly-distributed within that region and biomass indices are more reliable than in Div. 3NO. The northern limit of snow crab distribution is the 2J-2H boundary and the distribution extends south throughout 3K and across northern 3L. It extends offshore beyond the 200 mile EEZ, around the Tail of Grand Bank, and the species is virtually absent from southern Grand Banks.

The fishery focuses in much the same area as the shrimp fishery, since both species have similar habitat preferences. Most information from stock assessment is available and the latest reports will soon be online. Commercial catch rate data are available from 1979 onwards for 3KL and from 1985 onwards for 2J, which could be useful for relating biomass back to 1979. Commercial catch rate data points at higher biomass now than in 1985. There is little information on snow crab diet, and the data available is old; a workshop will be held next month to plan future initiatives in snow crab research.

Cannibalism has been documented in the northern Gulf of St. Lawrence and has been hypothesized as a potential density-dependent mechanism that regulates recruitment. It was suggested that the group be split based on legal size limit (95 mm) or at one moult interval smaller (76 mm).

Fisheries have a major and quantified impact on legal sized crabs (landings), and less transparent impact on discards of immediate sub-legal sized crabs. As reported in Bundy *et al.* (2000), the trawl surveys probably underestimate biomass, particularly of sub-legal sized males and females. Catchability of trawls is unknown, but relatively similar from 76 mm to 140mm. Catch rates were increasing, which could be an indication of good recruitment in recent years (the increase has been noticed mostly in the inshore fleet). Catches are exclusively from traps, and there is no bycatch.

At the workshop Tony Pitcher wanted to know if lobster should be split from the group, and Barb Neis suggested that it would make sense to coastal fishermen if we have them separately. Alida Bundy then indicated that the biomass of lobsters is very low, but Barb insisted that lobsters would have an important TEK component. She suggested that for crabs, TEK can be helpful to understand changes in catchability with the introduction of GPS, changes in fishing strategies, etc. Edward Dalley suggested that snow crab probably don't need to be separated out because they are already dominant in the functional group, but back in time their biomass may have been more equal to other crabs. Paul Fanning agreed that it is required for us to separate the lobsters out.

Model Parameters

At present this compartment includes American lobster, *Homarus americanus*, snow crabs, *Chionoectes opilio,* and other non-commercial species such as toad crabs, *Hyas* spp.

Snow crab (DFO, 2000): The Newfoundland fishery began in Trinity Bay in 1968, first as bycatch of gillnet fisheries and later as a directed trap fishery in inshore areas along the northeast coast of the Island. In the mid-1980s there was a large decline in catches in traditional areas in 3K and 3L while at the same time new fisheries started in 2J, offshore 3K and also on 3Ps and 4R. Landings have increased steadily since the late 1980s and reached a record peak of 32,000 tonnes in 1995 (most of the increase came from div 3K and 3L). The average catch in 1995-1999 was 14,000 tonnes in 3K, 19,800 tonnes in 3LNO, and 4,400 tonnes in 2J. Considering that 90% of the catches in 3LNO came from 3L (from 1990 to 1995), the total catch in the period is estimated at 36,220 tonnes. The average residual biomass (post-fishing) in 1995-1999 was ca. 54,800 tonnes. A total biomass of 93,000 tonnes is obtained by summing residual biomass and catches in the period.

The average catch of lobster in 2J3KL in 1995-97 was 490.3 tonnes. The same procedure as that used by Bundy et al (2000) will need to be used to calculate biomass from catches and exploitation rate.

Biomass of other crab species for the period 1995-1997 was reported in Bundy as 2,901 tonnes.

In the preliminary 1995-199 and early 1900s models, biomass of large crustaceans were estimated by the model.

References

DFO (2000) Newfoundland and Labrador Snow Crab. C2-01, 2000. 9 pp.

BENTHIC INVERTEBRATES

Dave Schneider
MUN

Important sources of information include a study by Hutchinson on the Grand Banks; a more recent survey from the Hibernia area carried out by independent consultants; localized studies showing changes in benthos density estimates before and after trawling; published estimated counts of benthic invertebrates by Schneider, Gagnon and Gilkinson (1987); and counts made by Kent Gilkinson. A caveat on density is that grab samplers do not sample epibenthos well. Another important factor to consider is the effect of trawling, which tend to take away considerable amounts of epibenthos. Some areas are trawled 3 times a year, and some species are not very resilient. An example is Icelandic scallops which don't seem to recover back quickly after heavy exploitation on St. Pierre Bank, Grand Banks and around Hibernia.

Barb Neis indicated that the scallop fishery has been expanding in the inshore and Edgar Dalley indicated that the Davis Strait must be of interest to this study. Dave Schneider said that the northern areas of the Grand Banks are also important, and that sponges occur in ecosystems on sand and gravel with strong vertical mixing. George Lilly said that sponges occur at depths greater than 500m.

Dave Schneider asked if epibenthos should be divided in size classes to improve computations and Alida Bundy replied that it would be ideal but there is not sufficient data for it to be viable. Dave then suggested that large epibenthic organisms could be split out of the group, and that it would be possible to ask fishers what they found in their trawl nets. Barb Neis replied that the seafloor fascinates fishers and Paul Fanning said that on the Scotian shelf, information could be obtained from photos and videotapes. Barb Neis also indicated that scallop dragging is now occurring in inshore areas, where it never occurred earlier, except dragging down the middle of Trinity Bay (*source O'Brien*). Dave Schneider said that beach seine data could provide density estimates for the 1990s and 1960s.

Model parameters

In the ecosystem model, benthic invertebrates were divided in 4 groups: Echinoderms, Mollusks, Polychaetes and Other Benthic Invertebrates. Biomass estimates for the 1995-1999 and early 1900s models were assumed to be the same as reported by Bundy (this volume) for the mid-1980s. Catches of 1,227 tonnes (0.003 tonnes/km²) of benthic groups (mostly Mollusks) are reported for the period 1995-1997 (NAFO database).

ZOOPLANKTON

Edgar Dalley
DFO, St John's

Data from 1994 to 1997 was originally used to parameterize the 1985-1987 model, but data is now also available for 1998 and (1999) No other information is available to allow historical comparisons and therefore it is assumed that the zooplankton biomass was the same between the mid-1980s and 1995- (1999) Biomass values for the past models will be guesswork.

It was suggested that large jellyfish (> 2 cm) be split from Large zooplankton group. Barb Neis suggested that it would be worthwhile to ask fishers if there have been any changes in jellyfish and Tony Pitcher asked if tunicates were important in this system?

Alida Bundy asked if fish larvae are included in the Large zooplankton group and Edgar Dalley said that the biomass data for fish eggs and larvae is available but it is not currently included in the preliminary model of mid-1980s. He suggested that capelin larvae are common, but otherwise there are not much larvae in the zooplankton samples.

Edgar Dalley also asked where we would put pelagic squids go as they have the most extensive distribution of any group, but present low abundances in the Grand Banks. Arctic squid remain pelagic up to 5 cm, after which they leave the system to depths greater than 1000 m. Adults don't show up in surveys. Dave Schneider said that an important contact for zooplankton is Don Deibel, and George Lilly suggested that we also speak to Pierre Pepin, who has done some research documents on zooplankton.

Tony Pitcher asked if the microbial loop was an important process in this system and Dave Schneider replied that Don Deibel and Pomeroy published a paper that stated that microbial loops are not important in cold water systems.

Model Parameters

Biomass of zooplankton in the present time model was assumed the same as the values estimated by Bundy (this volume) for the mid-1980s, since their estimates were based on data from the mid-1990s. Biomass of large zooplankton is 18.343 tonnes/km² and small zooplankton, 25.3 tonnes/km². Ecopath was left to estimate the biomass of the early 1900s by using an Ecotrophic efficiency of 0.95.

WORKSHOP NOTES ON PHYTOPLANKTON AND KELP

Marcelo Vasconcellos, Melanie Power, Sheila Heymans and Tony J. Pitcher
Fisheries Centre, UBC

Paul Fanning indicated that data on phytoplankton for the 1980s could be obtained from the coastal zone colour scanner, and Alida Bundy said that primary production estimates for the 1990s are already available. Paul also asked if there was any Continuous Plankton Recorder data available for the 1950s and Tony Pitcher wanted to know if there are any correlates available for temperature data and phytoplankton? George Lilly suggested that we speak to Pierre Pepin and Don Diebel to answer these questions.

Paul Fanning asked if macrophytes are present and George Lilly suggested that kelp does occur but no kelp forests such as in the west coast. Eelgrass is also present but it does not occur more than 1 meter below the intertidal zone.

Barb Neis asked what about 'slub' and Dave Schneider again suggested that we speak to Don Deibel about this.

Model parameters

Primary production data for the mid-1980s and 1998 are shown in Table 1 (Bundy, pers. comm.). Data suggests that primary productivity is lower in 1998 compared to the mid-1980s, although differences may be accounted for by methodology biases. Biomass and P/B ratio for the early 1900s model were assumed to be the same as the mid-1980s.

Table 1: Primary production, biomass and P/B ratios for the Newfoundland area.

	PP (g.m².year)	Biomass (g.m²)	P/B ($year^{-1}$)
1985-1987	2,822	27.25	103.6
1998	1,920	31.7	60.6

Preliminary Mass-Balance Models of Past Ecosystem States

Marcelo Vasconcellos and Tony J.Pitcher
Fisheries Centre, UBC

Preliminary mass-balance models of the east coast ecosystem during the early 1900s and present time were built based on a model of the mid-1980s (Bundy, this report), literature review and from inputs received during this science workshop.

The table below shows the biomass values input to Ecopath, and also the functional groups that should be included in the next iteration of the model. In the table "estimated" means that the biomass was estimated during Ecopath model balancing.

These models take account of a literature review and inputs received during this science workshop. The ecosystem models have subsequently been under a process of continual refinement. The most recent versions can be downloaded from www.fisheries.ubc.ca.

Table 1. Biomass estimates for the Newfoundland shelf model for the three time periods. * = Estimated from the Ecopath mass-balance model. Tonnes per square km.

Group Name	1900s	1985-1987	1995-2000
Whales	0.292	0.146	0.146
Harp Seals	0.744	0.248	0.3
Hooded Seals	0.138	0.046	0.064
Seabirds	0.024	0.012	0.012
Cod > 35cm	8.23	2.572	0.22
Cod <= 35 cm	1.162	0.363	0.084
G.halibut>40cm	0.608	0.469	0.201
G.halibut<=40cm	1.135	0.811	2.109
Aplaice>35cm	1.589	0.883	0.229
Aplaice<=35cm	1.336	0.742	0.193
Flounders	estimated	0.458*	0.029
Skates	0.300	0.150	0.005
Redfish	8.964	1.734	0.173
L.Dem.Feeders	1.02	1.020	0.204
S.Dem.Feeders	estimated	2.210*	estimated
Capelin	estimated	16.097*	estimated
Sand lance	estimated	1.722*	1.722
Arctic cod	estimated	4.031*	5.643
L.Pel.Feeders	estimated	0.024*	estimated
Salmon		To be included	
Pisc. SPF	estimated	0.993*	0.069
Squids		To be included	
Plankt. SPF	estimated	3.418*	2.031
Herring		To be included	
Shrimp	estimated	0.998*	2.994
Large Crustacea	estimated	1.988*	estimated
Large Crustacea <76 mm		To be included	
Large Crustacea >76 mm		To be included	
Lobster		To be included	
Echinoderms	70.6	70.6	70.6
Molluscs	16.4	16.4	16.4
Polychaetes	8.8	8.8	8.8
O.Benthic Inver	2.7	2.7	2.7
L.Zooplankton	estimated	23.334*	18.4
S.Zooplankton	estimated	34.646*	25.3
Phytoplankton	27.25	27.25	31.7
Detritus	389	389	389

CANADA'S WEST COAST

System Boundaries for Canadian West Coast Ecosystem Models

Marcelo Vasconcellos
UBC Fisheries Centre

The case study area in the west coast of Canada encompasses the Northen BC shelf region of Hecate Strait and Queen Charlotte sound (Fig. 1 below). The region is located within the Pacific Coastal Biome, and is representative of the Alaska Downwelling Coastal Province (Longhurst 1998). This biogeographical province comprises the coastal boundary region from Queen Charlotte Sound to the end of the Aleutian chain of islands, and from the velocity maximum of the Alaska current, beyond the shelf slope, to the coastline. Two important watersheds, the Skeena and Nass rivers, drain into the study area. For modelling purposes, the study area was delimited by 10 DFO fisheries statistical areas, from waters of Dixon Entrance at the north end of Queen Charlotte Islands (DFO's Statistical Area 1) to the northern tip of Vancouver Island (Statisitical Area 10), incorporating a surface area of approximately 70,000 km².

Reference

Longhurst, A. (1998) Ecological geography of the sea. Academic Press. 398 pp.

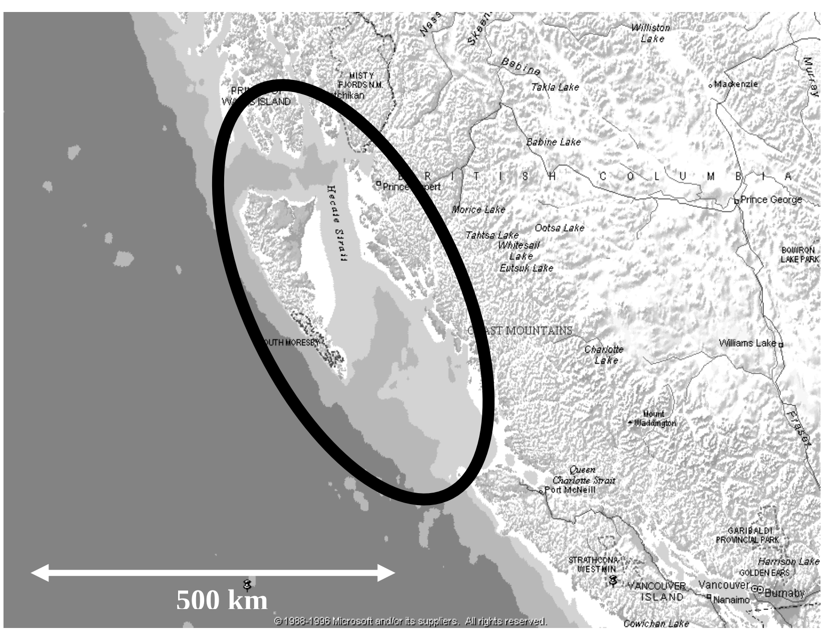


Figure 1. The Hecate Strait study area. Approximate boundaries of the modelled region.

Historical Reference Points For Models of Past Ecosystems in Northern British Columbia

Marcelo Vasconcellos and Tony Pitcher
UBC Fisheries Centre

This brief review of the history of marine resources exploitation in the west coast is aimed at identifying periods in the historical development of fisheries that were likely to be associated to distinct ecosystem states.

Two basic attributes were used to define historical reference points, the type of use of resources, including species harvested, technology, and management systems; and the changes in ecosystem structure/function and services, such as loss of species, yield, resource collapse, etc. This review of fisheries development in the west coast of Canada was based mainly on the work of Irwin (1984), Forester and Forester (1975), Ormsby (1971) and Carrothers (1941). Other complementary sources are cited in the text.

Pre-contact fisheries

Large supplies of food from the sea enabled Aboriginal peoples from the west coast to live in permanent settlements along the coast. Many Northwest coast tribes used the marine resources of central-north BC waters – Haida Gwaii (the Queen Charlotte Islands) are inhabited by the Haida, and the shore and coastal islands are inhabited by the Tsimshian, Nuxalk (Bella Coola). Heiltsuk (Bella Bella), Oweekeno and Kitasoo. Salmon was the staple native diet. Spring salmon was the most abundant species on the Nass, Skeena and Campbell rivers. In Haida Gwaii, salmon were less plentiful; the Haidas relied more on halibut and cod for fresh food, while pink salmon was the main food stored and consumed during winter months. Dried spring salmon was the main winter food for the coastal Tsimshian, but they also depended on eulachon, cod and halibut.

The fishing technology used by First Nations in the west coast was the most advanced on the continent (Stewart 1977). Spawning salmon was generally caught in rivers, streams and narrow channels. Fishing methods were mostly weirs and traps, but also drift seining, hook and line, and trolling from canoes. Irwin (1984) noted that the 'Nootka' (Nuu Chah Nulth) were responsible for the first fish-stocking in North America – they moved salmon eggs from one stream to another to create a salmon run in a stream that didn't have one before. Rivers were carefully studied to determine the place to put a trap and the type of trap. The best fishing locations were owned by villages, clans or families, constituting one of the few instances of property ownership rights among First Nations. Carrothers (1941) stated that large quantities of salmon were taken by First Nations, and the existence of salmon was believed to be so endangered that their use by First Nations was forbidden in parts of the northwest coast during the early 1900s.

Herring, eulachon and pilchard were important foods and commodities for First Nations of coastal BC. Herring was used for bait, eaten fresh and also smoked or dried in long strings, while herring eggs were held in high esteem and were eaten raw or dried and served with seal oil. Fishing was carried out with 'rakes', or sometimes with nets or baskets. Eggs were harvested from those spawned on kelp or on branches of fir, pine, cedar or hemlock trees. Eulachon were caught in the early spring when they gathered to spawn in rivers and streams. Eulachon oil, commonly called 'grease' was a condiment for many foods, and represented an important trading commodity, so that the inland routes used for trading became known as "grease trails".

Large halibut and codfish were caught with hook-and-line or were speared with harpoons. Halibut was the second most important species, after salmon for Pacific coast First Nations. Part of the catch was consumed fresh and the remainder cut into strips and dried for winter use. The Haida caught halibut with wooden hooks armed with a barb of stone or bone. Fish lines were often supported at the surface by wooden buoys or floats made from the bladders of sea mammals. Halibut was the species that most bottom-fishing efforts were directed toward. Lingcod was a species of lesser importance to the coastal people, which utilized wooden gorges to catch them. Lures were used to catch codfish. Spears were used to catch flounders, octopus and sturgeon. Sturgeon was speared by Salish tribes along the Columbia and Fraser rivers. They were harpooned much like salmon during the summer months when spawning in the shallows, but also speared in deep waters using specialized techniques (Stewart 77). Dogfish was used by First Nations for many purposes (Ketchen 1986): the skin was used to polish wood carvings and implements; liver and body oil was possibly used as preservatives for cedar canoes and as a waterproofing and softener of clothing woven from fine strands of cedar bark; oil was also possibly used in the cooking of other foods, but not likely as a food in itself; possibly used in oil-tanning of leather

Virtually all coastal people engaged in hunting for seals, porpoises, sea lions, sea otters and several species of whales at sea. Large marine mammals were not an important food supply, but were used for equipment making and as a means to demonstrate spiritual power and hunting ability. Whale hunting was almost exclusively carried by the Nuu-chah-nulth on the west coast of Vancouver Island. Sealing was carried out by First Nations setting out in canoes to meet the herd of seals traveling north to the rookeries in the Pribilof Islands in the Bering Sea, and was carried out with spears. Seal meat and blubber were used as food. Seal oil and especially pelts were valuable trade items with the white newcomers. Sea otters were of secondary importance prior to the Russian fur trade, but were nonetheless harvested for their soft fur even in pre-contact times. Sea otter pups were snatched by First Nations in their canoe and used to lure adults close by to be speared.

Pre-contact catches of salmon for consumption by native groups in the Northwest coast were estimated at 14,120,000 pounds of fresh fish per year by Hewes (1973). Also, it is estimated that First Nations caught as much as 3 million pounds of halibut in one year, more precisely 3,165,000 pounds in 1885, and after 1888 they consumed over 600,000 pounds annually (Carrothers 1941). Carrothers (1941) cites an estimate of fish consumption by First Nations in BC of about 25 million pounds per year, comprised of about 17.5 million pounds of salmon, 3 million pound of halibut, ¼ million pound of sturgeon, herring, trout, and other fish, as well as eighty thousand gallons of fish oil.

European contact and the fur trade

Russian captain Alexi Cherikov, sailing in a sister ship with Vitus Bering and in charge of finding a land bridge between the Kamschatka Peninsula and North America, was perhaps one of the first white men to contact west coast Aboriginal peoples. The crew of their ships brought sea otter pelts to Russia; that started the quest for furs in the Pacific Northwest by Russian fur-traders "promishlenniki" (Irwin 1984). Exploitation of sea-otter pelts started in 1741 and continued unregulated for 170 years. The take of sea-otters in the Northwest Pacific region between 1740 and 1911 was likely to be in the order of half a million animals (Kenyon 1975; VanBlarion and Estes 1988).

Interest in the Northwest Pacific as an area for sea otter fur-trade for both Russians and British grew after the visit of Captain Cook to Prince William Sound, Nootka Sound and Cook Inlet. In his quest for a northern passage to Hudson Bay, Cook found shelter in Nootka Sound and traded furs with First Nations. While the Russians traded mostly with the Aleuts,

> *... the great variety of their trade goods soon enabled the British traders to persuade the Haida and other Northern First Nations to barter skins.* (Irwin 1984).

By the 1780s sea-otter pelts were very valuable in China. Two British ships, the "King George" and the "Queen Charlotte" arrived in Canton with the largest cargo of furs to reach that port up to that time: about 2,500 pelts were brought from the Pacific Northwest. The centre of the trading was Nootka Sound and Prince William Sound. In fact, a factory for sea-otter trade was established at Nootka Sound in 1788.

The Hudson Bay Company and the Salmon Trade

In 1821, the Northwest Company of Montreal was assimilated by the Hudson Bay Company (HBC) which then started operating in the Columbia Department (much of present day British Columbia, Oregon, and Washington). The company's expansion into the Columbia Department was part of a drive to conserve and replenish the depleted stocks of beaver, east of the Rockies, by relying on new sources from the Columbia department.

The Columbia Department produced 8% of the 18.5 million hides and pelts exported from North America from 1821 to 1849 (Hammond 1993). Beaver was not the only product sought after by HBC, a diversity of other animals were also exploited and exported to Europe. The commercialization of wildlife products began by sending samples of potential products from the hinterland posts to London, from Grizzly bears to small marmots. Once these samples reached London, the company sought informed opinions as to their relative quality, value, market and potential competitors. Hammond cites several products made from North American wildlife that thus supplied the European market:

> *... beaver pelts for the felt hat industry; military contracts for bear skins; deer horns or stag horns for pen knife handles; dentists used "sea horse teeth" (walrus tusk) to make dentures, castoreum from the glands of beavers was sold as scent lure for beaver traps and as a component in medicinal preparations and perfumes; isinglass, a pure gelatin extracted from the sturgeon's float bladder, helped clarify wine and beer; feathers, such as the down of the trumpeter swan, was sold for powder puffs.*

The Hudson Bay Company started exporting salmon from BC waters in 1821 (they had exclusive rights to trade with First Nations at that time). At first salmon traded was used only as a food supply for the Company's fur trading posts. When the fur trade failed, cured salmon become an important article of trade. The Company engaged in fishing activities on the San Juan Islands ca. 1850. While much of the export continued to be to the Orient, over the next decades from 1858, the gold rush brought settlers and good local market. Local markets absorbed the early catches of cod, sole and halibut, while salmon continued as the bulk of the export trade.

The year of 1834 is the earliest record of American whalers in the Pacific Northwest (American whalers from Nantucket and New Bedford in the Atlantic coast had been sailing around Cape Horn to hunt in the Pacific since 1820). By the 1860s, the American civil war, and more efficient ways of producing petroleum drove Americans away from whaling grounds in the Pacific. In 1859 the Norwegian, Svend Foyn, invented the harpoon gun to be used for hunting whales.

By the 1860s, First Nations began to shift from traditional subsistence fishing to commercial fishing, mainly due to the introduction of fish canning in BC and the demand for salmon increased. The canning industry attracted Europeans, Americans and later Japanese immigrants who were experienced in commercial fishing. First Nations no longer controlled the fishing waters but instead began selling catches to canneries and the native women worked in the canning plants (Brown 1994; Newell 1989). In 1864 drift nets were introduced to the Fraser River fisheries, while gillnets were introduced later, by which time they were the most efficient method of catching fish. Drag seines, beach seining and open sets were used earlier in BC fisheries. In 1865 the Sealing industry started with 2 or 3 schooners making their catches just a few miles offshore. For close to a decade (1865 to 1875) the 5 schooners were taking an average of 1,500 to 2,000 skins per vessel. From 1843 to 1864 a few dozen fur seal skins were taken annually by the First Nations. Their take increased steadily up to 1869 when the total amounted to 5 thousand skins.

Last decades of the 19th Century

During the last decades of the 19th century sealing developed into a thriving new industry. "Pelagic sealing" was developed to explore areas offshore. First Nations and their canoes were loaded onto schooners to take them to the hunting grounds. From 1878 the number of schooners increased steadily: from 13 in 1882 to 65 in 1895, with a capacity for 4,292 tons (the record catch of a single schooner was 4,268 skins). As the fleet expanded, so did the hunting ground, moving closer to the rookeries in the Bering Sea. In 1886, a political incident with the United States and Alaska Company (which was granted rights to exploit the herds in Alaska) occurred after the Canadian fleet started sealing in Alaskan waters.

Halibut fishing increased rapidly once the transcontinental railroad linked BC and markets in eastern Canada. It could not be canned, so shipments required faster transportation and refrigeration (both factors had limited the development of halibut trade). The commercial halibut trade, relatively insignificant in 1888, rapidly moved to a total catch of millions of pounds annually. Giants (mostly females) of 500 pounds were caught, and 200-pound halibut were not uncommon in the early days. Off the Queen Charlotte Islands, the water near Rose Spit and Bank Island were at one time filled with halibut. They were reported to literally "pave the bottom of the sea" (Forester and Forester 1975). In 1893 a tugboat caught 180,000 pounds of halibut in the short space of 7 hours. Some halibut weighted 140 pounds and

> *.. so crowded were the waters that the baited hook scarcely reached the bottom before the fish seized them.* (Forester and Forester 1975).

Bella Coola and Prince Rupert were the main ports for halibut fishers. Few of the early attempts at commercial fishing of halibut were financially successful and most of the fish were still caught by First Nations who used small boats and consequently were confined to the halibut banks in sheltered waters. The increasing scarcity of halibut on the North Atlantic, which supplied the markets in Boston and New York, led to a rise in prices, which assisted the Pacific industry. Trade connections were developed and improvements made in the handling of the catch. At first only halibut banks near the coast were fished, but gradually the fishery was extended to grounds six hundred miles north of Cape Flattery. The first successful halibut fishery was developed in 1893 on Porcher Island, near Freeman's Pass, in Hecate Strait. The first steamer specially built and equipped for halibut fishing begun operations in 1898, and landed 1,600,000 pounds of halibut during six months of the season 1898-1899. Other steamers followed, marking the definite decline of shore fisheries as steamers enabled fishermen to move much further (in fact only a small part of the BC coast was charted by then, and the uncharted areas were surveyed by early halibut skippers). At first the size and period of catches were limited by market and seasons, but with increasing demand and the operation of steamers, the fishery was extended throughout the year. Fishing was initially done from two-man dories carried in the steamers.

The first reference to dogfish as a commercial item did not appear in the Dominion Government's Ministry of Marine and Fisheries until 1872.

> *It was noted that in 1870 the steadily progressing fishery for dogfish (conducted entirely by First Nations) exceeded in importance of that of whaling.*

The period from 1870 to 1916 marks the first phase in the commercial fishery for dogfish, when liver and body oil was extensively used for various industrial lubrication requirements and lighting purposes, and the bodies used for production of fertilizers (Ketchen 1986).

The 1890s were years of expansion for the canning industry. Canned salmon were exported to Europe and also shipped to domestic markets in eastern Canada. The industrialization of salmon fisheries at the mouth of the Skeena River begun as early as the 1870s. The crew of salmon fishing boats in this northern area were largely First Nations. First signs of problems in the industry were recorded as

> *cyclic fluctuations in the size of the salmon runs added further ups and downs to the overall picture...*

The depression of 1893 marked the first time workers in the fisheries made a concerted effort to stem the effects of such fluctuations by demanding set prices for fish for an entire season. In 1897, salmon ran in vast numbers, and canners, for the first time in their history, put up over a million cases of salmon (remarks exist of catches being much higher than the capacity of canners to process the fish). In 1900 the introduction of new canning, handling equipment, and the "Iron Chink" introduced automated industrialization to the salmon industry. In 1884, 900 salmon nets were reportedly in use in the province. It took up to 16 men to haul in the net on the large seine boats. In 1899 trolling became part of commercial fishing in BC.

Up to this period little attempt had been made to use pink and chum salmon in the canning industry. Canning of these species began in 1899 and in 1900 5,700,000 pounds of salted chum were exported, and 6,340,000 pounds were canned, constituting a very valuable extension to the industry – the growing demand for salted chum salmon led to the development of this industry in the Queen Charlotte Inland (Carrothers 1941). From 1890 to 1898 an average of 167,590 cases of sockeye salmon were produced in Northern BC waters (Table IV in Carrothers 1941).

The first attempt to put up herring in barrels for export was made in 1877. Japanese fishermen opened new markets when they established salteries to produce salted herring for shipment to Japan and China. At the same time, oil from herring was extracted on a commercial basis in Burrard Inlet. Demand for herring products increased during the 1890s, and with the development of the halibut industry herring was used as bait.

The commercial exploitation of 'cod' (grey cod, black cod, ling cod, red and rock cod) began in the late 1800s. In 1880, twenty-two vessels were operating and in 1889 stations were established on the west coast of the Queen Charlotte Islands. Very little increase in the catch was made until 1909 when 10,827 hundredweight (546 tons) of cod were taken. 'Cod' taken on halibut hooks, previously discarded, became valuable, and were sold fresh, frozen, hard salted, pickled, kippered and smoked.

Early 1900s

With the Fraser River salmon runs showing signs of overfishing in the early 1900s, the salmon canning industry was progressively pushed to the Northern parts of the province. Fraser River salmon production peaked in 1901. The Skeena, Rivers Inlet, Smith's Inlet, Nass inlet, and outlying streams of BC culminated much later (1918 – 1920), with the increased fishing effort to satisfy the booming market following the end of WWI. From 1902, the number of canneries on the Fraser River started declining. All five species of salmon became widely accepted by the canneries. Gasoline engines powered the gill net fleet, although they were not allowed in the northern areas of the province until 20 years later. Regulations were imposed to forbid the use of powerboats on the Skeena River. Purse-seiners were illegal in BC until the early decades of 1900s (1937 was probably the year purse seiners were introduced). In the early days of purse seining, the sets were made by two large rowboats each carrying a portion of the net. By the late 1920s, vessels up to seventy feet in length, with engines 40 to 80 HP entered the fleet (diesel engines came into use); power driven rollers on the seine table eased the work of hauling and shooting the net. Crews of 7 to 8 men were aboard in purse seiners.

By 1917 the demand for halibut and salmon had grown so much that it was difficult to satisfy. The pack of pink and chum salmon increased particularly with the decreasing runs of sockeye on the Fraser River. Canning of spring salmon for commercial purposes began in 1912 and the use of trolling was developed mainly in connection with the catching of spring salmon (Carrothers 1941).

In the first decade of the 20th century, cold storage plants were built in Prince Rupert and Victoria. Prince Rupert became a halibut centre with the arrival of the Railroad, and served both Canadian and American fishers.

In 1915, concerns by both Canada and US about the declining stocks of halibut resulted in the Halibut Convention (which was signed only in 1923). The number of steamers operating on the BC coast increased from 6 in 1906, to11 in 1909 and 13 in 1911. Gasoline engines were used in the fleet starting 1903, and diesel engines were introduced in 1921. Parallel changes occurred in fishing gears, as vessels moved from dories to longlines. Advantages of longline fishing were the increased safety, reduced number of fishermen, increasing fishing time with the ability to fish in worse weather, in both daylight and in the dark , and faster handling of the gear and catches. Dory fishing declined rapidly after 1921, and by 1934 the proportion of halibut caught from dories was less than 1% of the Pacific coast total. Dories were prohibited by law in 1944 (Alverson *et al.* 1964).

Other fishing methods, such as trawlers were used for several years prior to 1944 when it was prohibited, bottom set nets and trollers were also used in halibut fishing. The deep-sea fishery commenced around 1910, leading to the discovery of new fishing banks off northern BC. By 1910 the banks off Hecate Strait had to be abandoned, particularly by large vessels because of stock depletion, and declining fish size. The catch per unit of standard size (prob. mean weight in the catch) fell from 272 pounds in 1906 to about 36 pounds in 1930 on the grounds of BC.

According to Ketchen (1986), the period from 1917 to 1939 corresponds to the second phase in the development of the commercial fishery for dogfish, when fish bodies were used not only for fertilizer production but also as a source of oil and fishmeal.

When purse seiners became legal in BC they were used extensively to fish for herring. In 1910 the reduction of herring into oil and guano was prohibited, and continued to be so until 1925 when the ban was lifted for the Vancouver and Prince Rupert Districts. Up to then most of the herring was sold fresh, salted, smoked, pickled and as bait for longline fisheries. Pilchards were taken by purse seiners during the 1920s and 1930s and used in reduction plants. Pilchard abundance increased along the west coast of Vancouver Island after 1916. Between 1925 and 1927 15 reduction plants were built between Kyuquot and Barkley sound. Purse seiners took practically all the catch during that time. The canning of pilchards on a commercial basis commenced in 1917, with a small market for canned or fresh product. The catch of Pilchard increased from an yearly average of 39,352 to 1,067,966 hundredweight reduction into oil and meal was authorized in 1924.

Trawlers were used to catch groundfish in Northern BC. A few trawl nets were used early in the century (most likely beam trawls). Otter trawls were introduced in BC fisheries about 1911, working mainly in the Strait of Georgia, English Bay, off Point Grey, Point Atkinson, and outside Prince Rupert (see Beattie this vol.). The WWI increased the demand for fresh fish, while catches declining after the war. Between 1921 and 1943, 800,000 pounds of flatfish were taken.

The Pelagic sealing fleet disappeared in 1911 as a result of the International Sealing agreement signed between Canada and US, which banned all hunting of seals at sea. Limited kills on land were permitted.

Whaling plants were built on the west coast of Vancouver Island and Queen Charlottes in the early 1900s. Nichol and Heise (1992) noted important changes in whaling during the early part of the century with the introduction of modern whaling equipment developed by Norwegian whalers - among the important technological changes were the replacement of sailing ships by steam powered chaser boats, harpoon guns and the development of steam powered winches for raising carcasses. In 1904, two 95-feet steel vessels with harpoon guns brought from Norway began BC's commercial whaling, which continued with only a few interruptions for a full 6 decades. Shore stations processed the catch (both meat and bones) using the latest technology at the time. Whale was used for canned meat, feed for mink, milk, glue, leather, oil (lamps and lubricants), and fertilizer ("dried guano"). An annual report of the Fisheries Department in 1906 stated that:

> *A trip from Victoria to the Nass river suffices to show how plentiful these valuable creatures are …schools of 2 to 20 individuals may been seen all day from the Strait of Georgia north….Nearly 250 whales (humpbacks and blues) have been caught in less than a year … some months showing a record of 50 whales killed..*

Several companies started whaling in BC in the early 1900s, these were the Pacific Whaling Company Limited (1905), Queen Charlotte Whaling Company (1910), and Canadian North Pacific Fisheries (1911). An article in the Victoria "Colonist" stated that:

> *Pacific Whaling Company brought 3-5 whales per day during the season, taking a total of 500 between April and August.*

The banner season was 1911 with 812 whales taken by the small fleet (prob. 14 vessels), yielding 158,000 gallons of oil and 3,315 tons of fertilizer. Further technological improvements to the whaling activity in BC included wireless telegraphy and the use of spotting planes in the 1920s to track whale migrations (Gregr 1999). Gregr (1999) also mentioned that advances in whale processing improved the profitability of the whaling industry, e.g., reduction techniques allowed the complete whale to be processed while refinement of the hydrogenation process removed the odor from whale oil. That increased the demand for whale oil and led to a steady increase in whale oil prices.

Sea-otters apparently became extinct on the BC coast during the 1920s.

Mid-1900s

In the 1950s, drum seiners were introduced in the salmon fishery. These took up the net with a power drum much larger then those used by gill-netters. Around the same time, a new type of power block, 'the puretic block', was introduced in the fishery. With this new equipment it took only 4 to 6 men to haul in the net. In 1953 the International North Pacific Fisheries Commission was established and an agreement signed between Canada, US and Japan to protect the Pacific fisheries (Northern Pacific and Bering Sea). Since the 1950s many actions were taken to protect stocks and habitats and to control harvesting have been implemented. In the 1950s, a program of obstruction removal and fishway installation was implemented. In the 1960s, a number of spawning channels and flow control projects were developed along with the beginnings of a hatchery program. In the late 1960s, licensing to limit entry to commercial fisheries were initiated to control the size of the fleet. In the mid-1970s, DFO embarked on the ambitious task of developing the Salmonid Enhancement Program (SEP), which was intended to increase annual salmon production by approximately 50 million pounds by (1997) The SEP was later (mid-1980s) integrated into the Pacific Region Salmon Resource Management Plan, which consisted of a 'Fleet Management Plan', and a 'Stock Management Plan' further sub-divided among Habitat restoration, Natural stock rebuilding, and Salmonid Enhancement.

Pilchards were gone from BC waters in 1946:

> *Of a time when boats had averaged 2,500 tons of pilchard per season and the total catch was well over 100,000 tons/year, suddenly nothing was left"* (Forester and Forester 1975).

By the 1940s, BC fishers were landing 80 to 85% of the total Canadian halibut catches.

Dogfish were taken during WWII for oil and vitamin A in their liver. The fishery produced a considerable amount of discarded carcasses. Ketchen (1986) identifies three phases in the development of the dogfish fishery from the mid-1900s: 1) The period from 1937 to 1950 with the rapid development and equally rapid collapse of the great fishery for liver oil as a source of vitamin A; 2) from 1951 to 1974, a lengthy interval of economic difficulty and of various attempts to resurrect a liver fishery or create a fishery for food with the aid of government subsidy programs; and 3) from 1975 to the late 1980s increasing interest in the spiny dogfish as a source of food for human consumption and development of markets in Europe and the Orient.

During the late 1950s, fishing effort by trawlers was intensified with the active participation of foreign vessels from the U.S., Japan, Russia and Poland. The important fishing grounds were the West coast of Vancouver Island, the Queen Charlotte and Hecate Straits (see Beattie, this vol).

Whaling activity in the northern Pacific declined after the 1930s; no takes occurred in 1928, 1931, 1932 and 1939. The reasons for the decline were the closing of the Japanese market in the Second World War and the global economic depression. The depletion of species and the competition from vegetable oil were also responsible for the decline of whaling in BC. Annual catches had decreased to less than 200 whales. In 1942, Consolidated Whaling, the last Canadian whaling company went bankrupt. But in 1948, with the decline in Antarctic whale catches, Norwegian, Russian and Japanese ships headed to the NW Pacific. The local industry revived with the formation of Western Canadian Whaling Ltd. (owned by BC Packers). At his time, Japanese and Russian factory ships were operating within 4 miles of the shore.

Western Canadian Whaling Ltd. operations closed in 1959. In 1962, Tokyo's Taiyo Gogyo Company brought in 6 whaling ships to operate on the Northwest coast (Forester and Forester 1975). In 1964 an estimated 18,000 whales were taken by foreign vessels, many in contravention of the International Whaling Agreement. The final whaling season was in 1968.

Controlled kills of seals and sea lions were continuously carried out by the Canadian government. Terry Glavin (1996) cites the slaughter of sea lions on the BC coast, reported in an official document from Fisheries Department:

> *.. 6,430 sea lions were machine-gunned in coastal waters between 1931 and 1937 because they stood in the way of the progress of the fishing industry.*

Present time

By the 1990s, the trawl fishery accounted for close to 60 per cent of all the fish caught on Canada's west coast. Bycatch and discards in the trawl fishery is an important concern. Glavin (1996) cites a report of the BC Aquaculture Research and Development Council which estimates discards of ca. 3,000 to 5,000 tons of turbot annually. Other important species present in trawlers bycatch include green sturgeon (which have been disappearing from trawlers catch during the last decades), eulachons, dogfish and salmon. In the following section, Beattie describes the development of the BC trawl fishery.

Reference points

Based on this review of fisheries development in the west coast we defined three reference points for the reconstruction of ecosystem models:

1. the present time
2. the early 1900s.
   Characteristics of this period as a reference point are:
   - the fact that sea otters became apparently extinct in BC waters in the beginning of the 20th century;
   - the apparent increase in Steller sea lion numbers up to the 1900s due to recovery from native kills (from the 1800s to 1900s BC's native population was reduced by almost half due to epidemics);
   - the period is prior to when whaling resumed in BC waters with the introduction of more efficient methods to kill and recover whales; prior to the introduction of purse seiners to catch herring and pilchards; and prior to the beginning trawl fisheries in the west coast.
   - the period also marks the beginning of a rapid increase in salmon and halibut fishing.
3. the mid 1700s, or pre-European contact.

References

Alverson, D.L., A.T. Pruter and L.L. Ronholt (1964) A study of demersal fishes and fisheries of the Northeastern Pacific Ocean. H.R. MacMillan Lectures in Fisheries, University of British Columbia. 190 pp.

Brown, Pamela T. (1994) Cannery Days: A Chapter in the Lives of the Heiltsuk. M.A. Thesis, University of British Columbia, 38pp.

Carrothers, W.A. 1941. The British Columbia fisheries. Political Economy Series 10. Toronto, University of Toronto Press. 136 pp.

Forester, J.E. and A.D. Forester. (1975) British Columbia's Commercial Fishing History. Hancock House Publishers. 224 p.

Glavin, T. (1996) Dead reckoning. Confronting the crisis in Pacific fisheries. Greystone Books, Vancouver, Canada. 181 pp.

Gregr, E. J. (1999) An analysis of historic (1908-1967) whaling records from British Columbia, Canada. M.Sc. Thesis, University of British Columbia. 101 pp.

Hammond, L. (1993) Marketing wildlife. The Hudson's Bay company and the Pacific Northwest 1821-49. Forest and Conservation History 37: 14-25.

Hewes, G.W. (1973) Indian fisheries productivity in pre-contact times in the Pacific salmon area. Northwest Anthropological Research Notes 7(2): 133-155.

Irwin, R. S. (1984) The Providers: Hunting and Fishing Methods of the North American Natives. Hancock House. 294 p.

Kenyon, K. W. (1975) The sea otter in the eastern Pacific Ocean. Dover Publications. 352 pp.

Ketchen, K. S. (1986) The spiny dogfish (*Squalus acanthias*) in the Northeast Pacific and a history of its utilization. Can. Spec. Publ. Fish. Aquat. Sci. 88: 78 pp.

Newell, D. (1989) The development of the Pacific Salmon Canning Industry. A Grown Man's Game. McGill-Queens University Press, Montreal, Canada.

Nichol, L. and K. Heise (1992) The historical occurrence of large whales off the Queen Charlotte Islands. Report prepared for South Moresby/Gwaii Haanas National Park Reserve, March 1992. 68 pp.

Ormsby, M. A. (1971) British Columbia: a History. MacMillan. 566 pp.

Sherman, K., Alexander, L. M. and B. D. Gold (Eds.). (1993) Large Marine Ecosystems: Stress, Mitigation and Sustainability. AAAS Press, Washington DC.. 376 pp.

Stewart, Hilary (1977) Indian Fishing: Early Methods on the Northwest Coast. Douglas & McIntyre, Vancouver. 181 pp.

Van Blarian, G. R. and J. A. Estes (Eds) (1988) The community ecology of sea otters. Spinger-Verlag. Germany. 247 pp.

A History of the British Columbia Trawl Fishery

Alasdair Beattie
UBC Fisheries Centre

The trawl fishery in British Columbia has recent roots, relative to the East Coast or European fisheries. The first record of an otter trawl either occurred in June 1903, in an attempt to find halibut near the Queen Charlotte Islands (Alverson 1961, Alverson *et al.* 1964), or an attempt was planned for this date (Forrester *et al.* 1978). The fishery can be divided into 6 historical periods or eras, the first five defined arbitrarily (but perhaps by fluctuating catch and effort levels) by Westrheim (1987), and one by this

Table 1. Historical periods and their average annual landings for the British Columbia rockfish fishery. From Westrheim (1987).

Era	Years	Annual landings (tonnes) Mean	Range
Paleozoic	1917-1942	160	49 – 113
Boom I	1943-1946	1,332	1,010 – 1,610
Neo-paleozoic	1947-1961	366	189 – 703
Renaissance	1962-1976	2,261	743 – 4,289
Boom II	1977-1995	19,638	10,037 - 28,859

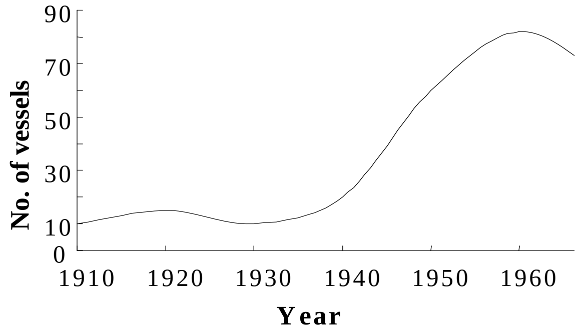


Figure 1. Number of trawl vessels active in the Canadian trawl fishery from 1910-70. Redrawn from Forester *et al.* (1978).

author. Those periods are (see also Table 1): the Paleozoic (1917 – 1942, but could also include any year prior to 1942), the second is Boom I (1943-1946), the third is the Neo-paleozoic (1947-1961), the fourth is the Renaissance (1962-1976), and the fifth is Boom II (1977-1995). The final period, from 1996-present, may be called the 'Modern' period.

The Paleozoic

The first record of trawl landings was in the Strait of Georgia near Vancouver in 1911, by a small (12m) vessel equipped with a 16-hp engine, using a type of side trawl gear (Forrester *et al.* 1978). The catch at this time consisted mainly of English sole. Vessels were few and small at this time (Figure 1), and remained so for some years, perhaps because the market for groundfish was not large and prices were poor (Forrester *et al.* 1978).

By 1918, the trawl fishery was literally at full steam, fuelled by an increasing demand for food fish brought about by World War I (Forrester *et al.* 1978). In this year, a reported 1.5 million kg of 'flounders', and 0.4 million kg of cod were landed by steam trawlers in British Columbian ports (Alverson *et al.* 1964). Catches of up to 36,000kg were reported for 48-hour trips. The total market value of catches for that year was from 377-500,000 $Can (in 1918 dollars, Alverson *et al.* 1964), or over 2,000,000 $Can today (Pauly *et al.* 2000). Though catches were large during this short period, demand was not sustained, and catches (except for a large dogfish liver fishery) fell off due to reduced effort (see Figure 2), and the steam trawlers were abandoned in favour of smaller, more economical boats of previous usage.

Boom I

Trawl remained a small fishery until near WWII. About then the discovery of the high vitamin content of dogfish liver, coupled with an increased demand for food fish and gun oils, caused a rapid expansion (Alverson *et al.* 1964). The expansion was not only marked by higher catches: a rapid expansion of the fleet into new fishing grounds also occurred (Fig. 2.3). Diesel became the main power source for vessels, coupled with better hold technology and icing techniques. This boom period was relatively short-lived however, the demand driven by WWII, catches dropped dramatically following the end of the war in 1945.

Neo-paleozoic

The neo-paleozoic era is characterized by gradually increasing catches dominated by the Pacific cod and the traditional flatfish. Expansion into new fishing grounds continued, while effort nearly ceased within the Strait of Georgia.

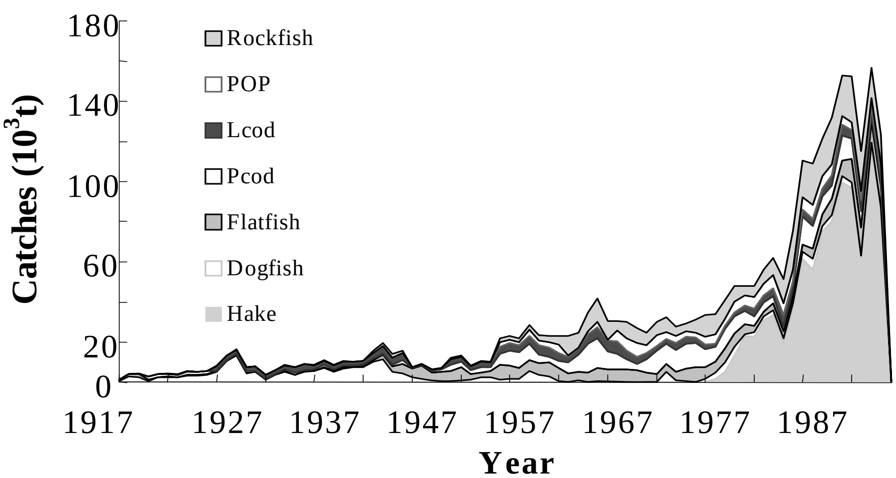


Figure 2. Catches by species for the Canadian trawl fleet for the years 1917 to (1994) Data from Forrester et al (1978), Westrhein et al (1986) and Pauly *et al.* (2000).

The fishing vessels remained relatively unchanged from the war years. They were small, averaging 29 t for the entire fleet (Forrester *et al.* 1978). The vessels did not need to be any larger, however, as the coastline offered plenty of shelter from storms, with the prime fishing grounds never more than 60 km away (Forrester *et al.* 1978), but for the first time gear technology was changing. Up until this point, most vessels were side trawlers, but in 1951 otter doors were introduced and quickly swept through the fleet (Forrester *et al.* 1978). The otter doors greatly increased the spread attainable in the net opening, and allowed for stern trawling, a safer and more efficient method. Some fishers objected, concerned about the destruction of the bottom habitat (Forrester *et al.* 1978), a concern common to fishers throughout the world (Matthews 1995, Fairlie *et al.* 1995), dating well back into history (Fairlie 1995).

The end of this period was marked by another new occurrence: the incursion of foreign fleets into the fishing grounds.

Renaissance

Although some fishing by U.S. based boats did occur for a long time before the 1950s, especially in the lower West coast of Vancouver Island region (Forrester *et al.* 1978), fishing effort by the U.S. and other foreign nationals, including vessels from Japan, Russia and Poland intensified during the late 1950s (Table 2). During 1955-57, approximately 60% of food fish taken by US vessels from the state of Washington was taken in BC waters, and greater than 50% of the effort by the Washington fleet occurred in BC waters (Alverson *et al.* 1964). The important fishing grounds were the West coast of Vancouver Island and, to lesser extent, the Queen Charlotte and Hecate Straits.

In the sixties the Canadian and U.S. fleets were joined by the USSR, then Japan and finally Poland. Most of the foreign fleets were targeting rockfish using trawl, mainly Pacific Ocean Perch (Table 3). Other rockfish were also targeted, most importantly the yellowtail, silvergray and canary rockfishes (Westrheim 1987).

This period is marked by some of the highest catches in the history of the fishery. The reliability of the data from the foreign fleets is questionable, partly because none of the fish were landed in Canadian ports, but were traded at sea or transferred to huge motherships that came in support of the smaller trawlers (Forrester *et al.* 1978). Furthermore, no information on discard practices is available, though we can assume it to be quite high, from 20% to as much as 2.2 times the landed weight (Alverson *et al.* 1994). Nevertheless, it is quite clear from what was actually reported that the foreign fleet catches in total far exceeded the Canadian catch for the same period (Figure 4).

By the late 1960s, concern was mounting over the impacts that foreign fleets were having on local fish stocks, and perhaps driven more by the large scale fisheries operating on the Atlantic coast, culminated in the declaration of a closed fishing zone on the East and West coasts (Anon 1971). For some years, foreign vessels were not prevented from fishing, but were required to register their intention to enter Canadian waters for fishing, and to obtain a license to do so (Forrester *et al.* 1978). It was not until 1977 that Canada declared the 200 mile zone closed to all foreign fishing (Anon 1976) and the phasing out of the foreign fleets began (Westrheim 1987).

At this time on Canada's East coast , a massive buildup of the fleets began in order to protect the newly declared ownership of the offshore fishing grounds (Matthews 1995, see also Wright in Bonfil *et al.* 1998). The Canadian government subsidized a new offshore trawl fleet of huge ships that essentially replaced the foreign fleets. On the West coast however, the fleet was already established, and changed little over the ensuing years. Pictures in Forrester *et al.* (1978) show vessels that were still fishing up until a few years ago; indeed, the author have spent time aboard one of these vessels.

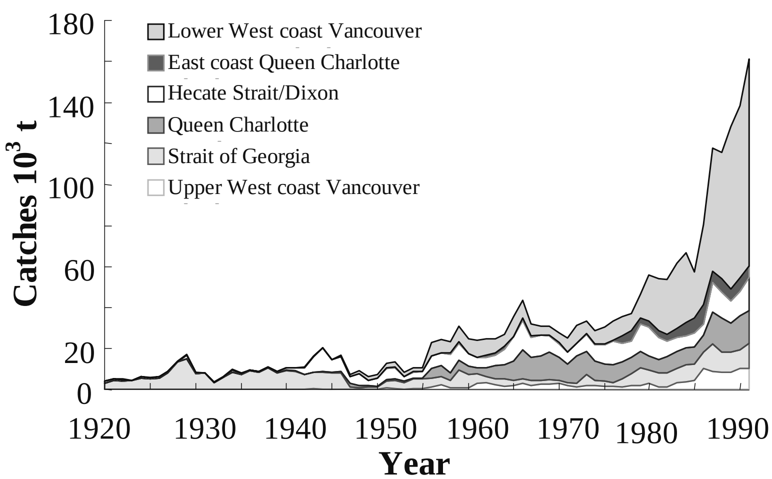


Figure 3. Catches of the Canadian fleet by area of the coast through time. The sequence is difficult to see, but moves first from the Strait of Georgia to lower then upper west coast of Vancouver Island, followed by a period of rapid expansion into the Hecate Strait/Dixon entrance area and finally the east coast of the Queen Charlotte Islands. The fishery in the Strait of Georgia is sustained today mainly by a large hake and dogfish fishery, similarly for the lower west coast Vancouver Island region

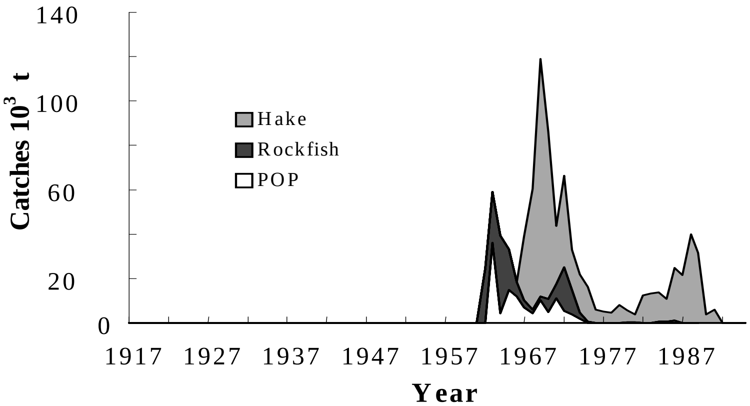


Figure 4. Catches by all foreign fleets from the beginning of the fishery. Hake landings continue today because of a large Joint venture fishery in the lower west coast of Vancouver Island area, involving Polish, Russian and sometimes Chinese vessels.

Vessels remained fairly small for the same reasons mentioned above, economically they were as large as was viable. The fleet had doubled its vessel size since the 1940s however, ranging from 24 – 30m in length, with an average tonnage of 60t and a maximum hold capacity of about 50t (Forrester *et al.* 1978). Gear improvements continued, including engine upgrades, better sounders, better nets and better technology to preserve the fish (pers. obs.). With the foreign fleets gone, and the improvements in gear technology, the West coast domestic fleet was ready for Boom II.

Boom II

This period is characterized by continually increasing catches by the domestic trawl fleet (Figure 2) and a continued expansion into new territories (Figure 3). It is also marked by a decrease in the importance of Pacific Ocean perch (POP) as a major component of the fishery, and the increase of other species of rockfish and flatfish as primary target species (Richards 1994). In the late 1960s, POP made up more than 50% of all rockfish landings, but by 1992 it comprised less than 10% (Forrester *et al.* 1983; Richards 1994, Table 3). However, the reduction in the landings of POP was not due to reduced fishing effort. Rather, it was due to new regulations (Richards 1994).

In 1978, annual quotas were first applied to the groundfish trawl fishery. Following this first attempt at controlling effort by the fleet, a variety of management approaches was applied. The different approaches included area specific or grouped area quotas, single species or species aggregate quotas and pulsed fishing (Richards 1994). From 1989 until 1997, management consisted of a combination of grouped area quotas, trip limits, and area/time closures (Richards 1994, and B. Leaman, Director IPHC, pers. comm.). The new management strategies were first introduced over concern about uncertain knowledge of the removals by the foreign fleets, but also because in 1981 the biology of 10 major species of rockfish was dramatically reassessed. New techniques were being developed that increased the accuracy in the aging of the major groundfish species (Leaman 1987). In 1981, these techniques were applied by Archibald *et al.* (1981) to 10 species of rockfish. The results elicited great concern. Estimates of M (natural mortality) for all species, including POP, were halved or more. Correspondingly, the F (fishing mortality) value for all the species was increased.

The new management approaches may, in fact, have had the opposite of the desired effect. Although they were successful in spreading fleet effort throughout the year, there was increasing evidence that fishers were devising ways around the limits. These included reporting catch from one area as being from another area, mis-reporting catch as a different species, and high rates of discards (Richards 1994). Such concerns are by no means isolated to the British Columbian trawl fishery. Discarding may be the single greatest problem associated with such management techniques, as shown in the Oregon-Washington groundfish fishery (Pikitch 1988) and the Scottish fishery (Fairlie 1995). Discarding has the effect of causing catch per unit effort (CPUE) to be underestimated, and consequently the exploitable biomass to be overestimated, possibly leading to overfishing (Richards 1994).

Furthermore, neither trip limits nor the quota

Table 2. Foreign fleets and the years they fished in west coast Canadian waters. From Westrheim (1987). a. before March 1st 1981; b. after March 1st 1981.

Period	Canada	USA	USSR	Japan	Poland
1956-64	✓	✓			
1965	✓	✓	✓		
1966	✓	✓	✓	✓	
1967-68	✓	✓	✓	✓	
1969-74	✓	✓	✓	✓	
1975-76	✓	✓	✓	✓	✓
1977	✓	✓	✓	✓	
1978-81[a]	✓	✓			
1981-85[b]	✓				

system were entirely effective at controlling the catch. The quotas for most species were exceeded almost every year. In 1995, DFO recognizing the failure of the management system and took drastic action: Quotas for many species had been exceeded by the late summer, so in September of that year, the fishery was closed coast wide, for the first time in its long history (DFO 1996). A new era in the management of the fishery was beginning.

Modern era

The fishery was reopened in October 1995, but with novel restrictions: it was limited to a midwater fishery, primarily for the yellowtail and widow rockfishes, and the presence of an observer on board at all times during fishing operations was required. During the next few years and until the present, the fishery has been characterized by the catches leveling out, and some of the greatest social and economic impacts it had ever faced.

The limitation to a midwater fishery was accepted in general by the fishers, although many disagreed with the scientists over how much fish was available in the water. Most realized that the new fishing year would bring more quota for the other species, and were happy to be able make some more money before Christmas. The presence of an observer was less easily accepted. Observers had been used with great success by Pikitch (1987 1991) and by Pikitch *et al.* (1998) (where? In Canada?) to identify at sea discard rates by trawl fishers and the rationale behind them. DFO was convinced that unbiased information on fishing activities and catch rates could only come from onboard observers. While many fishers agreed in principle with the program, all objected to the user pay system that was imposed upon them in order to fund the complete coverage of the fleet. For many fishers, the introduction of trip limits and limited entry had already caused some economic hardship, typical of such measures (Fairlie 1995, Hilborn and Walters 1992).

Furthermore, neither the fishery, nor the vessels were as large as in those fisheries to which observer programs had been applied elsewhere. Thus, especially for the smaller vessels, space concerns were paramount in their minds. Many reported having to let crew members go in order to make way for the observers, (Various skippers, pers. comm.). This had the additional effect of increasing the workload for the remaining crew, while income did not significantly increase, since the extra money otherwise available paid for the observer fees and food.

Despite the complaints of economic hardship, fleet activity actually increased over the next year, due to impending introduction of individual vessel quotas (IVQs) for the fleet. Everyone wanted to fish, for many the first time in years. A total of 142 trawl licenses existed, but many were

Table 3. Catches by all nations of Pacific Ocean perch (POP) and other rockfish species in west coast Canadian waters. Note that landings by the US continue until 1982, they were the last nation to leave in the 'phasing out' process after Canada declared its EEZ. From Westrheim (1987).

	Canada		U.S.		USSR		Japan		Poland		Total		Rockfish	POP
Year	Rockfish	POP	Rockfish	POP	Rockfish	POP	Rockfish	POP	Rockfish	POP	Rockfish	POP	(% total)	(% total)
1956	239	154	4820	2240							5059	2394	68	32
1957	215	91	3909	2034							4124	2125	66	34
1958	426	319	3596	1306							4022	1625	71	29
1959	544	247	5290	2581							5834	2828	67	33
1960	445	357	5385	2927							5830	3284	64	36
1961	267	124	6538	3561							6805	3685	65	35
1962	860	534	9366	5160							10226	5694	64	36
1963	815	454	10544	7151							11359	7605	60	40
1964	930	471	8052	5555							8982	6026	60	40
1965	1781	1395	9584	6585	16896	1220					28261	9200	75	25
1966	2696	2366	12565	8247	47952	34700	3206	3206			66419	48519	58	42
1967	743	391	9297	6193	17824	12900	13047	12874			40911	32358	56	44
1968	1314	876	10805	5725	11503	8300	16472	14772			40094	29673	57	43
1969	2439	1504	13756	5707	132	100	13093	11686			29420	18997	61	39
1970	2915	2099	11633	5971	378	270	7628	7164			22554	15504	59	41
1971	2285	1337	8939	3990	1030	750	4787	4326			17041	10403	62	38
1972	4113	2327	8696	3871	499	360	11003	10374			24311	16932	59	41
1973	2820	1398	8160	2609	10	10	9991	3598			20981	7615	73	27
1974	2658	1529	6127	2443	?	?	22883	10843			31668	14815	68	32
1975	3253	2040	4179	1310	?	?	10169	5428	12873	<48	30474	8826	78	22
1976	4289	1745	5485	1323	?	?	7750	3531	3931	<17	21455	6616	76	24
1977	7952	2716	8710	1959	?	?	3047	2140			19709	6815	74	26
1978	10472	3864	6771	1285			110	21			17353	5170	77	23
1979	8781	2819	6771	1136			74	2			15626	3957	80	20
1980	9766	5290	5479	900			23	1			15268	6191	71	29
1981	9960	5103	4668	280			26				14654	5383	73	27
1982	11076	5983	6770	238			40				17886	6221	74	26
1983	12674	5653									12674	5653	69	31
1984	15210	6698									15210	6698	69	31
1985	17641	6111									17641	6111	74	26

owned by multi-license holders, often by those who held other very lucrative Individual transferable quota (ITQ) or IVQ licenses, such as a blackcod (=sablefish) trap license. IVQs are most often established based on a combination of vessel length and vessel history, but because of the uncertainties surrounding the landings over the previous decades, the history portion of the allocation did not extend past (1995) The typically high value of IVQs (Fairlie 1995, Hilborn and Walters 1992) in effect forced many of the fishers to fish more than they otherwise would have, as competition for an ever declining resource mounted. In 1996, more than 113 vessels recorded at least some fishing activity, almost 50% more than the previous high several decades before.

In March 1997, the IVQs were allocated to each vessel (DFO 1998). Many vessels received too small a quota to be economically viable and trading and selling of quota was fast and furious. In the end, fleet activity settled out at around 60 vessels, slightly less than the 75 or so that regularly plied the waters in the 1980s and early 1990s. This represents a loss of over 60 full time positions for crew and skippers in the fleet. The price of a trawl license skyrocketed, though most decline to publicize the value of their licenses (though they all say they are for sale). An indication of the value of a trawl license can however be arrived at from the sale of the Sena II, a large, unseaworthy old converted wooden schooner with a lower than average quota, listed at over 1,000,000 $Can in late (1997) These prices create impossible barriers of entry for young fishers who don't inherit a license, and tend to consolidate the licenses in the hands of those who do have the cash, most often large companies (Fairlie *et al.* 1995). Some fishers recognized the probability that these economic barriers would be raised with the addition of IVQs to the fleet and objected, but were either too few in numbers or did not object too vociferously because many of them stood to gain the most (D. March, Chairman of the British Columbia Groundfish Conservation Society, pers. comm).

The introduction of IVQs was a *fait accompli*. DFO was intent on their introduction, despite historical proof that IVQs encouraged illegal sales, high grading at sea, and often resulted in bankruptcies with large market price fluctuations. This was at least partly because DFO intended to continue the 100% coverage of the fleet by on-board observers. From DFO's perspective, this effectively outweighed all negative possibilities in the management of the fishery, except for bankruptcy. DFO felt that the benefits of IVQs administered under this approach far outweighed the costs, thus the ends justified the means (B. Turris, former groundfish Manager for the West coast, DFO, Nanaimo, pers. comm.). As far as fisheries go, DFO scientists now have one of the best data sets being developed anywhere in the world.

The Future

Economically, the future looks fairly bright for the trawl fishery in British Columbia. There is some stability in the ownership of IVQs that has allowed many of the owners to relax for the first time in years. Over the holidays and during the bad weather months, many vessels for the first time in years are tied up, secure in the knowledge that no one else can take their fish, and that the markets are reasonably stable. The fishers can choose where, when and what to catch in order to obtain top dollar. Throughout 1997 and 1998, effort remained more stable than at any other time in the history of the fishery (S. Stebbins, Archipelago Marine Research, Victoria, BC, pers. comm.). There are, however, some warning signs that should be heeded.

First, the increasing regulation of catches has resulted in an increase in the number of species being landed. This was recognized as early as 1987 by Westrheim (op. cit.), who noted a new fishery for 'redfish', for export to Japan. These fisheries, primarily for the rougheye rockfish, have expanded in recent years to include the thornyhead rockfishes, a very deep, long-lived species, about which relatively little is known. These fish, primarily the longspine thornyhead, (*Sebastolobus altivelis*) are caught in high quantities and frozen at sea. Several boats in the fleet depend upon this fishery almost exclusively for their livelihoods. These vessels have suffered a little in 1998 due to the 'Asian flu' syndrome, but another nasty surprise may await them. Recent evidence has shown that the CPUEs for the species has been falling for several years, although it is not yet clear whether this is because it is such a new fishery or because the population is in decline (J. Schnute, DFO, pers. comm.). In the future, greater restrictions on these species may be in store.

Second, data acquired by at-sea observers has shown that for species like POP, the majority of the catch comes from one or several 'hotspots' along the coast (J. Schnute, DFO, pers. comm., Walters and Bonfil 1998). If these hotspots are simply population sinks, at some point the fishery may find that almost no fish remain to recolonize those hot spots. Such high catchabilities suggested by the data indicate much lower exploitable biomasses than previously thought (Walters and Bonfil 1998).

Third, the fishery has been continually landing a wider and wider variety of new species, in an effort to make ends meet. Besides the thornyhead rockfish, the fishery has been developing markets for other new species, such as skates (Raja spp.), used in the production of faux scallops, dogfish and arrowtooth flounder (*Reinharditius stomias*). All of these species were previously discarded, due to limited hold space, in favour of other more lucrative species. Recently Pauly *et al.* (1998) showed that world fisheries were moving down the trophic levels and catching less by weight. These trends, also present in fisheries landings of west coast of Canada (Pauly *et al.* 2000), suggest dire consequences for the future. The implications of this effect are as yet unclear; though the decline occurred despite a continuing expansion of the fishery until very recently, it is also occurring in the face of increasingly stringent regulation. Nevertheless, caution should be taken.

One final troubling note remains: the continued degradation of bottom habitat that may be important in the ecology of many species, by trawling. These concerns are not new, nor are they unique to this fishery (Fairlie 1995, Norse and Watling 1998; Matthews 1995). In this fishery, large amounts of a coral called 'red tree' are often landed, and then discarded, as are sea pens (pers. obs.). Recent evidence in the form of underwater observations from Alaska (Watson, unpub. data) and from the hook and line fishery here in BC (S. Buchanan, Archipelago Marine Research, pers. comm.) strongly indicate that both the coral and the seapens are important habitat for rockfish. Little is known about the growth rates or the age structure of these invertebrate communities, nor the effects of their removal. However, there is evidence from areas with a long history of trawling, including Hong Kong harbour and areas in the North Sea, that suggest that uniform, highly trawled bottoms do not maintain the same populations or communities of fish that existed pre-trawl.

References

Alverson, D.L. (1961) Pacific coast groundfish. Western Fisheries Magazine, 61 (3).

Alverson, D.L., A.T. Pruter and L.L. Ronholt (1964) A study of demersal fishes and fisheries of the Northeastern Pacific Ocean. H.R. MacMillan Lectures in Fisheries, University of British Columbia. 190 pp.

Alverson, D.L., M.H. Freeberg, S.A. Murawski and J.G. Pope (1994) A global assessment of fisheries bycatch and discards. FAO Fish. Tech. Paper. 339: 233 pp.

Anon 1976. Safeguards built into 200-mile legislation. Western Fish. 93: 12-13

Anon (1993) It can't go on forever: the implications of the global grab for declining fish stocks. Greenpeace International, Netherlands.

Archibald, C.P., W. Shaw and B.M. Leaman (1981) Growth and mortality estimates of rockfishes (Scorpaenidae) from BC coastal waters 1977-1979. Can Tech. Rep. Fish. Aquat. Sci. No. 1048, 57 pp.

Wright, M. and Bonfil, R. (1998) Case Sudy: Newfoundland Cod Fishery 1950-1992. Pages 68-76 in Bonfil, R., Munro, G., Sumaila, U.R., Valtysson, H., Wright, M., Pitcher, T., Preikshot, D., Haggan, N. and Pauly, D. (eds) Distant water fleets: an ecological, economic and social assessment. Fisheries Centre Research Reports 6 (6): 111pp. (*also issued under the same title by WWF International, Godalming, Surrey, UK, 111 pp.*)

DFO (1996) Groundfish Management Trawl Plan for 1996 .

DFO (1998) Groundfish Management Trawl Plan for 1998. 35 pp.

Fairlie, S. (1995) Who is weeping crocodile tears? Britain's fishing industry & the EU common fishing policy. Ecologist 25(2/3): 105-114.

Fairlie, S. M. Hagler and B. O'Riordan (1995) The politics of overfishing. Ecologist 25(2/3): 47-73.

Forrester, C.R., A. J. Beardsley, and Y. Takahashi (1978) Groundfish, shrimp and herring fisheries in the Bering Sea and Northeast Pacific – historical catch statistics through 1970. Int. North Pac. Fish. Comm. Bull. 37: 147 pp.

Forrester, C.R., R.G.. Bakkala, K. Okada and J.E. Smith (1983) Groundfish, shrimp and herring fisheries in the Bering Sea and Northeast Pacific – historical catch statistics through 1971-76. Int. North Pac. Fish. Comm. Bull. 41: 100 pp.

Hilborn, R. and C.J. Walters (1992) Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapter 9: Delay difference models, pp330-348, Chapman and Hall, New York.

Leaman, B.M. (1987) Incorporating reproductive value into Pacific Ocean perch management. Proc. Int. Rockfish Symposium, p. 355-368. October 1986, Anchorage, Alaska.

Matthews, D. R. (1995) Commons versus open access: The collapse of Canada's East coast fishery. Ecologist 25(2/3): 86-96.

Norse, E.A. and L. Watling (1998) Effects of mobile fishing gear on marine benthos. Conservation Biology 12 (6): 1178-1239.

Pauly, D.P., V. Christensen, J. Dalsgaard, R. Froese and F.T.Jr. (1998) Fishing down marine food webs. Science 279: 860-863.

Pauly, D.P., A.I. Beattie, A. Bundy, N. N. Newlands, M. Power and S.S. Wallace. (2000) Not just fish: Value of marine ecosystems on the Atlantic and Pacific coasts. Pages 34 – 46 in H. Coward, R. Ommer and T. Pitcher (eds). Just Fish: Ethics and Canadian Marine Fisheries. ISER books, Memorial University of Newfoundland, Canada. 304 pp.

Pikitch,E.K. (1987) Impacts of management regulations on the catch and utilization of rockfish in Oregon.

Proc. Int. Rockfish Symposium, Pages 369-382. October 1986, Anchorage, Alaska.
Pikitch, E.K. (1991) Technological interactions in the U.S. West coast groundfish trawl fishery and their implications for management. ICES Mar. Sci. Symp. 193: 253-263.
Pikitch, E.K., D.L. Erickson and J.R. Wallace (1998) An evaluation of the effectiveness of trip limits as a management tool. NMFS Seattle, Processed Report 88: 27 pp.
Richards, L.J. (1994) Trip limits, catch, and effort in the British Columbia rockfish trawl fishery. N. Am. J. Fish. Mgmt. 14: 742-750.
Sissenwine, M.P. and A.A. Rosenburg (1993) Marine fisheries at a critical juncture. Fisheries 18(1): 6-14.
Walters, C. J. and R. Bonfil (1998) Multispecies spatial assessment models for the British Columbia groundfish trawl fishery. Can. J. Fish. Aquat. Sci. 56: 601-628.
Westrheim, S.J. (1986) The rockfish fisheries off western Canada 1860–1985. Pages 43-49 in Proc. Int. Rockfish Symposium, October 1986, Anchorage, Alaska.

WHALES IN NORTHERN BC: PAST AND PRESENT

Edward J. Gregr
Marine Mammal Research Unit, Fisheries Centre, UBC, & Facet Decision Systems Inc., Vancouver

Overview

Based on historic whaling records, it appears that all of the large whale species were once found within 200 nautical miles of British Columbia. This includes the large baleen species: blue (*Balaenoptera musculus*), fin (*Balaenoptera physalus*), sei (*Balaenoptera borealis*), humpback (*Megaptera novaeangliae*) right (*Balaena glacialis*), and gray (*Eschrichtius robustus*) whales, as well as the largest odontocete, the sperm whale (*Physeter macrocephalus*). A small number of Baird's beaked (*Berardius bairdii*) and minke whales (*Balaenoptera acutostrata*) were also caught at the British Columbia whaling stations.

What is known about the natural history and migration patterns of these species allows certain predictions to be made about their relative occurrence in the relatively sheltered, on-shelf waters of British Columbia.

Baird's beaked and minke whales are pelagic species, typically occurring well offshore. These two species are now, and likely always were, relatively rare in the coastal waters of British Columbia.

Sei, fin, blue, Gray and humpback whales all engage in extensive migrations between summer feeding grounds (north) and winter breeding grounds (south). Historically, this migration brought them within reach of the coastal whaling stations (i.e. within 200 nmi of shore). While the sei whales appear to have migrated past British Columbia, subpopulations of fin and possibly blue whales may have used sections of the British Columbia coast as feeding areas (Gregr *et al.* 2000). Right whales are also known to feed in on-shelf waters, while Gray and humpback whales both make extensive use of coastal habitat.

Based on these generalities, it is reasonable to assume that Gray, humpback and right whales were once relatively common in Hecate Strait. Fin whales were likely common in the more exposed portions of the study area, and blue whales, although considered an offshore species, may have also spent time feeding in the exposed, on-shelf waters of British Columbia. Both these species would be somewhat unexpected in the more sheltered waters of Hecate Strait. Sei whales appear to have migrated past and away from the British Columbia coast (Gregr *et al.* 2000). Their occurrence in Hecate Strait would therefore be unusual.

Sperm whale distributions in the Pacific appear to be range based, with females ranging over areas of 1,000's of kilometers. Males are believed to make use of substantially larger ranges due to a putative breeding migration to southern latitudes from northern feeding grounds (Reeves and Whitehead 1997). While typically found in deeper waters, sperm whales have been observed in open, on-shelf waters (Pike and MacAskie 1969).

History of North Pacific Whaling

Contact on the west coast of Canada can be considered to begin with the arrival of Captain Cook in Nootka Sound, on the west coast of Vancouver Island, in 1778. By 1791, Yankee whaling expeditions were regularly entering the Pacific.

The whalers began exploiting the Kodiak grounds shortly after reaching Hawaii. The fishery moved from sperm whales – the original target of the Yankee whale fishery - to the slow moving, oil-rich right and bowhead whales. Thus, these two populations were significantly impacted between 1750 and 1850, with the pelagic fishery taking 193,522 right whales worldwide between 1804 and 1876.

Whales enjoyed a brief respite from whaling as populations of sperm, right, bowhead, and Gray whales were depleted, and whalers turned their attention to the sea otter for approximately 50 years (1850 – 1900). However with the subsequent depletion of sea otter populations and the introduction, at turn of 20th century, of modern whaling techniques (steam power and exploding harpoons), the attention of the whalers turned to the remaining whale species that were previously too difficult to catch.

A detailed description of whaling in the North Pacific is provided by Robert Lloyd Webb in *On the Northwest* (1988). An excellent discussion of worldwide whaling is available in *The History of Modern Whaling*, by Tonnessen and Johnsen (1982).

Population estimates

The data presented here are intended to help quantify the abundance of these species in the waters of Hecate Strait during three periods: Pre-contact (mid-1700s), turn of the century (1900-1905) and present day (1995-2000). A description of the whale distributions in the British Columbia catch record is provided (Tables 2 & 3) to help allocate the population estimates between Hecate Strait and adjacent waters.

Estimates of North Pacific whale populations prior to exploitation vary widely, and were the subject of intense research in the 1970s and 1980s by both the Japanese Whale Research Institute and by the International Whaling Commission. For the purposes of consistency, the estimates for initial population sizes are taken from Breiwick and Braham (1984).

Blue Whales

Blue whale population sizes and the distribution of stocks throughout the North Pacific remain very unclear. Gambell (1976), cited in Breiwick and Braham (1984), estimated pre-exploitation stocks for the entire North Pacific at 4,900 and current (1976) stocks at 1,600. Current populations are limited. Estimates of 1,400 blue whales in the eastern tropical Pacific, 2,250 in the California/Mexico stock have been suggested. No data are available to estimate population size for any other North Pacific blue whale population. These estimates demonstrate the degree of uncertainty associated with the estimates for this species.

Recently, Reeves *et al.* (1998) suggested that there may be as many as five subpopulations in the North Pacific. Gregr *et al.* (2000) suggest that one of these sub-populations – the eastern Gulf of Alaska stock - may have used southeast Alaska and northern British Columbian waters as a feeding ground. While Pike and MacAskie (1969) suggest that blue whales were found mostly offshore, the British Columbia catch record shows that almost 33% of the blue whales caught by coastal stations were on the continental shelf (i.e. depths ≤ 200 m. See Table 2.). Further, of the blue whales caught north of 51.5 N, the majority were on shelf (Table 3).

Accepting the assumptions that 1) there are five stocks in the North Pacific, and 2) that they contain the same proportion of animals, and 3) that the British Columbia catch proportions (Table 3) reflect how much of this stock may have frequented the on-shelf waters of Hecate Strait (30%), then the pre-contact population can be estimated to have been (5,000/5 * 30%) 330 animals. With close to 300 animals caught be the British Columbian stations between 1905 and 1967, and minimal recovery, the number of blue whales that frequent Hecate Strait is likely somewhere between 10 and 50 (Table 4). Since harvesting of blue whales did not start in earnest until the modern whaling era, the turn of the century population can also be assumed to have been around 300 animals.

Fin Whales

Large numbers of fin whales were taken only after modern whaling was introduced to the North Pacific at the turn of the 20th century. The North Pacific is estimated at between 42,000 and 45,000 before whaling began, to a 1974 population of 14,620 – 18,630. Of these, 8,520 – 10,970 were estimated to be the eastern Pacific stock. While the IWC recognizes a sub-population only in the East China Sea, The US Marine Mammal Protection Act recognizes three stocks (Hawaii, Alaska, and California-Washington) in American waters (SAR 1997a). Gregr *et al.* (2000) supported previous suggestions that a sub-population of fin whales used British Columbian waters as a feeding ground. The relative size of this stock, and its relationship to the putative stocks off California and Alaska, is not known, however a total of 4,860 animals were taken off the coast of North America between 1919 and 1987 (SAR 1996).

Assuming the pre-exploitation size of the eastern North Pacific was 10,000 animals, if these all used the British Columbia feeding grounds then according to Table 3, 12% of this population - 1,200 animals - would have occasionally been found in the waters of Hecate Strait. Current estimates of approximately 16,000 animals in the North Pacific, divided according to the proportions used above, would suggest a total of (11,000/45,000 * 16,000 * 12%) 425 animals today. Since fin whales only became the target of whalers in the 1900's, the turn of the century population can also be assumed to have been around 1,200 animals (Table 4).

These are likely upper estimates for this species, given that the habitat frequented by fin whale would likely be limited mainly to Dixon Entrance and Queen Charlotte Sound. Nevertheless, while the catch of fin whales peaked in 1958, this species contributed a significant portion of the catch right through to 1967 (Gregr *et al.* 2000).

Sei Whales

Sei whales were not harvested extensively until after the introduction of modern whaling techniques. Catches of sei whales in the eastern North Pacific in the early 1900s were relatively small compared to the fin and humpback whale catches. Sei whales became the preferred target of the British Columbian coastal fleet only after the stocks of larger rorquals were significantly depleted (circa 1955-1960).

The pre-exploitation population size for the North Pacific is estimated at about 45,000 whales, and the 1974 population at 7,260 to 12,620. While not recognized by the IWC, Masaki (1976, 1977), cited in Breiwick and Braham (1984), believed there to be three stocks of sei whales distributed according the longitude, with the eastern stock located east of 155 degrees west. SAR (1997b) recognizes an eastern North Pacificstock east of 180 degrees longitude. The relative population sizes are not known, nor do there appear to be any recent population projections.

Assuming two stocks, and an equal distribution of animals between the stocks, the pre-contact and 1900 population for the eastern North Pacific can be estimated at 22,500 animals. With 3% of the British Columbia catch coming from Hecate Strait, this suggests that approximately 675 animals may have occasionally been found in the study area. However given the offshore habits of this species, it is likely that their occurrence in Hecate Strait was considerably less than this. The present day estimate for Hecate Strait can safely be assumed to be zero (Table 4).

Humpback Whales

A pre-1905, North Pacific population of about 15,000 was reduced to less than 1,200 by 1984. Of the remaining animals, a sub-population of 550 – 790 animals is believed to winter in Hawaiian waters, and feed in southeast Alaska and northern British Columbia. Baker and Herman (1987) gave a mark recapture estimate for this sub-population of around 1,400 animals, while Cerchio (1994) suggested that the size of this stock could be anywhere from 2,000 to 5,000 animals (both cited in Clapham *et al.* 1999). Calambokidis *et al.* (1997) (cited in Clapham *et al.*,1999), provided the only current basin-wide estimate of between 6,000 and 8,000 animals, and provides evidence for 3 populations in the North Pacific.

Humpback whales were one of the first targets of the coastal whalers. Whaling occurred in the Strait of Georgia between 1866 and 1873, and again in the winter of 1907-1908, although the largest catches by British Columbian stations occurred between 1908 and 1917 (Gregr *et al.* 2000). By 1925, the coastal whalers had turned their focus to different species, but humpback whales continued to appear in the catch right through the 1960's (Gregr *et al.* 2000).

If we assume that the three putative North Pacific stocks were once of equal size, then the pre-contact population of the Hawaiian stock can be estimated at 5,000 animals. Further, if we accept the suggestion by Gregr et al (2000) that the Hawaiian stock was historically composed of three distinct subpopulations, and that these were of equal size, then as many as 1,600-1,700 animals could have once frequented British Columbia waters. Of these, 11% (Table 3), or 150-200, may have regularly appeared in Hecate Strait (Table 4). The turn of the century population can be assumed to be the same, since exploitation in the study area did not start until the early 1900's. Using the same assumptions, and an estimated size of 3,000 for the Hawaiian stock, today's population in Hecate Strait can be estimated at 11% of 1,000 or 100 animals.

Right Whales

Given the early (1800's) decimation of this species, estimates of population sizes are very poor. The best guess for the unexploited population size is that two thirds of the 100,000 to 300,000 animals worldwide were in the northern hemisphere. This suggests that 1/6 or 16,500 to 50,000 may have been in the North Pacific. Current estimates of the northern right whale populations indicate less than 200 individuals in the North Pacific Ocean. The North Pacific population occurs across the entire North Pacific Ocean above 35°N, primarily in continental shelf regions. Sightings have occurred as far south as Central Baja California and the Yellow Sea in the winter, and far north as the Bering Sea and the Sea of Okhotsk in the summer. Only 29 reliable sightings have occurred since 1900 (NOAA 1991).

For Hecate Strait, a pre-exploitation population estimate of 250 to 1,000 animals is simply a wild guess. However, turn of the century and current population size can safely be assumed to be zero (Table 4).

Gray Whales

The initial, unexploited population size of gray whales in the eastern North Pacific was likely between 15,000 and 30,000. By the 1900s, this population had been so heavily harvested that the species was thought to be extinct. Today, with an estimated population size of approximately 21,000 animals, it is believed to have recovered to near historic levels (Clapham et al 1999).

Given the overexploitation of Gray whales during the second half of the 19th century, very few were caught by British Columbian coastal stations. Their migration is often very close to shore, making it likely that Gray whales pass through Hecate Strait as part of their migration. However, the proportion of the population that passes through the Strait is difficult to estimate.

Using an arbitrary proportion of 20%, gives a pre-contact and present day estimate of approximately 4,000 animals. The turn of the century estimate can be assumed to be zero (Table 4).

Sperm whales

Sperm whales are widely distributed throughout the Pacific Ocean. Females are generally distributed below 45 degrees North, thus, females would not be expected in Hecate Strait. Males are found as far north as the Bering Sea. Initial (1910) population estimates for males in the North Pacific are 142,700, and current (1982) estimates are 111,400.

Since distributions are believed to be range based (Reeves and Whitehead 1997), it is difficult to estimate the proportion of the total population that would have been accessible to the British Columbia stations, however the catch of this species never declined significantly (Gregr *et al.* 2000). This, and the population estimates suggest that the stock was only moderately over-exploited.

Assuming that, as with the North Pacific population, 30% of the Hecate Strait population was removed by whaling, and that the majority of animals were taken between 1925 and 1967, then we can estimate the pre-contact and turn of the century Hecate Strait populations at (277 * 100/30) or 900 or 1,000 animals. However given that the only suitable sperm whale habitat is at the edges of the study area (in Dixon Entrance and south of the Queen Charlotte Islands) this is most likely an upper estimate. If only 10-20% of the study area is considered suitable habitat, then a more reasonable estimate might be 100-200 animals. There is little evidence to suggest that current population sizes are outside this range.

Table 1. Total number of kills, by species, for the entire coastal whaling period (1908-1967).

Species	Number killed
Baird's Beaked Whale	41
Blue whale	1398
Fin whale	7605
Gray whale	11
Humpback whale	5638
Minke whale	1
Right whale	8
Sperm whale	6158
Sei whale	4002

Table 2. Catch numbers for on (to 200 m) vs. off (>200 m) the continental shelf.

Species	On Shelf	Off Shelf
Baird's Beaked Whale	2	27
Blue whale	91	191
Fin whale	581	3351
Gray whale	5	6
Humpback whale	239	614
Minke whale	0	1
Right whale	3	1
Sperm whale	380	2955
Sei whale	123	2843

Summary of whaling records from the BC Historic Whaling database

Tables 1 through 3 present a summary of the whaling records from the British Columbia coastal whaling stations. Table 1 shows the total kills *(n=24,862)* for the entire period of coastal whaling in British Columbia (1908-1967). Tables 2 & 3 provide a simple spatial analysis of the georeferenced records only *(n=11,413)* intended to assist in evaluating the proportions of the populations that may have frequented Hecate

Strait.

Table 3. Proportion of the total catch, by species, that was at or above 51.5 degrees north, and at a depth of 200 m or less – i.e. the proportion that was within Hecate Strait.

Species	Out-side	Hecate Strait	Proportion of catch Hecate Strait (%)
Baird's Beaked Whale	27	2	7
Blue whale	199	83	29
Fin whale	3448	484	12
Gray whale	11	0	0
Humpback whale	756	97	11
Minke whale	1	0	0
Right whale	1	3	75
Sperm whale	3058	277	8
Sei whale	2867	99	3

Table 4. Population estimates of whales in the Hecate Strait during Pre-Contact, 1900-1905 and 1995-2000.

Species	Pre Contact	1900s	1990s
Baird's Beaked Whale	0	0	0
Blue whale	330-420	300-400	10-50
Fin whale	<1200	<1200	425
Gray whale	4000	0	4000
Humpback whale	150-200	150-200	100
Minke whale	0	0	0
Right whale	250-1000	0	0
Sperm whale	100-200	100-200	100-200
Sei whale	<<675	<<675	0

References

Breiwick, Jeffrey M, and Howard W. Braham (eds.) (1984) The status of endangered whales. Marine Fisheries Review 46(4). National Marine Mammal Laboratory, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, Seattle, WA.

Clapham, Phillip J., Sharon B. Young, and Robert L. Brownell Jr. (1999) Baleen whales: conservation issues and the status of the most endangered populations. Mammal Rev. 29(1): 35-60.

Gregr, E. J., L. Nichol, J. K. B. Ford, G. M. Ellis, and A.W. Trites (2000) Migration and population structure of Northeastern Pacific whales off coastal British Columbia: an analysis of commercial whaling records from 1908-1967. Marine Mammal Science 16: 699-727.

Gregr, E. J. (2000) An analysis of historic (1908-1967) whaling records from British Columbia, Canada. M.Sc. Dissertation. University of British Columbia. 101 pp.

NOAA (1991) http://www.nmfs.noaa.gov/ prot_res / species/Cetaceans/rightwhales.html

Pike, G.C. and I.B. MacAskie (1969) Marine Mammals of British Columbia. Bulletin 171, Fisheries Research Board of Canada, Ottawa.

Reeves, R.R., P.J. Clapham and R.L.J. Brownell (1998) Recovery plan for the blue whale (Balaenoptera musculus). National Marine Fisheries Service.

Reeves, R.R. and H. Whitehead (1997) Status of the sperm whale, *Physeter macrocephalus*, in Canada. Canadian Field-Naturalist 111:293-307.

SAR (1997a) Species at Risk Status report. for fin whales. (http://swfsc.ucsd.edu/sars/sar1996/ Finw.htm)

SAR (1997b) Species at Risk Status report. for sei whales. (http://swfsc.ucsd.edu/sars/sar1996/ Seiw.htm)

Tilman, M.F. (1977) Estimates of population size for the North Pacific sei whale. Rept. Int. Whal. Commn., Special Issue 1: 98-106.

Tonnessen, J.N. and Johnsen, A.O. (1982) The history of modern whaling. University of California Press, Berkeley. 798 pp.

Webb, R.L. (1988) On the Northwest: Commercial Whaling in the Pacific Northwest, 1790-1967. University of British Columbia Press, Vancouver, 425 pp.

PREVIOUS ECOSYSTEM MODELS OF NORTHERN BRITISH COLUMBIA

Marcelo Vasconcellos and Alasdair Beattie
UBC Fisheries Centre

Previous mass-balance models of the study area in the west coast were constructed by Beattie (1999) and by Beattie (2001). Beattie (1999) constructed models of the Hecate Strait ecosystem, defined as DFO statistical areas 5C and 5D and Dixon Entrance, representing the early 1900s and early 1990s. These models, particularly the early 1900s, were based in part on knowledge from local resource users obtained during a workshop held in Prince Rupert, BC, in May (1998) A total of 27 functional groups were represented in both models.

A more detailed model of the Hecate Strait and Queen Charlotte sound for the present time (1990s) was later built by Beattie (2001), and included a total of 50 functional groups. Table 3.1 lists the functional groups represented in each model previously built for the study area. The more recent version of Beattie (in press) increased detail on salmonids, rockfish, plankton, benthos, primary producers, besides splitting many groups into juvenile and adult pools to account for ontogenic changes in diet.

The latter model was adapted and used here as reference point to construct ecosystem models of the Hecate Strait and Queen Charlotte sound at present and historical time periods. Specifically, the past models were build by combining 1) the present day model structure and parameters such as consumption and production rates; 2) scientific and archival information about the past biomass/abundance of functional groups; and 3) scientific and archival information about the presence of functional groups absent in the present day model. Preliminary models of past and present day ecosystems were then subjected to validation by local scientists during science workshops. The iterations with local experts are reported here as recommendations for model improvement and, in some cases, were used directly to modify/adjust model structure and parameters for functional groups in both past and present models. For instance, table x shows the structure of the models in this report and highlights groups that were added after first iteration with scientists. In this iteration, groups were added not necessarily because of a distinct ecological function, but because of a common sense of their socio-economic importance for coastal communities, which would adjust the model to local management issues.

References

Beattie, A.I. (1999) The Hecate Strait: a preliminary present-day model. Pages 13-27 in Haggan, N. and A. Beattie (eds) Back to the Future: reconstructing the Hecate Strait ecosystem. Fisheries Centre Research Reports 7(3): 65 pp.

Beattie, A.I. (2001) A new model for evaluating the

Table 1. Functional groups in present and previous mass-balance models of the Hecate Strait and Queen Charlotte Sound ecosystems.

Haggan & Beattie (1999)	Beattie et al. (2001)	This report
1. Transient orcas	1. Adult sablefish	1. <u>Sea otters</u>
2. Odontocetae	2. Seals, sea lions	2. Seals, sea lions
3. Pinnipeds	3. Odontocetae	3. Adult sablefish
4. Lingcod	4. Coho salmon	4. Odontocetae
5. Pacific halibut	5. Adult Pacific cod	5. Coho salmon
6. Sablefish, juvenile	6. Adult lingcod	6. Adult Pacific cod
7. Sablefish, adult	7. Chinook salmon	7. Adult lingcod
8. Turbot	8. Squid	8. Chinook salmon
9. Seabirds	9. Adult turbot	9. Squid
10. Flatfish	10. Juvenile turbot	10. Adult turbot
11. Ratfish, skates	11. Adult halibut	11. Transient salmon
12. Pacific cod	12. Inshore rockfish	12. Juvenile turbot
13. Walleye pollock	13. Seabirds	13. Adult halibut
14. Spiny dogfish	14. dogfish	14. Inshore rockfish
15. Rockfish, small	15. Adult planktivorous rockfish	15. Seabirds
16. Benthic fish	16. Juvenile lingcod	16. Dogfish
17. Mysticetae	17. Small squid	17. Adult planktivorous rockfish
18. P.O. Perch	18. Pollock	18. Juvenile lingcod
19. herring small	19. Mysticetae	19. Small squid
20. Pelagic fish	20. Juvenile sablefish	20. Pollock
21. Salmon juvenile	21. Skates	21. Mysticetae
22. Carnivorous jellies	22. Ratfish	22. Juvenile sablefish
23. Crustaceans	23. Adult POP	23. Skates
24. Macrobenthos	24. Adult piscivorous rockfish	24. Ratfish
25. Zooplankton	25. Adult herring	25. Adult POP
26. Phytoplankton	26. Juvenile halibut	26. Adult piscivorous rockfish
27. Detritus	27. Juvenile pollock	27. Adult herring
	28. Shallow water benthic fish	28. Juvenile halibut
	29. Forage fish	29. Juvenile pollock
	30. Juvenile piscivorous rockfish	30. Shallow water benthic fish
	31. Juvenile planktivorous rockfish	31. Eulachon
	32. Adult flatfish	32. Forage fish
	33. Juvenile herring	33. Juvenile piscivorous rockfish
	34. Juvenile POP	34. Juvenile planktivorous rockfish
	35. Juvenile flatfish	35. Adult flatfish
	36. Juvenile Pacific cod	36. Juvenile herring
	37. Carnivorous jellyfish	37. Juvenile POP
	38. Large crabs	38. Juvenile flatfish
	39. Euphausiids	39. Juvenile Pacific cod
	40. Epifaunal invertebrates	40. Carnivorous jellyfish
	41. Commercial shrimp	41. Large crabs
	42. Small crabs	42. Euphausiids
	43. Infaunal carnivorous invertebrates	43. Epifaunal invertebrates
	44. Infaunal invertebrate detritivores	44. Commercial shrimp
	45. Copepods	45. Small crabs
	46. Corals and sponges	46. Infaunal carnivorous invertebrates
	47. Macrophytes	47. Infaunal invertebrate detritivores
	48. Phytoplankton	48. Copepods
	49. Discards	49. Corals and sponges
	50. Detritus	50. Macrophytes
		51. Phytoplankton
		52. Discards
		53. Detritus

optimal size, placement and configuration of marine protected areas. M.Sc. Thesis, University of British Columbia.

Reconstructing Past Ecosystem Models of Northern British Columbia: Workshop Notes and Sources on the Ecosystem Groups

Marcelo Vasconcellos and Tony J. Pitcher
Fisheries Centre, UBC

A west coast BTF science workshop was held at St. John's College, UBC, during 11th and 12th of September, (2000) The objective was to receive input from local scientists on the current status of the main fisheries resources and functional groups of the Hecate Strait-Queen Charlotte ecosystem, and to obtain their knowledge about the likely status of resources in two historical time periods: the early 1900s and at pre-European contact (mid-1700s). A list of participants and affiliations are given at the end of this report.

In the morning of the first day of the workshop there were introductory presentations by Tony Pitcher, Nigel Haggan and Marcelo Vasconcellos, which were followed by discussions on the objectives, approach and modeling of the Back to the Future project. Discussions centreed on the choice of ecosystem boundaries, and the ability of the BTF approach and model to account for climate and regime shifts, species losses, species outbreaks and the recolonization of the area by species that were depleted or gone in the past. Regarding past ecosystem status, it was suggested that a large proportion of the northwest coast ecosystems probably had been untouched 30-50 years ago. In response to that there were comments on the importance of halibut fisheries in the past, the intense activity of foreign trawlers in the mid-1900s, and population control programs for orcas and other marine mammals carried out since the turn of the century. The important role of local ecological knowledge to the goals of the project was generally consensual.

During the afternoon of the first day, discussions on each functional group centred around four issues:

1. What are the sources of information for each functional group?
2. How reasonable are the values for parameters B, P/B, Q/B and Diets?
3. What was the likely biomass/abundance in the past relative to now?
4. Should the group be split (based on ecological, policy constraints)?

Some of the sections that follow were prepared by participants after the workshop discussions. In some cases, experts that could not attend the workshop agreed to prepare a contribution addressing the issues raised during the workshop. Finally, some sections report results from literature review and the discussions during the meeting, authored by the postdoc, editors and the session rapporteur. In addition, reports of discussions on each particular functional group are added to each individual section. In these notes, participants are identified by their initials.

Workshop Notes on Sea Otters

Marcelo Vasconcellos and Tony J. Pitcher
Fisheries Centre, UBC

The distribution of the sea otter, *Enhydra* sp. in the Pacific Ocean ranges from Lower California to Northern Hokkaido (Japan) in the Northwest Pacific (Von Blarion and Estes 1998). Commercial exploitation of sea otters begun with the discovery of Alaska and the Aleutian Islands by the Vitus Bering expedition of 1741. Sea otters were exploited for their pelts for over 170 years. In 1911, with the near extinction of the species, exploitation was halted and sea otters received protected status. The sea otter became apparently extinct on the BC coast during the 1920s. Kenyon (1975) reports the scarcity of sea otters found by an expedition of the National Museum of Canada in the Queen Charlotte Islands and northern BC coast in 1919. (See also Jones and Ryan, This Vol.)

Given the above, it seems reasonable to assume that sea otters were practically absent (or in very low numbers) in the Hecate Strait in the early 1900s and that they are absent at the present time. By the 1970s, the population size of ca. 30,000 animals occupied approximately 1/5 of the original coastal range of sea otters in the north Pacific. Kenyon (1975) used this information to estimate the total virgin population size between 100,000 and 150,000 animals. Assuming that the Hecate Strait covers approximately 1/20th of sea otter coastal range, and using the same reasoning as Kenyon (1975), it is possible to estimate a pre-contact sea otter population of approximately 5,000. With an average weight of 22.4 kg (Bodkin *et al.* 1998) the density of sea otters in the pre-contact period is estimated at 0.0016 tons/km^{-2}.

Sea otter kills in the early 1900s can also be considered insignificant. Before the intensive exploitation beginning in 1740, it is assumed that sustainable harvesting rates were adopted, in the order of the rate of population growth of 2.5% per year (Kenyon 1975). Bodkin *et al.* (1998) estimated an instantaneous mortality rate of 0.13 year^{-1}, based on average age of 7 years in the Prince William Sound area.

Sea otters forage in the benthos of rocky and soft-sediment communities, as well as within the algal understory and canopy (Riedman and Estes 1988). Feeding areas are mostly close to shore, mostly inside the 40 m isobath. Diet off California consists almost exclusively of macroinvertebrates, mainly abalone, rock crabs and sea urchins, but also includes kelp crabs, clams, turban snails, mussels, octopus, barnacles, scallops, sea stars, chitons and echiuroid worms. Predation on seabirds is also known to occur occasionally. In northern areas of the range, fish sometimes form an important part of the diet (especially rock greenling, *Hexagrammos lagocephalus* and other nearshore fishes). Note that sea otter may act as a keystone species, through their diet of urchins that graze kelp: ecosystems with sea otters may therefore have a very different kelp community than those without (Pitcher 1998) .

In the model the diet was split as follows: 50% epifauna invertebrates, small crabs 20%, large crabs 1%, shallow water benthic fish 10%, juvenile pollock 10%, squid 9%. Free-ranging adults may consume food equivalent to 23% to 33% of their body weight daily, which is equivalent to Q/B ratios between 83 and 120 year^{-1}.

References

Bodkin, J.L Monson, D. H. and G. E. Esslinger (1998) Mammals: Sea otters. In T. Okey and D. Pauly (Eds). Trophic Mass-Balance Model of Alaska's Prince William Sound Ecosystem, for the Post-Spill Period 1994-1996. Fisheries Centre Research Reports 6(4). 144 pp.

Kenyon, K. W. 1975. The sea otter in the eastern Pacific Ocean. Dover Publications. 352 pp.

Pitcher, T.J. (1998) Pleistocene Pastures: Steller's Sea Cow and Sea Otters in the Strait of Georgia. Pages 49-52 in Pauly, D., T. Pitcher and D. Preikshot (Eds) Back to the Future: Reconstructing the Strait of Georgia Ecosystem. Fisheries Centre Research Reports 6(5): 99pp.

Riedman, M. L. and J. A. Estes. 1988. A review of the history, distribution and foraging ecology of sea otters, p. 4-21 In: Van Blarian, G. R. and J. A. Estes (Eds). The community ecology of sea otters. Spinger-Verlag. 247 p.

Van Blarian, G. R. and J. A. Estes (Eds). 1988. The community ecology of sea otters. Spinger-Verlag. 247 p.

Workshop Notes on Baleen Whales

Marcelo Vasconcellos and Tony J. Pitcher
Fisheries Centre, UBC

Nichol and Heise (1992) present a review of whaling activity in the Queen Charlotte Islands. Historically, the principal species of baleen whales feeding along the BC coast were fin, sei, humpback, blue, right and gray whales. However, numbers of all 6 species of baleen whales were severely reduced by commercial whaling through the late 1800s and early 1900s. Gray and right whales were commercially extinct by 1900, and were soon followed by humpback and blue whales. Whaling activity was intensive between 1905 and the beginning of the First World War. A second era of whaling occurred following the Second World War and ended in 1967.

Nichol and Heise (1992) and Gregr (2000) used catch records from whaling operations in British Columbia to describe the occurrence, abundance and biology of whales that were hunted. Right whales were the slowest swimmers, and as a consequence, were harvested to commercial extinction in the North Pacific by the mid-1800s. Practically all species of baleen whales harvested migrate north to the Gulf of Alaska and Aleutian Islands to feed during the summer and to tropical areas in the winter to breed. The areas most frequently visited in the region were off the west coasts of Vancouver Island and the Queen Charlotte Islands, which are highly productive upwelling areas.

Blue whales were encountered in the open water of the Pacific, but rarely in Hecate Strait. Fin whales were considerably more abundant off BC than blue whales and were frequently caught in Hecate Strait. Sei whales were not abundant around the Queen Charlotte Islands, and were only rarely found in Hecate Strait. Humpbacks often congregate in coastal waters. They were caught between Cape St. James and the North end of Vancouver Island, and also ventured into Hecate Strait in channels and inlets along the coast. They were also found throughout Dixon Entrance. Right whales were extremely rare along the coast of BC, and remain so today. Only 8 animals were caught between 1910 and 1934, all of them off the west coast of the Queen Charlottes.

Gray whales were not commercially harvested during the period of intensive commercial harvesting off BC. They were commercially extinct by 1900, but have since recovered to historic levels. They are commonly reported feeding in shallow waters (<30m) along the eastern shores of Graham and Moresby Islands, and in Skidegate Inlet. They are also frequently sighted off Cape St. James.

Gray whales are more abundant today then during the early 1900s. By 1875 there were only ca. 4,400 whales in the North Pacific, and by 1900s they were commercially extinct. Right whales have never recovered from exploitation. They were commercially extinct in the mid-1800, so the present population size should be close to the population size in the early 1900s, which was estimated at 0 in the Hecate Strait.

Humpback is the second most rare of the large whales in the North Pacific, while blue whales show no worldwide signs of recovery from exploitation.

Present Fin and Sei whale populations of 17,000 and 14,000 are only 21 and 22 % of historical population size in North Pacific (Nichol and Heise 1992). Biomass in Pre-contact, the early 1900s and of the current populations are estimated from Gregr (Table 4 see Section 2.2 in this document) and using the average weight of each species, Trites and Pauly (1998) (Table 1).

Table 1. Biomass of baleen whales in the Hecate Strait in Pre-contact, 1900-1905 and 1995-2000.

Species	Avg. weight (t)	Pre-contact	1900s	1990s
Blue whale	102.7	33904	30822	3082
Fin whale	55.6	66708	66708	26127
Gray whale	15.7	61480	0	61480
Humpback	30.4	5322	5322	3041
Minke whale	6.6	0	0	0
Right whale	23.4	14613	0	0
Sei whale	16.8	5043	5043	0
Total Biomass		2.672	1.541	1.339

Harvest of baleen whales in the three models can be considered insignificant. Pre-contact catches may be considered minor since whales were not an important food supply (see section 2). The early 1900s marks the period when commercial whaling subsided in BC waters due in part to the depletion of gray and right whales and the lack of technology to chase the fast moving whales. Finally, commercial whaling in BC waters ended in the late 1960s, and commercial catches have not been allowed since then.

Stomach contents of commercially caught whales contained mostly euphausiids and copepods. For instance, diet of fin whales off BC were made up mainly of euphausiids (ca. 90%), followed by copepods (9%), squid (0.3%), hagfish (0.3%) and octopus (0.3%) (Flinn *et al.* in press). Herring and saury can also occur (but are not as important) in the diet of Humpback and Sei whale (Nichols and Heise 1992).

References

Beattie, A. (1999) The Hecate Strait: a preliminary present-day model, p. 13-27 In: Haggan, N. and A. Beattie (eds). Back to the Future: reconstructing the Hecate Strait ecosystem. Fisheries Centre Research Reports 7(3) : 65 pp.

Flinn, R. D., Trites, A. W., Gregr, E. J. and R. I. Perry (*submitted*) Diets of fin, sei and sperm whales in British Columbia: an analysis of commercial whaling records 1963-1967. (*Submitted to: Marine Mammal Science, Sept. 2000.*)

Gregr, E. J. (2000) An analysis of historic (1908-1967) whaling records from British Columbia, Canada. M.Sc. Thesis, University of British Columbia. 101 pp.

Nichol, L. and K. Heise (1992) The historical occurrence of large whales off the Queen Charlotte Islands. Report prepared for South Moresby/Gwaii Haanas National Park Reserve. 67 pp.

Trites A. and D. Pauly (1998) Estimating mean body masses of marine mammals from maximum body lengths. Can. J. Zool. 76: 886-986.

Workshop Notes on Odontocetae (Toothed whales)

Marcelo Vasconcellos and Tony J. Pitcher
Fisheries Centre, UBC

The Odontocetae includes sperm whales, Baird's beaked whale, killer whales, dolphins and porpoises.

Sperm whales made up a significant part of whaling catches in the Queen Charlotte Islands. Most of the catches were made of males (larger), since females do not migrate as far north as males do. Sperm whales are deep-water species, and are rarely observed in coastal waters. Stomach contents of sperms from Coal Harbour show that the species feed mostly on deepwater fish and squids (Flinn et al, in review). Baird's beaked whales were caught off the Queen Charlotte Islands (only 10 were reported during the years of operation of whaling stations (Nichol and Heise 1992)), but are usually found in waters deeper than 1000m. The present population size of sperm whales in the North Pacific (1,000,000) is ca. 80% of the historical size (1,250,000) (Nichol and Heise 1992), and the abundance in Hecate Strait was estimated at 300-400 by Gregr (this volume).

Both resident and transient populations of killer whales occur year-round in BC waters. Residents, which are fish-eaters, are more abundant during peak salmon season, while the peak occurrence of transient killer whales coincides with the period when harbour seal pups are being weaned.

Killer whales were the target of population control programs in the early 1900s due to their perceived threat to fisheries (Baird 1999). Culling of killer whales involved the Canadian Air Force, which used animals as practice targets, as well as shooting by fishers and the federal fisheries department (Baird 1999). Baird (1999) suggested that resident populations of killer whales are probably today still recovering from the effect of culling earlier in the 1900s.

Killer whales were also under two other direct sources of mortality. Animals have been hunted for oil and meat, which was used for human and animal consumption, fertilizer and bait. Killer whales off the B.C. coast were also targeted by live-capture fisheries for public display in oceanaria (the last animal taken was in 1977), although most of the animals removed were from the southern resident population (Baird 1999). Given the above sources of mortality it seems reasonable to assume that the biomass of killer whales at the present time is smaller than during the early 1900s and pre-contact.

As in Beattie *et al.* (1999), it is considered that the biomass of killer whales, dolphins and porpoises in the Hecate Strait was ca. 20% larger during the early 1900s than at present time (estimation based on fishers and Aboriginal people). Pre-contact biomass was assumed the same as the early 1900s biomass.

The estimates of sperm whale abundances given in Gregr (this volume) were added to the estimates of toothed whales in Trites & Heise (1996) to give an average biomass of toothed Odontocetea in Hecate Strait.

References

Baird, R.W. (1999) Status of Killer Whales in Canada. Contract report to the Committee on the Status of Endangered Wildlife in Canada, Ottawa, 43 pp.

Beattie, A., Wallace, S. and N. Haggan (1999) Report of the BTF workshop on reconstruction of the Hecate Strait Ecosystem. Pages 1-12 in Haggan, N. and A. Beattie (Eds), Back to the Future: reconstructing the Hecate Strait ecosystem. Fisheries Centre Research Reports 7(3). 65 pp.

Flinn, R. D., Trites, A. W., Gregr, E. J. and R. I. Perry (*submitted*) Diets of fin, sei and sperm whales in British Columbia: an analysis of commercial whaling records 1963-1967. (*Submitted to: Marine Mammal Science, Sept. 2000.*)

Nichol, L. and K. Heise (1992) The historical occurrence of large whales off the Queen Charlotte Islands. Report prepared for South Moresby/Gwaii Haanas National Park Reserve. 67 pp.

Trites, A. and K. Heise (1996) Whales and dolphins. In Pauly, D., V. Christensen, and N. Haggan (Eds) (1996) Mass-Balance Models of North-Eastern Pacific Ecosystems. Fisheries Centre Research Reports 4(2). 131 pp.

WORKSHOP NOTES ON SEALS AND SEA LIONS

Marcelo Vasconcellos and Tony J. Pitcher
Fisheries Centre, UBC

The two principal species residing in the Hecate Strait region were Steller's sea lions and Pacific harbour seals. Male California sea lions rarely migrate this far north. Some northern fur seals would have passed through this region, but hunting records indicate that the majority of the herd traveled along the west coast of the Queen Charlotte Islands. Haida usage of seals and other maine mammals is documented in Jones (2000).

Steller's sea lions were culled under population control programs conducted by Canadian fisheries agencies from 1913 to 1968 (Bigg 1985). The programs involved organized kills and commercial takes for meat, blubber and hides. In 1970, Steller sea lions were protected in British Columbia under the Canadian federal Fisheries Act. Bigg (1985) reports nine major censuses of the eight main Steller sea lion rookeries in BC (all of them in the study area) between 1913 and 1982. He also reports total numbers killed (mainly on rookeries). Figure 1 shows the estimated population size and kills of Steller sea lions in the study area.

Bigg (1985) estimated that the 1971-1982 population was only about 27-34% of the 1913 population (i.e., 3,800 – 5000 in 1971-1982, and

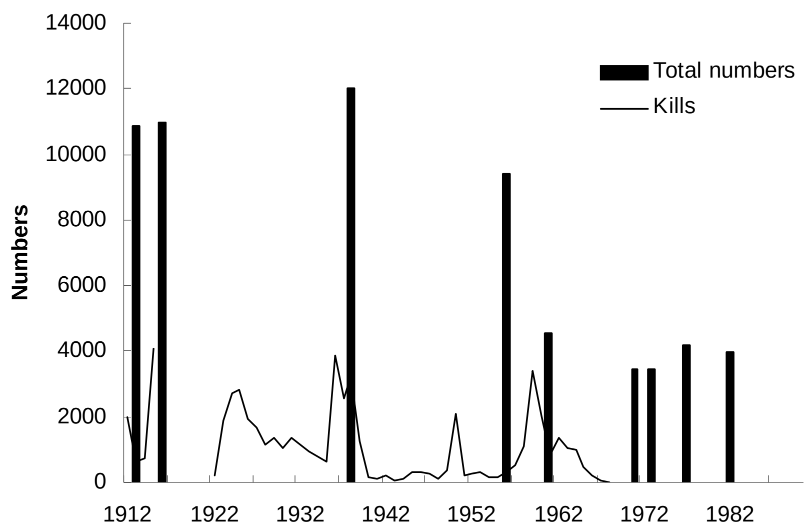


Figure 1. Population numbers and kills of Steller sea lion in the study area (source Bigg 1985).

approximately 14,000 animals in 1913). Data from the Scott Island rookery complex suggest that Steller sea lions may have increased by about 25% between 1982 and 1989, and may have continued to increase after 1989. Applying a rate of increase of 3.5% per year (i.e. 25% in 7 years) from 1989 to 2000 (white bars in the graph) suggests that the 2000 population is about 50% of the early 1900s population size.

Harbour seals are common in coastal areas, inlets and estuaries throughout BC. As with Steller sea lions, harbour seals were also culled during the early 1900s. Substantial numbers were also harvested for pelts. From 1913 to 1969, a total of 200,000 to 240,000 seals were killed in BC. Since the early 1970s, the species has been protected in BC and US waters (Olesiuk *et al.* 1990). Olesiuk *et al.* 1990 estimated that Harbour seal populations in BC have been increasing at about 12.5% per year since they were protected in 1973. Total post-pupping population in BC was estimated at 75,000 - 80,000 in 1988 compared with 9,000 – 10500 in 1970. Using total kills and life tables, Bigg (1969) estimated an average population size of 35,000 during 1913-1964. Olesiuk *et al.* (1990) estimate that harbour seal populations in BC have increased by almost 10 fold during 1970-1988 and may have reached historic levels at that time. It is very likely therefore that the biomass of harbour seals at present is close to the 1900s value.

Census data suggests that populations of harbour seals and Steller sea lion were probably equally abundant in the study area. For instance, the sum of harbour seals in the Skeena River (1,590) and the Queen Charlotte Islands (3,030) in 1988 was 4,620 animals. At that time, the Steller sea lion population in Queen Charlotte and Hecate Strait area was estimated at ca. 4,900 individuals. Based on the above, and considering the trends in abundance of both populations, the biomass of seals and sea lions the present time is probably ca. 75% of the historical biomass at early 1900s.

The number of seals and sea lions in B.C. probably increased during the late 1800s and early 1900s due to a reduction in the native population that hunted them. Biomass in the pre-contact model was therefore assumed to be the same as in the present day (2001) model, i.e. 75% of the early 1900s model. Harvest of seals and sea lions in the three periods was assumed insignificant.

Diet compositions in the present and past models were adjusted to account for consumption of salmon. Based on the diet of harbour seals and Steller sea lion reported for a southern BC model by Trites and Heise (1996), it is assumed that seal and sea lion diets consisted of an average of 10% coho, chinook, and migratory, transient salmon This proportion was decreased from the proportion of squids and forage fish in the diet of seals and sea lions in Beattie (2001) model. Seven percent of the salmon in the diet was assumed to be made up of resident stocks (4% for coho and 3 % for chinook) and 3% of transient, migratory salmon.

References

Beattie, A.I. (2001) A new model for evaluating the optimal size, placement and configuration of marine protected areas. M. Sc. Thesis, University of British Columbia.

Bigg, M. A. (1969) The harbour seal in British Columbia. Bull. Fish. Res. Board Can. 172: 33 pp.

Bigg, M. A. (1985) Status of the Steller Sea Lion (*Eumetopias jubatus*) and California Sea Lion (*Zalophus californianus*) in British Columbia. Canadian Special Publication of Fisheries and Aquatic Sciences 77: 20pp.

Jones, R.R. (1998) Haida names and utilization of common fish and marine mammals. In Haggan, N and A. Beattie (Eds) Back to the Future: A Re-construction of the Hecate Strait Ecosystem as it Might Have Been in the early 1900s. Fisheries Centre Research Reports 7(3). 65pp.

Olesiuk, P. F., Bigg, M. A. and G. M. Ellis (1990) Recent trends in the abundance of harbour seals, *Phoca* *vitulina*, in British Columbia. Can. J. Fish. Aquat. Sci. 47: 992-1003.

Trites, A. and K. Heise (1996) Marine mammals. In Pauly, D., V. Christensen and N. Haggan (Eds). Mass-balance models of north-eastern Pacific ecosystems. Fisheries Centre Research Reports 4(2). 131 pp.

SEABIRDS IN NORTHERN BRITISH COLUMBIA

Gary W. Kaiser
Victoria, BC

Hecate Strait is the most important body of water for seabirds on the Canadian Pacific Coast. British Columbia's coastal waters support three very large groups of marine birds: colonial seabirds that breed locally, water birds that breed in the interior but winter on the coast, and migrants from the southern hemisphere that come north during the austral winter. Most areas are important to only one or two of these groups. The Strait of Georgia and Chatham Sound off Prince Rupert, support large numbers of winter birds and the west coast of Vancouver (Campbell *et al.* 1990).

Island is important to the austral migrants but Hecate Strait is important to all three groups and has large numbers of birds at all seasons. Most of Canada's populations of Pacific seabirds breed around its periphery; large numbers of seaducks and other waterbirds exploit shellfish and other prey along its coasts; and many of the 20 million or more austral migrants pass through it (Table 1). The presence of three discrete groups makes their history and conservation too complex to more than skim over here.

Before the incursion of the Europeans, the birds of Hecate Strait were exploited as seasonal food and their bones are frequently found in coastal middens. However, birds are small and are more difficult to catch in large numbers than fish, so it is likely that they were only a major component of the diet when less energetically expensive prey were unavailable. On the other hand, many villages and temporary camps are currently the site of new seabird colonies, suggesting that there may have been some competition for space between human and avian populations and that seabird numbers may have increased.

Until 1900, the effect of contact between native people and Europeans may have been of benefit to seabirds, at least in Hecate Strait. Closer to Esquimalt, Victoria, and Vancouver, the introduction of firearms and a cash economy led to a market for seabird eggs and wild fowl. Local gull colonies were commercially exploited and market hunting occurred at Esquimalt Lagoon and in the Fraser Estuary. Further north, the markets were much smaller and commercial exploitation was less organized. Seabird populations probably expanded as epidemic and cultural disaster overtook the native population and many parts of the coast became depopulated. In addition, European foods became commonplace and many traditional items became special treats collected only for ceremonial occasions.

In contrast to the locally breeding birds, populations of austral migrants were hit very hard by human activity, but not in Canada. The settlement of Australia and New Zealand led to industrialized exploitation of nesting birds for oil, meat, and feathers. Visiting whalers and sealers destroyed bird populations on many remote islands, leaving behind rats and cats that continue to prevent re-establishment of colonies. The harvest of Short-tailed Shearwaters continues in Australia and New Zealand but population numbers have rebounded with careful management and protection.

In the twentieth century, human activity in British Columbia often had a negative impact on the marine birds of British Columbia. Rats arrived in 1792 (Moziño 1970) and spread to towns, villages and canneries along the coast. It seems likely that many were spread by the creation of remote military posts during World War II. Fur-bearing predators such as mink were intentionally placed on seabird colonies (Scott Islands, Goose Group) where they could exploit the "free" food. Douglas squirrels that readily eat eggs were scattered around the Queen Charlotte Islands to facilitate spruce cone collection and in 1948, government agents released raccoons there.

Industrial development created unforeseen stress on seabird populations throughout coastal British Columbia. In the 1950s, the herring fishery killed thousands of birds in nets set beside breeding colonies. Lighthouses and brightly-lit ships attracted and killed thousands of birds on foggy nights. From 1920, the conversion of ships to oil-fired boilers made oil spills on the coast a regular (weekly) event. The effect of the current wave of fish farms and sport fishing lodges has not been assessed. It stresses many birds out of favoured winter foraging areas and competes with them for space. Because these developments occur in remote areas, government has been particularly inept in their management. Environmental impact assessments have been cursory and incompetent. One sport fishing lodge was even issued a permit for construction atop a seabird breeding colony. Industrial fishing has had a particularly serious impact on the austral migrants and placed some species on the endangered list. These birds are caught on long lines all along their migration route and in Chile and the Russian Far East huge numbers are drowned in nets.

Industrialization had a positive impact on birds. Baleen whales have been nearly exterminated, reducing competition for the euphausiids and sand lance on which many seabirds prey. Government policies suppressed First Nation traditions and prevented egg collecting and other traditional harvests. Commercial and sport-hunting of seabirds became illegal in 1917, while hunting regulations limited the harvest of seaducks. In 1980, only one or two of the 100 or more seabird colonies around Hecate Strait were protected as Ecological Reserves. Today, only a half dozen along the whole coast do not have special status. Only those sites in National Parks are truly secure, however; the provincial government's habitat policies are subject to change with successive governments.

Some water birds that spend their non-breeding periods in Hecate Strait have declined significantly during the 20th century. Loons and grebes have been harassed off large lakes by power boats. Tree-nesting ducks, such as goldeneye, have lost much of their interior habitat and trout that compete for their food have been widely introduced. The Pacific Brant or sea goose has abandoned many of its wintering areas, possibly because of hunting, and has declined to about 200,000 birds from a historic population several times that number. However, many interior-breeding waterfowl nest in northern areas where human populations are very sparse and are still very abundant on the coast. The decision by Alberta to log huge tracts of such habitat may have an effect in the next few years.

While local extermination of seabirds by rats and raccoons has had some effect on seabird populations and oil spills have killed 10s of thousands at a time in British Columbia, it seems likely that positive and negative effects of human activity have cancelled each other out. The total biomass of seabirds and other marine birds in Hecate Strait, at least, is likely little different from 1900 and possibly little different from the numbers in the 1700s.

Workshop notes

Resident seabird populations feed on the upwelling zones. Many other species migrate through the area, or feed during a certain period of the year. Impacts to seabird populations are from introduced species (raccoons, rats) in nesting areas, direct harvest, bycatch and oil spills (recently). GK suggested that there were probably not many changes from 1700s to 1900s and present time. Biomass was therefore assumed the same among the three periods.

References

Campbell, R.W., N.K. Dawe, I. McTaggart-Cowan, J.M. Cooper, G.W. Kaiser, and M.C.E. McNall. (1990)

Table 1. Summer seabird populations (1000s) occurring in and around Hecate Strait, British Columbia.

Location	Ancient Murrelet	Cassin's Auklet	Rhinoceros Auklet	Tufted Puffin	Other	Total
Breeding Birds						
South and southeast QCI	125	191	17	1	5	339
Scott Islands	0	1034	50	72	40	1196
Queen Charlotte Sound	0	7	72	0	1	80
Mainland Coast	0	23	117	0	45*	185
Non-breeding Birds						
South and southeast QCI	50	76	7	0	50**	183
Scott Islands	0	414	10	29		453
Queen Charlotte Sound	0	3	29	0		32
Mainland Coast	0	9	47	0	300**	356
Total	175	1757	349	102	441	2824
Average Weight (kg)	0.21	0.19	0.52	0.78	0.4	
Total Biomass (tonnes)	37	334	181	80	176	808
Biomass in Hecate St (tonnes)	37	42	181	80	176	516

*Marbled Murrelet, Pigeon Guillemot, Common Murre, Pelagic Cormorant, Glaucous-winged Gull, (Fork-tailed and Leach's Storm-Petrels have been omitted).
** Mostly Sooty and Short-tailed Shearwaters given as an estimate of the average daily population from May - Sept.

The Birds of British Columbia Volumes 1 and 2. Royal B.C. Museum, Victoria.
Moziño, J. M. 1970. Noticias de Nutka: an account of Nootka Sound in 1792. (I.H. Wilson Engstrand ed.) University of Washington Press, Seattle.

WORKSHOP NOTES ON DOGFISH

Marcelo Vasconcellos and Tony J. Pitcher
Fisheries Centre, UBC

The centre of abundance of Spiny dogfish in northeastern Pacific lies in BC-Washington region (48° to 54° N). Northern Hecate Strait appears to be the approximate northern limit of large commercial concentrations of dogfish (Ketchen 1986). Ketchen (1986) noted that the first reference to dogfish as a commercial item did not appear in the Dominion Government's Ministry of Marine and Fisheries until 1872. By 1876 the fishery was rapidly developing. Landings in the order of 2,000 and 3,000 tons were recorded since 1882. Operations in the Queen Charlotte Islands apparently ceased after 1916 and would not resume until nearly 25 years later. During World War II, catches of dogfish in the Hecate Strait area rose to over 10,300 tons (1945), declining afterwards due in part to stock depletion.

Ketchen (1986) reports data from gillnet fisheries in Hecate Strait, which indicate a decline of ca. 60% of stock abundance between 1943 and 1947. The fishery for spiny dogfish collapsed in 1950, but recovered rapidly after a couple of years. Government dogfish control programs were put in place to kill substantial amounts of animals, as they were blamed for destroying fishing gear and also predating on other more valuable species.

Ketchen (1986) estimated total landings of dogfish based on commercial production records of liver oil. The average landings of dogfish from the Queen Charlotte/Hecate Strait area in the period of 1900 to 1905 was between 756 and 1,585 tons (average of 0.017 $t.km^{-2}.year^{-1}$). Based on estimates provided by Wood *et al.* (1979, *apud* Ketchen 1986), it seems reasonable to assume that the current population size is close to the level observed in the Hecate Strait area prior to the short but intense fishery of the 1940s. This is consistent with Walters and Bonfil (1998) estimates of the ratio of B_{1996}/B_{Virgin} for dogfish in Hecate Strait between 0.72 and 0.96. That was also the assumption made by Beattie *et al.* (1999). Therefore, dogfish biomass in the model of the early 1900s was assumed to be the same as in the present time model. Given the history of the commercial fishery prior to 1900, with landings in the order of 3,000 tons per year since 1882, it is expected that the biomass in pre-contact period was higher than what was observed throughout the twentieth century. We therefore tested the hypothesis that biomass in pre-contact could be 50% higher than 1900 and 1990s models. Pre-contact First Nations' catch was assumed to be insignificant.

Workshop notes

According to Jeff Fargo stocks now are considered to be at or near the conditions probably encountered in the beginning of the 1950s. Values included in the preliminary models were considered to be probably reasonable. JF also mentioned that it is not known whether dogfish in BC represents only one population or more than one population.

References

Beattie, A., Wallace, S. and N. Haggan (1999) Report of the BTF workshop on reconstruction of the Hecate Strait Ecosystem. Pages 1-12 in Haggan, N. and A. Beattie (eds). Back to the Future: reconstructing the Hecate Strait ecosystem. Fisheries Centre Research Reports Vol. 7(3): 65 pp.
Ketchen, K. S. 1986. The spiny dogfish (*Squalus acanthias*) in the Northeast Pacific and a history of its utilization. Can. Spec. Publ. Fish. Aquat. Sci. 88: 78pp.
Walters, C. J. and R. Bonfil (1998) Multispecies spatial assessment models for the British Columbia groundfish trawl fishery. Can. J. Fish. Aquat. Sci. 56: 601-628.
Wood, C. C., Ketchen, K. S. and R. J. Beamish 1979. Population dynamics of spiny dogfish (*Squalus acanthias*) in British Columbia waters. J. Fish. Res. Board Can. 36: 647-656.

WORKSHOP NOTES ON PACIFIC SALMON

Marcelo Vasconcellos and Tony Pitcher
Fisheries Centre, UBC

In the model salmon were treated as two separate functional groups, representing transients (fish that migrate rapidly throught the area as smolts and, later in their life history, as returning adults) and resident stocks.

Historical catch data for salmon in the area (Figure 1) was obtained from Hewes 1973, Argue

Table 1. Proportion of catches by gear type in Hecate/Q. Charlotte areas (DFO areas 1-10) in 1997.

Species/Gear	Gillnet	Seine	Troll	Troll freezer
Coho	0.166	0.061	0.268	0.505
Chinook	0.194	0.023	0.266	0.512
Sockeye	0.610	0.310	0.020	0.060
Pink	0.196	0.682	0.023	0.099
Chum	0.559	0.389	0.009	0.042
Transient [a]salmon	0.455	0.460	0.017	0.067

a = average of sockeye, Pink, Chum.

et al. 1986 and DFO. Pre-contact catches of salmon for consumption by native groups in the northwest coast was estimated at 14,120,000 pounds (ca. 6,404 tons) of fresh fish per year (Hewes 1973). Catches were estimated based on dietary requirements and population numbers of the following native groups: northern Tlingit, southern Tlingit, Haida, Tsimshian, Nisga'a, Gitksan, Haisla, Oweekeno, Heiltsuk and Bella Coola. This harvest rate by First Nations was probably maintained until the mid 1800s, when First Nation populations declined rapidly (Hewes 1973). Argue *et al.* 1986 estimated the annual commercial catch of Pacific salmon species for 15 fishing areas in BC between 1876 and 1985.

Source data for catches prior to 1950 were statistics on the amounts of canned, salted, fresh/frozen, mild-cured and other salmon products produced along the BC coast. From 1951 to 1985, catches in tonnes were mostly taken from DFO. Commercial salmon catches for the present time model were split among gear types according to DFO data for 1997 (Table 1).

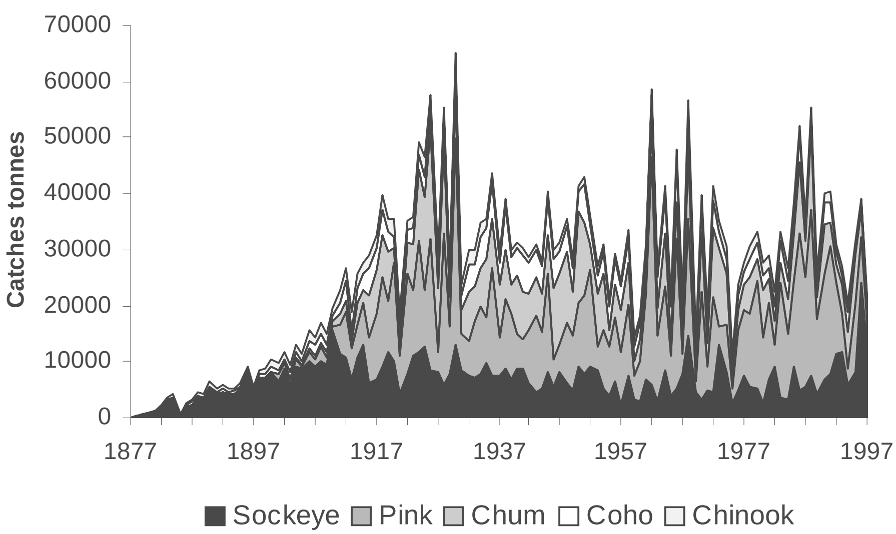


Figure 1. Reported catches of Pacific salmon in the study area.

Transient salmon

Transient salmon include sockeye, pink and chum salmon that only occur in the area for a short period of time when they are migrating to spawning rivers. The average catch for the group during 1995 to 1997 is 28,852 tonnes, or 0.412 $t.km^2$. The exploitation rate at present is considered to be about 70% (DFO, 1999, reports that exploitation rate for aggregated Skeena sockeye salmon run has averaged 65% in the 1990s, but exceeded 70% in 1992, 1996 and 1997). Biomass at the present time was therefore calculated as the ratio between catches and exploitation rate, i.e. 0.588 $tons.km^{-2}$. For the 1900-1905 model, the total average catch was 8,789.3 tonnes, or 0.126 $t.km^2$. Gresh *et al.* (2000) reports exploitation rates ranging between 0.35 and 0.75 in the beginning of the century in many Pacific northwest rivers.

Considering that the fisheries in northern BC culminated later (by 1920s) than those in the Fraser river, we assumed that values closer to the lower end of the range are probably more representative of the area during the early 1900s. Biomass in the 1900s model was therefore estimated by the ratio between catches and the exploitation rate of 15%, i.e 0.840 $t.km^{-2}$.

Input catches and biomass of transient salmon species in the pre-contact model were based on the following assumptions: first, not all estimated catches by native groups were made of transient species. For instance, spring (chinook) salmon was the most abundant species on the Nass, Skeena and Campbell rivers, and represented the main winter food for the coastal Tsimshian. On the other hand, pink salmon was the main food for storage and winter consumption for the Haidas in the Queen Charlotte Islands. We therefore opted to split pre-contact catches equally between transient and resident species. Catches of transient stocks are therefore estimated at 0.046 $t.km^{-2}$. Biomass in the pre-contact model was tentatively assumed to be ca. 20% higher than in the early 1900s, or 1 $t.km^{-2}$.

A P/B value of 2.48 $year^{-1}$ was calculated as the average P/B for transient salmon reported by Newlands (1998). Annual Q/B ratios for pink, sockeye and chum are 12.2, 4.6 and 8.2 $year^{-1}$, respectively (Christensen 1996). An average of 8.33 $year^{-1}$ was entered in the models.

Transient salmon do not feed on the shelf, therefore their diet was imported from outside the model area. In general transient salmon stocks spend only 12 – 20 days in the area while migrating at about 1 body length per second to reach the spawning rivers (L. Huato, pers. comm.). Predation mortality during this short temporal window ought also to be low. In allocating predators diets to salmon species in the model it is considered that only 5% of the salmon in the diet of predators is made of transient stocks; the other 95% is allocated to coho and chinook.

Coho and Chinook salmon

Coho and chinook are considered resident in the area for part of the year. Biomass in historical periods was calculated by dividing reported catches by an exploitation rate of 15% (the same rationale as for transient salmon). Total catch of coho in 1900-1905 was 842 tonnes a year, 0.012 $t.km^{-2}$, and biomass estimated at 0.08 tonnes km^{-2} (representing a 70% decrease in biomass between past and present models). The catch of chinook in 1900-1905 was 1,313 tons, 0.018 t. km^{-2}, and the biomass was estimated at 0.120 t. km^{-2} (about an 85% decrease in biomass between past and present models). Both estimates are above the range of 41 to 61% historical decrease in Pacific salmon biomass reported by Gresh *et al.* (2000).

As for transient salmon, pre-contact catches of coho and chinook were assumed to be half of the estimated total salmon consumption by First Nations, i.e. 0.046 $t.km^{-2}$, which was split equally between both species. Biomass in the pre-contact period was assumed to be ca. 20% higher than in the early 1900s, i.e. 0.096 $t.km^{-2}$ for coho and 0.144 $t.km^{-2}$ for chinook.

Workshop notes

AT talked about his research on salmon carrying capacity using watershed mapping. He estimates a virgin population size of steelheads in the order of 80 to 100,000 individuals. Similarly to sockeye, steelheads do not stay in the area modeled. For sockeye he reckoned that the population now is as big as it used to be in the past (1900s) due to salmon enhancement efforts. AT agreed that there were probably local depletions of some populations but that enhancement has probably balanced the losses. In other words, diversity seems to be declining but abundance is probably being maintained. Coho salmon seems to be in a much worst situation than sockeye.

NH commented on the work of Walters and Morlin, which indicates that the decline in the coho population since the 1970s seems to be related to the effect of climatic changes on juvenile survival, rather than to patterns of land use.

AT questioned the criteria used to make some species explicit in the model – he suggested that perhaps socio-economic importance should also be used as criteria instead of only ecological criteria such as biomass – the example being the need to include steelhead in other salmonid groups.

References

Argue, A. W., Shepard, C. D., Shepard, M. P. and J. S. Argue (1986) A compilation of historic catches by the British Columbia commercial salmon fishery 1876 to 1985. Can. Tech. Rep. Fish. Aquat. Science.

Gresh, T., J. Lichatowich and P. Schoonmaker (2000) An estimation of historic and current levels of salmon production in the Northeast Pacific ecosystem: Evidence of a nutrient deficit in the freshwater systems of the Pacific Northwest. Fisheries, 25(1): 15-21.

DFO (1999) Skeena river Sockeye salmon. DFO Stock Status Report D6-10 (1999). 5pp.

Christensen, V. (1996) Balancing the Alaska Gyre model. In Pauly, D., and V. Christensen (Eds) Mass-balance models of north-eastern Pacific ecosystems. Fisheries Centre Research Reports 4(2). 131 pp.

Hewes, G. W. (1973) Indian fisheries productivity in pre-contact times in the Pacific salmon area. Northwest Anthropological Research Notes 7(2): 133-155.

Newlands, N. (1998) Salmon Population Parameters. In D. Pauly, T. Pitcher and D. Preikshot. (Eds) Back to the Future: Reconstructing the Strait of Georgia Ecosystem. Fisheries Centre Research Reports 6(5). 99 pp.

HALIBUT

Dorothee Schreiber
Fisheries Centre, UBC

Commercial fishing for Pacific halibut began in the 1880s. By 1909 fishermen already noticed that most of the formerly productive inshore areas had been depleted, and they began actively searching for previously unfished offshore grounds. A publication from 1912 reports that "in the last three years, many of the grounds such as Cape Scott, Hecate Strait, Rose Spit, North Island and grounds in the channels and bays of southeast Alaska have shown signs of depletion."

There are numerous accounts of small halibut fishing banks being fished out by a few vessels in a matter of weeks. For example, one place near the north point of the Queen Charlotte Islands, 5 miles wide and 15 miles long, was frequented from 1895 to 1908, and although it was named the "most prolific spot of halibut fishing in the world", little was found there after 1908.

Although it is difficult to provide quantitative estimates, it seems reasonable to assume that around the turn of the century, halibut biomasses were significantly lower than in the 1700s. Fishermen in the early 1900s reported that "one fish to 2 acres of ground is a catch seldom taken" (Alexander 1912).

Since fishing for halibut was carried out in approximately 35 fathoms of water (Dean 1973) with a maximum depth of about 80 fathoms (Alexander 1912), and knowing the approximate distributions of water depths in Hecate Strait, it may be possible to calculate a rough figure for the minimum halibut biomass that must have been available during this time period. Assuming that the average density was half of the above-mentioned figure 1 fish per 4 acres is equivalent to 63 fish per square kilometer of water shallower than 80 fathoms (146m). Catch per unit effort in 1910 was around 250 pounds (or 114kg) (Bell 1981, Crutchfield and Zellner 1963), but depletion had already become a serious problem. CPUE dipped down to 47.3 in 1982, but rose again to 190 pounds (86kg) in 1997 (Sullivan *et al.* 1997). But in fact, CPUEs are difficult to compare due to changes in hook type and spacing over the last 100 years.

Biomass estimates are complicated by issues of climatic change in the North Pacific over the last 100 years (Clark *et al.* 1998). Transitions between regimes occurred in the mid-1920s, mid-1940s and mid-1970s. Since the climate regime shift of 1976-77, the individual growth of halibut has decreased dramatically in Alaska but not in British Columbia. Recruitment has increased dramatically in both areas. Conditions in the 1920s and 1930s are very similar to those at present.

Pacific halibut spawn in deep water in winter, but remain on the same shallow-water feeding grounds on the continental shelf year after year. Detailed descriptions of halibut as predators and prey are given in an IPHC report (Best and St. Pierre 1986). Juveniles become bottom-dwellers at a size of 2-3 cm, and they are no longer vulnerable to predation when they reach 40-50 cm in length. Small juveniles <30 cm in length feed on small crustaceans, especially shrimp. As halibut increase in size, larger crustaceans and fish such as walleye pollock, sand lance, and tanner crabs become more important components of their diet.

Adult halibut tend to be opportunistic feeders on octopus, crabs, flatfish, sand lance, and Pacific cod. Several studies of food webs in the North Pacific have been unable to show that halibut is heavily utilized by any predator. Although marine mammals such as the Steller sea lions are notorious for preying on halibut hooked on setline fishing gear, halibut does not appear to be of major importance in their overall diet.

Halibut by-catch in the trawl fishery was negligible until the early 1960s, and was relatively stable at around 1.6 million pounds annually in the early 1990s (DFO Management Plan. Anon 2000). The bycatch of halibut in the groundfish trawl fishery was reduced to 215,000 pounds in (1997) Halibut caught in trawls are primarily juveniles between 4 and 6 years of age.

References

Alexander, A.B. (1912) Preliminary examination of halibut fishing grounds of the Pacific coast. Department of Commerce and Labor. Bureau of Fisheries Document No. 763.

Anon. (2000) Pacific Region Integrated Fisheries Management Plan for halibut. Fisheries and Oceans Canada.

Bell, F.H. (1981) The Pacific halibut: the resource and the fishery. Alaska Northwest Publishing Company, Anchorage. 267 pp.

Best, EA and G. St.-Pierre (1986) Pacific halibut as predator and prey. IPHC Technical Report No. 21.

Clark, W.G., S.R. Hare and A.M. Parma (1998) Decadal changes in growth and recruitment of Pacific halibut. Canadian Journal of Fisheries and Aquatic Science 56 (2): 242-252.

Crutchfield J. and A. Zellner (1963) Economic aspects of the Pacific halibut fishery. Fishery Industrial Research. Volume 1 Number 1.

Dean, L.J. (1973) The eastern Pacific halibut fishery 1888-1972: an evolutionary study of the spatial structure of a resource-based complex. M.A. Thesis, University of British Columbia.

Sullivan, P.J., Parma, A.M. and W.G. Clark (1997) The Pacific halibut stock assessment of 1997 IPHC Scientific Report No. 79.

Workshop Notes on Halibut

Marcelo Vasconcellos and Tony J. Pitcher
Fisheries Centre, UBC

The species present ontogenetic changes in diet. Juveniles are in the shelf, adults are found also in outer shelf areas. Participants agreed that there were probably changes in production rates due to changes in growth rates – fisheries selection of fish with fast growth. Halibut is smaller at age now than before. DH suggested a PSARC paper on halibut by Jackie King as a good reference.

Model parameters

It is estimated that First Nations caught as much as 1.4 thousand tonnes of halibut per year prior to the commercial fisheries, and after 1888 they consumed over 270 tonnes annually (Carrothers 1941).

On the other hand, the commercial halibut fisheries, which were practically insignificant in 1888, rapidly moved to a total catch of thousands of tonnes annually. The commercial fishery in the Hecate Strait and Queen Charlotte area began around 1894. The average annual catch in Area 2 (South of Cape Spencer to southern Vancouver Island) between 1901 and 1904 was 11,340 tonnes (Bell 1981). It was not possible to estimate total catch in the study area (IPHC areas 9 to 13 in Area 2) with the data available for the early 1900s. But taking the average contribution of sub-areas 9 to 13 to the overall catches in Area 2 from 1921 to 1929 as an indicator, it is possible to estimated that catches in Hecate Strait must represent at least 50% of total area catch. Therefore, it is estimated an average catch in the period 1900-1905 of about 5,670 tonnes per year.

At first, fishing was very localized, but as catches fell, the fishing area was extended to new grounds. By 1906 most of the shallower grounds in this region were being exploited (Thompson *et al.* 1931). Halibut grounds were depleted early on in the development of the fishery. Thompson *et al.* (1931) cites the significant decline in abundance of halibut in this area between 1906 and 1928 (CPUE had fallen to 19% of its original value).

Accompanying the depletion of the banks, there was a decrease in the weight of fish caught: catch per unit of standard size declined from 123 Kg in 1906 to about 16 Kg in 1930. The depletion of shallow coastal banks made the industry move to deeper waters, especially after 1910 (areas such as north-west Queen Charlotte). Landings declined afterwards, and as a result, a conservation convention was signed by US and Canada in 1923 to investigate the condition of halibut stocks. The primary goal of the convention (and of the commission that was formed later on, IPHC) was to rebuild halibut stocks from their overfished state and attain maximum sustainable yields. Regulations implemented apparently led to a recovery of the stocks beginning in 1932.

Since 1932, halibut production has increased from about 20 thousand tonnes annually to an average level of about 31 thousand tonnes. Practically all of the increase in production since regulatory measures were introduced has been accounted for by the Canadian fleet. The changes in stock size over the years have been attributed to variations in fishing pressure and environmental factors (the Thompson and Burkenroad debate, Hilborn and Walters 1992). By the late 1950s most segments of the population appeared recovered (Bell 1981). Figure 1 shows the estimated trend in halibut biomass in the west coast and the trend in CPUE in area 2B (Queen Charlotte to west Vancouver Island) (Clark and Hare, 2001).

Halibut biomass in the early 1900s might be higher than at present, although the recovery of the stock support the hypothesis of the same biomass in the past as at the present time. That is corroborated by the fact that climatic conditions in the early 1900s were similar to those at present

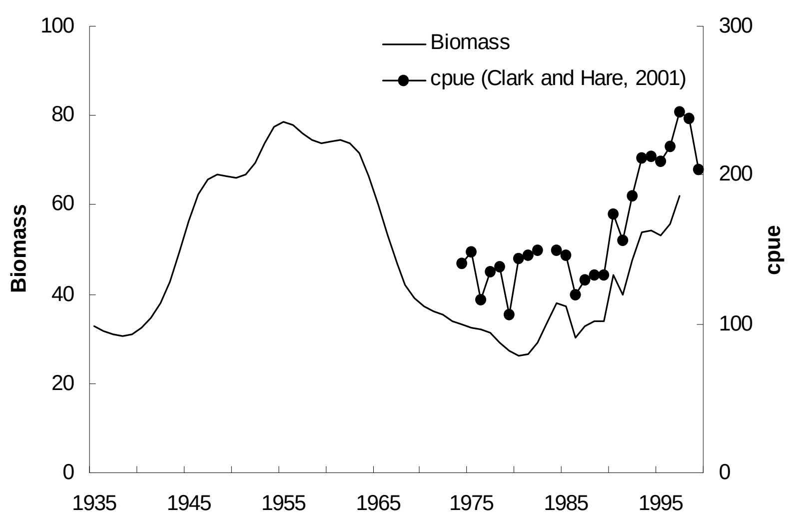


Figure 3. Trend in halibut biomass (Quinn *et al.* 1985) and CPUE in area 2B (Clark and Hare 2001).

(Schreiber, this volume). Beattie *et al.* (1999) reported another scenario, where fishers and First Nations agreed that there are more halibut today (twice as many) than there was 100 years ago. The assumption being used in this report is that biomass at present time is the same as 100 years ago. Halibut biomass in pre-contact period is considered higher than in the 1900-1905 period, given that pre-contact catches (ca.0.019 $t.km^{-2}.year^{-1}$) were approximately 4 times smaller than reported commercial catches in the early 1900s. A hypothesis is tested that pre-contact biomass was double that of the early 1900s.

References

Beattie, A., Wallace, S. and N. Haggan (1999) Report of the BTF workshop on reconstruction of the Hecate Strait Ecosystem. Pages 1-12 in Haggan, N. and A. Beattie (eds). Back to the Future: reconstructing the Hecate Strait ecosystem. Fisheries Centre Research Reports 7(3): 65 pp.

Bell, F.H. (1981) The Pacific halibut. The resource and the Fishery. Alaska Northwest Publishing Company, Anchorage, Alaska. 267 pp.

Carrothers, W.A. (1941) The British Columbia fisheries. Political Economy Series 10, University of Toronto Press. 136 pp.

Clark, W. G. and S. R. Hare (2001) Assessment of the Pacific Halibut stock in (2000) Int. Pac. Halibut. Comm. Report of Assessment and Research Activities 2000. Also online at **Error! Hyperlink reference not valid.**

Hilborn, R. and C.J. Walters (1992) Quantitative fisheries stock assessment. Choice, dynamics and uncertainty. Chapman and Hall, New York. 570 pp.

Quinn II, T. J., Deriso, R. and S. H. Hoag (1985) Methods of population assessment of Pacific halibut. IPHC Scientific Report 72.

Thompson, W. F., Dunlop, H. A. and F. H. Bell (1931) Biological statistics of the Pacific halibut fishery. Report of the International Fisheries Commission 6: 108 pp.

WORKSHOP NOTES ON GROUNDFISH SPECIES

Marcelo Vasconcellos, Alasdair Beattie and Tony Pitcher
Fisheries Centre, UBC

The model represents groundfish species in several functional groups describing Pacific cod (see above), rockfish , flatfishes, and sablefish.

There are two assessment units for Pacific cod in the study areas, one in Hecate Strait and the other in the Queen Charlotte sound. AS suggested that biomass ratios proposed by Walters and Bonfil (1998) are close to values derived from DFO stock assessment results. The population shows at least 3 major cycles in the biomass during last 50 years, driven by recruitment fluctuations. Some relationship exists between Pacific cod oscillations and herring biomass (e.g. Walters 1987).

There are many stocks of Pacific Ocean Perch in the Hecate Strait. DNA studies show the presence of discrete stocks east and west of the Queen Charlotte islands and in Queen Charlotte sound (JF). The oldest fish were 30 to 40 years or age. Other rockfish species such as rougheye and yellowmouth school with POP. Biomass in Moresby Gulley is estimated to be in the order of 30,000 tons. Biomass estimates are problematic, but some improvements are expected from acoustic work (JF). AB commented on the very high foreign catches of POP in the past, around 50 to 60 thousand tonnes. DH noted the existence of trawl surveys conducted between BC and Alaska in areas relatively untouched by trawlers in the 1960s – this information could be used to get some background information on biomass.

In the present time model, rockfish species were split between planktivorous and piscivorous rockfish. AB suggested during the workshop that the two groups should be merged since their diets are not very different. TP commented that some of the rockfish species may live 250 years and that P/B ratios are expected to be low. JF commented that not much is known about most of the rockfish species, and that the Walters and Bonfil (1998) paper is probably the best source for biomasses in the area.

JF presented a review on flatfishes in Hecate Strait. Rock sole and English sole feed on sand lance and herring. The maximum age of the species is around 20 years. Abundance time series since the 1940s shows a long-term decline up to the mid-1980s, a recent period of increase in biomass until the 1990s due to good recruitment, and a subsequent decline again in biomass. The present biomass is probably close to the 50year average. Recruitment varies with temperature and Ekman transport in Hecate Strait during the spawning period. There is CPUE data on Dover sole going back to the 1970s, a limited amount of age composition data and biomass estimates. The maximum age of Dover sole is around 50 years. Other sole species were very abundant in the 1940s, and supported an important fishery until the 1960s. All the species have had large fluctuations in biomass.

JF also reviewed the information on turbot. The current biomass is probably the same as 100

Table 1. Groundfish biomass in present conditions ($B_{present}$), in the early 1900s (B_{1900s}), and the ratio between biomass in 1996 to the estimated virgin biomass (Walters and Bonfil 1998).

Groundfish species	$B_{present}$	B_{1996}/B_{Virgin}	B_{1900s}
Juvenile POP	0.065	0.423	0.154
Adult POP	1.819	0.423	4.300
Inshore rockfish[f]	0.100	1[c]	0.100[c]
Juvenile piscivorous rockfish[d]	0.007	0.643	0.011
Adult piscivorous rockfish	0.654	0.643	1.017
Juvenile planktivorous rockfish[e]	0.136	0.545	0.249
Adult planktivorous rockfish	1.207	0.545	2.215
Juvenile turbot	0.214	1[b]	0.214
Adult turbot	1.530	1[b]	1.530
Juvenile flatfish[a]	0.259	0.741	0.349
Adult flatfish[a]	0.392	0.741	0.529
Juvenile Pacific cod	0.089	0.171	0.520
Adult Pacific cod	0.163	0.171	0.953
Juvenile sablefish	0.119	0.762	0.156
Adult sablefish	0.301	0.762	0.395
Juvenile lingcod	0.031	0.05 - 0.609	0.051 – 0.620
Adult lingcod	0.034	0.05 - 0.609	0.056 – 0.680

a. Includes data for rock sole, Dover sole and English sole, probably the most important flatfish species in the area. b. Biomass considered the same as the present time model (as in Beattie et al). c. Needs more information, left the same as present day model; d. Includes rougheye, shortraker, and yellowtail; e. Includes silvergrey, canary, yellowmouth, shortspine; f . Includes yelloweye (*Sebastes ruberrinus*), quillback (*S. maliger*), copper (*S. caurinus*), china (*S. nebulosus*), black (*S. melanops*), tiger (*S. nigrocinctus*).

years ago. It is one of the most abundant species in the Hecate Strait. The maximum age of turbot is 40 to 50 years, but most of them are 5 to 10 years of age. JF suggested Rick as the contact person in DFO for biomass and bycatch information. Bycatch values are probably in the same order of magnitude of a possible sustainable harvest. Stock recruitment data is also available for this species.

Model parameters

Changes in groundfish biomass between the present time and 1900s were based on the assumptions that: i) all species were relatively unfished by the turn of the century; ii) the ratio between biomass in 1996 to Virgin biomass (B_{1996}/B_{Virgin}) can be used to obtain 1900s species biomass from present time biomasses in the model built by Beattie (2001). The first assumption is supported by the fact that the B.C. trawl fishery was practically insignificant until WWI (see section x). Biomass ratios (B_{1996}/B_{Virgin}) of groundfish species in different fishing grounds of the Hecate Strait area were obtained from the multispecies spatial assessment model of Walters and Bonfil (1999). Table 12 shows the biomass ratios used to estimate biomasses in the early 1900s. Biomasses at pre-contact were assumed to be the same as the early 1900s.

Martell (1999) estimated that lingcod biomass in Hecate Strait at the present time is ca. 41% of the biomass in 1955. Lingcod stocks were probably already being depleted before 1955. Beattie *et al.* (1999) suggested, based on Georgia Strait BTF, a reduction of 95% in lingcod biomass from the 1900s.Walters and Bonfil (1999) estimated the ratio B_{1996}/B_{Virgin} for lingcod at 0.609. In table x we opted to leave a range of values of biomass in the past to contrast the two estimates.

Information about trends in flatfish biomass was also obtained from DFO (1999a; 1999b; and 1999c). English sole shows an increase in abundance since the 1980s. Petrale sole shows a decrease in landings since the 1940s when the species was targeted by U.S. vessels fishing in Canadian waters - the peak year in catch was 1948 when ca. 5,000 tonnes were landed. Dover sole shows an increase in catches and consequent decrease in biomass during the 1990s. Rock sole presented a marked increase in biomass since 1945, the current biomass is considered above the 50 year average. Based on Walters and Bonfil (1998) the biomass of flatfishes in the early 1900s was estimated to be 1.35 times higher than at present (Table 1).

Pacific Ocean Perch is the most important rockfish species in BC trawl fishery (Schnute *et al.* 1999). A fishery for POP have existed since the 1950s (the foreign fishery was active from 1956 to 1982; the largest catches by Soviet and Japanese landed between 1965 and 1970s), but Canadian catches only became significant in the 1970s. The catches by foreign fleets apparently reduced the POP stock to 1/3 of what is was in 1965 (DFO 1999d). There are indications by fishers of an increase in biomass of POP in recent years. Walter and Bonfil (1998) estimated the ratio B_{1996}/B_{Virgin} for POP at 0.423.

References

Beattie, A.I. (2001) A new model for evaluating the optimal size, placement and configuration of marine protected areas. M.Sc. Thesis, University of

British Columbia.

Beattie, A., Wallace, S. and N. Haggan (1999) Report of the BTF workshop on reconstruction of the Hecate Strait Ecosystem. Pages 1-12 in Haggan, N. and A. Beattie (eds). Back to the Future: reconstructing the Hecate Strait ecosystem. Fisheries Centre Research Reports 7(3): 65 pp.

DFO 1999a. Petrale sole British Columbia (Areas 3C-5D). DFO Stock Status Report A6-06, 1999. 3 pp.

DFO 1999b. Dover sole west coast. Vancounver Island (3C-D) to Queen Charlotte Islands (Areas 5A-E). DFO Stock Status Report A6-04, 1999. 3 pp.

DFO 1999c. English Sole Hecate Strait (Areas 5C-D). DFO Stock Status Report A6-05, 1999. 3 pp.

DFO 1999d. Pacific Ocean Perch British Columbia Coast. DFO Stock Status Report A6-11(1999). 5 pp.

Martell, S. (1999) Estimating lingcod biomass in Hecate Strait using stock reduction analysis Pages 49-55 in Haggan, N. and A. Beattie (eds). Back to the Future: reconstructing the Hecate Strait ecosystem. Fisheries Centre Research Reports 7(3): 65 pp.

Walters, C. J. 1987. Non-stationarity of production relationships in exploitable populations. Can. J. Fish. Aquat. Sci. 44 (Suppl. 2): 156-165

Walters, C. J. and R. Bonfil (1998) Multispecies spatial assessment models for the British Columbia groundfish trawl fishery. Can. J. Fish. Aquat. Sci. 56: 601-628.

Schnute, J. T., N. Olsen and R. Haigh (1999) Slope rockfish assessment for the west coast of Canada. Canadian Stock Assessment Secretariat Research Document 99/184.

PACIFIC COD

Alan Sinclair
DFO, Nanaimo

Pacific cod are thought to be a relatively short lived, high turnover species. The instantaneous rate of natural mortality may be as high as 0.6 (Fournier 1983).

There are 2 Pacific cod "stocks" in the study area, one occupying the Dixon Entrance-Hecate Strait area (DFO Management Areas 5CD), and the second the Queen Charlotte Sound area (5AB). The most recent stock assessment of Pacific cod in area 5CD covers the period 1956-1998 (Haist and Fournier, PSARC Working Paper F98/6). Stock biomass estimates were cyclic, spanning almost an order of magnitude with a maximum of 24,000 t in 1965 and a minimum of 2,500 t in 1970 (Figure 1).

There were other periods of relatively high biomass in the mid-1970s and late 1980s. No long-term trend was apparent. Stock biomass is largely recruitment dependent and these periods of high biomass correspond with large year-classes. Little is known about what drives this variation in recruitment.

There is little or no information on fisheries for this species in the early 1900s or at the time of first contact with Europeans. A comprehensive review of Pacific cod biology and fisheries is available in Westrheim (1996).

References

Fournier, D. A. (1983) An analysis of the Hecate Strait Pacific cod fishery using an age structured model incorporating density-dependent effects. Can. J. Fish. Aquat. Sci. 40: 1233-1243.

Haist and Fournier, D. (1998) PSARC Working Paper F98/6.

Westrheim, S.J. (1996) On the Pacific cod (*Gadus macrocephalus*) in British Columbia waters, and a comparison with Pacific cod elsewhere, and Atlantic cod (*G. morhua*). Can. Tech. Rept. Fish. Aquat. Sci. 2092: 390 pp.

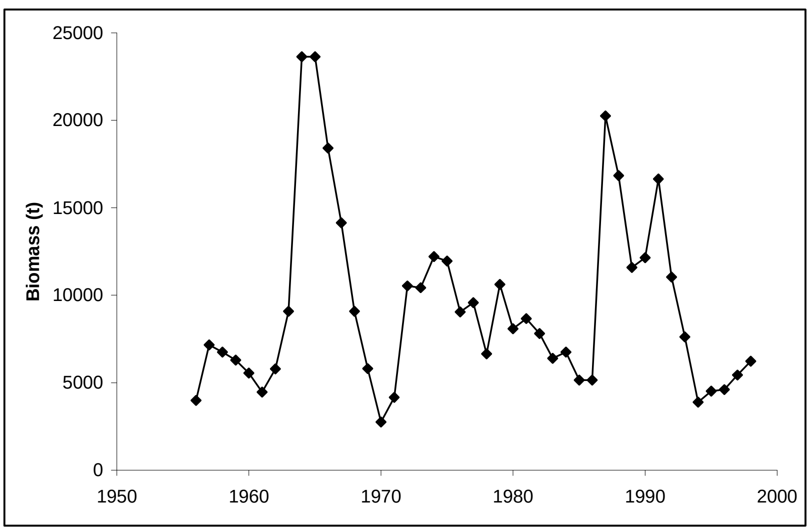


Figure 1. Trend in population biomass of Pacific cod in Area 5CD.

A HISTORICAL PERSPECTIVE FOR FATFISH SPECIES IN HECATE STRAIT

Marcelo Vasconcellos and Jeff Fargo
Fisheries Centre, UBC &
DFO, Nanaimo

Commercial Fishery

In 1910 cold storage facilities were built in the Queen Charlotte Islands to process flatfish and a number of gadoid species (Forrester *et al.*

1978). At that time the trawl fleet consisted of three steam trawlers, about 120 feet in length, and operated by local fishermen. This operation was largely unsuccessful due to limited markets for the catch and difficulty in transporting it. During the 1920s and 1930s the small boat trawl fleet in British Columbia increased steadily in numbers (Forrester *et al.* 1978) and flatfish species were the dominant component in the landings from the commercial fishery (Ketchen 1952).

By the mid 1940s flatfish landings in British Columbia amounted to about 3000t with the fleet concentrating especially on the harvest of rock sole, English sole and Petrale sole (Pruter 1966). Much of this catch was taken by U.S. trawlers operating in Hecate Strait (Ketchen and Forrester 1966). In the 1950s the Canadian trawl fleet underwent a rapid expansion and by the mid 1970s the fishery was expanding to deeper depths in Queen Charlotte Sound. In the late 1970s Canada declared extended jurisdiction over its offshore resources and the Canadian fleet began to explore offshore grounds in deepwater. A deepwater fishery for Dover sole was initiated in 1977 off of the Northwest coast of the Queen Charlotte Islands, and off the West Coast of Vancouver Island in the late 1980s (Fargo and Workman 1995). Landings from these fisheries reached a peak of about 3500 t by (1996) Since the late 1990s annual landings of flatfish from the British Columbia trawl fishery have averaged about 8000 t (Fargo 2000).

Abundance of Flatfish Stocks

Since the early 1950s research surveys have been directed at the study of commercially important flatfish species off the west coast of Canada. Most of the research emphasis has centred around the Queen Charlotte Islands where these species are most abundant. The abundance of flatfish species undergoes the type of characteristic fluctuations observed due to a changing environment. However the coefficient of variation for recruitment for flatfish species is among the lowest for any marine fish species. Data time series for the important commercial species extend back to the mid 1940s.

The maximum abundance for rock sole and English sole in Hecate Strait in 1999 was estimated at about 4000 t and 2500 t, respectively (Fargo *et al.* 2000). Abundance for these species in the mid 1940s was lower in comparison, about 2000 t for each. There is no information prior to the mid 1940s on which to base abundance estimates. However, the unfished equilibrium biomass for these species has been estimated at 8500 t for rock sole and 5200 t for English sole (Fargo *et al.* 2000).

Arrowtooth flounder ("turbot") accounts for a significant proportion of the biomass of all fish species in Hecate Strait. Its biomass in 1980 was estimated at about 32000 t (Fargo *et al.* 1980). The unfished equilibrium biomass for this species was estimated at 56000 t (Fargo 1988).

Dover sole, is the other important commercial flatfish species in Hecate Strait. In 1997 Dover sole biomass was estimated at 6500 t (Fargo 1998). The unfished equilbrium biomass for this species was estimated to be about 14000 t (Fargo 1999).

There are twelve other species of flatfish known to be resident in Hecate Strait. Current biomass estimates for these species range from a few hundred tonnes to thousands of tonnes. These estimates are based on the expansion of research survey catch rates from the biennial groundfish trawl survey in Hecate Strait (Workman *et al.* 1996). There is no historical information for these species on which to base biomass estimates.

References

Fargo, J. (1999) Flatfish Stock Assessments for the west coast of Canada for 1998 and recommended yield options for 1999. Canadian Stock Assessment Secretariat Research Document 99/17.

Fargo, J. (1988) Flatfish. In Fargo, J, M.W. Saunders and A.V. Tyler [Eds]. Groundfish Stock Assessments for the West Coast of Canada in 1987 and Recommended Yield Options for 1988. Can. Tech. Rep. Fish. Aquat. Sci. 1617: 304pp.

Fargo, J., A.R. Kronlund, J.T. Schnute and R. Haigh (2000) Flatfish Stock Assessments for the west coast of Canada for 2000 and recommended catches for 2001. Canadian Stock Assessment Secretariat Research Document 2000/166.

Fargo, J. and G.D. Workman (1995) Results of the Dover sole (*Microstomus pacificus*) Biomass Survey Conducted off the West Coast of Vancouver Island February 13-27, 1995. Can. Manuscr. Rep. Fish. Aquat. Sci. 2340: 75 pp.

Forrester, C.R., A.J. Beardsley and Y. Takahashi (1978) Groundfish, shrimp and herring fisheries in the Bering Sea and Northeast Pacific – historical catch statistics through 1970. Int. North Pac. Fish. Comm. Bull: 37: 147 pp.

Ketchen, K.S. (1952) The British Columbia trawl fishery. Can. Dept. Fish., Trade News 4: 3-8.

Ketchen, K.S. and C. R. Forrester (1966) Population Dynamics of the Petrale sole, *Eopsetta jordani*, in waters off western Canada. Bull. Fish. Res. Board Can. 153: 195 pp.

Pruter, A.T. (1966) Commercial fisheries of the Columbia River and adjacent ocean waters. Fish. Industrial Res. 3(3): 17-66.

Workman, G.D., J. Fargo, B. Beall and E. Hildebrandt (1997) R/V W.E. RICKER and F/V STEADFAST Trawl Survey of Hecate Strait, May 30 – June 13, 1996. Can. Data Rep. Fish. Aquat. Sci. 1010: 155 pp.

PACIFIC HERRING IN NORTHERN BRITISH COLUMBIA

Jake Schweigert
DFO, Nanaimo

Pacific herring within the Hecate Strait area are most likely components of three major migratory stocks, which spawn on the lower east coast of the Queen Charlotte Islands, in the vicinity of Prince Rupert on the north coast of BC, and on the Central Coast of BC in the vicinity of Bella Bella. In addition, there are a number of small, probably localized spawning groups, which may migrate into Hecate Strait to some degree. Fisheries and Oceans Canada conducts annual assessments of five major herring stocks in British Columbia, including the three that contribute fish to Hecate Strait. The assessments are based on surveys of spawning ground size and egg density and on a catch-at-age analysis for the period 1951-(2000) During this period, abundance of all three herring populations has fluctuated markedly.

All three populations experienced a collapse due to heavy fishing and poor survival conditions in the late 1960s, but recovered rapidly in the 1970s following a 4-year fishery closure. Harvest rates have been maintained at a conservative 20% of forecast abundance since 1983 and abundance has remained stable or increased slightly in the Prince Rupert and Central coast areas while abundance declined from the recent high in 1981 in the Queen Charlotte Islands, but has recovered slightly in recent years (Figure 1).

The available data on spawning bed size and egg deposition as well as total catch for the period prior to 1950 to the beginning of the century is incomplete. However, the available data does not indicate any significant differences in total abundance relative to levels observed in recent decades. In other words, there is no indication of extensive herring spawning areas that no longer exist or spawning intensity many times higher than has been observed in recent years. In fact, herring show a remarkable conservatism in spawning intensity with egg density rarely exceeding several layers. Research has demonstrated that higher egg density invariably leads to high mortality as the inner eggs slowly suffocate. The pattern appears to be that the total area of herring spawn deposition expands and contracts as total population abundance fluctuates.

Any comment on herring abundance pre-contact, i.e. 1700s, is purely speculative since there is little if any documentation available of larger spatial distribution. However, it is evident that herring in many areas of BC are strongly influenced by fluctuations in environmental conditions. Thus, relative and absolute abundance would be determined by climatic factors at that time. During the 20th century we have observed that warm water periods are co-incident with poor herring survival and decreases in total abundance while the converse is true during cool periods. Recent analyses of re-constructed temperature series from tree ring data reveal temperatures similar to the present century so there is no expectation that herring abundance levels at that time would differ markedly from the present conditions.

WORKSHOP NOTES ON PACIFIC HERRING

Marcelo Vasconcellos and Tony Pitcher
Fisheries Centre, UBC

There are three stocks of herring in the Central BC coast. The main spawning areas are in Bella Bella, Prince Rupert and also in the Queen Charlotte. Some of the spawners seem to move to the west coast of Vancouver Island. Adult stock biomass by area is approximately 20 to 25 thousand tons in the Queen Charlotte, 30-35 thousand tons in Prince Rupert and 20 - 40 thousand tons in the Central coast. It was suggested that present herring biomass levels are similar to the 1900s.

TP commented that DFO's position about the current status of herring is contrary to local knowledge, which points to the disappearance of localized stocks and possibly a smaller biomass at the present time. DH replied by showing information on herring spawning areas going back to the 1930s, which indicate fewer number of spawning areas, but more fish being produced than before. TP suggested that homing should be the default assumption for fish species (citing Phillip Cury's work). DH replied showing that homing is scale dependent – high fidelity in the region and statistical areas, but not in the

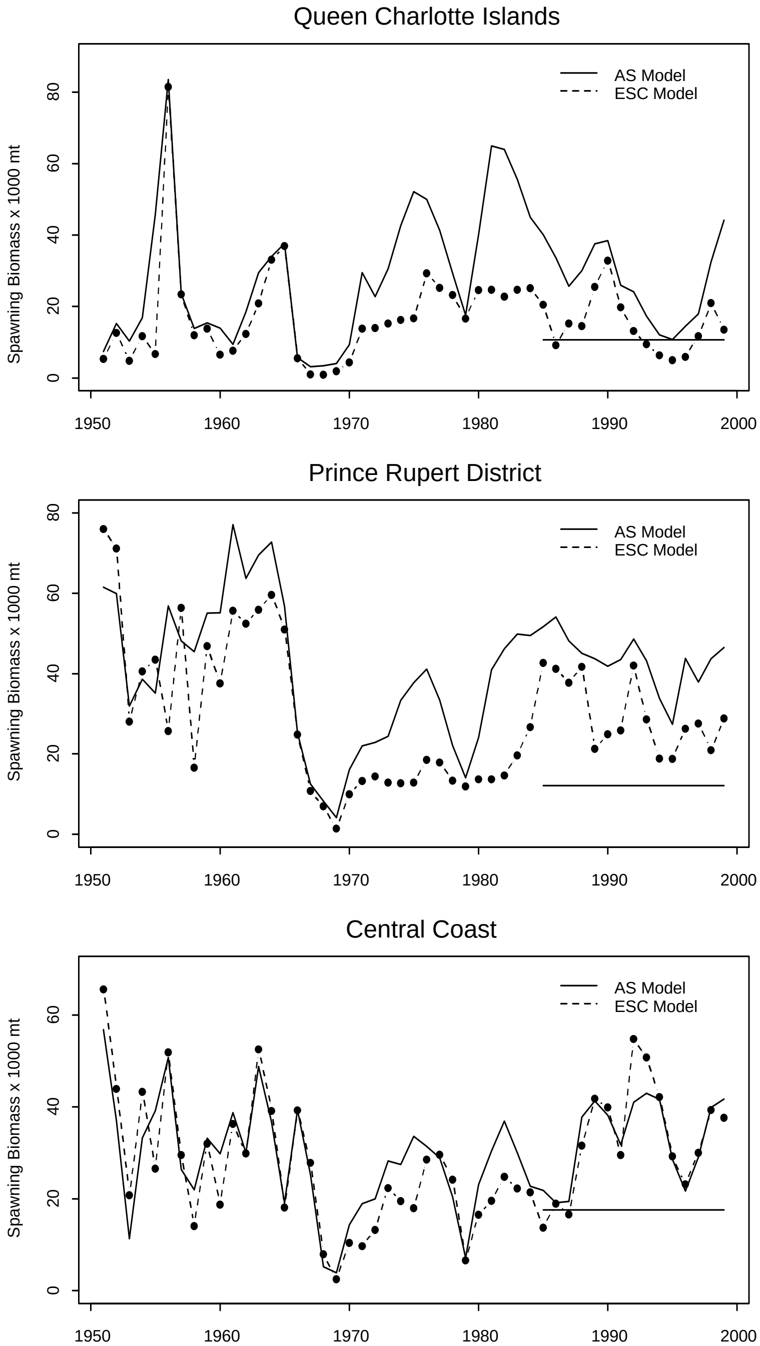


Figure 1. Estimated pre-fishery biomass for Pacific herring populations in the Hecate Strait area 1951- (1999) Horizontal line indicates the fishing threshold or cut-off level.

locations (<10km). JS reminded us that DNA analysis shows little difference between herring stocks in Hecate Strait.

Regarding diets, DH showed that herring juveniles eat more copepods than euphausiids, while the opposite is true for adults.

Model parameters

Herring biomass in the past was a issue of debate during the workshop. On the one hand, spawning biomass indices from DFO suggest that the present biomass levels are most likely to be in the same order of magnitude as levels prior to the reduction fishery and early 1900s (see Schweigert, this vol.). On the other hand, a decrease in biomass of ca. 75% between past and present periods, is supported by resource users (Beattie *et al.* 1999). Climatic data also supports the hypothesis of similar biomass between pre-contact and present conditions (Schweigert, this vol.).

We opted to leave the biomass of herring to be estimated by the model so that production can match consumption by predators in the different historical models. In the present day model herring catches were split between two fleets according to the following proportions: gillnet 0.64 and seine 0.36 (based on DFO database).

References

Beattie, A. Wallace, S. and N. Haggan. (1999) Report of the BTF workshop on reconstruction of the Hecate Strait Ecosystem, p. 1-12 In Haggan, N. and A. Beattie (eds). Back to the Future: reconstructing the Hecate Strait ecosystem. Fisheries Centre Research Reports 7(3). 65pp.

Jones, R.R. (2000) The Herring Fisheries of Haida Gwaii. Pages 201-224 in Coward, H., R. Ommer and T. Pitcher (Eds) (2000) Just Fish: Ethics and Canadian Marine Fisheries. ISER Books, St. Johns. Newfoundland. 304pp.

Workshop Notes on Forage fish

Marcelo Vasconcellos and Tony Pitcher
Fisheries Centre, UBC

The forage fish group in Beattie *et al.* (1999) include Pacific sandlance, anchovies, sardines, capelin, smelts and eulachon. Eulachon were separated from other forage fish due to their importance for native fisheries.

Pilchard were fished by First Nations in the past (Forester and Forester 1975). BC commercial pilchard fisheries commenced in 1917 with a small market for canned and fresh product. Catches increased rapidly once reduction into oil and meal was authorized in 1924. The fishery increased from initial catches of ca. 70 tons in 1917-1918 to 44,000 tons in 1926-1927. Catches in this order of magnitude were sustained until 1947-1948 when a total of 444 tons were landed. Pilchards were practically gone from BC waters by the late 1940s. The area of distribution of Pacific sardine ranges from northern Mexico to southeastern Alaska, although the main centres of concentration ranged from southern California to the southern portion of British Columbia (Schweigert 1987). The main fishing localities in BC were off the west coast of Vancouver Island - not many sardines were apparently caught in the Hecate Strait area. Assuming the hypothesis of sardine collapse and disappearance from BC waters is from climate fluctuations and overfishing, it is likely that biomass at present time is smaller than in the past.

The Strait of Georgia is the southernmost spawning edge of capelin in the Pacific (Hay 1998). Capelin is apparently common in the study area, with intermittent occurrence off the east and north coast of the Queen Charlotte Islands and Prince Rupert. There were no commercial fisheries for capelin. However, there were small recreational fisheries in the past, specifically for the Georgia Strait area and this is probably also true for the Hecate Strait.

Workshop notes

DH reviewed the information about forage fish species. Surf smelts might be important players in the inshore zones, where biomass is probably in the order of thousands of tons. Capelin is ephemeral in the area, present only in small residual populations; the species probably has never been an important player in the ecosystem.

On the other hand sandlance seems to be very important, being present in the diet of many species, but not much is known about them. Sand lance larvae are very abundant. KC commented on the presence of sandlance in grab samples of sediments in the area (one or two fish in each 10 samples in the Hecate Strait). Besides these incidental catches, sandlance are not caught by any fishery in B.C. Sardines were present in the area 50 years ago, then they disappeared and now they seem to be back again - a few were taken by the roe fishery in the Queen Charlotte area. Anchovies are also present in the area but not much is known about them.

References

Beattie, A., Wallace, S. and N. Haggan. (1999) Report of the BTF workshop on reconstruction of the Hecate Strait Ecosystem, p. 1-12 In Haggan, N. and A. Beattie (eds). Back to the Future: reconstructing the Hecate Strait ecosystem. Fisheries Centre Research Reports 7(3). 65pp.

Forester, J. E. and A. D. Forester (1975) British Columbia's Commercial Fishing History. Hancock House Publishers. 224 pp.

Hay, D. (1998) Historic changes in capelin and eulachon populations in the Strait of Georgia. p. 42-44 In Pauly, D.; Pitcher, T and D. Preikshot (eds). Back to the Future: reconstructing the Strait of Georgia ecosystem. Fisheries Centre Research Reports 6(5): 99 pp.

Schweigert, J. (1987) Status of the Pacific sardine, *Sardinops sagax*, in Canada. Canadian Field-Naturalist 102(2): 296.

The Eulachon in Northern British Columbia

Douglas Hay
DFO, Nanaimo

Distribution

The eulachon (*Thaleichthys pacificus*) is an anadromous smelt (Osmeridae) that spawns in the lower reaches of coastal rivers and streams from northern California to the southern Bering Sea. Within the Pacific, the distribution of eulachons, like most of the other smelts, is Boreal and eulachons are found only on in the eastern Pacific, from northern California to the eastern Bering Sea. In North America, eulachon distribution coincides closely with areas known as the coastal temperate Rain Forest (Simenstad *et al.* 1996). Throughout much of its range, from California to south-eastern Alaska, eulachons have declined, especially in the last 20 years. Over a longer term, it seems probably that there has been a decline in eulachons in the northern areas of BC and present abundance in many rivers may be much less than it was 100 years ago.

Distribution of spawning rivers

All known eulachon spawning rivers in British Columbia are listed, from north to south, in Table 1 (From Hay and McCarter 2000). Not all rivers shown in Table 1 receive spawning every year, but

Table 1. List and classification of known and probable eulachon spawning areas, and adjacent marine areas, estimated from larval surveys (McCarter and Hay 1999) and information from Eulachon Research Council Minutes (1998 and 2000), and other documents. The column headed by 'R/I' indicates rivers where spawning is mainly regular, 'R' (occurring most years), irregular (I) or unknown (?). The next column, headed 'A/C' indicates whether assessments are done annually (A) and whether they are regular A_r or irregular A_i , and whether annual catch data (C) is indicated as recorded regularly (C_r) or irregularly (C_i). The next column indicates whether the river is routinely fished by First Nations (FN) or a commercial Fishery (Co). Estimated river size and spawning run sizes are roughly estimated by width as very small (V, < 5m), small (S, ~10m), medium (M, >20m), or large (L, >100m). The column 'estuary' shows common estuarine waters for different rivers. (Table from Hay and McCarter 2000).

	Eulachon Spawning Areas	R/I	A/C	FN/Co	Size	Estuary	Marine areas
1	Nass	R	A_i,C_r	FN	M-L	PI - 1	Portland Inlet
2	Skeena	R	A_i	FN	L-S	CS - 2	Chatham Sound
3	Kitimat River	R	A_i,C_r	(FN)	S-M	DC - 3	Douglas Ch - Kitimat Arm .
4	Kildala River	R		FN	S-S	DC - 3	Douglas Ch - Kitimat Arm
5	Giltoyees Inlet	I			V-V	DC - 3	Douglas Ch.
6	Foch Lagoon	I			V-V	DC - 3	Douglas Ch.
7	Kitlope River	R		FN	M-M	GC - 4	Gardner Canal - head
8	Kowesas River	R		(FN)	S-S	GC - 4	Gardner Canal - Chief Matthew's Bay
9	Kemano/Wahoo River	R	A_r,C_r	FN	M-M	GC - 4	Gardner Canal - Kemano Bay
10	Khutze River	?			V-V	*NC -*	Princess Royal Ch. - Khutze Inlet
11	Aaltanhash River	?			V-V	*NC -*	Princess Royal Ch. - Aaltanhash Inlet
12	Kainet or Lard Creek	?			V-V	*NC -*	Kynoch Inlet - Mathieson Ch.
13	Bella Coola River	R		FN	M-M	DC - 5	Dean Ch. North Bentick Arm
14	Kimsquit, Dean Rivers	R		FN	M-M	DC - 5	Dean Ch.
15	Noeick River	?		FN	S-S	DC - 5	South Bentinck Arm
16	Taleomy River	?		FN	S_S	DC - 5	South Bentinck Arm
17	Skowquiltz River	?		FN	S-S	DC - 5	Dean Ch. - west side
18	Cascade Inlet	?		FN	V-V	DC - 5	Dean Ch.
19	Kwatna River	?		FN	S-S	DC - 5	East side Burke Channel
20	Chuckwalla/Kilbella	R		FN	M-M	RI - 6	Rivers Inlet - Queen Charlotte Strait
21	Wannock/Oweekeno	R	A_i	FN	M-M	RI - 6	Rivers Inlet - Queen Charlotte Strait
22	Clyak River, Moses Inlet	?			S-S	RI - 6	Rivers Inlet-Moses Inlet
23	Hardy Inlet (unknown s'ce)	?			S-S	RI - 6	Rivers Inlet
24	Nekite River, Smith Inlet	?			S-S	SI -	Smith Inlet
25	Kingcome River	R	A_i	FN	M-M	KI - 7	Kingcome Inlet
26	Kakweiken River	?			S-S	*JS -*	Thompson Sound - Johnstone Strait
27	Klinaklini River	R	A_i,C_i	FN	L-M	KI - 8	Knight Inlet
28	Franklin River	?		FN	S-S	KI - 8	Knight Inlet
29	Port Neville	?			V-V	*JS -*	Johnstone Strait
30	Stafford/Apple Rivers	?			V-V	*LI -*	Loughborough Inlet
31	Homathko River	I		(FN)	M-S	*BI -*	Bute Inlet - Johnstone Strait
32	Squamish River	I		(FN)	M-S	*GS -*	Howe Sound
33	Fraser River	R	A_r,C_r	FN,Co	L_L	GS - 9	Georgia Strait

those that do are indicated as 'R', for regular spawning, in a separate column. The classification of some rivers may be incomplete because some rivers that are not indicated by an 'R' may have regular, or nearly regular spawning, and vice versa. Even though there may be some subsequent additions to Table 1, it is clear that there are not a large number of eulachons in BC - with a total of 33 spawning rivers listed, of which only 14 are classified as having regular spawning. In contrast, there may be 10,000 different runs or populations of Pacific salmon (all species) over the same range (Slaney *et al.* 1996).

Distribution in the sea

The 2-3 year period between hatching and spawning appears to be spent mainly in near-benthic habitats in marine waters (Hay and McCarter 2000), but we do not know the extent to which some populations may reside in nearshore waters, within inlets. Based on analyses of distribution as incidental capture during research trawls and as bycatch in shrimp trawls, - eulachons appear to live near the ocean bottom in waters of moderate depth (20-150 m). The distribution of eulachons in the marine waters off BC has been compiled from review of all incidental catches of eulachons from research surveys.

Biology

The age of sexual maturity is uncertain because age determination is uncertain (Hay and McCarter 2000) but probably is about age 3 for most fish. Probably eulachons die after spawning and there is substantial post-spawning mortality in most rivers. The best evidence for post-spawning mortality, however, is from teeth. Spawning eulachons in rivers have few teeth, probably because most have resorbed the calcium and other minerals prior to spawning, with only a few eulachons retaining some teeth. In contrast,

Table 2. List of eulachon spawning biomass estimates for specific years and ranges of catches (t for short tons and mt f metric tonnes) estimated for different rivers in BC, showing the source(s) of information (adapted and updated fro McCarter and Hay 1999). *(Author's comment: the report of a 4500 ton catch*, reported as 90,000 cwts (or units of hundr pounds) in 1929 in the Nass seems to be high, perhaps by a factor of 10. The next available report, for year 1931, was for 9,000 cw or about 450 tonnes. This latter estimate seems more reasonable in view of the magnitude of catches in other years, and the sing biomass estimate, made in 1983, of 1700 tonnes for the Nass). (Table from Hay and McCarter 2000).*

River	Period	Biomass	Catch /year tonnes	Source
Nass	Early 1900s		~500	Nisga'a Fisheries, MS 1990
	1929		4500	Stacey, MS 1996
	1931		450	Stacey, MS 1996
	1954		500	Stacey, MS 1996
	1970-71		150-200	Langer *et al.* 1977
	1983	1700	239	Orr 1984 MS and McCarter and Hay 1999
	1989		105	Nisga'a Fisheries, MS 1990
	2000		168	Barner, 2000, Eulachon Research Council Minutes
Skeena	1997		3	Lewis, MS 1997
Kitimat	1993	23		Pederson et al 1995
Kemano	1991	340	~120	Triton, MS 1991
Klinaklini	1996	~120	50-100	Berry, MS 1996; Stacey 1998
Kingcome	1997	14		Berry, MS 1998
Wannock	1997	Nil		Berry, MS 1998
Bella-Coola	1944-1996	Max~70		Stacey, MS 1996, and Table 7, this report.
Fraser	<1950	100-500		Ricker *et al.* 1954
Fraser	>1990s	50-1700	20-30	Hay *et al.* 1997b

all eulachons captured in offshore marine waters have large pronounced teeth. From the analyses of both the incidental research data, we know that there is seasonal variation in eulachons catch rates (kg/hour) with most incidental capture taken in the summer months. Eulachons are found in waters up to 500 m but most are taken in the depth range of about 100 m (Hay and McCarter 2000).

Trophic Relationships

Eulachons have long been known to be a prey species for many marine fish, and are documented as prey in hake, *Merluccius productus (*Outram and Haegele 1972), dogfish, *Squalus acanthias* (Jones and Geen 1977), and Pacific cod, *Gadus macrocephalus* (Westrheim and Harling 1983). Outram and Haegele (1972) found that about 5% of hake off the southern west coast of Vancouver Island, examined over a 10 day period in 1970, contained eulachons. Hake biomass is sometimes very high and although they eat mainly euphausiids, even modest predation by an abundant predator on a relatively scarce prey species like eulachons, may have a substantial impact. Beamish and MacFarlane (1999) described a recent northward movement of hake, as they have expanded to waters of southeaster Alaska. As hake move into previously unoccupied habitats in Hecate Strait - at least within the last century-their substantial predatory biomass might have resulted in local depletion of eulachons.

Eulachons are sometimes identified as prime prey for marine birds and marine mammals. Predation may be intense just prior to spawning when pre-spawning eulachons concentrate in the lower reaches of rivers. Eulachon stomachs from offshore waters indicate that mainly consume the euphausiid *Thysanoessa spinifera*. It is not clear, however, if apparent changes in *Thysanoessa* spp. are related to changes in eulachon abundance.

Assessments

There are few direct estimates of spawning biomass from any river in BC, but the available estimates were summarized by McCarter and Hay (2000) and an updated version is shown here in Table 2. There are few catch data and most of the available data were recorded informally. Larval samples have been used to assess the abundance of the Kitimat and Fraser River adult eulachon spawning biomass (Pedersen *et al.* 1995 and Hay *et al.*1997b). In some rivers, total larval production can be estimated as the product of the mean larval density (numbers per m^3) and the river discharge (m^3 per second). The conversion from larval numbers to spawning biomass uses estimates of 'relative' fecundity which is about 600-700 eggs per gram of spawning female or 300-350 eggs/g with males included. Therefore spawning biomass = [mean larval density] x [discharge]/relative fecundity). A few such assessments have been made on rivers, including one from the Nass, based on unpublished data from U. Orr (DFO) and shown in Table 2.

A few other assessments were based on direct observations and estimates of the dimensions of pre-spawning or spawning eulachons in rivers adjacent to Hecate Strait. This was done by helicopter survey and, after adjusting for differences in structure and density of schools, resulted in an estimate of 3.2 million spawners or about 150 tonnes (Triton, MS 1991). Obviously this method requires relatively clear water and logistical support. Even when directly observed, the estimates could be coarse, although with experience and corroborative information, this method may have application in a few non-turbid rivers (Kemano River, Triton, MS 1990 and 1991).

We have only a few estimates of the biomass from rivers in the central coast of BC (Table 2). An estimate was made for the Kitimat River in 1993 (Pedersen *et al.* 1995) of about 23 tonnes (based on an estimate of the number of discharged larvae of 5.7 x 10^9 and a relative fecundity of 250 egg/g). From aerial surveys, Triton Consultants (MS 1991) estimated a mean spawning escapement of 4.96 x 10^6 fish plus 1.875 x 10^6 fish taken in the fishery. At an approximate mean weight of about 50g/fish, the total spawning run (before catch) would have been about 340 tonnes, and this estimate was regarded as conservative because it did not include fish that entered and left the river prior to the survey, or after the survey. In 1991, eulachons may have spawned in other rivers in the Gardner Canal, such as the Kitlope and Kowesas, and their spawning biomass is unknown. Therefore we can only guess at the total biomass, but it seems probable that the upper Gardner Canal, which drains 3 major eulachon rivers (Kemano, Kitlope and Kowesas) could support eulachon spawning populations

Table 3. Summary of catch data from BC rivers, and an 'offshore index' estimated from analyses of eulachon densities in data collected during offshore shrimp surveys (from unpublished data from N. Olsen, DFO). + indicates year of high offshore biomass (1992, 2000); - years (1993) when catches declined in the Fraser and Columbia rivers (see text for discussion). * years when no data was available, and 'nr' (not recorded) indicates years when a catch of unknown size was observed. Bella Coola River catches from unpublished data provided by Russ Hilland, DFO, Bella Coola, BC. (Table modified from Hay and McCarter 2000). t = tonnes.

Year	Nass t	BellaCoola t	Knight t	Fraser t	Columbia t	Offshore Index
1929	450	*	*	*	*	*
1930	45	*	*	*	*	*
1938	*	*	*	*	520.80	*
1939	*	*	*	*	1548.20	*
1940	*	*	*	*	1541.25	*
1941	*	*	*	50.14	1265.90	*
1942	*	*	*	152.74	1343.00	*
1943	*	*	*	154.79	1988.65	*
1944	80	nr	*	65.70	1134.25	*
1945	*	~8	*	73.87	2859.65	*
1946	*	~10	*	115.71	1638.00	*
1947	*	nr	135.0	231.10	772.45	*
1948	*	20.0	*	112.80	1987.05	*
1949	*	8.5	70.0	102.70	1666.80	*
1950	*	44.0	100.0	36.20	741.25	*
1951	*	10.0	20.0	189.30	758.45	*
1952	*	12.3	27.5	421.00	637.45	*
1953	2250	41.7	*	158.60	855.50	*
1954	1750	69.4	*	151.60	942.15	*
1955	*	7.6	*	238.80	1118.55	*
1956	575	6.2	*	235.50	841.95	*
1957	267	5.6		33.20	789.50	*
1958	260	8.4	*	92.10	1308.20	*
1959	250	7.0	45.0	132.00	878.05	*
1960	300	0.3	60.0	84.00	586.10	*
1961	350	2.0	*	216.90	526.15	*
1962	450	2.8	70.0	178.20	736.80	*
1963	300	8.4	*	159.30	538.55	*
1964	*	22.4	*	105.50	420.90	*
1965	20	11.8	100.0	87.80	455.35	*
1966	66	9.2	*	101.90	514.15	*
1967	35	11.5	100.0	86.80	500.40	*
1968	415	10.6	100.0	46.00	473.75	*
1969	260	7.8	80.0	29.80	541.85	*
1970	250	9.2	40.0	71.70	591.95	*
1971	200	16.8	20.0	34.50	888.35	*
1972	300	6.7	50.0	53.20	821.75	*
1973	200	12.3	40.0	53.10	1217.20	329
1974	*	10.6		75.30	1180.90	
1975	*	12.0		27.70	1038.80	987
1976	*	50.0	*	36.70	1537.55	1076
1977	*	35.0	50.0	32.20	876.50	2240
1978	300	25.0	*	38.60	1340.15	1269
1979	*	19.8	*	22.30	578.35	1157
1980	*	33.0	*	24.40	1605.75	1304
1981	*	38.5	*	21.20	836.15	992
1982	*	22.0	*	13.70	1105.00	2139
1983	239	30.5	*	10.80	1365.20	291
1984	*	30	*	11.80	249.00	
1985	*	nr	*	29.20	1019.00	1419
1986	*	nr	*	49.60	1919.40	
1987	*	nr	*	19.30	947.85	1822
1988	*	nr	*	39.50	1433.85	1937
1989	105	nr	*	18.70	1533.40	932
1990	8	nr	*	19.90	1392.10	1502
1991	*	nr	*	12.30	1475.20	1252
1992 +	*	nr	*	19.60	1836.90	3016
1993 -	*	nr	*	8.70	256.95	1301
1994	*	20.0	*	6.10	21.70	181
1995	135	22.0	*	15.50	220.00	280
1996	nr	nr	*	63.20	4.55	522
1997	147	nr	*	closed	29.30	721
1998	*	nr	*	closed	6.00	324
1999	*	0	*	closed	10.45	460
2000 +	168	0	*	closed	0.00	3163

of 500-1000 tonnes or more. If so, the 1997 estimate of spawning biomass from the larval surveys of 113 tonnes (which includes the Kitimat and Kildala Rivers) would represent about 10-20 % of the spawning biomass in (1991)

Larval surveys described in McCarter and Hay (1999) in estuarine waters provide independent very approximate and conservative estimates of spawning biomass. These estimates indicate that central coast eulachon populations are small, with a low total biomass, at least in the 1990s. This is corroborated by a comparison of single point population biomass estimates made for certain years at different rivers, and by a comparison of catch data among different rivers Table 2).

Eulachon spawning biomass and catch data from BC rivers

There are very few biomass estimates available for any eulachon populations, and most are available only in informal reports. In nearly all instances, these estimates are available for only a single year on rivers adjacent to Hecate Strait and Queen Charlotte Sound: the Nass, Skeena, Kitimat, Kemano, Oweekeno (Bannock), and Kingcome. The available catch data are shown for each river, by year, from 1929 to 2000 in Table 3.

Eulachon populations have supported small commercial fisheries on the Columbia and Fraser Rivers for most of this century. There was a relatively large commercial fishery for eulachons on the Nass River in the early 1900s, when the eulachon was the fifth most important commercially landed species in BC (Langer *et al.* 1977). This has changed so that, except for the Fraser River, the present fisheries are conducted mainly by First Nations people for the production of grease and as a source of food. In the 1940s and 1950s, the commercial fishery on the Fraser River was mainly for a source of food for fur animals and for small local markets for human consumption. The price was low, however, so it is not clear if the historical catches reflected eulachon abundance (catchability) or markets, or both. The limited commercial value probably accounts for the minimal attention paid to this species since the 1940s.

During the last 20 years, nearly all runs in the southern part of their range (California to mid-BC) have declined. In 1994, there was a sudden sharp decline in spawning runs in 3 southern rivers: the Fraser, Columbia and Klinaklini (Knight Inlet) and perhaps in a few other rivers. This 1994 decline led to the continuing closure of the only two commercial eulachon fisheries (Fraser and Columbia Rivers).

The status of eulachons has also changed in other rivers. During the last two decades a run of eulachons in the Kitimat River was impacted by industry (Mikkelson *et al.* 1996). The size of the spawning run diminished and the spawning fish became chemically tainted by effluent and rendered unpalatable. Since the 1950s, another important eulachon spawning river, the Kemano, has had changes in discharge volume as a consequence of diversion of the Nechako River into the Kemano. It is not clear, however, if this change has been deleterious to eulachons. There have been apparent declines in other rivers, but the explanations are uncertain. Forestry-induced impacts are possible, particularly as logging might affect the hydrology of spawning streams, but this has not been thoroughly investigated. Concurrently, there have been changes in the marine habitats of eulachons. One change is the rapid growth of the shrimp trawl fisheries, and eulachons have long been known to be part of the discarded bycatch. Furthermore, there have been some striking changes in the ocean climate, but the direct effects of this on eulachons have not been determined.

The increasing scarcity of eulachons in these and other rivers have concerned many people, especially many First Nations, for whom the eulachon is a very important species. Climate change, as a general explanation for the declines, is consistent with all of the available information about this species, but many people do not readily accept this explanation. Instead, most explanations for changes in eulachon distribution and abundance tend to be related to local concerns, and usually involve habitat damage caused by logging or industry, or bycatch in other fisheries. These issues are summarized in Hay and McCarter 2000.

Factors affecting abundance of eulachons

Fisheries directed at eulachons

There was a commercial fishery on the Nass River in the early 1900s, and the catches were substantial, perhaps several thousand tonnes. This estimate is uncertain however (Hay and McCarter 2000) but it is clear that the Nass supported a large fishery at the turn of the century - and the Nass eulachon fishery was the fifth largest fishery in the Province (Langer *et al.* 1976). In comparison the next largest eulachon fishery is in the Columbia River which is relatively large, at several thousand tonnes per year (Table

1). This catch was maintained for decades at fairly consistent levels, until the mid-1990s when it collapsed.

Except for the Fraser, all other river fisheries for eulachons are conducted by First Nations for their own requirements, of which the rendering of eulachon oil to 'grease' is most important. The significance of the First Nations fishery transcends the collection of fish biomass for consumption. Rather, the collection, rendering and subsequent distribution of grease is an integral part of coastal First Nations culture, and so in some ways it is inadequate to refer to the First Nation's use of eulachons simply as a 'fishery'. The catching, subsequent processing and distribution of eulachons carries much more significance (see Drake *et al.* 1991).

The total catches of First Nations are not available for all rivers, but some data are available. Nass River catches are usually about several hundred tonnes per year. Similarly, the Haisla catches in the rivers within Gardner Canal may amount to approximately 100 tonnes per year. Estimates for rivers in the central coast (Dean Channel, including the Bella Coola) are modest, perhaps 20-30 tonnes per year. Catches from the Klinaklini River may be as high as 50-100 tonnes per year (Stacey 1998). In short, the total eulachon catch is modest.

It seems probable that the present scale of catches may be related to present abundance. That is, if eulachons were ten times as abundant, present catches would be larger. It also seems reasonable to assume that past catches (> 100 years bp) were greater than present. Probably the extensive First Nations grease trading network could not have developed and been sustained with catches at present day levels. This, however, is speculation but it could be subjected to further analysis by determination of the approximate amount of grease production by various First Nations. Therefore potential future work could be directed at obtaining better estimates of past First Nations' catches, because the ratio of raw eulachons to grease production is known (Kuhnlein *et al.* 1982). Similarly, there are estimates of *per capita* grease consumption so it may be possible to estimate the probable catches of previous years.

Habitat change

In rivers adjacent to Hecate Strait, the Kitimat has been subjected to contamination by pollution from industry (Mikkelson et al 1996, Beak Consultants, MS 1998). The impact of extensive logging in the vicinity of fish-bearing streams is better known for salmonids, but there are potential impacts on eulachons as well (Tchaplinsky, in Eulachon Research Council Minutes, 2000). The most plausible impact is a change in the volume and discharge patterns of rivers draining forested areas. There appear to be a number of potentially suitable rivers that eulachons do not use for spawning. Therefore, a concern is that logging may render presently utilized spawning habitat unusable. This could come from subtle changes in water flow or changes in suitable spawning sediments. These are valid concerns, worthy of future diligence relative to habitat protection, but these probably cannot explain the recent decline in eulachons. Rather, in some ways it seems that eulachons are both fussy about their habitat and carefree, spawning in turbid, polluted mud-bottomed areas.

The factors that induce eulachons to spawn in these areas remain unknown. Log handling and booming in rivers was a concern in past years, but now is a concern only in some rivers such as the Fraser. Debris from booming may have direct deleterious impacts on eulachon eggs, although the extent of spawning beneath booming areas is not clear. Log booms in some marine areas may affect both eulachon larvae and juveniles. Perhaps the greatest concerns are in the headwaters of estuaries, where debris and associated anoxic water, could accumulate behind sills. Indeed, perhaps there are no deleterious impacts of booming in marine or estuarine waters, but that remains to be demonstrated. Until it is, caution should prevail.

Offshore trawling and bycatch

In offshore areas, eulachons often are captured and killed as bycatch during trawling operations. In particular, small mesh shrimp trawls sometimes have significant bycatch of eulachons (Hay *et al.* 1998 and 1999). In response to concerns about eulachon bycatch in shrimp trawls, a coast-wide observer program was started in (1997) Estimates of the total catch of eulachons are complicated by many variables in the data. There are several types of shrimp fishing gear, which operate during different seasons and many different fishing areas, some of which have no eulachons, such as the Strait of Georgia. Further, the data used to make the estimates consists of relatively large, complex databases from on-board observers, logbooks of fishing effort, and 'hailed' catch rates. The distribution of commercial fishing effort for 1997 and 1998 is summarized in Fig. 2, and also shows the key eulachon spawning rivers, defined in Fig. 3.

Although we point out that the estimates of total bycatch are only approximate, in general the magnitude of bycatch when compared to the probable sizes of eulachon spawning runs in rivers, is not large. For instance, there probably was about 15-20 tonnes taken by both gear types in 1997 and 1998, off the west coast of Vancouver Island. In contrast, in most years the Fraser River eulachon spawning stock probably is at least several hundred tonnes and in some years, such as 1996, perhaps several thousand tonnes (Hay *et al.* 1997 a). On the other hand, in the Queen Charlotte Sound area, the estimated bycatch was relatively large in 1997 and estimated at 61 tonnes (see Table 8 for Otter trawlers in 1997, in Hay *et al.* 1999), although subsequent analyses with a more complete data set have revised this estimate upwards to about 94 tonnes (N. Olsen, Pers. Comm).

We do not know the spawning biomass of eulachon in the rivers adjacent to the Queen Charlotte Sound area, but probably it is not high, even when runs are considered to be normal. Based on observations and surveys of similar sized rivers in the Gardner Canal (i.e. the Kemano and Kitlope), the main rivers in Smith Inlet and Dean Inlet may have eulachon spawning biomass populations of similar size or several hundred tonnes each, when runs are at 'normal' sizes. When runs are low, the spawning biomass may be much lower. For instance, Pedersen *et al.* (1995) estimated the 1993 spawning biomass of the Kitimat River at about 20 tonnes. If similar biomass levels occurred in 1997 in the central coast areas, then the impact of a 94 tonne bycatch in 1997 is a concern.

On the other hand, based on indices of trawl surveys, there may be 900 or more tonnes of eulachons in marine waters in Queen Charlotte Sound, and this was observed in 2000 (Olsen, Pers. comm.). An optimistic view is that this relatively high biomass estimate, which probably consists of several year classes (see Hay and McCarter 2000 for a discussion of eulachon ages), may represent the first signs of an eulachon 'recovery'. The hope is that this will develop into improved spawning escapement in local rivers in the near future.

Although the shrimp trawl industry probably has not caused the recent decline in eulachons, we cannot rule out the possibility that it could be a factor in limiting the recovery of certain stocks. This is a specific concern in 2000 for central coast (or Queen Charlotte Sound) stocks, some of which may have had no runs for the last 2 years (1999 and 2000). For this reason, shrimp fishing in that area did not occur in (2000)

Ocean Conditions

Although they spawn in fresh water rivers and streams, eulachons are mainly a marine fish, spending over 95% of their total life in marine waters. Except for a brief period of a few months as pelagic larvae and juveniles, they live close to the bottom, on the shelf. Therefore eulachons probably are very susceptible to changes in ocean conditions. Throughout much of their range, from northern California to the southern Bering Sea, ocean climate has changed during the last few decades (DFO 2000). Although changes in ocean climate may account for changes in eulachon populations (Hay *et al.* 1997a) the mechanisms of such change are uncertain. Although relative temperature changes have been significant, the absolute changes are small (~ 1^{o}C) and therefore do not pose any unprecedented thermal limits to the habitation of eulachons throughout most of their range.

Probably the impact of climate change on eulachons occurs through changes in food composition and availability, or in the distribution and abundance of eulachon predators. In this regard, as a possible example, we elaborate on an earlier suggestion that a predator like hake (*Merluccius productus*) may affect eulachons. The recent change in the distribution of hake corresponds roughly to the apparent decline of eulachons, beginning in the south and moving northwards. Probably hake predation is most intense on the smallest, youngest (age 1+) eulachons so the effect of intense predation may not be felt for 2 or 3 years. Although this suggestion is speculative and provided only as an example of how climate change may affect eulachons (through changes in hake distribution) we note that the 1999 year class (observed in 2000 as age 1+) in southern BC waters appears to be strong relative to previous years. At the same time the abundance of hake in the same waters in 2000 was lower in the summer of 2000 (M. Saunders, Pers. Comm). Although we do not understand these relationships the general topic of the effect of ocean conditions on fish populations is receiving a lot of attention. Consequently our general understanding of the effects of climate change may improve in the future, but such understanding may not help to improve the relative abundance of eulachons.

References

Beamish, R.J and G. A. MacFarlane (1999) Sardines return to British Columbia waters. PICES Scientific

Report No 10: 77-82. In Freeland, H.J., Peterson, W.T. and A. Tyler. (Eds) Proceedings of the 1998 Science Board Symposium on the impacts of the 1997/98 El Niño event on the North Pacific and its marginal seas. North Pacific Science Organization. Sidney, BC. 131 pp.

Berry, M. D. (1997) MS. Eulachon research on the Kingcome and Wannock Rivers – final report to the Science Council of British Columbia (SCBC # FR 96/97 – 715). 62 pp.

Berry, M.D. (1996) MS. Knight Inlet – Klinaklini R. Eulachons – (1995) Draft report submitted for the Tanakteuk First Nation, Alert Bay, BC. 17 pp.

DFO (2000) 1999 Pacific Region state of the ocean. DFO Science Ocean Status Report 2000/01; 38 pp.

Drake, Allene and Lyle Wilson (1991) Eulachon, A Fish to Cure Humanity. Museum Notes No. 32, UBC Museum of Anthropology, Vancouver. 37pp.

Eulachon Research Council (2000) Eulachon Research Council, May 2000 Minutes summarizing meetings in New Westminster, Terrace and Bella Coola, BC. Informal joint report prepared jointly by BC Forests and Fisheries and Oceans, Canada. 24 pp.

Eulachon Research Council (1998) Eulachon Research Council, March 1998 Minutes summarizing meetings in Terrace and Simon Fraser University, Vancouver, BC. Informal joint report prepared jointly by BC Forests and Fisheries and Oceans, Canada. 16 pp.

Hay, D.E. and P.B. McCarter (2000) Status of eulachons *Thaleichthys pacificus* in Canada. Can. Stock Assessment Research Document (2000) 145: 92 pp.

Hay, D.E., J. Boutillier, M. Joyce and G. Langford (1997a) The eulachon (*Thaleichthys pacificus)* as an indicator species in the North Pacific. Wakefield Fisheries Symposium. Alaska Sea Grant College Program 97-01: 509-530.

Hay, D.E., P. B. McCarter, M. Joyce, and R. Pedersen (1997b) Fraser River eulachon biomass assessments and spawning distribution based on egg and larval surveys. PSARC Working Paper, November 1997. 60 pp.

Hay, D.E., R. Harbo, C. E. Southey, J. R. Clarke, G. Parker, P. B. and P.B. McCarter (1998) Catch composition of British Columbia shrimp trawls and preliminary estimation of bycatch - with emphasis on eulachons. PSARC Working Paper, January 1998. 40 pp.

Hay, D.E., J. Boutillier, M. Joyce and G. Langford (1997a) The eulachon (*Thaleichthys pacificus)* as an indicator species in the North Pacific. Wakefield Fisheries Symposium. Alaska Sea Grant College Program 97-01: p 509-530.

Kuhnlein, H.V., A.C. Chan, J.N. Thompson and S. Nakai (1982) Ooligan Grease: a nutritious fat used by Native people of coastal British Columbia. J. Ethnobiol. 2: 154-161.

Langer, O.E., B.G. Shepherd and P.R. Vroom (1977) Biology of the Nass River eulachon. 1977. Dept. of Fisheries and Environment Tech. Rep. Series PAC/T-77-10. 56 pp.

Jones, B.C. and G.H. Geen (1977) Food and feeding of spiny dogfish (*Squalus acanthias*) in British Columbia waters. 1977. J. Fish. Res. Bd. Can. 34: 2067-2078.

Lewis, A.J.L. MS. (1997) Skeena eulachon study. A report prepared by Triton Environmental Consultants for the Tsimshian Tribal Council. 23 pp.

McCarter, P.B. and D.E. Hay (1999) Distribution of spawning eulachon stocks in the central coast of British Columbia as indicated by larval surveys. PSARC P99- 8: 64 pp.

Mikkelson, P., J. Paasivirta, I.H. Rogers and M. Ikonomou (1996) Studies on Eulachon Tainting Problem: Analyses of Tainting and Toxic Aromatic Pollutants. In Servos, Munkittrick, Carey and Van Der Kraak (Eds) *Environmental Fate and Effects of Bleached Pulp Mill Effluents*. Delray Beach, FL, 327-333 .

Nisga'a Fisheries crew and Nortec Consulting. MS. (1990) Nisga'a Eulachon Fishery 1990. Nisga'a Tribal Council. 24 pp.

Orr, U. MS (1984) 1983 Eulachon sampling on the lower Nass in relation to log handling. Draft Report, Fisheries and Oceans. North Coast Habitat Management. Price Rupert. 25 pp.

Outram, D.N. and C. Haegele (1972) Food of Pacific hake (*Merluccius productus*) on an offshore bank southwest of Vancouver Island. J. Fish. Res. Bd. Can. 29: 1792-1795.

Pedersen, R.V.K., U.N. Orr and D. E. Hay (1995) Distribution and preliminary stock assessment 1993 of the eulachon , *Thaleichthys pacificus*, in the Kitimat River, British Columbia. Can. Man. Rep. Fish. Aquat. Sci. 2340. 40 pp.

Ricker, W.E., D.F. Manzer and E.A. Neave (1954) The Fraser River eulachon fishery 1941-1953. Fish. Res. Bd. Canada. MS.Rep. Biol. Sta., No. 583, 35 pp.

Simenstad, C., M. Methier, C.D. Levings, and D.E. Hay (1996) The land-margin interface of coastal temperate rain forest ecosystems: shaping the nature of coastal interactions. *In* The Rainforests of home: an explanation of people and place. Ecotrust, Island Press. 618 pp.

Slaney, T.L., K.D. Hyatt. T.G. Northcote & R.J. Fielden (1996) Status of anadromous salmon and trout in British Columbia and Yukon. Bulletin of the American Fisheries Society 21: 20-35.

Stacey, D. (1996) Eulachon, Eulachon, Eulachon. MS. Unpublished report on the historical eulachon fisheries of BC. Prepared for the Department of Fisheries and Oceans. 75 pp.

Stacey, D. (1998) MS. An historic overview of the Kwawkewlth, Knight, and Kingcome Inlet oolachon fishery. Unpublished report on the historical eulachon fisheries of BC. Prepared for the Department of Fisheries and Oceans. 13 pp.

Triton (1991) MS. Freshwater life history of the eulachon (*Thaleichthys pacificus)*, of the Kemano and Wahoo Rivers, B.C. Draft Report. Triton Consultants.

Triton (1990) MS. Life history of the eulachon (*Thaleichthys pacificus)*, of the Kemano and Wahoo Rivers, B.C. Draft Report. Triton Environmental Consultants.

Westrheim, S.J. and W.R. Harling (1983) Principal prey species and periodicity of their incidence in stomachs of trawl-caught Pacific cod (*Gadus macrocepahlus*), Rock sole (*Lepidopsetta bilineata*), and Petrale sole (*Eopsetta jordani*) landed in British Columbia 1950-1980. Can. MS. Rep. Fish. Aquat. Sci. 1681: 38 pp.

WORKSHOP NOTES ON EULACHON

Marcelo Vasconcellos and Tony Pitcher
Fisheries Centre, UBC

Drake *et al.* (1991) give a historical perspective on eualchons in First Nations culture. DH reviewed the information about eulachon in the model area. The central and north coast populations are in bad shape. For instance, the eulachon fishery in the Nass river was the 5th largest fishery in BC in the early 1900s, but now the biomass is probably much lower. Not much is known about the runs of the Skeena river. DH guessed that eulachon biomass in the past should be one order of magnitude higher than at the present time. He also suggested that the pristine biomass in the Skeena could be calculated from grease production data.

Shrimp fishery bycatch data is also available, and could be used to estimate eulachon biomass in the shelf area (e.g. in some cases bycatch of eulachon can sum up to 10kg/hour trawling). Eulachon are demersal and their diet is based mostly on Euphausiids. Given their demersal habitat, their importance to sea birds diet should be reduced in the model. The importance of the species in marine mammal diets should be further investigated.

Model parameters

Assuming that catches in the 1990s reported by Hay (this vol.) in Table 2 are representative of the average catches to the present time period, the total catch is estimated at ca. 366 tonnes. As stated by Hay (this vol) catches, and biomass, in the past were probably much higher than in the present. There are records of eulachon catches by Nisga'a tribes in the Nass river in the order 300 tonnes in the 1890s (Figure 1).

There was a common knowledge among fishers and First Nations in the Prince Rupert BTF workshop (Beattie *et al.* 1999) that biomass of eulachon is down 25 to 30% between past and present conditions. In northern BC, eulachon is protected from commercial fisheries, and only First Nations maintain a fishery for them. They were plentiful in some spawning rivers but their abundance has declined sharply in recent years (DFO 1999). In the Skeena and other northern BC rivers there were usually three or four runs, and each run was used for a different purpose by First Nations, due to change in oil content.

First Nations told of a decrease in abundance and reduction in the number of runs in recent years. Hay (this vol) discussed the decline in abundance of eulachon in recent years, and suggested some possible reasons (pollution, habitat changes, bycatch in shrimp trawlers, etc.). It seems that the 1999 eulachon run was unprecedentedly low in most BC rivers.

Biomass of eulachon in the three historical periods was estimated by the model, with an ecotrophic efficiency of 0.95, and the remaining parameters were assumed to be the same as for other forage fish.

A tentative catch value for the early 1900s was estimated assuming that catches were one order of magnitude higher than in the present time, i.e. 3,000 tonnes/year. The same value was input to the pre-contact model. Eulachon are probably most vulnerable to predation during spawning months (April and May), when they aggregate in large schools and migrate up the rivers. In the model it was therefore assumed that 1/6th of the predation on forage fish was directed to eulachon.

References

Beattie, A. Wallace, S. and N. Haggan (1999) Report of the BTF workshop on reconstruction of the Hecate Strait Ecosystem, p. 1-12 In Haggan, N. and A. Beattie (eds). Back to the Future: reconstructing the Hecate Strait ecosystem. Fisheries Centre Research Reports 7(3): 65 pp.

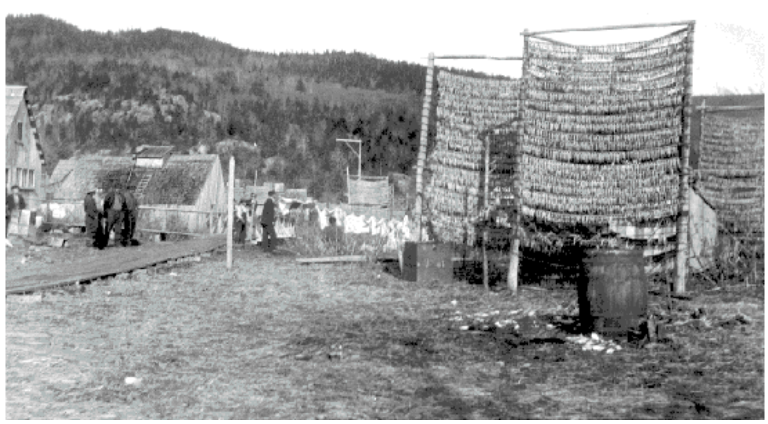


Figure 1. Picture of First Nations drying eulachon in the Nass river ca. 1890 (source BC Archives, c-07435, www.bcarchives.gov.bc.ca)

DFO (1999) Eulachon. DFO Stock Status Report B6-06 (1999). 5pp.
Drake, Allene and Lyle Wilson (1991) Eulachon, A Fish to Cure Humanity. Museum Notes No. 32, UBC Museum of Anthropology, Vancouver. 37pp.

WORKSHOP NOTES ON INVERTEBRATES

Marcelo Vasconcellos and Tony Pitcher
Fisheries Centre, UBC

Aboriginal fisheries for invertebrates always existed. Commercial fisheries for some species started only in the mid-1900s. The species harvested include barnacles, clams, crabs, sea urchins, sea cucumbers, crabs and shrimp. An industrial fishery for Dungeness crab was already established in northern BC by the 1930s (DFO 1999a). It is now the second most valuable invertebrate fishery in the province. All stocks are considered to be fully exploited. Commercial fisheries use traps deployed from small boats operating in estuaries and coastal inlets. Fishing effort has increased substantially along all areas of the coast during the last decade (DFO 1999a).

A commercial fishery for geoduck has existed on the north coast since 1980 (DFO 1999b). Geoduck is managed under a 1% per year exploitation rate.

The commercial fishery for green and red sea urchins started in BC in the 1980s (DFO 1999c; 1999d) - it is a roe fishery, conducted by divers, with the product exported to Asia. The red sea urchin is managed with a target exploitation rate of 2 to 3%.

The north coast fishery for sea cucumbers was opened in 1986 (DFO 1999e). The central and north coast now supports ca. 80% of the fishery in BC. Sea cucumbers are managed by a 4.5% harvest rate approximated quota.

The fishery for shrimps (*Pandalidae*) in BC was initiated in the 1960s (DFO 1998). Historically, the main fishing grounds were the Georgia Strait where the fishery is conducted by small beam trawl vessels, the inshore inlets of the North Coast by small local beam trawl vessels, and off the west coast of Vancouver Island where the fishery is conducted by otter trawls. In 1996, the fishery expanded to offshore areas of the Central coast using small and large vessels. The west coast of Vancouver Island has historically been the main shrimp fishing ground, accounting for 80 to 90% of total BC landings. Surveys conducted in this regions show marked declines in shrimp biomass. There are no survey data for the north and central coast.

The 'prawn', *Pandalus platyceros*, the largest species of shrimp in BC, is also fished with traps deployed on longlines (DFO 1999f). The annual catches from this fishery has been increasing since the 1980s, catches in the late 1990s exceeded 1,700 tones in the whole BC coast. About 23% of total catches are taken in northen BC, DFO areas 1 to 10 (DFO 1999f).

Opal squid, *Loligo opalescens*, are fished primarily as bait for sablefish, crabs and halibut, mostly using seine nets (DFO 1999g). DFO presents catch records since 1984. Historically the west coast of Vancouver Island was the main fishing ground for opal squid, but recently, (1995 1997 and 1998), the north coast was responsible for most of the BC landings. A new fishery for the neon flying squid, *Ommastrephes bartrami*, is currently being promoted by Canada (DFO 1999h), but has not yet acquired significance.

In the absence of biomass data for invertebrates, the groups were assigned the same biomass in the three preliminary models. Harvest in the early 1900s and pre-contact models was assumed to be insignificant.

Workshop notes

Glenn Jamieson presented an overview of the status of invertebrate fisheries in BC. The bottom of Hecate Strait is carpeted with benthic invertebrates, feeding mainly on detritus. Shrimps are present in the area with a small population of *Pandalus borealis*. Tanner and snow crabs had weak recruitment in Queen Charlotte sound in recent years. An important fishery existed for Dungeness crabs up to 1968, carried out only a few miles offshore by many U.S. boats; the fishery collapsed after 1968. In the 1980s ca. 12,000-13,000 tons of Dungeness were landed along the BC coast, but only 3-4 tons in the Hecate Strait. The fishery now exploits ca. 1/3 of the population, mostly males. It appears that Hecate Strait is intermittently served by an influx of larvae from the southern area.

There is a suspicion that the large population of sandlance may keep down the population of Dungeness crabs, as sandlance consume recently settled crabs.

Not much is known about squids. Red squids occur in deeper waters, while opal squids are closer to Vancouver Island. Recent fishing experiments for squids were conducted in the study area. Biomass of squids in the past is probably the same as now.

Sea urchins and geoduck are fully exploited, both fisheries started in the late 1980s. Urchins have an average age of 3 to 15 years, but may live up to 40 years; geoducks have a median age of 50 years, but may live up to 100 years. There are no large fisheries for sea cucumbers, although the species may be abundant in certain areas.

Secondary production in the area is probably driven by copepods and not much by euphausiids. Concentrations of zooplankton are associated with oceanographic /upwelling domains on the shelf. DH suggested papers by Perry which identifies oceanographic domains in the area (Perry 1994, Perry & Dolke 1986, Perry & Waddell 1994).

There are no indications that overfishing of higher trophic level organisms has changed the plankton biomass in Hecate Strait. Primary and secondary production were assumed the same among the three reference periods.

References

DFO (1998) Shrimp trawl fishery off the west coast of Canada. DFO Stock Status Report C6-08, 1998. 4 pp.

DFO (1999a) Dungeness crab coastal fisheries. License areas B, E, G, H, I & J. DFO Stock Status Report C6-14, 1999. 4 pp.

DFO (1999b) Geoduck clam. DFO Stock Status Report C6-05, 1999. 3 pp.

DFO (1999c) Red sea urchin. DFO Stock Status Report C6-09, 1999. 3 pp.

DFO (1999d) Green sea urchin. DFO Stock Status Report C6-11, 1999. 4 pp.

DFO (1999e) Giant red sea cucumber. DFO Stock Status Report C6-10, 1999. 5 pp.

DFO (1999f) The prawn (*Pandalus platycerus*) off the west coast of Canada. DFO Stock Status Report C6-07, 1999. 4 pp.

DFO (1999g) Opal squid. DFO Stock Status Report C6-04, 1999. 3 pp.

DFO (1999h) Neon flying squid. DFO Stock Status Report C6-12, 1999. 4 pp.

Perry, R.I. (1994) Plankton blooms of the British Columbia northern shelf: seasonal distributions and mechanisms influencing their formation. Ph.D. Thesis, University of British Columbia. 220 pp.

Perry, R.I., and B.R.Dilke (1986) The importance of bathymetry to seasonal plankton blooms in Hecate Strait, B.C. Pages 278-296 in M.J. Bowman, C.M. Yentsch and W.T. Peterson (Eds) Tidal Mixing and Plankton dynamics. Lecture Notes on Coastal and Estuarine Studies. Springer-Verlag, New York.

Perry, R.I., and B.J.Waddell (1994) Zooplankton in Queen Charlotte Island waters: distribution and availability to marine birds. Canadian Wildlife Service Occasional Paper Series. 32pp.

HEXACTINELLID SPONGE REEFS ON THE BRITISH COLUMBIA SHELF

Kim W. Conway
Geological Survey of Canada, Sidney, BC

Hexactinellid sponge reefs occur in the broad, glacially scoured troughs of Hecate Strait and Queen Charlotte Sound (DFO 2000). The reefs consist of dense populations of siliceous sponges that cover bioconstructions that are up to 18 m high and kilometres wide. The three main sponge species associated with reef construction are all members of the Subclass Hexactinosa with a siliceous, rigid framework skeleton. Sponge biomass is estimated to be approximately 300t/km^{-2} in areas of sponge reef that have not been affected by bottom trawling and other forms of seafloor impacts. In areas that have been trawled, nearly complete removal of these fragile, slow growing benthos has occurred. Submersible dive transects across sponge reefs indicate that in some areas living sponges cover the entire surface of the reef. Repetitive side-scan sonar surveys at one reef complex in Queen Charlotte Sound in 1988 and 1999 suggest that impacts by otter trawl equipped vessels have impacted an outer zone of the complex within this time period. We estimate that 30-50 % of the total sponge reef area has been affected by trawling and other forms of seafloor impacts through fishing.

Sponge reefs were discovered on the continental shelf of western Canada in 1987 and 1988 during regional geophysical surveys (Conway *et al.* 1991). The total area covered by sponge reefs or sponge mud mounds is about 700 km^2 and the height of the largest bioconstructions is 20 m. The numbers of sponges can be as high as 10 per square metre and the sponges can cover virtually the entire seafloor. These reefs are of great interest to earth scientists due to their similarity to extinct reef types which were widespread in Mesozoic time. These reefs are considered to be a type of "living fossil" (Krautter *et al.* 2000). The sponges are thought to grow slowly, about 1 cm per year (Conway *et al.* 1991) and the oldest reefs began to grow about 8500-9000 years ago (Barrie *et al.* 2000).

General observations of sponge densities on reef areas suggest that areas of high relief have increased sponge population density while low lying, flat accumulations display less dense sponge communities. The density of sponges in all areas is quite variable and ranges from 0 - 10 sponges/m². The size of individual sponges may be up to 3 m wide and 1.5 m in height. The coverage of the reef surface by living sponges varies from 0 - 100 % with an average or normal coverage of about 25%. We estimate from submersible dive data that the numbers and size of sponges that exist on an "average" area of reef to be 0.5 sponges, 50 cm in height per m². Hexactinosan sponge skeletons are very light. For example a 1-m tall *Chonelasma calyx* sponge skeleton is about 1.5 kg dry weight. Even though the sponge surface area is large, the organic, respiring tissue of the sponge is only about 5 % of this weight (W. Austin personal communication, 2000). Using these assumptions then, the biomass (including the skeletal weight) of the sponges on the surface of the reefs is likely to be on the order of 0.3 kg/m² or approximately 300 t/km².

The areas subject to impact by trawling and other types of fishing are estimated to be between 30-50 % of the total area of the sponge reef complexes. Dive data were only collected at the Hecate Strait sites and not in Queen Charlotte Sound so a large uncertainty exists regarding the nature and extent of impacts sustained to date. Types of damage observed in dive transects include broken sponges removed at the base, swaths of crushed sponges and abraded or broken distal portions of sponges (Conway 1999). Some areas have essentially no living sponges on the surface of the reefs, normally in what are considered to be heavily impacted areas. Seafloor areas of high relief are most likely to have abundant living sponges whereas low relief areas of sponge reefs are less populated. The periphery of the sponge reef complexes seems to be most susceptible to trawling impacts (Conway *et al.* 2000). If a 30 – 50 % reduction in sponge populations has occurred since the initiation of bottom dragging then the biomass value we would assign to all the sponges on the sponge reefs in total would be on the order of 150 – 210 t/km².

Workshop notes

Kim Conway showed results from surveys conducted in Hecate Strait using side-scan sonar data and submersible video. These sponges form highly structured agglomerations, some 20 meters high from the sea floor, in places as deep as 165-200 meters.

These sponge reef complex (Hexactinellid sponges) were believed to have vanished during the Cretaceous. Much of southern Europe seafloor was once covered by a 7,000 km long sponge reef structure, perhaps the largest biotic structure that ever existed on earth (more than 3 times the size of Australia's Great Barrier reef). Sponges' patchy distribution was apparently limited to places were they could anchor. It is estimated that these structures (15 x 15 km) cover approximately 1,000 km² of the sea floor. In the present day model we currently have estimates in the order of 750 km², which should be increased to match this estimate.

The growth rate of these sponges has been estimated at 1cm/year. It was suggested that P/B ratio should be in the order of 0.01 year^{-1}, instead of 0.05 year^{-1} as it is now in the model. Although trawlers operate mostly in the periphery of the sponges complex (they tend to avoid trawling in the areas of sponges), he reckoned that some areas must have been impacted by trawling in the past which points to relatively smaller biomass now relative to the early 1900s. The fauna associated with sponges was composed mainly of shrimps, crabs and juvenile rockfishes.

References

Barrie, J.V., Conway, K.W., Krautter, M., Austin, W.C. and Neuweiler, M. (2000) Siliceous Sponges as Ultra-conservative Reef Builders: Submersible and Geophysical Observations of Modern Hexactinellid Reefs. Geological Association of Canada Annual Meeting. Program with Abstracts.

Conway, K.W. (1999) Hexactinellid sponge reefs on the British Columbia continental shelf: geological and biological structure with a perspective on their role in the shelf ecosystem. Canadian Stock Assessment Secretariat Research Document 99/192.

Conway, K.W., Barrie, J.V., Austin, W.C. and Luternauer, J.L. (1991) Holocene sponge bioherms on the western Canadian shelf. Continental Shelf Research, 11: 771-790.

Conway, K.W., Krautter, M., Barrie J.V., Austin, W.C. and Neuweiler, M. (2000) Extant hexactinellid sponge reefs: our endangered seafloor heritage. Geological Association of Canada Annual Meeting. Program with Abstracts.

DFO (2000) Hexactinellid sponge reefs on the British Columbia continental shelf: geological and biological structure. DFO Pacific Region Habitat Status Report 2000/02.

Krautter, M, Barrie, J.V., Conway, K.W., Austin, W.C. and Neuweiler, M. (2000) Hexactinellid sponge reefs in the past, present and future. Geological Association of Canada Annual Meeting. Program with Abstracts.

MACROPHYTES OF THE HECATE STRAIT

Norm A. Sloan
Parks Canada, Queen Charlotte City, BC

The plant-structured communities are important to the nearshore ecosystems of Hecate Strait. Conspicuous Macrophytes, associated with rocky shores to ~35 m depth, include kelp (large brown seaweed) forests. These provide tissue for herbivores, detritus into coastal food webs and shelter for many species (nurseries for juveniles - habitat for adults). The main harvest of kelp is for First Nations and commercial herring spawn-on-kelp. The ecologically important marine vascular plant (seagrass) meadows rooted along sheltered sediment shores are not discussed here.

Hecate Strait is biogeographically interesting as it represents the southern extreme of the northern seaweed flora (Sloan and Bartier 2000). Further, the Haida Gwaii (oceanic outer coast) side of Hecate Strait has floristic differences compared to the (fjordic, continental inner coast) mainland. For example, within Southeast Alaska (~60° N to Dixon Entrance), O'Clair *et al.* (1996) identified three seaweed areas: "*outer coast*" (warmer, higher salinity), "*northern inside waters*" (colder, lower salinity) and "*southern inside waters*" (warmer, lower salinity). Although they share many species, each area also had distinct species.

Essential to understanding the role of macrophytes is the extirpation of sea otters (*Enhydra lutris*) from the region around the end of the 19th century (Watson *et al.* 1997). This likely led to an explosion of their herbivorous sea urchin (*Strongylocentrotus* spp.) prey with attendant kelp deforestation and the formation of urchin-dominated "barrens". Barrens occur as a band of encrusting coralline algae on rocks denuded of fleshy algae seaward of kelp forests. For example, ~50% of rocky coastline of Gwaii Haanas National Park has kelp forest, half of that also has urchin barrens (Sloan and Bartier 2000). The likely return of sea otters throughout Hecate Strait could promote significant kelp reforestation as urchins are eaten by otters. Animals from Alaska were returned to the northwest of Vancouver Island in 1969-1972 and expanded rapidly. In Hecate Strait, an established population has been known from the Goose Islands since 1989. Population increase could be rapid as otters can expand at >15% annually in new areas within their historical range (Watson *et al.* 1997).

Although the impacts of episodic storms and oceanographic events such as El Nino / La Nina (Tegner *et al.* 1997) are unknown for Hecate Strait macrophytes, they likely could be modeled for based on inferences from research done elsewhere.

Our knowledge of north coast macrophytes and their ecology is poor (Sloan and Bartier 2000). Between 1977 and 1981, the B.C. Ministry of Environment published five parts of its "Kelp Inventory 1976" of this region shown in Figure 4.1 (Coon *et al.* 1981). These are the most recent published kelp standing crop biomass estimates. They focus only on the two largest, canopy-forming species: giant kelp, *Macrocystis integrifolia* / bull kelp, *Nereocystis luetkeana*. Survey areas ranged from 885 to 2,375 ha and biomass from 25.9 to 47.4 tonnes per ha (2,590 t/km^2 to 4,740 t/km^2). These are crude estimates based on two species among the region's 26 species of the kelp Order Laminariales and in a region where there are >350 seaweed species (Sloan and Bartier 2000).

The B.C. Land Use Coordination Office [LUCO] (http://www.luco.gov.bc.ca) has completed biophysical shore classification of most of Hecate Strait. Haida Gwaii and the north mainland coast south of Prince Rupert to Washington State are classified. The mainland coast north of Prince Rupert to Stewart is currently being done. Shore morphology and exposure (wave climate) provide an hierarchical framework that underpins biotic description. The shoreline is segmented into homogenous units according to substrate, grade and exposure. The biotic component uses this framework for overlaying the bio-bands (zonation) and species data. Therefore, it would be possible to infer the linear extent of macrophytes (kelp forest) around Hecate Strait from LUCO databases, and perhaps to calibrate kelp forest area using Coon *et al.* (1981) methods and data.

Local commercial red sea urchin (*S. franciscanus*) landings began in the early 1980s. Mean entire north coast annual landings from 1993 to 1999 were ~5,500 tonnes. It is questionable whether increased kelp biomass resulting from current urchin harvest is detectable.

Little is known of the extent of macrophytes in the region at ~1900. Sea otter populations were likely extirpated throughout much of Hecate Strait leading to intense urchin grazing and generally lower regional kelp forest biomass compared to pre-contact.

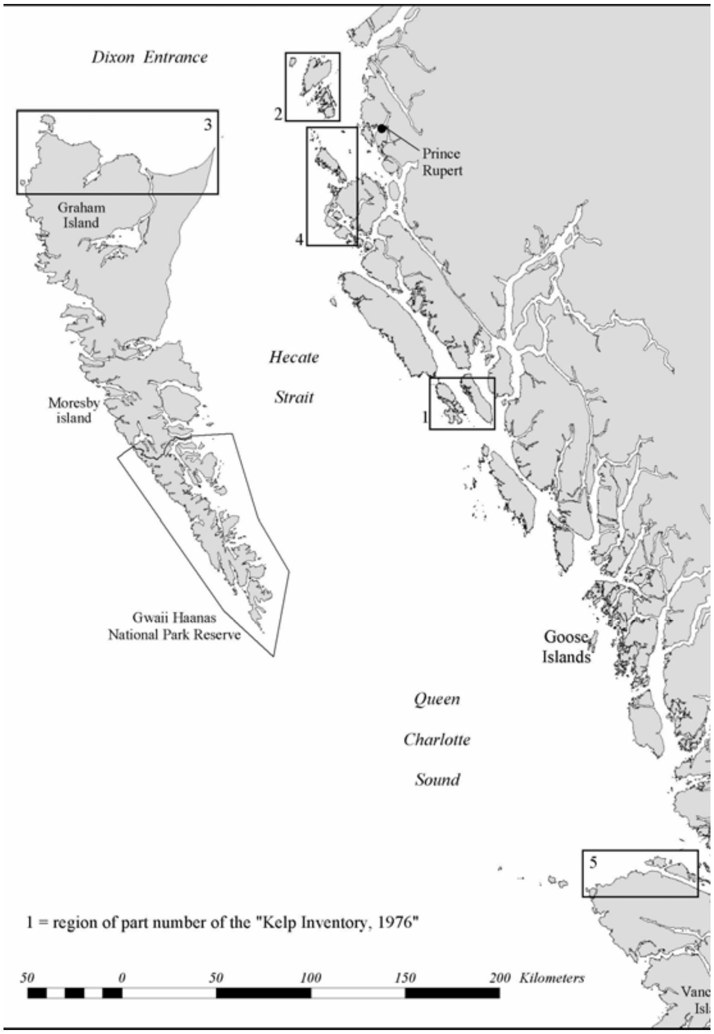


Figure 1: Map of Hecate Strait indicating the Goose Islands and the five locations of the B.C. "Kelp Inventory 1976" (courtesy of P.M. Bartier, Gwaii Haanas).

Aboriginal hunting could have indirectly influenced biomass of macrophytes. On the one hand, intense sea otter hunting for the post-contact fur trade did not occur. On the other, aboriginal populations were much greater and more dispersed along the coast e.g., Moresby Island - Acheson (1998). Localized hunting for domestic use perhaps created low otter populations adjacent to human settlements. Overall, there would likely have been more otters, and more kelp forest, than around 1900.

The ecological role of Steller's sea cow (*Hydrodamalis gigas*) in this region was discussed by Sloan and Bartier (2000). This large, non-diving kelp grazer lived in herds throughout the North Pacific, were extirpated from many regions for centuries and finally became extinct by 1780. Speculation on the ecological relationships of Steller's sea cow include it's role as specialized grazer of kelp forest canopy maintained in quantity by sea otter predation on sea urchin herbivores. Removal of sea cow herds would likely have led to greater kelp biomass (Pitcher 1998) .

Workshop notes

Parks Canada has a database of seagrass occurrence in Haida Gwaii. The database includes maps with kelp distribution. NS commented that *Sargassum* was introduced in Hecate Strait, but has been present since 1900s. Mediation effects of seagrasses with juvenile fish were suggested to be included in model simulations. Much of the dynamics of seagrasses should be linked to the presence of sea otters. Probably the biomass now is the same as 1900s, but it was likely higher in the 1740s when sea otters were abundant.

Model Parameters

Macroalgae biomass in the present time model is 5.28 $t.km^{-2}$ (Beattie 2001). Sloan and Bartier (2000) suggested processes occurring at historical reference points that were likely to result in changes of macroalgae biomass. First the extirpation of sea otters throughout much of Hecate Strait in the early 1900s might have led to intense urchin grazing and lower kelp biomass compared to pre-contact.

Second, the current exploitation of sea urchin in the study area may cause an increase in kelp biomass, although the changes are difficult to detect. In the preliminary models we assumed that biomass in the early 1900s was the same as the present time model, and that biomass at pre-contact was 2 times higher than the present time, i.e. 10.56 $t.km^{-2}$.

References

Acheson, S.R. (1998) In the wake of the *ya'aats' xaatgaay* ["Iron People"]: a study of changing settlement strategies among the Kunghit Haida. British Archaeol. Rep. Internat. Ser. 711: 209 p.

Beattie, A.I. (2001) A new model for evaluating the optimal size, placement and configuration of marine protected areas. M.Sc. Thesis, University of British Columbia.

Coon, L.M., W.G. Roland, E.J. Field, E.A.C. Clark and W.E.L. Clayton 1981. Kelp inventory 1976. Part 5. North coast Vancouver Island, Hope, Nigei and Balaklava Islands. Mar. Res. Branch Fish. Dev. Rep. 20: 20 p.

O'Clair, R.M., S.C. Lindstrom, and I.R. Brodo (1996)

Southeast Alaska's rocky shores seaweeds and lichens. Plant Press, Auke Bay, AK. 152 p.
Pitcher, T.J. (1998) Pleistocene Pastures: Steller's Sea Cow and Sea Otters in the Strait of Georgia. Pages 49-52 in Pauly, D., T. Pitcher and D. Preikshot (Eds). Back to the Future: Reconstructing the Strait of Georgia Ecosystem. Fisheries Centre Research Reports 6(5): 99pp.
Sloan, N.A. and P.M. Bartier (2000) Living marine legacy of Gwaii Haanas. I: Marine plant baseline to 1999 and plant-related management issues. Parks Canada, Halifax, NS, Tech. Rep. Ecosystem Sci. 27: 104 pp.
Tegner, M.J., P.K. Dayton, P.B. Edwards and K.L. Riser (1997) Large-scale, low-frequency oceano-graphic events on kelp forest succession: a tale of two cohorts. Mar. Ecol. Prog. Ser. 146: 117-134.
Watson, J.C., G.M. Ellis, T.G. Smith, and J.K.B. Ford (1997) Updated status of the sea otter, *Enhydra lutris*, in Canada. Can. Field-Nat. 11: 277-286.

USING TRADITIONAL ECOLOGICAL KNOWLEDGE IN 'BACK TO THE FUTURE' MODELLING

Russ Jones and Teresa Ryan
Haida Fisheries Program &
UBC Fisheries Centre

First Nation cultures are repositories of valuable knowledge about the environment, special places and inter-species interactions. This may include local observations of biological and behavioral interactions between species within their ecosystems, sometimes known as Traditional Ecological Knowledge (TEK). While it has been proposed that TEK would be useful in Back to the Future analysis (Pitcher, 1998; Beattie *et al.*, 1999), a major difficulty will be that it may not be readily accessible to the researcher. Obtaining TEK for use in BTF analysis will require in-depth research, such as interviews, archival research, analysis and verification to ensure that the information is accurately interpreted. An example of the useful application of TEK in Back to the Future (BTF) models would be the assessment of the presence or absence, place and time of occurrence, and relative abundance of species (Pitcher, 1998). This information may be particularly important for defining limits on model parameters. This article discusses some of the issues associated with applying TEK in development of BTF models for the study area: Dixon Entrance, Hecate Strait and Queen Charlotte Sound.

First Nations bordering the study area include Tlingit, Nisga'a, Tsimshian, Haida, Haisla, Nuxalk (Bella Coola), Oweekeno and Heiltsuk (Bella Bella), with the latter grouping including the Xai-xais. Tribes or lineages within each culture area maintained permanent winter settlements with an annual round of food-gathering activities to nearby camps or resource-gathering sites. The degree of resource utilization by First Nations depended both on demography and subsistence patterns. First Nation's organized societies, territorial rights to resource areas, and surplus food production also led to trade and a highly complex regional economic system. Another pattern of use different from the present day was that fishing and gathering activities were generally limited to within a few kilometers of the shore of major water bodies such as Hecate Strait, Dixon Entrance or Queen Charlotte Sound. Because of this, these areas would have functioned as large natural refugia for many fish populations. First Nation's organized societies, territorial rights to resource areas, and surplus food production also led to trade and a highly complex regional economic system.

Knowledge about aboriginal systems for control and management of resource harvesting is important for understanding resource use (e.g. Blackman 1990; Halpin and Seguin, 1990; Niblack, 1970). Ecological knowledge may be inseparable from the related complex cultural systems (Hamilton and Walter, 1997; Ryan, 2000) so the cultural context for TEK is also important. Family or village lineages controlled resource sites and associated activities such as fishing locations, berry-picking grounds and beaches where stranded whales might be found (MacDonald, 1984; Niblack, 1970, p. 335).

The ocean, rivers and coastal forests provided First Nations on the Pacific Northwest coast with a diverse assemblage of species that were available for food and trade. Development of food preservation techniques allowed long-term storage of necessary foods and would have increased trade of surplus production. Salmon were likely the most important quantitatively for all groups. An exception may be the Haida who also harvested halibut in large quantities (Blackman, 1990). Chum salmon was particularly important because the low fat content of spawners that returned late in the season allowed it to be preserved for longer periods. Other fish species were also important, and were harvested depending on availability, such as eulachen, sablefish, herring and rockfish. Seabirds and their eggs were utilized in season. Marine plants were also utilized and sometimes traded such as black seaweed. As well, many sea mammals were hunted including seal, sea lion, sea otter, and porpoise.

Potential sources of TEK include personal interviews, ethnographic accounts, historical documents, and archaeological studies. Early explorers and ethnographers did not focus on resource use so some reconstruction is needed from past and present-day sources. While ethnographic accounts are important sources of information about First Nation culture and practices, details about resource use are often limited. Review of historical manuscripts (e.g. early explorers, fur traders, mineral exploration, missionary life, government records) can be laborious and has similar limitations with regard to access to comprehensive and complete data. Finally archaeological studies may provide information about resource use and settlement patterns prior to the contact period but geographic coverage may also be limited. Given the many sources and fragmentary nature of the data, a comprehensive approach is recommended. This includes recognition of the proprietary nature of the information, and presentation of archival data to the appropriate communities for verification or further elucidation (Union of B.C. Indian Chiefs, 2000).

TEK that can be recovered from present generations is likely to be less comprehensive than from previous generations due to cultural change including social systems that actively discouraged maintenance of language and cultural practices. In these circumstances, language and names can be important sources of embedded cultural and biological information that can be tapped (e.g. Palomares *et al*., 1999; Jones 1999; Watkinson 1999).

Following are a few examples of insights that TEK and historical information may provide:

- Sea otters have a major influence on their environment, affecting invertebrate populations, particularly red sea urchins, that in turn affect the size of kelp beds that are important nursery areas for juvenile fish. Exploitation of sea otters in the study area peaked around 1800 due largely to market demand and introduction of firearms (Gibson 1992). Little is known about the persistence of remnant sea otter populations, although this may be important for understanding changes in invertebrate population e.g. sea urchins, abalone. There is considerable information about sea otter landings available in fur trade records. Surprisingly, it is still possible to retrieve information about sea otter populations from local sources. One example is an account passed on by a relative of one of the authors born in the 1850s. As a young girl, she vividly recalled going out as a passenger on a canoe to hunt sea otter on the west coast of Haida Gwaii, particularly the cries of the animal after it was struck. Also, a Haida elder in his 80s recalled finding a sea otter in a trap at Carmichael Passage (Louise Island) as a young man, but not recognizing at the time what it was.

- Herring play an important role in the food web and were the focus of intensive commercial fisheries in the 1940s, 50s and 60s that led to a collapse of the fishery. Historic abundance and the impact of the fishery on local spawning populations are subjects of current debate. Herring spawn was harvested in a important traditional fishery. Elders are one source of information about the abundance of herring, spawns, predators prior to the onset of industrial fisheries (Jones 2000) that may be important in reconstructing past herring abundance.

- Salmon and halibut were important food and, sometimes, trade items for coastal peoples. The limiting factor in salmon production was not the number of fish that could be caught but the number of women available to process it by slicing and drying (Blackman 1982, 36). Similar limits would apply for halibut, if available in large quantities. This provides a secondary means to estimate salmon and halibut use and illustrates how knowledge about traditional practices can help in estimation of resource use.

In summary, the study area supports a variety of cultural groups, with highly complex societies, and similar resource use strategies directed at a diverse assemblage of species. And there is likely a considerable body of TEK that would provide insights into the past and help in development of BTF models. We suspect, however, that in-depth studies will be required to provide reliable information and the time and effort needed to gather and document this information will be challenging. It will be important to keep in mind that there are a variety of secondary benefits to gathering TEK aside from improving BTF models and forecasts. Recovery of TEK can be valuable and rewarding for First Nations and broader Canadian society by documenting First Nations' history and their connections and relationships to places and promoting stewardship of important areas.

Workshop notes

RJ noted that the major contribution of First Nations' TEK to the project will be in the characterization of pre-contact abundances. He reminded us that the problem with this source of information is that it is not well documented.

Examples of marine resource use by First Nations were provided. Sea-otters: there was a sustainable harvest of sea otters conducted by First Nations in the past. He recalled a report from an Elder stating that the last year he trapped a sea otter in the Haida Gwaii was in the 1910s. Whales: there was some whaling activity by First Nations in the study area. Herring was fished but with probably little impact to the population. Salmon: chum salmon was harvested by Haida, sockeye was important in the Skeena, coho was trapped for consumption. Halibut was a very important food species - catches were limited by the quantity of fish that could be dried. Pacific cod: elders recall catching very large Pacific cod close to shore. Skidegate Inlet in the Queen Charlottes used to be a very rich area; there was an overall decrease in diversity and abundance of fish in this area during the last century.

Discussions that followed RJ's presentation pointed to the need for new estimates of native population numbers along BC central and north coast. These numbers would be needed to estimate the magnitude of native catches in pre-contact periods. NS raised the point that Parks Canada has a database with information on sea otter trade, which could be used to re-cast past abundance of sea otters in the area. RJ also suggested that community research with First Nations should be based on interviews rather than workshops.

References

Beattie, A., S. Wallace, and N. Haggan (1999) Report of the BTF workshop on reconstruction of the Hecate Strait Ecosystem. Back to the Future: Reconstructing the Hecate Strait Ecosystem. Fisheries Centre Research Reports Series 7(3). 65pp.

Blackman, M. (1982) *During My Time, Florence Edenshaw Davidson, A Haida Woman*. Seattle, University of Washington Press. 172 pp.

Blackman, M. (1990) Haida: Traditional culture. In W. Suttles [Ed.], *Northwest Coast, Volume 7 of Handbook of North American Indians* (p. 240-260). Smithsonian Institution, Washington, DC.

Gibson, J.R. (1992) *Otter Skins, Boston Ships, and China Goods; the Maritime Fur Trade of the Northwest Coast, 1785-1841*. Montreal: McGill-Queen's University Press. 422 p.

Halpin, M., and M. Seguin (1990) Tsimshian peoples: Southern Tsimshian, Coast Tsimshian, Nishga, and Gitksan. Pages 267-284 in W. Suttles [Ed.], *Northwest Coast, Volume 7 of Handbook of North American Indians* Smithsonian Institution, Washington, DC.

Hamilton, R., and Walter, R. (1999) Indigenous ecological knowledge and its role in fisheries research design: A case study from Roviana Lagoon, western Province, Solomon Islands. *Traditional Marine Resource Management and Knowledge*, 11:13-25.

Jones, R. (1999) Haida names and utilization of common fish and marine mammals. In N. Haggan and A. Beattie [Eds.], Back to the Future: Reconstructing the Hecate Strait Ecosystem. Fisheries Centre Research Reports, 7(3).

Jones, R. (2000) The herring fisheries of Haida Gwaii: An ethical analysis. Pages 201-224 in H. Coward, R. Ommer and T. Pitcher (Eds) Just Fish: Ethics and Canadian Marine Fisheries. ISER books, St John's. 304 pp.

MacDonald, G.F. (1984) The epic of Nekt. Pages 65-81 in M. Seguin (Ed.) The Tsimshian: Images of the Past, Views for the Present. UBC Press, Vancouver.

Niblack, A.P. (1970) *The Coast Indians of Southern Alaska and Northern British Columbia*. New York: Reprinted by Johnson Reprint Corporation. 386 pp.

Palomares, M.L. C. V. Garilao and D. Pauly (1999) On the biological information content of common names: a quantitative case study of Philippine fishes. p. 861-866 *In:* B. Séret and J.-Y. Sire (eds). Proc. 5th. Indo-Pac. Fish Conf. Nouméa, 1977. Societé Française d'Ichtyologie, Paris.

Pitcher, T. (1998) "Back to the Future": A novel methodology and policy goal in fisheries. Pages 4-7 in D. Pauly, T.J. Pitcher and D. Preikshot (Eds) Back to the Future: Reconstructing the Strait of Georgia Ecosystem. University of British Columbia, Fisheries Centre, Research Report 6(5): 99 pp.

Ryan, T. (2000) Defining cultural resources: Science, law, and resource management for sweetgrass *Schoenoplectus pungens* in Grays Harbor, Washington. M.Sc. Thesis, Central Washington University, Ellensburg, Washington.

Suttles, W. (Ed.) (1990) *Northwest Coast. Handbook of North American Indians, Vol. 7*. Smithsonian Institution. Washington, DC.

Union of British Columbia Indian Chiefs MS (2000) Protecting Knowledge: Traditional Resource Rights in the New Millennium. In 'Protecting Knowledge 'Conference, University of British Columbia campus, February 23-26, 2000.

Watkinson, S. (1999) An annotated list of Tsimshian (Sm'algyax) words pertaining to the marine ecosystem. In N. Haggan and A. Beattie [Eds], Back to the Future: Reconstructing the Hecate Strait Ecosystem. Fisheries Centre Research Reports, 7(3): 65pp.

PRELIMINARY MASS-BALANCE MODELS OF PAST ECOSYSTEM STATES

Marcelo Vasconcellos and Tony Pitcher
Fisheries Centre, UBC

Table 1 shows the Bomass values used in our preliminary mass-balance models of past ecosystem states in Northern British Columbia. Preliminary mass-balance models of the west coast ecosystem during the early 1900s and during pre-contact were built based on a model of the present time (Beattie 2001).

As with the East coast, these ecosystem simualiton models are under a process of continual refinement by the research team. The most recent versions can be downloaded from www.fisheries.ubc.ca.

Table1. Bomass values for preliminary mass-balance models of past ecosystem states of Northern BC: 1750, 1900 and present day. (NOTE: A 1950s model has subsequently been constructed). Estimated = biomass estimated by the mass-balance Ecopath model.

Model Functional Group	Present time (2000)	Early 1900s	Pre-contact (1750)
Sea otters	<0.0001	<0.0001	0.0016
Mysticetae	0.323	0.576	0.605
Odontocetae	0.022	0.028	0.028
Seals, sea lions	0.052	0.069	0.052
Seabirds	0.016	0.016	0.016
Transient salmon	0.588	0.840	1.000
Coho salmon	0.024	0.080	0.096
Chinook salmon	0.018	0.120	0.144
Small squid	Estimated	Estimated	estimated
Squid	Estimated	Estimated	estimated
Ratfish	0.517	0.517	0.517
Dogfish	Estimated	Estimated	estimated
Juvenile pollock	0.210	0.210	0.210
Pollock	0.359	0.359	0.359
Forage fish	Estimated	Estimated	estimated
Eulachon	Estimated	Estimated	estimated
Juvenile herring	2.265	Estimated	estimated
Adult herring	2.265	Estimated	estimated
Juvenile POP	0.065	0.154	0.154
Adult POP	1.819	4.300	4.300
Inshore rockfish	0.100	0.100	0.100
Juvenile piscivorous rockfish	0.007	0.011	0.011
Adult piscivorous rockfish	0.654	1.017	1.017
Juvenile planktivorous rockfish	0.136	0.249	0.249
Adult planktivorous rockfish	1.207	2.215	2.215
Juvenile turbot	0.214	0.214	0.214
Adult turbot	1.53	1.53	1.53
Juvenile flatfish	0.259	0.349	0.349
Adult flatfish	0.392	0.529	0.529
Juvenile halibut	0.608	0.608	1.216
Adult halibut	0.608	0.608	1.216
Juvenile Pacific cod	0.089	0.520	0.520
Adult Pacific cod	0.163	0.953	0.953
Juvenile sablefish	0.119	0.156	0.156
Adult sablefish	0.301	0.395	0.395
Juvenile lingcod	0.031	0.051 – 0.620	0.051-0.620
Adult lingcod	0.034	0.056 – 0.680	0.056-0.680
Shallow water benthic fish	0.509	0.509	0.509
Skates	0.335	0.335	0.335
Large crabs	estimated	estimated	estimated
Small crabs	estimated	estimated	estimated
Commercial shrimp	0.061	0.061	0.061
Epifaunal invertebrates	estimated	estimated	estimated
Infaunal carnivorous invertebrates	13.000	13.000	13.000
Infaunal invertebrate detritivores	34.000	34.000	34.000
Carnivorous jellyfish	3.000	3.000	3.000
Euphausiids	8.700	8.700	8.700
Copepods	13.000	13.000	13.000
Corals and sponges	0.203	0.290-0.406	0.290-0.406
Macrophytes	5.280	5.280	10.560
Phytoplankton	15.406	15.406	15.406
Discards	1.000	1.000	1.000
Detritus	10.000	10.000	10.000

Participants and affiliations East coast Science Workshop

Alida Bundy	DFO-MFD	bundya@mar.dfo-mpo.gc.ca
Barbara Neis	Memorial University of Newfoundland	bneis@mail.mun.ca
Becky Sjare	DFO – St. John's	sjare@dfo-mpo.gc.ca
David Schneider	Memorial University of Newfoundland	a84dcs@mun.ca
Earl Dawe	DFO-Newfoundland	dawe@athena.nwafc.nf.ca
Edgar Dalley	DFO – St. John's	dalleye@dfo-mpo.gc.ca
George Lilly	DFO – St. John's	lillyg@dfo.mpo.gc.ca
George Rose	Marine Institute, Memorial University of Newfoundland,	grose@caribou.mi.mun.ca
Ian Stenhouse	Biopsychology Programme, Memorial University of Nefoundland	iansten@play.psych.mun.ca
Marcelo Vasconcellos	UBC Fisheries Centre	m.vasconcellos@fisheries.ubc.ca
Melanie Power	UBC Fisheries Centre	m.power@fisheries.ubc.ca
Nigel Haggan	UBC Fisheries Centre	n.haggan@fisheries.ubc.ca
Paul Fanning	BIO, DFO, Halifax	fanningp@mar.dfo-mpo.gc.ca
Sheila Heymans	UBC Fisheries Centre	s.heymans@fisheries.ubc.ca
Tony Pitcher	UBC Fisheries Centre	t.pitcher@fisheries.ubc.ca

Participants and affiliations West coast Science Workshop

Alan Sinclair	DFO-PBS Nanaimo	sinclairal@pac.dfo-mpo.gc.ca
Alasdair Beattie	UBC Fisheries Centre	a.beattie@fisheries.ubc.ca
Art Tautz	BC Provincial Govt. Fisheries Ministry	art.tautz@gems2.gov.bc.ca
Dorothee Schreiber	UBC Fisheries Centre	dschrieb@zoology.ubc.ca
Doug Hay	DFO-PBS Nanaimo	hayd@pac.dfo-mpo.gc.ca
Gary Kaiser	Independent consultant,Victoria, BC	wingary@telus.net
Glenn Jamieson	DFO-PBS Nanaimo	jamiesong@dfo-mpo.gc.ca
Jake Schweigert	DFO-PBS Nanaimo	schweigertj@dfo-mpo.gc.ca
Jeff Fargo	DFO-PBS Nanaimo	fargoj@dfo-mpo.gc.ca
Kim Conway	Geological Survey of Canada Sidney, BC	conway@pac.dfo-mpo.gc.ca
Marcelo Vasconcellos	UBC Fisheries Centre	m.vasconcellos@fisheries.ubc.ca
Melanie Power	UBC Fisheries Centre	m.power@fisheries.ubc.ca
Nigel Haggan	UBC Fisheries Centre	n.haggan@fisheries.ubc.ca
Norm Sloan	Parks Canada, Haida Gwaii	norm_sloan@phc.gc.ca
Russ Jones	Haida Fisheries, Haida Gwaii	r.jones@island.net
Teresa Ryan	UBC Fisheries Centre	t.ryan@fisheries.ubc.ca
Tony Pitcher	UBC Fisheries Centre	t.pitcher@fisheries.ubc.ca