The catch of living marine resources around Greenland from 1950 to 2010[1]

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Abstract

The catches of marine living resources taken in Greenland's waters are estimated from 1950 to 2010, including estimates of discards, unreported commercial catch and subsistence catch. Reconstructed total catch by Greenland in its own waters is just over 7 million t, which is around 30% higher than the 5.5 million t of landings reported by FAO and ICES on behalf of Greenland. The commercial fisheries make up the majority of the total catch, with the industrial sector representing 61% and the artisanal sector representing 37%. Unreported subsistence catches contribute 141,000 t to the time series and represent only 2% of the total catch. Atlantic cod (*Gadus morhua*) is the most important species in the subsistence sector, representing 56% of that catch. The northern prawn (*Pandalus borealis*) represents 54% of the total reconstruction and is the greatest single species contribution. The discrepancies between the reported baseline and the reconstructed catch are mostly due to discards in the commercial fisheries, which represent 20% of the total reconstruction. Overall, Greenland's catches in its own waters are estimated to have increased from 29,000 t in 1950 to 202,000 t in 2010, but this still only accounts for less than half the annual catch taken from Greenland waters due to large catches by foreign vessels. Together, catches reported by foreign vessels and the reconstructed domestic catches increased from approximately 208,000 t in 1950 to 482,000 t in 2010. The Marine Trophic Index for the foreign and domestic catches declined by 0.26 t·trophic level per decade, and is the largest decline noted for this index due to the fishery changing from one primarily targeting Atlantic cod to one targeting shrimp. The mean maximum lengths of the marine living resources in the catch also declined with fisheries having a mean decline of 18.0 cm per decade, and a downward trend is noted for marine mammals and seabirds, as well. The catch of seals, narwhal and harbour porpoises has been increasing, but the catch of beluga whales has declined, and the population size is of concern. There has also been a steep decline in the number of seabirds caught since 1993 with an approximate 5-fold drop in the number of thick-billed murres caught.

Introduction

Greenland is the third largest country in North America, and its coastline spans the Arctic Sea, the Northeast Atlantic and the Northwest Atlantic (Figure 1). Currently, Greenland's economy is highly dependent upon commercial marine fisheries, mining, tourism, as well as transfer payments from Denmark. Being mainly an Inuit culture, there is also a high dependence on living marine resources including fish, marine mammals and seabirds for local consumption. Since 1950, the people of Greenland have shifted from a subsistence-based economy to a mixed economy, and as they have undergone this transition, there have also been changes in the use of living marine resources. Here, I use reported catches of fisheries, marine mammals, and seabirds and add estimates of unreported catches to examine the change in living marine resource use in Greenland from 1950 to 2010.[2] Reported catches by foreign fishing fleets area also included because of their importance throughout the time period.

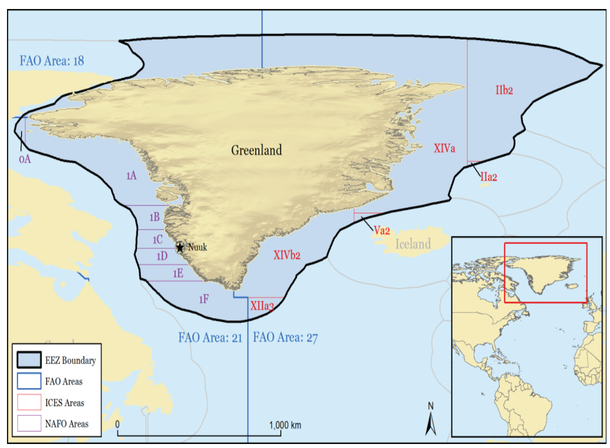

Figure 1. Exclusive Economic Zone (black line), and FAO areas (solid blue line), ICES areas (solid red line) and NAFO areas (purple lines) of Greenland. Greenland's fisheries occur in NAFO area 1 within FAO area 21, and in ICES area XIV within FAO area 27. Currently no fisheries occur in the Arctic (FAO area 18).

Similar to Canada's east coast, the commercial fishery switched from one concentrated on Atlantic cod (*Gadus morhua*) to one primarily targeting northern shrimp (*Pandalus borealis*) during the 1990s, as a result of overfishing and poor cod recruitment linked to decreasing ocean temperatures (Hamilton *et al.* 2003).

Whaling of large cetaceans continues as part of the Aboriginal Subsistence Whaling program of the International Whaling Commission with minke whales being numerically most important. Small mammals, especially ringed seals (*Pusa hispida*), beluga (*Delphinapterus leucas*) and narwhal (*Monodon monoceros*) are culturally important, but the current population status of belugas within Greenland are of concern—the population is estimated to be 22%

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[2] For database purposes of the *Sea Around Us*, marine mammal and seabird catches are not considered.

of the size it was in 1954 and they are no longer found in many areas where they were previously harvested (Alvarez-Flores and Heide-Jørgensen 2004). Several species of seabirds are still hunted and eggs are collected for personal use; this has detrimental effects on some seabird's populations, such as thick-billed murres (Christensen 2001).

Currently, fisheries and the fish processing sector account for approximately 92% of exports and 25% of employment, making it the key driving force of the economy (Anon. 2005). Greenland changed from a hunting economy, targeting mainly seals, to a fishing economy in the early 1900s, primarily targeting cod when it became apparent that hunting could no longer support the rapidly growing population (Mattox 1971). More recently, Greenland became reliant on earnings from the shrimp fishery. Cod became more abundant from 1917 due to increasing ocean water temperatures. However, this also adversely affected seal hunting because of changes in climatic conditions that affected the occurrence and extent of pack ice—seals are more abundant when there is heavy pack ice. The seal hunt off Newfoundland may also have decreased the numbers migrating to Greenland's waters after the breeding season (Mattox 1971). More recent research has shown that the climatic conditions are linked to changes in the North Atlantic Oscillation Index and atmospheric pressure fields that affect recruitment and population levels of some of the main commercial species (Buch *et al.* 2004). Thus, over the past 100 years, there has been a transition from hunting to fishing, and then to shrimping because of human population growth, climatic fluctuations affecting marine animal populations, and overexploitation.

In addition to reported catch, estimates of unreported catches of marine resources are included here, as they are not generally accounted for in reported statistics. The responsible and sustainable use of living marine resources is paramount for Greenland since it is the only renewable resource that it can depend on. The Marine Trophic Index (MTI) is used as an index to account for changes in the mean trophic level of fisheries landings through time (Pauly *et al.* 1998). In the case of Greenland, there should be a sharp signal because of the noted transitions in fisheries abundance and use. In order to note changes in the use of the other living marine resources used, we also look at the change in the mean maximum length of the resources used.

Methods

Fisheries related data include reported landings from the International Council for the Exploration of the Sea (ICES 2011), the United Nations Food and Agriculture Organization (FAO 2012), and the Northwest Atlantic Fisheries Organization (NAFO 2011). Data from ICES are used for the east coast of Greenland, while for the west coast, FAO data are used. For foreign fleets fishing in the waters of West Greenland, NAFO data are used. Marine mammal data include reported data from a variety of publications, estimates of struck and lost animals, as well as unreported catches. For seabirds, we rely upon the reported catch data that have been collected since 1993—this is known to be an underestimate because it does not include illegal catches (Christensen 2001), or estimate of struck and lost birds.[3]

Human population data

We used human population data with regional consumption rates to estimate subsistence fisheries catches. Total population data for Greenland are available for the years 1951, 1956, and continuously since 1961, and also for each community since 1977 from Greenland's national statistics office (Statistics Greenland 2011). We interpolated between years to estimate the human population for years with no data, and used the annual predicted change from 1951-1956 to estimate the total population in 1950. To estimate the population in each region for the pre-1977 period, we used data in Mattox (1971) who describes the population of west Greenland in 1960 and for all of Greenland in 1966. We assigned each community to its current municipality in order to estimate each municipality's proportion of the total population in 1966. Since data for east and north Greenland are missing in 1960, we assumed that these areas represented the same proportion of the 1966 municipal population. We interpolated between the estimated proportions between 1960 and 1966, and to the ones reported in 1977. Prior to 1960, we assumed that each municipality's proportion of Greenland's total population was the same as in 1960.

Commercial fisheries

Commercial fisheries in Greenland, as in other northern countries, are dependent on only a few species. Targeted fisheries include those for Atlantic cod (*Gadus morhua*), northern shrimp (*Pandalus borealis*), Greenland halibut (*Reinhardtius hippoglossoides*), beaked and golden redfish (*Sebastes mentella*, and *S. norvegicus*), capelin (*Mallotus villosus*), lumpfish (*Cyclopterus lumpus*), and arctic charr (*Salvelinus alpinus*). In the past, the salmon (*Salmo salar*) driftnet fishery was also of importance, but with the Atlantic-wide decline of this species, the Organization of Fishermen and Hunters in Greenland received monetary compensation and agreed to suspend the commercial fishery and only fish for subsistence purposes (Chase 2003). Two invertebrates, the Iceland scallop (*Chlamys islandica*) and queen crab (*Chionoecetes opilio*), are also targeted in directed fisheries. Main bycatch species from targeted fisheries include Greenland cod (*Gadus ogac*), wolffishes (*Anarhichas lupus* and *A. minor*), and haddock (*Melanogrammus aeglefinus*) from the cod directed fishery (ICES 2009). Atlantic halibut (*Hippoglossus hippoglossus*) was also treated as a bycatch species, although currently part of the longline fleet does target them occasionally (Riget and Boje 1988; ICES 2009), but total landings for this species are very low.

[3] For the purposes of the *Sea Around Us* and the global database of reconstructed fisheries catches, marine mammal and seabird data were not used.

Fisheries landings data by weight are available from ICES and FAO for the period 1950-2010, but we treated the 2010 data as preliminary, and extend the data from 2009 forwards one year. These data were used as reported landings for all species, except for the fishery for Atlantic cod, northern shrimp, scallop, and wolffishes. For the Atlantic cod fishery, we relied on data provided by Horsted (2000) who provides a complete history of the fishery from 1911 to 1995; thereafter, we used the data reported by FAO and ICES. For shrimp, we relied on data from Hvingel (2001) who reviews the fishery from 1970 to 2001, and on the update from Arboe and Kingsley (2010). For the scallop fishery, we used data from Pedersen (1994) for 1984-1991 and Siegstad (2000) for 1999. For the wolffish fishery, we relied on data from Smidt (1981) for 1950 to 1979. Each of these studies has detailed accounts during the respective time periods. For salmon, data from ICES (Anon. 2010) are used because catches are reported from both coasts.

The commercial fisheries in Greenland are reported as being caught in either 'inshore' or 'offshore' waters based on distance from shore and vessel size classes (Statistics Greenland 2011). Offshore vessels (75 GRT) can only operate in waters 3 nm from shore, whereas the inshore fleet (75 GRT) is largely confined to waters within 3 nm from shore; however, some of the larger vessels of the inshore fleet operate in the offshore areas. Here, for convenience, inshore fisheries are considered to be part of the small-scale artisanal fleet, and offshore is considered to be large-scale industrial. Catches taken by foreign vessels in Greenland's waters (all deemed large-scale, industrial) are those reported to NAFO and ICES, and do not include estimates of unreported catches.

Industrial and artisanal IUU catches

Illegal, Unreported and Unregulated (IUU) commercial catches taken by Greenland include estimates from the Greenland shark (*Somniosus microcephalus*), arctic charr, and Atlantic halibut fisheries prior to them being reported to FAO or ICES, as well as some minor positive adjustments made to the reported data for Atlantic salmon (*Salmo salar*) and redfishes (*Sebastes* spp.). Export data from Mattox (1971) were used to estimate catches of arctic charr from 1950 to 1966, Atlantic halibut for 1953-1962, and Greenland shark from 1950-1969. Data are reported by ICES and FAO for arctic charr and Atlantic halibut in later years, but for Greenland shark, we assumed that the fishery ended in 1969 because the two main products, shark skins and liver oil, were in sharp decline by 1966, a result of low demand (Mattox 1971).

Discards

Discards from both the industrial and artisanal sectors were estimated for all targeted fishery species. Discard rates were applied to the reported commercial landings of targeted species to estimate the amount of discards by weight (Table 1).

Table 1. Discard rates applied to reported fisheries landings to estimate discards (by weight).

Common name	Discard rate	Sector	Source
Arctic charr[1]	0.050	Artisanal and Industrial	Kelleher (2005)
Atlantic cod	0.304	Industrial	Riget and Hovgård (1991)
Atlantic cod	0.172	Artisanal	Riget and Hovgård (1991); Kelleher (2005)
Blue whiting[2]	0.013	Artisanal and Industrial	Kelleher (2005)
Capelin[3]	0.010	Artisanal and Industrial	Kelleher (2005)
Atlantic herring	0.100	Artisanal and Industrial	Kelleher (2005)
Greenland halibut[4]	0.033	Artisanal and Industrial	Kelleher (2005)
Iceland scallop[5]	0.264	Artisanal and Industrial	Kelleher (2005); Garcia *et al.* (2006)
Lumpfish[6]	0.231	Artisanal and Industrial	Kelleher (2005)
Queen crab[7]	0.167	Artisanal and Industrial	Kelleher (2005)
Redfish[8]	0.077	Artisanal and Industrial	Kelleher (2005)

[1] Discard rate as average of Norway's coastal line caught fish and gillnet; [2] average of Norway and Iceland; [3] average of Norway's pelagic trawl and purse seine rates, and Iceland's purse seine rate; [4] average of Norway's line and gillnet fleet; [5] average of Canada's and Iceland's dredge fisheries; [6] rate for Norway's gillnet fleet; [7] rate for Canada's pot fishery; [8] average of Canada's and Iceland's trawl fleets.

Shrimp discards include those estimated from boat-based operations, and also from overpacking and quality discards at the processing plants (Hvingel 2003; Arboe and Kingsley 2010). Government regulations require that shrimp greater than 2 grams be kept, but in the offshore fleet, shrimp in this size-range are still discarded due to quality, while those less than this size are discarded due to value, and in some hauls can be as much as 50% (Lehmann and Degel 1991). Overpacking products led to an underestimate of the actual amount of shrimp sold, and quality discards are associated with inshore fisheries that land at processing plants, which discard low quality shrimp. Size-related discards in the offshore fisheries were reported to be 40% per year in 1990 (Lehmann and Degel 1991), 19% per year in 1991 and 14% per year in 1992 (Siegstad 1993), and discards due to low quality have been estimated to be 6% of the catch (Carlsson and Kanneworff 1992). We used the average of the first two years (29.8%) as the discard rate backwards in time to 1975 to estimate size-related discards for the offshore fleet. The large-scale commercial shrimp fishery was just starting in 1970, and so the discard rate is set to zero in 1969, and we interpolated to the value in 1975. After 2004, we used a discard rate of 6% per year to reflect the introduction of the mandatory use of sorting grids in 2002, and regulations concerned with overpacking (Appendix A1). Fish discards associated with the shrimp fishery are documented for 1977-2009 (Arboe and Kingsley 2010) and for 1950-1976 the average rate of fish discards for 1977 and 1978 was applied to the reported shrimp catches to estimate fish discards from the shrimp fishery.

Subsistence catches

Subsistence catches are estimated using fish consumption rates from community survey data, and extending these rates to other communities within the same region that lacked estimates (Table 2). Consumption rates for each region were combined with the human population data for each region to estimate yearly catches taken for subsistence purposes. The four regions were based on communities that had consumption data, and these coincide with northwest Greenland (NWG), central western Greenland (CWG), southern Greenland (SG), central eastern Greenland (SEG) and southeastern Greenland (SEG). Each community was placed in one of these regions to assign a consumption rate from available data and we assigned each community to its present municipality. The communities in the municipalities of Qaasuitsup and Sermersooq were split between regions (Appendix A2), whereas the communities in Kujalleq and Qeqqata form part of the southern Greenland region. We assumed that the catches estimated for subsistence purposes do not form part of the reported statistics since Horsted (2000) states that a non-registered component of the cod catch for local consumption should be added to the reported landings, and Mattox (1971) also states that reported catches until 1966 did not include the portion of the catch taken for home consumption.

Table 2. Community consumption rates used to estimate subsistence catches for Greenland (see text for details).

Year	Region	Communities	Consumption rate ($kg{\cdot}day^{-1}$)	Source
1953	CWG	Disko Bay & Ilulissat	0.629	(Hansen *et al.* 2008)
1996	CWG	Disko Bay & Ilulissat	0.067	(Johansen *et al.* 2004)
1976	NWG	Uummanaq	0.090	(Hansen *et al.* 2008)
1999	NWG	Uummanaq	0.065	Deutch and Hansen (2003)
2004	NWG	Uummanaq	0.047	(Hansen *et al.* 2008)
1987	NWG	Qaanaaq	0.040	(Hansen *et al.* 2008)
1978	SEG	Tasiilaq	0.200	(Hansen *et al.* 2008)
2001	SEG	Tasiilaq	0.096	Deutch and Hansen (2003)
2000	CEG	Ittoqqortoormiit	0.038	Deutch and Hansen (2003)
1953	SG	Qaqortoq	0.191	(Hansen *et al.* 2008)
2006	SG	Narsaq	0.031	(Hansen *et al.* 2008)

Marine mammal data

Marine mammal data include Greenland's reported and unreported catches by number. Unreported catches include estimates of the number of animals in years when no data are reported for all of Greenland, and also unreported catches of narwhals for the community of Qaanaaq. Estimates of struck and lost animals that are shot, but not retrieved are also included as unreported catches. Reported data for seal species are taken from statistics provided to FAO, and data for the large whales are taken primarily from publications of the International Whaling Commission. For narwhals and belugas, data are reported in publications from the North Atlantic Marine Mammal Commission (Heide-Jørgensen and Rosing-Asvid 2002; Heide-Jørgensen 2009).

The number of bearded seals (*Erignathus barbatus*), harbour seals (*Phoca vitulina*), harp seals (*Pagophilus groendlandicus*), hooded seals (*Cystophora cristata*), and ringed seals (*Pusa hispida*) are reported in FAO statistics, but these records are incomplete, particularly during the early period. Data are reported for harp and hooded seals since 1954, ringed seals since 1969 and for bearded and harbour seals since 1970. The data gaps for bearded seal (1950-1965), harbour seal (1950, 1954-1968) and ringed seals (1950-1968) are taken from Kapel (1975). Stenson (2008) provides data on the number of harp seals taken in 1953 and 1952, and we used the same number (16,400) for 1950 and 1951. For hooded seals, a five-year average (861) from the first years of reported data (1954-1958) is used.

Struck and lost rates are considered to represent a rate of the reported catch for each seal species. Struck and lost rates vary by species, and seasonally, due to weather and different sinking rates of seals after being shot (Anon. 2006). Struck and lost rates from 1950-2010 were 100% per year for bearded seals assuming 68% of the reported catch is taken by rifle, 14% per year for harbour seals using data from Alaska (Anon. 2003; Angliss and Outlaw 2006), 100% per year for hooded seals (Stenson 2008), and 17% per year for harp and ringed seals. Ringed seals are hunted primarily by rifle (68%), and, for harp seals, 34% of the full-time and leisure hunters report struck and lost seals, having a combined mean shot and lost rate of 0.22 (Anon. 2006). We assumed that 68% of the total annual catch for both species is by rifle with a shot and loss rate of $0.22{\cdot}year^{-1}$. Thus, unreported catches associated with struck and loss for harp and ringed seals were estimated as a ratio of the unreported fraction (0.22*0.66) to the reported fraction (1-(0.22*0.66)) to derive the rate of 17% per year.

Blue whales (*Balaenoptera musculus*), sperm whales (*Physeter macrocephalus*), and northern bottlenose whales (*Hyperoodon ampullatus*) were taken in small numbers until 1976 with sperm whales being the most important. The numbers of animals taken each year are provided in Kapel (1979). We did not expand the reported statistics to account for struck and lost animals as we excluded these species from subsequent analysis. Bowhead (*Balaena mysticetus*), fin (*Balaenoptera physalus*), humpback (*Megaptera novaeangliae*) and minke (*Balaenoptera acutorostrata*) whales are taken under the jurisdiction of the Aboriginal Subsistence Whaling program of the IWC and catches including the number of struck and lost animals are reported by the IWC for the year 1985 onwards (IWC 2012). Prior to 1995, the numbers of fin whales taken are reported in Kapel (1979) for 1950-1976, and in the IWC white paper on the hunting of large whales in Greenland for 1977-1984 (Ugarte 2007). Humpback whale catch numbers are reported in Witting (2007) for the period 1950 to 1972, and also in Ugarte (2007) for 1973-1984. The catch of minke whales from 1950 to 1976 are reported in Kapel (1979), and we interpolated from the number of whales reported in 1976 to the reported number of whales in 1985 to estimate the catches in missing years.

Smaller cetaceans including belugas (*Delphinapterus leucas*), narwhals (*Monodon monoceros*), killer whales (*Orcinus orca*), harbour porpoises (*Phocoena phocoena*), and pilot whales (*Globicephala melas*) are also hunted in Greenland. Belugas and narwhals have always been important culturally and account for the largest portion of catches. Beluga catches are rare on the east coast, and the belugas caught along this coast are believed to originate from the Svalbard population (Anon. 2000), and thus, here we only considered catches to occur along the west coast. Beluga whale catch statistics from 1954 to 1998 were reviewed by Heide-Jørgensen and Rosing-Asvid (2002) and we used the average of the medium and high option as the reported catch including the estimates of the number associated with ice entrapments and unreported catches. After 1999, we relied on reported catches from Statistics Greenland and estimate the unreported catches by using a three-year average ratio (0.15) of unreported catch to reported catch from the last three years of data (1996-1998) in Heide-Jørgensen and Rosing-Asvid (2002).

Narwhal catch statistics for 1949 and 1954 to 2008 including reported and unreported data were reviewed by the Joint Working Group, with members from NAMMCO and the Canada/Greenland Joint Commission on Conservation and Management of Narwhal and Beluga Scientific Working Group (Anon. 2009). We interpolated between catches in 1949 and 1954 to fill in the first few years of missing total catches, and after 1996 we used data from Greenland's national statistical agency as reported catches (Statistics Greenland 2011). The community of Qaanaaq, on the northwestern coast of Greenland, reports no catches from 1950-1960, 1965-1973, and from 1985-1992 and, since it is an important community in terms of narwhal catches, we estimated the unreported catches for the missing time periods. In 1949 and 1961, Qaanaaq accounted for approximately 62% and 66% of the total narwhal catch, respectively. We used the average (64%) as the fraction of unreported catches to estimate the number of narwhals taken by Qaanaaq from 1954-1960 from the reported total. For 1965-1973, we interpolated between the proportion of the total catch reported in 1964 (0.88) and 1974 (0.51), to estimate Qaanaaq's unreported catches. Similarly, for 1985-1992, we estimated unreported catches by interpolating between Qaanaaq's proportions of the total catch between 1984 and 1993.

Traditionally, harbour porpoises were taken in small amounts, but since the late 1990s catches have increased. Data concerning the catch are available for 1950, and from 1954 to 1992 (Teilmann and Dietz 1998), and for 1998 to 2009 (Statistics Greenland 2011). We interpolated between the reported catch amounts for years of missing data (1951-1953) to estimate catches in missing years. Pilot whales are irregularly reported in catch statistics with catches ranging between 2 and 365 whales·year^{-1} for the period 1978-2009 with 9 years having no reported data. We considered pilot whales to be hunted every year, and use a five-year average (33 animals) taken from the first five years of reported data (1978-1982) to use as an estimate of the average yearly catch between 1950 and 1977. NAMMCO reports the number of pilot whales taken between 1978 and 1999, and Statistics Greenland (2011) reports the number of whales taken from 2000-2009. To fill in years of no reported data, we interpolated between reported catch numbers. Killer whales are reported for the period 1998 to 2009 (Statistics Greenland 2011), but catches are not extended backwards in time.

Seabird data

Seabirds are part of the traditional Inuit diet, and are hunted extensively. Hunting data for seabird species have been collected since 1993 for thick-billed murres (*Uria lomvia*), common eider (*Somateria mollissima*), king eider (*Somateria spectabilis*), black guillemot (*Cepphus grylle*), little auk (*Alle alle*) and black-legged kittiwakes (*Rissa tridactyla*). Data concerning the number of birds taken each year are available from Christensen (2001) for 1993 to 1996 and from Statistics Greenland (2011) for 1998-2009. We interpolated between the reported catch in 1996 and 1998 to estimate the catch of each species in 1997. Formerly, during the commercial salmon driftnet fishery, a large number of seabirds were caught as bycatch, leading to significant mortalities especially of thick-billed murres (Piatt and Reddin 1984), but these are not considered here.

Ecosystem indices

The Marine Trophic Index (MTI) is a metric used to estimate the changes in fisheries catches based on the mean trophic level of catches from marine ecosystems. The annual proportion of each species catches relative to the total catches is multiplied by the trophic level of the species, *i.e.*,

$$MTI = \sum(Y_{ik}/Y_k)*TL_{ik}$$

where Y_{ik} represents the catch of species/group i in year k, Y_k is the total annual catch, and TL_{ik} represents the trophic level of species/group i in year k. We used this metric for fisheries catches for each year to compute a time series of the MTI.

We also estimated the mean maximum length of catches through time to reflect the changes in the size of catch through time. The mean maximum length of the catch can be defined as the annual proportion of each species catches relative to the total catches multiplied by the maximum length measurement of the species, *i.e.*,

$$MML = \sum(Y_{ik}/Y_k)*ML_{ik}$$

where ML_{ik} represents the maximum length of species/group i in year k. We used standard length for fishes (Table A3; www.seaaroundus.org),[4] carapace length for invertebrates (www.sealifebase.org)[5] and the wingspan of seabirds (Table A4; www.bto.org).[6] A mean maximum length for marine mammals is estimated from the mean weight (Trites and Pauly 1998) using length-weight relationships from SeaLifeBase (www.sealifebase.org). The mean maximum lengths from fisheries and those for marine mammals and seabirds are computed separately.

4 http://www.seaaroundus.org [Accessed: June 2012]

5 http://www.sealifebase.org [Accessed: June 2012]

6 http://www.bto.org [Accessed: May 2012]

Results

Human population

The human population of Greenland increased from approximately 23,000 people to 56,000 from 1950 to 2010 (Figure 2). The population growth was greatest from 1960 to 1970, increasing at approximately 4% per year, but has since slowed and from 2000-2010 it declined to 0.1% per year. The municipalities of Qaasuitsup and Sermersooq, where the capital Nuuk is located, have seen the greatest increase in population.

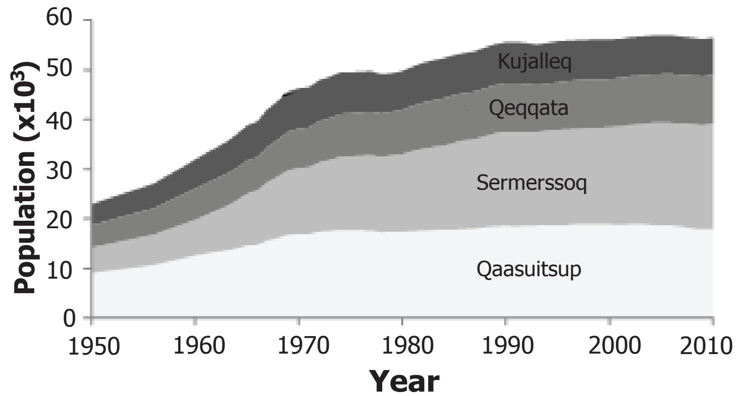

Figure 2. Estimated total population of Greenland by municipality, 1950-2010.

Fisheries catches

Total fisheries catches for Greenland's domestic fishing fleet in its western and eastern waters, including reported landings and all unreported catches, exceeded 7 million t and were estimated to increase approximately 7-fold from over 29,000 t in 1950 to approximately 202,000 t in 2010 (Figure 3a). Catches were dominated by northern shrimp and Atlantic cod (Figure 3b). From 1950 to 1979, Atlantic cod dominated, making up approximately 60% of the catches, but from 1980 onwards, Atlantic cod only represents 16% of the fisheries catches. Northern shrimp catches averaged 25% of the catches from 1950 to 1979, but increased in importance, accounting for approximately 63% of the catches from 1980 onwards. Greenland halibut is also important, averaging 5% of the total catches between 1950 and 1989, but increased afterwards to average 14% of the total catches between 1990-2010. All other taxa make up 11% of the total catches during 1950-2010. Catches are overwhelmingly taken in the waters of West Greenland (94%).

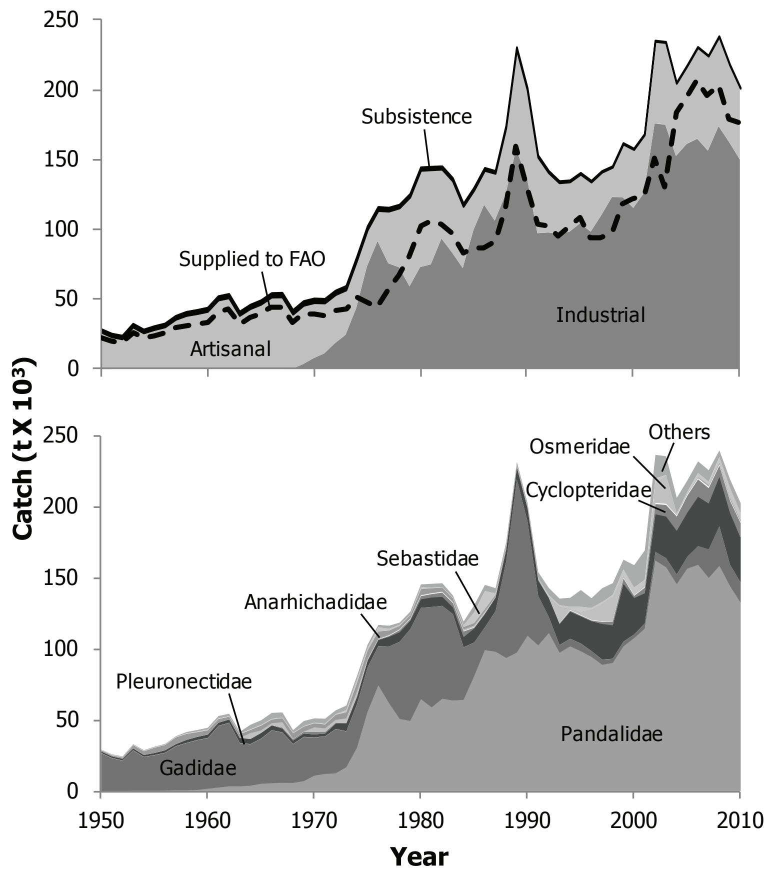

Figure 3. Reconstructed total catch of Greenland, during the period 1950-2010 (a) by sector with data as reported by FAO overlaid as line graph; and (b) by taxonomic group, others represent 10 other families.

Greenland's commercial catch totalled 6.9 million t for the 1950 to 2010 period (Figure 3a). Until 1968, Greenland's commercial fisheries were strictly small-scale artisanal, but by 1980 catches by the large-scale industrial fleet had reached 50% of the catch. In 1989, catches by the industrial fleet accounted for 68% of the commercial catch, and since then have averaged approximately 73%. Discards from the commercial fishery increased from 3,700 t in 1950 to 69,000 t in 1976, and since then have averaged 34,000 t·year^{-1} from 1977-2010. Discards represent 21% of the reconstructed total catch, and were dominated by shrimp (72%).

The unreported landings component of Greenland's catches was estimated to decrease from 2,700 t in 1950 to approximately 800 t in 2010, and was dominated by Atlantic cod (47%). The majority of IUU came from subsistence fishing (78%), while 16% and 6% was represented by the artisanal and industrial sectors, respectively. IUU catches from commercial fisheries of Greenland shark were approximately 9,500 t from 1950 to 1969. IUU catches of Atlantic halibut from 1953 to 1962 were estimated to be approximately 350 t and IUU catches of arctic charr from 1950-1964 were approximately 400 t. Subsistence catches were estimated to increase from about 2,600 t in 1950, peaking at approximately 3,500 t in 1969, and is currently estimated to be less than 1,000 t annually (Figure 3a). Consumption rates associated with subsistence fisheries catches fell from approximately 112 kg·person·year^{-1} in 1950 to 14 kg·person·year^{-1} in 2009.

Marine mammal catches

Unreported catches of seals were higher in the 1950s and 1960s because of the limited amount of FAO data, but after this time the unreported catches are associated mainly with struck and lost animals (Figure 4a). Of the five species of seals, ringed seals and harp seals are the most important in catches accounting for, on average, 65% and 26% of the total catches, respectively (Figure 4b). Hooded and bearded seals account for approximately 7% and 1% respectively, and harbour seals comprise less than 1% of the catches. Unreported catches of seals from 1950-1968 average 86% of the total estimated catches, but decline afterwards to average 0.18 t·year^{-1}, although in 1986 unreported catches were estimated to be 79%. Seal catches are distributed more evenly than fisheries catches with the west coast accounting for, on average, 80% of the total estimated catches (Figure 4c).

Blue, bottlenose and sperm whales catches from 1950 to 1973 (the last year of a reported catch) were reported to be 122 whales, with sperm whales being by far the most important at 110. We excluded these whales from further analysis and concentrate on the remaining marine mammals still targeted. For the remaining large whales, we relied on reported numbers, since the IWC Aboriginal Subsistence whaling statistics from 1985 onwards include struck and lost whales. Catches of bowhead, fin, humpback, and minke whales are dominated by minke whales, although from 1950-1957 fin whales and minke whales were taken in nearly equal numbers (Figure 5). Bowhead whales have only begun to be hunted again in the last two years with 3 individuals taken in 2009 and 2010. From 1950 to 1962, reported catches of large whales were estimated to average 50 individuals·year^{-1}, but reported numbers increased to average 200·year^{-1} afterwards. Similar to fisheries catches, 95% of large whales are taken in the west.

Small cetaceans (belugas, narwhals, killer whales, harbour porpoises, and pilot whales) have slowly increased over time (Figure 6a). Unreported catches of small cetaceans during the period from 1950-1995 were highly variable ranging from 4%-72%, but since 1996 have averaged only 0.02 t·year^{-1} (Figure 6a). From 1950-1969, catches averaged 1,860 t·year^{-1}, increased to 2,402 t·year^{-1} during 1970-1989, and since 1990 have averaged 3,091 t·year^{-1}. However, the composition of the catches through time has changed. Beluga whale catches have been declining in catches since the early 1980s. During the 1970s and 1980s catches averaged 1,039 t·year^{-1}, but have declined to 585 t·year^{-1} since the 1990s (Figure 6b). Narwhal catches have increased in importance averaging 265 t·year^{-1} from 1950-1969, 463 t·year^{-1} from 1970-1989, and since 1990 have increased to 626 t·year^{-1} (i.e., 100 t·decade^{-1}). Harbour porpoises have increased in importance, especially in the last decade. From 1950-1989, annual catches averaged 870 t·year^{-1}, increased slightly during 1990-1999 to 1,190 t·year^{-1}, but have nearly doubled that amount in the last decade rising to 2,277 t·year^{-1}. Estimated pilot whale catches average 33 t·year^{-1} from 1950-1977, and for the remaining years catches fluctuate from a low of 2 t·year^{-1} to a high of 365 t·year^{-1}. Killer whale catches from 1998 to present average 7 t·year^{-1} with none reported in 2006 and a high of 26 taken in 2008. The area in which most small cetaceans are taken is not recorded, but for narwhal 88% of the annual average catch is taken in western waters.

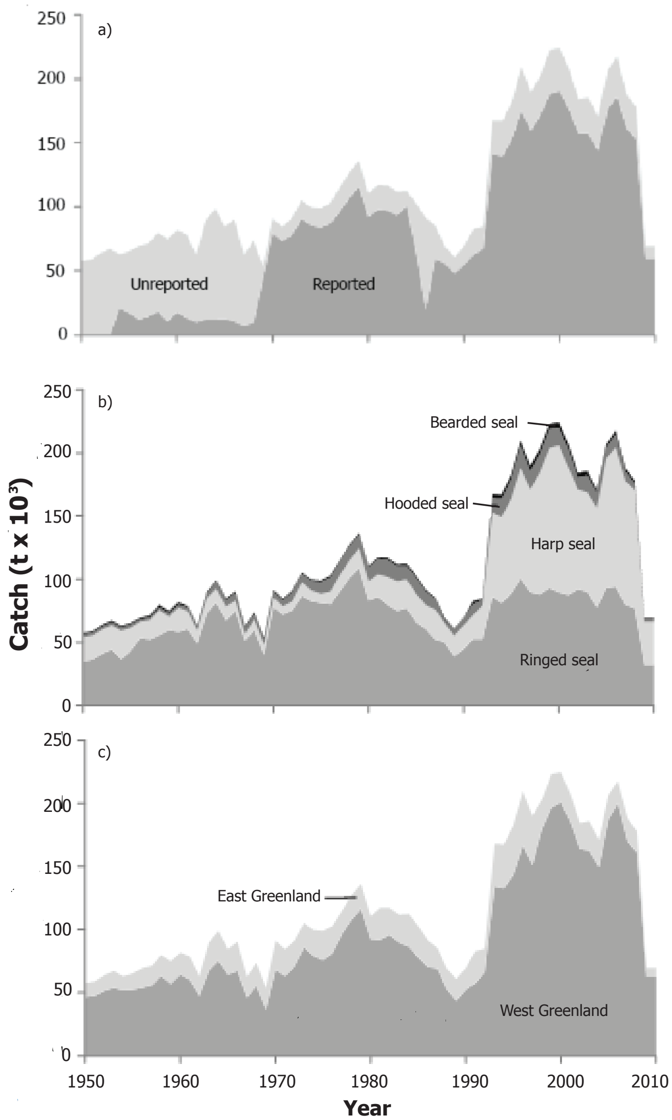

Figure 4. Estimated marine mammal catches (in t x 10³), including (a) reported and unreported seal catches; (b) seal catches by species; (c) seal catches by coast.

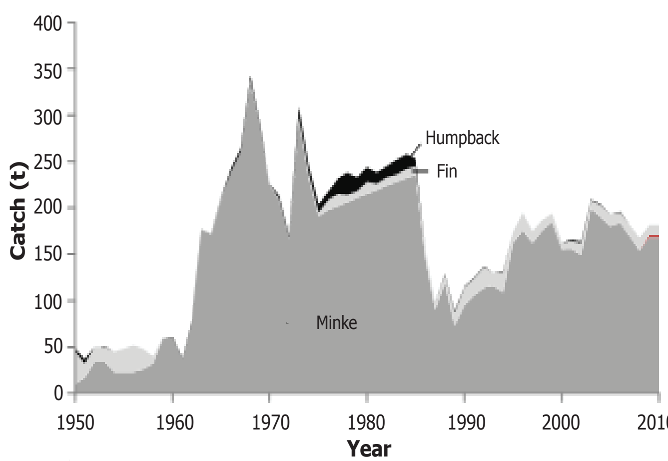

Figure 5. Estimated large whale catches by species, during the period 1950-2010.

Seabird catches

Seabird data are limited, but catches have declined nearly 4-fold between 1993 and 2008, declining from approximately 450,000 birds in 1993 to approximately 114,000 in 2008 (Figure 7). Preliminary numbers for 2009 are just over 46,000 and this would indicate a 10-fold drop from the number reported in 1993. Thick-billed murres are the most important species, accounting for 50% of the catches, with eider being the next most important, averaging 16% of the reported total catches.[7]

Ecosystem indices

The MTI has decreased from 4.39 in 1950 to 3.26 in 2010, due mostly to the declining importance of Atlantic cod and the increasing importance of northern shrimp (Figure 8). The rate of decline is approximately 0.26·trophic level·decade^{-1}. In order to exclude bottom-up effects (Caddy *et al.* 1998), the MTI was also calculated for species of trophic level 3.5 and above, and the decline in the MTI is then 0.07·trophic level·decade^{-1}.

The various length measurements of the catch have also decreased since 1950, although for marine mammals it is noticeable only after the moratorium on the hunting of large whales (Figure 6). The mean maximum length of estimated fisheries catches have declined from 149 cm in 1950 to 40 cm in 2010 (18 cm·decade^{-1}), and the average wingspan of seabird harvests have declined from 72 cm in 1963 to 65 cm. The mean maximum length of marine mammals have not declined significantly since 1950, but there is a slight trend downwards from 1976 (181 cm) to 2010 (169 cm).

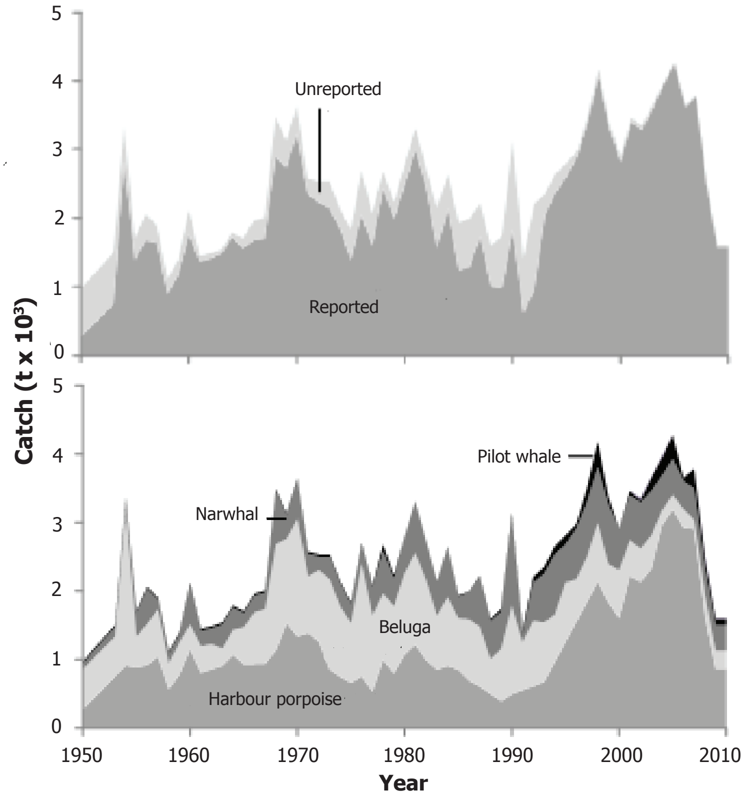

Figure 6. Estimated marine mammal catches (in t x 10^3), including (a) reported and unreported small cetacean catches; (b) small cetacean catches by species.

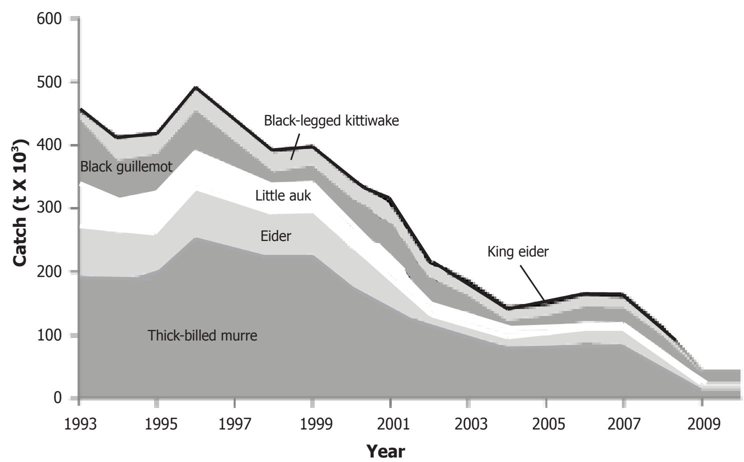

Figure 7. Reported catches of seabirds in Greenland from 1993-2010.

Discussion

The decline of the MTI in the Greenland fishery is the most dramatic case recorded so far (Table 3), and reflects a change in the fishery of one primarily targeting Atlantic cod to one primarily targeting shrimp. The recent collapse of Atlantic cod in Greenland waters is due in part to climatic forcing, but also due to overfishing. The profit of the fishery went to foreign countries' fishing fleets prior to Greenland declaring its EEZ in 1977 when, from 1950 to 1976, the foreign fleets caught over 6 million t of cod in West Greenland waters, approximately 10 times the Greenland catch during the same period.

The decline in the length of the catch is also indicative of an ecosystem that is moving towards smaller sized individuals. In fisheries, because size is related to trophic level, this is also a sign of fishing down marine food webs, but other living marine resources of the ecosystem are also moving towards one comprised of smaller individuals. Seabirds and marine mammals, in comparison to fish, have a relatively stable trophic level throughout their lives, whereas fish have trophic level changes as they grow and age (Cheung *et al.* 2007). Although here, we used one measure of trophic level for fish, the trophic level of fish would change

Table 3. The rate of decline in the Marine Trophic Index (MTI) for several marine ecosystems.

Ecosystem	Study Period	MTI rate of change	Source
Greenland	1950-2010	0.26 TL·decade^{-1}	This study
Canada's east coast	1950-mid 1997	0.16 TL·decade^{-1}	(Pauly *et al.* 2001)
Canada's west coast	1900-mid 1996	0.03 TL·decade^{-1}	(Pauly *et al.* 2001)
Iceland	1950-2000	0.05 TL·decade^{-1}	(Valtýsson and Pauly 2003)
India	1950-2000	0.06 TL·decade^{-1}	(Bhathal and Pauly 2008)

[7] For the purposes of *Sea Around Us* and the global database of reconstructed fisheries catches, marine mammal and seabird data were not used.

through time, reflecting the change in size of the fish and therefore the diet composition; however it has been shown that this effect is small (Pauly *et al.* 2001). Including marine mammals and seabirds in the MTI dampens the decline, but it still declines as a result of the decline in the mean trophic level of fisheries landings.

Fisheries, in the case of Greenland and other Arctic countries, are only one living marine resource that Inuit rely on. Ringed seals, belugas, and seabirds are also important in terms of subsistence use and therefore food security. After 1990, when the Atlantic cod had all but disappeared, Greenland halibut catches increased, but there was a significant increase in the catch of ringed and harp seals, and also of small whale species. Ringed seals and small whales are an important component of the diet of Greenlanders, and the decline of the beluga population since 1950 is of special concern.

The economy of Greenland is presently reliant on export earnings from fisheries, particularly shrimp. However, the country must be resilient to changes to its marine ecosystems, given that the Arctic is most affected by climate change. The transition from cod to shrimp was also associated with social effects because of differences between communities' abilities to adapt to shifts in marine resource distributions (Hamilton *et al.* 2003). As is the case for other Inuit, there is a high reliance on living marine resources for cultural, subsistence and economic use, and some of these marine populations will decline if global warming continues, adversely affecting food security for communities that are not able to adapt.

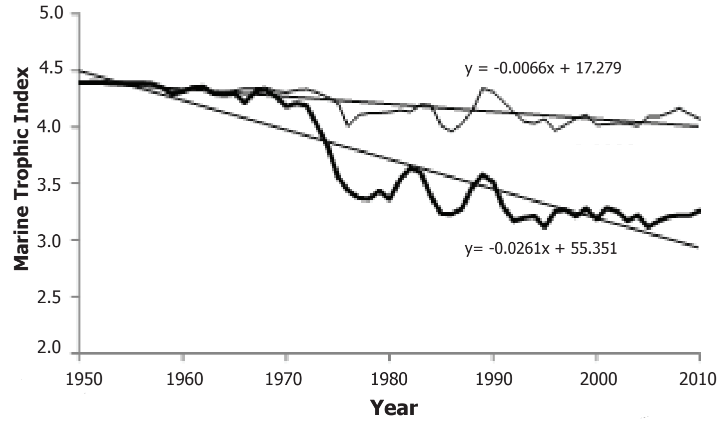

Figure 8. The decline in the Marine Trophic Index, 1950-2010.

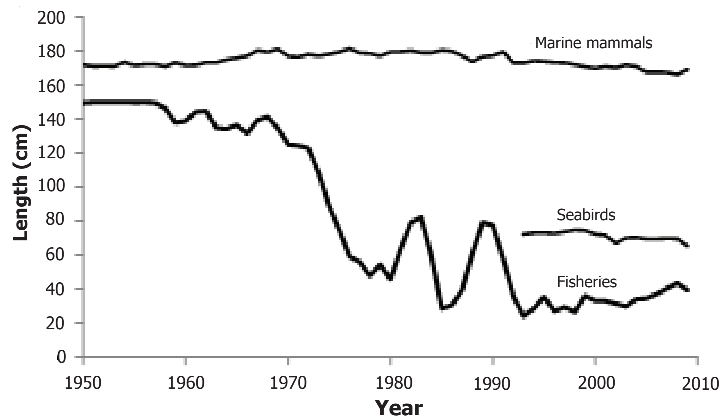

Figure 9. Changes in the mean maximum length measurement of catches of fisheries, marine mammals, and seabirds.

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Appendix Table A1. Unreported discard rates of shrimp as a rate of reported landings. Unreported catches include estimates for boat-based discards, and overpacking and quality discards that are processor-based (see text for details).

Year	Large-scale	Small-scale
1950-1969	n.a.	0.063
1970	0.310	0.310
1971	0.365	0.365
1972	0.691	0.691
1973	1.085	1.085
1974	1.993	1.993
1975	4.705	4.705
1976	6.588	6.588
1977	3.153	3.153
1978	2.861	2.861
1979	1.447	1.447
1980	0.796	0.796
1981	0.638	0.637
1982	0.599	0.591
1983	0.598	0.587
1984	0.547	0.534
1985	0.509	0.496
1986	0.549	0.525
1987	0.511	0.484
1988	0.563	0.527
1989	0.558	0.528
1990	0.580	0.544
1991	0.401	0.389
1992	0.364	0.360
1993	0.271	0.267
1994	0.274	0.267
1995	0.199	0.193
1996	0.310	0.303
1997	0.388	0.382
1998	0.291	0.288
1999	0.285	0.281
2000	0.249	0.245
2001	0.320	0.317
2002	0.525	0.525
2003	0.859	0.862
2004	0.073	0.041
2005	0.073	0.047
2006	0.072	0.047
2007	0.070	0.051
2008	0.065	0.068
2009	0.061	0.082
2010	0.061	0.082

Appendix Table A2. Communities located in the municipalities of Qaasuitsup and Sermersooq and the region they were assigned for estimating subsistence catches.

Community	Region[1]	Municipality	Community	Region[1]	Municipality
Aasiaat	CWG	Qaasuitsup	Ukkusissat	NWG	Qaasuitsup
Akunnaaq	CWG	Qaasuitsup	Upernavik	NWG	Qaasuitsup
Ikamuit	CWG	Qaasuitsup	Upernavik Kujalleq	NWG	Qaasuitsup
Illimanaq	CWG	Qaasuitsup	Uummannaq	NWG	Qaasuitsup
Ilimanaq	CWG	Qaasuitsup	Attu	SG	Qaasuitsup
Ilulissat	CWG	Qaasuitsup	Iginniarfik	SG	Qaasuitsup
Kangerluk	CWG	Qaasuitsup	Ikerasaarsuk	SG	Qaasuitsup
Kitsissuarsuit	CWG	Qaasuitsup	Kangaatsiaq	SG	Qaasuitsup
Oqaatsut	CWG	Qaasuitsup	Niaqornaarsuk	SG	Qaasuitsup
Qasigiannguit	CWG	Qaasuitsup	Illoqqortoormuit	CEG	Sermersooq
Qeqqertaq	CWG	Qaasuitsup	Itterajivit	CEG	Sermersooq
Qeqertarssuatsiaq	CWG	Qaasuitsup	Nerlerit Inaar	CEG	Sermersooq
Qwqertarsuaq	CWG	Qaasuitsup	Sermiligaaq	CEG	Sermersooq
Qeqertat	CWG	Qaasuitsup	Uunarteq	CEG	Sermersooq
Saqqaq	CWG	Qaasuitsup	Orsuiassuaq	SEG	Sermersooq
Aappilattoq	NWG	Qaasuitsup	Pikuillit	SEG	Sermersooq
Dundas	NWG	Qaasuitsup	Ikkateq	SEG	Sermersooq
Ikersak	NWG	Qaasuitsup	Isortoq	SEG	Sermersooq
Illorsuit	NWG	Qaasuitsup	Kulusuk	SEG	Sermersooq
Innaarsuit	NWG	Qaasuitsup	Kuumiut	SEG	Sermersooq
Kangersuatsiaq	NWG	Qaasuitsup	Narsalik	SEG	Sermersooq
Kullorsuaq	NWG	Qaasuitsup	Qernertuarsuit	SEG	Sermersooq
Maarmorilik	NWG	Qaasuitsup	Tasiilaq	SEG	Sermersooq
Moriusaq	NWG	Qaasuitsup	Timmiarmiut	SEG	Sermersooq
Naajaat	NWG	Qaasuitsup	Tinit eqilaaq	SEG	Sermersooq
Niaqornat	NWG	Qaasuitsup	Arsuk	SG	Sermersooq
Nutaarmiut	NWG	Qaasuitsup	Avigaat	SG	Sermersooq
Nuugaatsiaq	NWG	Qaasuitsup	Ivittuut	SG	Sermersooq
Nuussuaq	NWG	Qaasuitsup	Kangeq	SG	Sermersooq
Qaanaaq	NWG	Qaasuitsup	Kangerluarsoruseq	SG	Sermersooq
Qaarsut	NWG	Qaasuitsup	Kapisillit	SG	Sermersooq
Qeqertarsuaq (Herbert Island)	NWG	Qaasuitsup	Nuuk	SG	Sermersooq
Saattut	NWG	Qaasuitsup	Paamiut	SG	Sermersooq
Savissivik	NWG	Qaasuitsup	Qeqertarsuatsiaat	SG	Sermersooq
Siorapaluk	NWG	Qaasuitsup	Qooqqut	SG	Sermersooq
Tasiusaq	NWG	Qaasuitsup	Qoornoq	SG	Sermersooq
Tunugassoq	NWG	Qaasuitsup	-	-	-

[1] CWG: central western Greenland; NWG: northwest Greenland; SG: southern Greenland; CEG: central eastern Greenland; SEG: southeastern Greenland)

Appendix Table A3. Trophic level (TL) and mean maximum standard length measurements of fisheries catches used for estimating changes in Greenland's marine ecosystem from 1950-2010.

Common name	TL	Length (cm)	Common name	TL	Length (cm)
Aesop shrimp	2.3	16	Lanternfishes	3.2	10
American angler	4.5	102	Lemon sole	3.3	52
American plaice	3.7	67	Ling	4.3	185
Angler	4.5	200	Lumpfish	3.9	49
Arctic charr	4.3	9	Megrim	4.2	49
Argentines	3.3	52	Monkfishes	4.1	97
Atlantic cod	4.4	150	Moras	4.0	280
Atlantic halibut	4.5	219	Navaga	4.2	35
Atlantic herring	3.2	45	Northern shortfin squid	4.0	27
Atlantic horse mackerel	3.6	62	Northerm shrimp	2.5	14
Atlantic mackerel	3.7	46	Northern wolffish	3.8	180
Atlantic redfishes	3.9	60	Ocean perch	3.9	60
Atlantic salmon	4.4	135	Ocean pout	3.4	54
Atlantic wolffish	3.2	165	Onion-eye grenadier	4.5	82
Baird's slickhead	3.9	100	Orange roughy	4.3	58
Beaked redfish	3.7	33	Pandalus shrimps	2.5	11
Black dogfish	3.9	82	Piked digfish	4.3	106
Black scabbardfish	4.5	110	Polar cod	3.1	35
Blue ling	4.5	145	Pollack	4.2	115
Blue skate	4.0	285	Porbeagle	4.5	227
Blue whitnig	4.0	42	Portugese dogfish	4.4	99
Bramble, sleeper, dogfish sharks	4.2	149	Queen crab	2.3	20
Brill	3.8	62	Rabbit fish	3.8	101
Capelin	3.2	18	Raja rays	3.8	117
Common dab	3.3	40	Ratfishes	3.9	74
Common sole	3.1	70	Rays, stingrays, mantas	3.8	135
Dealfishes	4.5	278	Redfishes	3.9	60
Deepwater rose shrimp	2.4	22	Roughhead grenadier	4.5	82
Dogfish shark	4.3	130	Roundnose grenadier	3.5	106
European conger	4.3	246	Ruffs, barrelfishes	3.9	150
European flounder	3.2	50	Saithe	4.4	107
European hake	4.4	130	Shagreen ray	3.5	98
European plaice	3.3	100	Silvery lightfish	3.0	6
European smelt	3.0	40	Skates	3.7	100
Forkbeards	4.0	65	Spotted ratfish	4.0	74
Golden redfish	4.0	87	Spotted wolffish	3.5	165
Greater forkbeard	3.7	97	Tusk	4.0	98
Greenland cod	3.6	65	White hake	4.2	115
Greenland halibut	4.5	72	Whiting	4.4	63
Greenland shark	4.2	606	Witch flounder	3.1	60
Haddock	4.1	86	Wolffishes	3.5	136
Iceland scallop	2.0	11	-	-	-

Appendix Table A4. Mean maximum length of marine mammals and the wingspan of seabirds used to estimate the change in lengths of catches from 1950 to 2010.

Common Name	Species Name	Length (cm)
Bearded seal	*Erignathus barbatus*	260
Beluga whale	*Delphinapterus leucas*	270
Bowhead whale	*Balaena mysticetus*	2010
Fin whale	*Balaenoptera physalus*	2110
Harbour porpoise	*Phocoena phocoena*	130
Harbour seal	*Phoca vitulina*	140
Harp seal	*Pagophilus groendlandicus*	150
Hooded seal	*Cystophora cristata*	260
Humpback whale	*Megaptera novaeangliae*	1330
Killer whale	*Orcinus orca*	480
Minke whale	*Balaenoptera acutorostrata*	810
Narwhal whale	*Monodon monoceros*	270
Pilot whale	*Globicephala melas*	420
Ringed seal	*Pusa hispida*	170
Black guillemot	*Cepphus grylle*	55
Black-legged kittiwake	*Rissa tridactyla*	108
Eider	*Somateria mollissima*	94
King eider	*Somateria spectabilis*	94
Little auk	*Alle alle*	44
Thick-billed murre	*Uria lomvia*	67

Appendix Table A5. FAO and ICES landings vs. reconstructed total catch (in tonnes), and catch by sector with discards shown separately for Greenland, 1950-2010.

Year	FAO	ICES	Reconstructed total catch	Industrial	Artisanal	Subsistence	Discards
1950	22,703	-	6,390	-	26,500	2,590	3,690
1951	19,620	-	6,170	-	23,100	2,670	3,170
1952	18,286	-	6,070	-	21,600	2,750	2,920
1953	25,751	-	7,170	-	30,100	2,830	3,950
1954	22,132	-	6,580	-	25,900	2,850	3,270
1955	23,887	-	7,250	-	28,300	2,870	3,460
1956	25,528	-	7,580	-	30,200	2,890	3,690
1957	29,093	-	9,420	-	35,600	2,960	4,310
1958	31,002	915	9,520	-	38,400	3,020	4,690
1959	32,177	642	10,000	-	39,700	3,080	4,960
1960	33,095	1,646	9,720	-	41,300	3,130	5,100
1961	40,660	1,199	10,840	-	49,500	3,170	6,270
1962	42,388	903	11,030	-	51,100	3,200	6,520
1963	32,386	904	8,310	-	38,400	3,210	4,470
1964	36,333	1,136	9,110	-	43,300	3,260	4,350
1965	39,743	887	9,100	-	46,400	3,330	4,780
1966	43,599	881	10,470	-	51,600	3,310	5,610
1967	44,116	753	10,290	-	51,700	3,420	5,440
1968	33,665	630	8,460	209	39,100	3,460	4,270
1969	38,745	627	9,800	3,452	42,200	3,500	5,160
1970	38,961	501	11,540	7,787	39,800	3,450	7,130
1971	37,754	535	12,490	11,182	36,200	3,360	7,750
1972	41,490	282	14,910	18,455	34,900	3,360	10,630
1973	42,411	251	17,380	24,452	32,300	3,270	13,200
1974	51,193	71	29,670	43,506	34,200	3,230	25,580
1975	47,369	226	55,390	73,214	26,600	3,120	51,300
1976	44,138	506	72,080	91,500	22,200	3,030	68,940
1977	58,013	1,852	56,290	75,654	37,600	2,930	53,200
1978	66,856	1,377	50,100	72,871	42,700	2,800	47,200
1979	80,360	2,775	42,940	59,183	64,200	2,720	39,680
1980	101,826	1,907	41,400	72,923	69,600	2,650	38,620
1981	106,443	1,043	38,100	74,864	68,100	2,600	35,370
1982	104,189	2,015	39,730	93,361	50,000	2,540	37,050
1983	97,402	1,919	38,030	83,225	51,700	2,470	35,490
1984	83,299	2,953	32,780	72,237	44,400	2,390	30,010
1985	86,539	8,411	35,610	99,373	28,900	2,320	31,920
1986	86,519	16,384	41,830	117,504	25,000	2,240	38,550
1987	91,411	9,002	42,070	106,166	34,200	2,160	38,310
1988	116,311	8,063	50,600	124,642	48,200	2,090	47,840
1989	158,850	9,770	62,660	157,118	72,200	2,010	60,300
1990	132,575	10,755	58,890	137,502	62,800	1,920	56,580
1991	103,025	11,137	39,610	97,161	54,800	1,820	37,100
1992	101,982	4,765	35,830	97,646	43,200	1,710	33,990
1993	94,938	14,593	25,680	96,816	36,800	1,610	24,050
1994	101,950	6,070	27,730	98,165	36,100	1,520	26,210
1995	108,574	9,527	23,090	104,264	35,500	1,420	21,640
1996	94,356	13,177	27,940	98,253	35,900	1,330	26,590
1997	94,096	17,561	30,770	110,095	31,100	1,280	29,470
1998	97,953	21,811	26,200	123,031	21,700	1,220	24,970
1999	118,461	14,461	29,600	122,900	38,500	1,170	25,090
2000	121,885	9,940	26,770	115,259	42,200	1,110	25,660
2001	124,149	10,414	34,430	125,955	42,000	1,050	33,380
2002	151,533	21,070	63,510	175,695	59,400	1,000	62,500
2003	130,367	25,198	79,590	174,746	59,500	940	78,640
2004	183,660	5,913	16,300	152,340	52,600	890	15,390
2005	194,620	6,774	16,860	161,012	56,400	850	15,990
2006	206,296	6,966	18,290	164,717	66,000	810	17,400
2007	196,170	9,973	19,170	156,176	68,300	810	18,270
2008	203,247	15,669	20,280	173,724	64,700	800	19,400
2009	178,611	22,143	18,160	162,235	55,900	800	17,270
2010	175,919	9,894	16,350	149,808	51,600	800	15,550

Appendix Table A6. Reconstructed total catch (in tonnes) by major taxa for Greenland, 1950-2010. 'Others' contain 27 additional families.

Year	Pandalidae	Gadidae	Pleuronectidae	Cyclopteridae	Osmeridae	Anarhichadidae	Sebastidae	Others
1950	319	26,400	1,080	89	118	852	119	156
1951	319	22,900	1,100	92	121	745	123	375
1952	319	21,200	1,120	95	125	889	127	451
1953	425	28,200	1,260	97	129	2,233	130	422
1954	425	23,600	1,300	98	130	2,568	131	460
1955	425	24,900	1,390	99	131	3,655	132	413
1956	531	26,400	1,690	99	131	3,636	133	487
1957	744	30,800	1,390	102	134	4,639	236	462
1958	744	33,100	2,060	104	137	4,142	306	867
1959	956	34,900	2,130	106	140	3,244	376	999
1960	1,903	35,400	2,330	108	142	2,969	445	1,155
1961	2,704	43,100	2,150	109	144	2,451	492	1,547
1962	3,573	44,400	2,260	110	145	1,862	281	1,652
1963	3,550	30,200	3,480	111	146	2,617	316	1,136
1964	4,006	29,000	3,530	112	4,188	2,238	372	3,110
1965	5,367	31,500	3,900	115	1,798	3,430	419	3,176
1966	5,715	37,000	3,400	114	1,523	2,633	444	4,081
1967	5,995	35,200	2,650	700	3,927	2,861	332	3,517
1968	5,955	27,100	2,380	981	359	3,974	295	1,721
1969	7,164	30,900	2,290	1,164	336	3,520	299	3,503
1970	11,045	26,700	2,010	1,816	3,312	2,864	330	2,968
1971	12,207	26,200	1,950	1,107	2,646	2,771	479	3,453
1972	12,668	30,900	3,820	620	2,088	3,621	399	2,568
1973	16,967	25,000	5,620	186	3,395	4,340	1,353	3,206
1974	30,656	30,500	5,100	155	3,653	5,898	2,563	2,442
1975	55,850	31,100	4,710	224	1,187	5,834	1,552	2,553
1976	74,198	27,500	4,480	247	617	5,068	2,965	1,631
1977	61,802	39,600	7,090	635	459	3,146	1,234	2,152
1978	50,696	54,000	7,010	1,588	427	2,296	803	1,488
1979	49,361	64,300	6,180	1,051	387	2,269	377	2,105
1980	64,560	64,000	6,410	2,271	405	4,143	1,343	2,001
1981	58,851	70,300	7,140	2,395	262	3,434	605	2,562
1982	64,905	65,000	6,740	3,105	223	2,902	405	2,672
1983	63,669	60,400	5,240	3,021	411	2,430	611	1,533
1984	64,099	36,800	7,420	3,992	1,188	1,710	1,194	2,602
1985	80,731	23,500	10,190	595	1,106	1,923	7,497	5,046
1986	98,910	16,000	9,550	310	1,276	1,844	12,607	4,278
1987	97,779	28,500	9,520	90	536	1,543	928	3,618
1988	93,419	68,000	8,020	313	229	1,995	361	2,626
1989	97,232	121,400	8,410	269	325	1,105	255	2,248
1990	108,977	80,100	9,320	94	370	802	405	2,101
1991	102,224	34,700	11,160	258	258	467	421	4,282
1992	110,829	11,200	13,490	201	203	273	1,374	5,016
1993	97,109	5,400	14,880	358	11,359	237	1,245	4,591
1994	101,549	5,300	19,390	765	716	178	1,555	6,264
1995	98,105	5,400	19,360	600	1,948	122	3,924	11,714
1996	94,170	4,000	21,320	570	7,314	121	1,167	6,778
1997	88,648	3,600	25,380	1,468	12,342	133	1,221	9,643
1998	89,932	2,900	23,850	2,679	17,142	92	1,281	8,141
1999	101,544	3,300	41,020	3,803	1,958	85	3,985	6,803
2000	107,347	2,500	26,060	1,529	73	111	5,303	15,693
2001	113,897	3,700	21,620	3,995	1,831	107	3,269	20,556
2002	161,605	6,200	27,100	7,233	13,682	201	3,537	16,575
2003	156,866	6,500	30,000	8,130	19,387	443	639	13,195
2004	144,999	7,000	31,220	10,165	310	364	712	11,138
2005	156,054	8,400	31,690	11,972	383	539	1,143	8,032
2006	158,602	13,200	35,420	12,308	77	802	2,975	8,156
2007	149,387	20,100	33,010	10,862	524	917	2,451	8,088
2008	157,865	27,900	35,510	7,950	177	1,267	3,906	4,666
2009	143,622	15,100	37,060	8,583	222	1,207	7,143	6,023
2010	131,967	14,300	31,730	10,642	127	1,235	5,065	7,084