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Marine Mammal Populations: Reconstructing historical abundances at the global scale

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by

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Reconstructing Historical Abundances at the Global Scale

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DIRECTOR'S FOREWORD

This Report presents reconstruction of the populations (at least back to 1950) of nearly half of the 115 species of marine mammals, i.e., of all those which are, or have been commercially exploited. This reconstruction uses a robust method and provides a first approximation of their populations. In many case, this is the first such reconstruction.

The data used for this are catches of different species of marine mammals, going back as far as possible into the past, in one case to 1530. These catches are of variable quality and hence the author emphasizes, quite rightly, that the reconstructed populations should not be viewed as 'assessment', and compared for example, with assessment by the International Whaling Commission.

Rather, this report should be viewed as the first exercise based on the first publicly available compilation of all catches of all marine mammals in the world, hence providing the basis for various generalizations, and a public dialog about marine mammals.

One such generalization is that it is the large whales which have been first hunted historically, with the result that the mean size of marine mammals killed by humans has been declining over time. We are now mainly killing dolphins and pinnipeds, though there is a move afoot to reinstitute large scale hunting of large whales. Another generalization is that overall the population of marine mammals has declined since 1950 by approximately 56% in terms of weight and by 11% in terms of numbers.

Although some single species of marine mammal have recovered spectacularly in the last decades, for example the North East Pacific gray whale, overall, marine mammals have still to recover from the great hunts of the past. This process is slowed down by the continuation of various fisheries which have marine mammals as 'by-catch' in various parts of the world.

The population estimates presented in this report will also allow adding a temporal dimension of the global overlap between marine mammals and fisheries. A study done at the Fisheries Centre, which pertained to the 1990s, suggested that this overlap is rather limited. The population trends presented here suggest that this overlap might have been even weaker in the early 20th century, because the fisheries then took smaller catches, from a smaller area than now. Using the reconstructed data in this report, we will now be able to investigate whether the large populations of marine mammals we had in the past are compatible with the extensive fishery we have now. The jury is still out on this scenario.

This report could also be used for comprehensive evaluation of the hypothesis presented by Ugo Bardi, who suggested that whales, because of their slow reproduction rates, can be treated as if they were a mineral resource, such as petroleum. This hypothesis, which was tested using a small data set (whale oil and bone from 19th century US whaling), suggests that whales can be treated that way, and hence can be fitted with Hubbert's 'Peak Oil' model[a]. This could be verified with the larger dataset presented here.

Thus, I welcome Ms Line Bang Christensen's comprehensive analyses and the catch data they relied on, included here in an Appendix, though I also wish to re-iterate her warning that these catch data need to be verified and, if need be, expanded. They will then allow widespread analyses of the interactions between marine mammals and humans, so as to enable us to coexist on our ocean planet.

[a] See Ugo Bardi and Leigh Yaxley 2006. How general is the Hubbert curve? The case of fisheries. Association for the Study of Peak Oil (see ww.aspoitalia.net)

ABSTRACT

This body of work is an adaptation of my M.Sc. thesis, which was completed September 2006 at the Fisheries Centre in the Resource Management and Environmental Studies Program at the Faculty of Graduate Studies, University of British Columbia.

The relationship between humans and marine mammals extends back for centuries and covers a multitude of facets; literature and spirituality, necessities (food) and luxuries (corsets). Their exploitation history changed from small-scale hunting for food/fur, to large commercial ventures for oil, to smaller constrained hunts as marine mammals became the poster child for environmental movements. The International Whaling Commission, and national and regional bodies assess the current status of marine mammals. Information on stock size relative to carrying capacities is, however, hard to come by. Assessments to date have been limited to a relatively small number of stocks/species because of data quality, availability and politics. To address concerns over stock status, the analyses have to be expanded to all exploited populations.

Employing a Bayesian approach to stochastic stock reduction analysis, I construct probability distributions over historical stock sizes. The method allows me to use historical catch time series to estimate a distribution over population parameters, the intrinsic rate of growth and carrying capacity, that give rise to extant populations. I tested this stock reconstruction approach on simulated data sets generated from a reference model, and then applied it to available catch and abundance data. Simulation tests indicate that parameter estimates were unbiased.

Globally, I find that aggregated information on all marine mammal populations indicate a decline of 22% (0-62%) in numbers, and 76% (58-86%) in biomass. The decline has been greatest for the great whales, with a 64% (40-79%) decline in numbers, and an 81% (69-89%) decline in biomass. My estimates are consistent with published estimates of carrying capacity. These estimates are intended to provide a status overview, rather than direct management advice, affording us the ability to begin calculating how humans have impacted these large fauna in their marine ecosystems.

The International Convention on the Regulation of Whaling (ICRW) predicates that stocks must be maintained at their most productive levels. Also, a moratorium on whaling exists, awaiting better science. This represents the fundamental conflict in interest between pro-whaling nations and those with moral/ethical opposition to whaling, intent on upholding the moratorium. Results in this report indicate that the Japanese hunt of minke whales could increase and abide by the ICRW, yet the majority of western IWC signatories want to see commercial hunting banned altogether.

INTRODUCTION

The relationship between humans and marine mammal extends back for centuries and covers a multitude of facets, from the literary adventures of Moby Dick (Melville, 1851) and First Nations' folklore/spirituality, to the necessities of life: blubber for light and food, fur for warmth, bladders for water carriers, and the luxuries: blubber for soap and perfume and baleen for corsets. The dynamics driving this relationship, as well as the relationship itself, have since changed drastically. Sven Foyn, a Norwegian, spurred much of the development that initiated the period referred to as modern whaling, which saw changes in technology and targeting beginning in the 1860s (Tønnessen, 1982). The great whales were reduced to the sum of their products: oil and baleen winning out over food, clothing and culture. It was a change from a hunt dominated by cultural identity to one dominated by a lifestyle en masse for the crews of larger industrial operations.

The question becomes how has this impacted marine mammal populations and the ecosystems they live in. Marine food webs have been fished down and with the exploitation, dynamics in the oceans have been radically altered (Christensen, 1996; Pauly *et al.*, 1998). But by how much, and what are the relative differences, in numbers and biomasses, of these top fauna of our marine ecosystems? This has not been quantified on a global scale, and I attempt to fill this gap in our knowledge. In addition, shifting baselines (Pauly, 1995) make for a world where it becomes difficult to imagine oceans full of whales - which surely influences management goals. Also, as a consequence of anthropogenic impacts, the current capacity of the oceans and their ability to support past marine mammal abundance levels is unknown.

In this report I have reconstructed population trajectories for documented exploited marine mammal species and stocks at the scale of ocean basins. This is done to help decipher what has happened to the stocks, defined as groups of animals of the same species occupying separate areas, over the last decades, and the scale at which exploitation has affected their abundances. By quantifying marine mammal population histories, it is possible to begin to calculate how humans have impacted their marine ecosystem food webs over time. I want to stress that the population trajectories developed are meant to be used in the context described above. Applying them within the context of management could be inappropriate because the scale at which they are assessed and reconstructed is too coarse. In addition, while single species assessment is the International Whaling Commission's (IWC) method of choice, the consequences of managing, in this manner, species that naturally co-exist and potentially affect each other (e.g., krill, minke whales and crabeater seals as described by Mori and Butterworth, 2005) should be considered. Walters *et al.* (2005) explain how managing all species at maximum sustainable yield is technically challenging because of complex ecosystem interactions that are not fully understood.

Stakeholders need to think about what population status objectives for marine mammal populations ought to be. Should populations be maintained at their most productive levels (as predicated by the International Convention on the Regulation of Whaling) or should the goal be to conserve and/or rebuild marine mammal stocks? This work is intended to set the stage so that stakeholders can make informed decisions when facing those options.

OBJECTIVES

The objective of this report is to quantify the history of marine mammal populations, in terms of both numbers and biomass, subsequent to the commencement of hunting, on a global scale. This is done for all exploited marine mammal populations with sufficient abundance and catch data. For each species, population trajectories are carried back to the year of the first documented hunting.

In the remainder of this section, I attempt to briefly summarize the history of marine mammal hunting. In the section on methods and materials, I describe the method I have selected to analyze the species histories, and evaluate potential bias in the method. Results for exploited marine mammal species and aggregated results for all marine mammals, including those that have not been subject to documented hunting are presented. Lastly, there is a discussion of the data obtained, methodology developed and results generated.

HISTORY OF MARINE MAMMAL HUNTING

Early hunting

The beginnings of aboriginal subsistence whale hunting are unknown. In the Arctic, hunting of bowheads was documented in Greenland from 800-1000 years ago; in Alaska the hunt dates back even farther (Reeves, 2002). In Korea, evidence of hunting dates back to a sandstone carving from 6000 BC showing a whale being harpooned from a boat (Baker and Clapham, 2002). The Neolithic times likely marked the beginning of subsistence hunting for seals, sea lions, walruses and sea otters (Baker and Clapham, 2002). In Northern Scandinavia, the hunt for ringed seals dates back to some 6000 – 4000 years before present (Nygaard, 1989).

In the 11th century whaling developed into an industry, as documented by tax records, led by the Basques who hunted the northern right whale in the Bay of Biscay (Aguilar; 1986, Clapham *et al.*, 1999; Baker and Clapham, 2002). By the end of the sixteenth century, this whaling had expanded into the New World, with Basque boats hunting bowhead and right whales in Labrador (Baker and Clapham, 2002). Following in their footsteps and often with Basque harpooners, whaling was expanded into the Arctic by the Dutch and Germans, the British, and the French (Baker and Clapham, 2002). In the early 17th century the Basque boats migrated to Spitsbergen, where they found Dutch, English, German, Danish and Norwegian whalers (Isachsen, 1929).

Marine mammals were hunted using a variety of techniques, many of them local to specific areas. One of the most common methods for the capture of whales was the harpoon-line-float contraption; here, hunters in boats could follow the harpooned whale, which would both be slowed down and marked by the float (Mitchell *et al.*, 1986). Other techniques included the harpoon-line-fast boat, the 'Nantucket sleighride' (where the harpoon line remained attached to the boat), electrocution, netting, drugs and poisons, gas injection and rifles (Mitchell *et al.*, 1986). An interesting hunting method was developed in the Philippines where mainly Bryde and Pygmy Bryde whales are hunted in Pamilacan by men who jump with big hooks from boats onto the animals. This method likely evolved from the manta ray hunt and dates back at least to the early 20th century (Reeves, 2002). The last technique is the mechanically propelled explosive harpoon, the device that brought with it modern whaling, with its extreme capability, i.e., range, power and precision.

Modern Whaling

"Optimism is a good characteristic, but if carried to an excess, it becomes foolishness.
We are prone to speak of the resources of this country as inexhaustible;
this is not so."

- Theodore Roosevelt (1907)

Modern whaling emerged rapidly, precipitated by an ingenious development by a Norwegian, Sven Foyn, in the late 1800s. Foyn's invention marked the beginning of the period of massive over-exploitation of many of the world's great whales. Foyn equipped a steam boat with a bow-mounted cannon capable of firing an exploding grenade harpoon (Tønnessen, 1982; Mitchell *et al.*, 1986). The harpoon would bury itself inside the mammal, the grenade would explode, and the dying whale, fastened to the boat by the harpoon line, was secured (Tønnessen, 1982). In this manner modern whaling saw its beginning in Norway's northernmost county, Finnmark (Tønnessen, 1982). According to Tønnessen (1982), modern whaling can be split into three categories: the Finnmark whaling described above (1864-1904), global whaling (1883-1924), and pelagic whaling (1925-1986). I would add a fourth period (1986-present) of scientific whaling and continued commercial Norwegian whaling. In the modern whaling era, steam allowed boats to go farther and faster, and the harpoon made whaling safer and more efficient. This would eventually lead to expansion both in terms of species caught and also new whaling grounds. The aggressive sperm whales and the cold Antarctic waters were no longer feared by the whalers, dry on their bigger, quicker boats. The major development that made large-scale pelagic whaling possible was the introduction of floating factory ships supplied by steam catcher boats. Slips and winches moved flensing, the removal of blubber in long strips from the whale carcass, from an outboard 'round' procedure, where the whale, attached to the side of the boat, rolled around in the water as it was flensed, to an onboard 'long' undertaking, where steam winches pulled up strips of blubber that men with flensing knives separated from the carcass much like it was done when shore-based, improving the processing efficiency (Isachsen, 1929). The onboard processing of blubber, in big boilers, allowed even more freedom, as whales no longer had to be towed to shore within a limited amount of time. Lastly, the development of technology, including radio, planes to spot whales, GPS, and so forth, helped find whales as they became increasingly sparse.

Both nationally and internationally, Norwegians were the pioneers of modern whaling. They formed the crew on most early expeditions, and maintained their positions as the best captains and harpooners for the bulk of the whaling years. The three companies that opened up Antarctic whaling were either entirely owned, or started and managed by Norwegians. The pioneers in that region were three Norwegians all hailing from Sanderfjord: C.A. Larsen (see below), Christen Christensen, who developed one of the first two floating factory steamships and worked with the refinement and transportation of oil (Tønnessen, 1982), and Adolf Amandus Andersen, who began western Antarctic whaling, though on a much smaller scale and less influentially than the two others (Tønnessen, 1982). The Compañía Argentina de Pesca Sociedad Anónima, established at Grytviken in South Georgia, can be named the pioneer of modern Antarctic whaling and was initiated by Captain C. A. Larsen, who also acted as technical leader and whaling manager (Hart, 2004).

But the scale of the whaling operations proved too much for the oceans, and Thomas Huxley's (1883) statement that "all the great sea-fisheries are inexhaustible" once again proved itself incorrect. The reason the scale and magnitude of the decline was possible was the ability of the operations to switch between species. This allowed the stocks to be almost completely depleted as the operations remained profitable for much longer than they would otherwise have been (e.g., Southern blue whales). However, according to Schneider and Pearce (2004), the 1986 moratorium was the result mainly of market forces, in terms of cost increasing per unit effort as stocks decreased, and to a lesser extent the influence of environmental organizations.

Presently, aboriginal subsistence hunting is allowed in a number of smaller communities. Seal 'culling' programs are in place in Canada, and seals are caught for subsistence purposes in a number of small communities. Whaling, as it existed before the moratorium, is gone. Norway, with its original abstention to the moratorium, still legally hunts minke whales. Japan has a legal scientific whaling program which has often found itself accused of being a disguise for a commercial whaling operation. Iceland was readmitted to the IWC in 2002, under a clause stating that commercial hunting could recommence in 2006 warranting adherence to IWC hunting regulations (Anon., 2002). The political forces at work in the whaling debate are complex. It is worth noting that the Wakayama school district in Japan has re-introduced whale meat in school lunches (Head, June 19, 2005) and Norway (citing bad weather) will be unable to fill their quotas in 2006 (Black, July 13, 2006). The 2006 IWC meeting saw a declaration, which included the following, passed:

"...

FURTHER NOTING that the moratorium, which was clearly intended as a temporary measure is no longer necessary, that the Commission adopted a robust and risk-averse procedure (RMP) for calculating quotas for abundant stocks of baleen whales in 1994 and that the IWC's own Scientific Committee has agreed that many species and stocks of whales are abundant and sustainable whaling is possible

CONCERNED that after 14 years of discussion and negotiation, the IWC has failed to complete and implement a management regime to regulate commercial whaling

...

DECLARE our commitment to normalize the functions of the IWC based on the terms of the ICRW and other relevant international law, respect for cultural diversity and traditions of coastal peoples and the fundamental principles of sustainable use of resources, and the need for science-based policy and rulemaking that are accepted as the world standard for the management of marine resources"

- St Kitts and Nevis Declaration, IWC Meeting 58

Reporting catches

Whaling operators have reported their landings since the late 1860s (Schneider and Pearce, 2004). In 1929, the Whaling Committee of the International Council for the Study of the Sea (later renamed the International Council for the Exploration of the Sea) recommended that the Norwegian government create an institution, *Komitéen for Internasjonal hvalfang-statistisk*, the Committee for Whaling Statistics or the Bureau of International Whaling Statistics (BIWS), appropriately located in Sanderfjord, to collect, collate and annually publish global statistics on the industry, including catches, effort and financial statistics (The Committee for Whaling Statistics, 1930; Grieves, 1972). When the IWC was set up, Article VII of the International Convention for the Regulation of Whaling (ICRW) included provisions to ensure that data were transmitted to BIWS (Grieves, 1972).

In other marine mammal hunts, catches may be documented by hunters, and possibly submitted to, and recorded by, national governments and institutions. National programs, aimed at interviewing members of whaling/sealing communities to extrapolate catch estimates, exist in some subsistence hunting nations. However, the accuracy of these estimates is variable, and their feasibility is usually dependent on annual funding.

HISTORY OF MARINE MAMMAL MANAGEMENT

International Governance

According to the ICRW, signed in 1946, whale stocks are "great natural resources" and management should aim at "achieving the optimum level of whale stocks" for future generations, as is in "the interest of the nations of the world". Part of the ICRW's mandate was the creation of an international management body, the IWC. The ICRW was ratified and came into force in 1948, and 1949 marked the first meeting of the IWC. Since then, the commission has met, on average, on an annual basis. In keeping with the objectives of the ICRW, the IWC placed a moratorium on all commercial whaling in 1986. The moratorium was instituted to allow recovery for severely depleted stocks and in order to enable scientists to complete a comprehensive evaluation of all stocks. This was done to ensure that the resources could be managed in accordance with ICRW regulations, aimed at keeping abundances at the levels that are postulated to produce the maximum sustained yield. This work was to be completed by 1990, at which time whaling would resume and follow well outlined catch limit rules (see section on materials and methods). Assessments have been started for all species, but the commission has only agreed to publish abundance information for 11 stocks from 7 species (6 great whales and pilot whales; Table 1) – the remaining stocks/species have not been assessed in detail, and/or the estimates have been deemed to have too much statistical uncertainty.

Table 1: Species for which the IWC has published abundance estimates (IWC, 2006)

Species	Population	Year(s) to which the estimate applies
Minke Whales	Southern Hemisphere	1982/83 – 1988/89*
	North Atlantic	1987-95
	North West Pacific and Okhotsk Sea	1989-90
Blue Whales	Southern Hemisphere	1980-2000
Fin Whales	North Atlantic	1969-1989
Gray Whales	Eastern North Pacific	1997/98
	Western North Pacific	Current
Bowhead Whales	Bering-Chukchi-Beaufort Seas stock	1993
Humpback Whales	Western North Atlantic	1992/93
	Southern Hemisphere south of 60S in summer (i.e., incomplete)	1988
Pilot Whales	Central and Eastern North Atlantic	1989

* This is now considered unreliable because of newer surveys, indicating a significantly smaller population than was previously estimated

The main reasons for this shortcoming are the complexity and difficulty of the task, due mostly to data limitations. It also relates, however, to the political situation and corresponding changes in objectives of some of the IWC member countries. Public attitudes in these countries have shifted dramatically with the development of environmental consciousness, partly due to the campaigns of non-governmental organizations (NGOs) (Raustiala, 1997). In particular, Greenpeace's "Save the Whale" campaign gathered considerable media attention. The plight of the whales came to symbolize the state of the environment, and the number of NGOs participating in IWC meetings grew rapidly (Oberthür, 1998). This marked a shift in values, whales had again become more than a resource, their intelligence was admired and they were attributed existence value. In fact, this has put a number of countries directly at odds with the International Convention for the Regulation of Whaling, to which they are signatories.

I just want to briefly suggest some of the reasons why the comprehensive assessments of the great whale stocks have not yet been completed. When the IWC finishes its assessments, a legal re-opening of whaling follows. This is something a shrinking proportion of IWC signatories, currently roughly half, are opposed to. Many new countries have joined the IWC, even though they have no historical whaling ties, for this reason. Japan has been accused of 1) leveraging development aid, and 2) presenting whales in the light of eating fish that would otherwise be available for human consumption, to encourage (poorer) nations to join and vote with the pro-whaling delegation (Kaschner and Pauly, 2004). Japan and Norway would like to see whaling legally resume in line with ICRW. The fact remains that the status quo is not bad (the anti-whalers have a moratorium and the pro-whalers are still whaling), but it can not last because the IWC becomes ineffectual as an institution. Japan has its scientific whaling program, which is opposed, but legal, Norway did not sign the moratorium, so they can legally hunt, and Iceland re-joined the IWC with a clause that legalizes hunting. The anti-whaling countries currently have a maintained ban on whaling as they would like, and are unwilling to accept any form of commercial-scale hunting. As I see it, a change in the underlying political framework is needed. Tough decisions must be made before the IWC falls apart because all confidence in the institution is lost. The ethical and moral arguments against whaling must be brought forward for discussion; leaving the decision to 'science' is not appropriate, as science can only inform on, but no decide on such issues. There exists a conflict in interest between those who do and those who do not believe that whaling should continue, and if there is to be a global perspective on the issue, it must be discussed. As it stands, the international convention sanctions whaling, while at the same time the international management board vetoes it.

I do not intend this to be a comprehensive critique of the IWC, nor do I profess to know all the intricacies of the Commission's work. In addition, this report deals with all exploited marine mammal populations, not just those that fall within the jurisdiction of the IWC. Along with the IWC, the North Atlantic Marine Mammal Commission (NAMMCO), which deals with the conservation, management and study of marine mammals in the North Atlantic Ocean, is an international management body. Otherwise, responsibility is delegated to individual countries to manage marine mammal populations within their exclusive economic zones. This, of course, is problematic as marine mammals do not respect national borders, often cover more than one exclusive economic zone and extend well into the high seas, and often do not have clearly identified migration patterns.

National Governance

National institutions also collect data on catch, incidental mortality and abundance of marine mammals as well as carrying out stock assessments to comply with national regulations. In the United States, this is done by the National Oceanic and Atmospheric Administration's Office of Protected Resources in accordance with the Marine Mammal Protection Act and the Magnus-Stevens Fishery Conservation and Management Act. In Canada, Fisheries and Oceans Canada (DFO) manages marine mammal populations.

Similarly, the rest of the world has marine mammal regulations specific to each country and its perceived need for management actions. Data on most marine mammals are collected by such groups and by university research groups, e.g., the Marine Mammal Research Unit at the University of British Columbia, Canada, and the Sea Mammal Research Unit at St. Andrews, Scotland.

MATERIALS AND METHODS

This chapter describes the modeling approach used to estimate population trajectories for the exploited marine mammal populations. Trajectories begin at the onset of recorded catches, which is assumed to be the actual onset of hunting for these purposes. Thus, the population size at this initial time is assumed to be the 'pre-exploitation' population size or the carrying capacity of the environment for this species. All models are run to year 2001 only (rather than to 2006) because of limitations in data availability, and for the sake of consistency.

DATA SOURCES

The catch data used originate from the International Whaling Commission's Bureau of International Whaling Statistics. These are data of catch records, by species and date, along with additional, but inconsistent information on, e.g., sex, length, weight and expedition dates. Other sources of catch data used in this report are mainly transcribed log-book entries from expeditions, and information collected or estimated nationally by individual governments and institutions. To find this information, Jordan Beblow and I conducted an extensive literature search. All catch and abundance data we could find and access were added to an existing database on recent abundance information for all marine mammal species that was set up by Kristin Kaschner (Kaschner, 2004). The database now contains information on catches and abundances through time, broken down by areas where they were reported. Model input abundance data and catch data are listed in Appendices IV and VI. The great whales were either assessed over their entire range, or were split into applicable stocks by the North Atlantic, North Pacific and Southern Hemisphere oceans. Exceptions to this are the gray whales, which were assessed by the northwestern and northeastern Pacific. The smaller mammals, which tend to have smaller ranges, were assessed by ocean basins where possible and otherwise by regions with reported catch, e.g., Japanese waters, West Ice (off East Greenland's coast), Newfoundland, Eastern Tropical Pacific, Baltic Sea and so on.

PRODUCTION MODEL

The production model is one of the simplest population models; it is a logistic growth model that assumes no errors in reported catch:

$$N_{t+1} = N_t + r_{\max} N_t (1 - \frac{N_t}{K}) - C_t \quad \textbf{(1)}$$

where N is numbers, r_{max} is the maximum intrinsic rate of population growth, K is the carrying capacity, C is observed catch, and t is the subscript for time. The production model depends on K, the carrying capacity which makes it density-dependent. To evaluate the population size (N_{msy}) that maximizes production, we take the derivative of the yearly population change, $N_{t+1} - N_t$, with respect to N_t, then set it to zero to find the inflection point and solve:

$$\frac{\partial(N_{t+1} - N_t)}{\partial N_t} = r_{\max} - \frac{2 r_{\max} N_t}{K} = 0 \quad \textbf{(2)}$$

which also gives:

$$N_{msy} = \frac{K}{2} \quad \textbf{(3)}$$

The International Convention for the Regulation of Whaling (ICRW) specifies that marine mammal populations must be managed at their optimal population sizes, where production is maximized. This means that stocks should be maintained at the N_{msy} level that is half their carrying capacity (3). The biological reference point B_{msy}, is taken to be N_{msy} times the mean weight of the adults of the species.

To estimate the r_{max} and K parameters as set up in (1), it is necessary for stock to have exhibited historical variation in size (Hilborn and Walters, 1992), i.e., we need to observe recovery in order to resolve confounding between r_{max} and K. There is a trade-off between these two parameters, in that a catch history, especially if that history is a one-way-trip, can be explained as either a highly productive small stock or a large stock with low productivity. Data to distinguish between these populations are often found in recovery and rebuilding information. This is a point we need to be very aware of, as many of the marine mammal stock histories follow from one-way-trip catch data, the result of increasing effort and declining catch per effort.

STOCHASTIC STOCK REDUCTION ANALYSIS

Population trajectories are modeled for all marine mammal species for which exploitation levels have been recorded. To do this we employ stock reduction analysis (SRA), a method first introduced by Kimura and Targat (1982). SRA allows the use of historical catch time series to estimate a range of possible population parameters (r_{max}, K), that give rise to extant populations. Given the available data and our objective to determine stock size over time, we implement a production model based on the logistic model of population dynamics and driven by removal information:

$$N_{t+1} = N_t + r_{\max} N_t (1 - \frac{N_t}{K}) e^{w_t} - C_t \qquad \textbf{(4)}$$

$$N_1 = K \qquad \textbf{(5)}$$

where N_t is the number of mammals in the population at time t (1,2, ... z, where z is the number of years for which we have data); r_{max} is net production, i.e., growth + new production – mortality; K is pre-exploitation numbers or carrying capacity; N_1 is assumed to be K at the onset of catches; C_t is the catch, in numbers, at time t; and w_t are independent process errors at time t. SRA generates a single population trajectory dependent on the selected parameter values of r_{max} and K. A stochastic SRA generates a single population trajectory conditional on r_{max}, K and a random anomaly sequence w_t. A more interesting question is determining the probability of a stock being at the observed abundance level(s) at time(s) t, given the observed removal information and the assumption that the stock followed a stationary production relationship with mean r_{max} and mean carrying capacity K, with realistic variation in these parameters.

Bayesian stochastic SRA (SSRA) (Walters *et al.*, 2006) proceeds by (1) generating several thousand trajectories of N_t's by randomly drawing from a prior distribution of r_{max}, K and w_t values. (2) simulating the N_t sequence conditional on the observed catches (C_t). (3) For each simulated N_t sequence calculating the likelihood of having obtained the observed abundances (y_t). (4) re-sampling each of the trajectories with sample probability proportional to its likelihood, giving us a posterior probability density for the parameters of interest.

To implement the SSRA as outlined above, I used the following procedure. First, draw values for r_{max}, K and w_t from prior distributions. A normal prior distribution was assumed for r_{max}, with mean 0.04 (standard deviation (SD) = 0.04) for cetaceans, 0.02 (SD = 0.02) for sperm whales and 0.12 (SD = 0.06) for pinnipeds (default mean values are from Wade, 1998). K was drawn from a uniform prior distribution between 'reasonable' population size bounds that gives rise to extant populations in the deterministic case (i.e., w_t = 0). Lastly, w_t 's were drawn from a random normal distribution with mean 0 and standard deviation = σ_w (these are the process error terms). A total error term, κ = 0.1 was specified and distributed amongst process errors $\tau_w = \sqrt{1-p} * \sqrt{\kappa}$ and observation errors $\sigma_y = \sqrt{p}\sqrt{\kappa}$, where p determines the proportion of the error allocated to each error term $(0.3 \le p \le 0.6)$ depending on the certainty associated with the observed abundances, y_t's. A population trajectory was then generated using equations (5) and (4) above.

The likelihood of obtaining the observed abundances, y_t, was calculated as:

$$L(y_t \mid r_{\max}, K, w_t) = n\left[\log(\sigma_y) + \frac{1}{2}\log(2\pi)\right] + \sum_{i=1}^{n} \frac{z_t^{\ 2}}{2\sigma_y^{\ 2}} \qquad \textbf{(6)}$$

where n is the number of abundance observations, σ_y is the standard deviation in the abundance estimate, the observation error. z_t is the lognormal residual:

$$z_t = \log(N_t) - \log(y_t) \qquad \textbf{(7)}$$

The r_{max} and K combination and their associated likelihood were stored, and the above steps repeated 50,000 times. At this point, the procedure had produced a prior distribution of population trajectories. The next step was to resample these trajectories based on their associated importance weights. This was done using the importance sampling procedure recommended by Schnute (1994) and McAllister and Ianelli (1997). The posterior probability density function was calculated by re-sampling from the set of trajectories stored above, with sample probability proportional to the importance weights/likelihoods.

Lastly, I calculated summary statistics including the marginal posterior for K. The marginal distributions are used to calculate the most likely estimate (the median), along with the 95% credible interval of the distribution values for K. This was done using the quantile function in R (R Development Core Team, 2005). I also calculated how much the population has been depleted, i.e.,

$$depletion = \frac{K - N_{2001}}{K} * 100\%\,. \qquad \textbf{(8)}$$

I have programmed all of the calculations discussed above in the statistical programming language R (R Development Core Team, 2005), and the code can be found in Appendix V.

The biggest advantage to this model, as compared to frequentist methods, is that it allows us to be explicit about the uncertainties in our estimate conditional on the assumed values of p and κ. The main reason I have selected the logistic model is that it requires only limited input data, a catch time series and one or more absolute abundance estimates and that it has a minimal number of parameters. Often for the marine mammal populations, this is all the data that are available.

APPLICATION TO SIMULATED DATA

To evaluate the potential bias in the model, I generated a set of simulated data using the production model described above and a time-series following the expansion and collapse trend that many of the marine mammal hunts underwent. I then ran the SSRA with the catch data and between one and three absolute abundance estimates all between the years 1970 and 2000 (with simulated observation error) to see if the model could reproduce the carrying capacity and intrinsic rate of growth parameters used to generate the simulated observed abundance estimates, within some reasonable bound. This is the first of two test conditions. The second test condition identifies whether the model can handle aggregated stocks, i.e., if there are two or more distinct stocks occupying a single ocean that are aggregated and assessed as one stock. These two test conditions are run under two sets of realistic catch scenarios. The first represents a one-way trip, i.e., little or no allowance is made for recovery of the stock, whereas the second catch history allows some recovery in stock size, with catches stopping in 1986, when the whaling moratorium came into effect.

To check for relative bias in the estimates of both for r_{max} and K, I created box-plots of the $\log_2$ ratios between estimated and observed parameter values. Note that a bias-ratio with a mean value of zero indicates no bias, an upward bias-ratio of 1 indicates overestimation of the parameter value by a factor of 2, and a downward bias-ratio of 1 indicates underestimation of the parameter value by a factor of 2.

First, to check that the model was set up correctly without bias, I set up a population with K=160,000 and for r_{max} = 0.04 and assumed no observation error when generating the abundance observations. In the estimation model, I assumed observation errors accounted for only 10% of the total error (κ), while process errors accounted for the remaining 90%. Total error κ = 0.1, observation error has mean = 0 and standard deviation = $\sigma_y = \sqrt{proportion} * \sqrt{\kappa} = \sqrt{0.01 * 0.1}$, and process error, mean = 0 and standard deviation = $\tau_w = \sqrt{0.9 * 0.1}$. When I did this, there was no bias in the r_{max} or K estimates, which indicated that my estimation model is capable of regenerating the simulated parameters (Figure 1).

I then added observation error to the simulated data, with mean = 0 and standard deviation = $\sigma_y = \sqrt{0.3 * 0.1}$, with κ = 0.1. The process errors, mean = 0 and standard deviation = $\tau_w = \sqrt{0.1 * 0.7}$, made up the remaining 70% of κ. I found that the model became just slightly biased, accepting a few more underestimates for the r_{max} parameter and correspondingly a few more overestimates for the K parameter (Figure 2). However, if I tightened the prior on the intrinsic rate of growth from mean = 0.04, standard deviation = 0.04 to standard deviation = 0.02, the estimates are unbiased (Figure 2). This is because we are telling the model to place more trust in the 0.04 estimate of r_{max}, countering the effects of the observation errors that cause the estimated trajectories to deviate from the real trajectory.

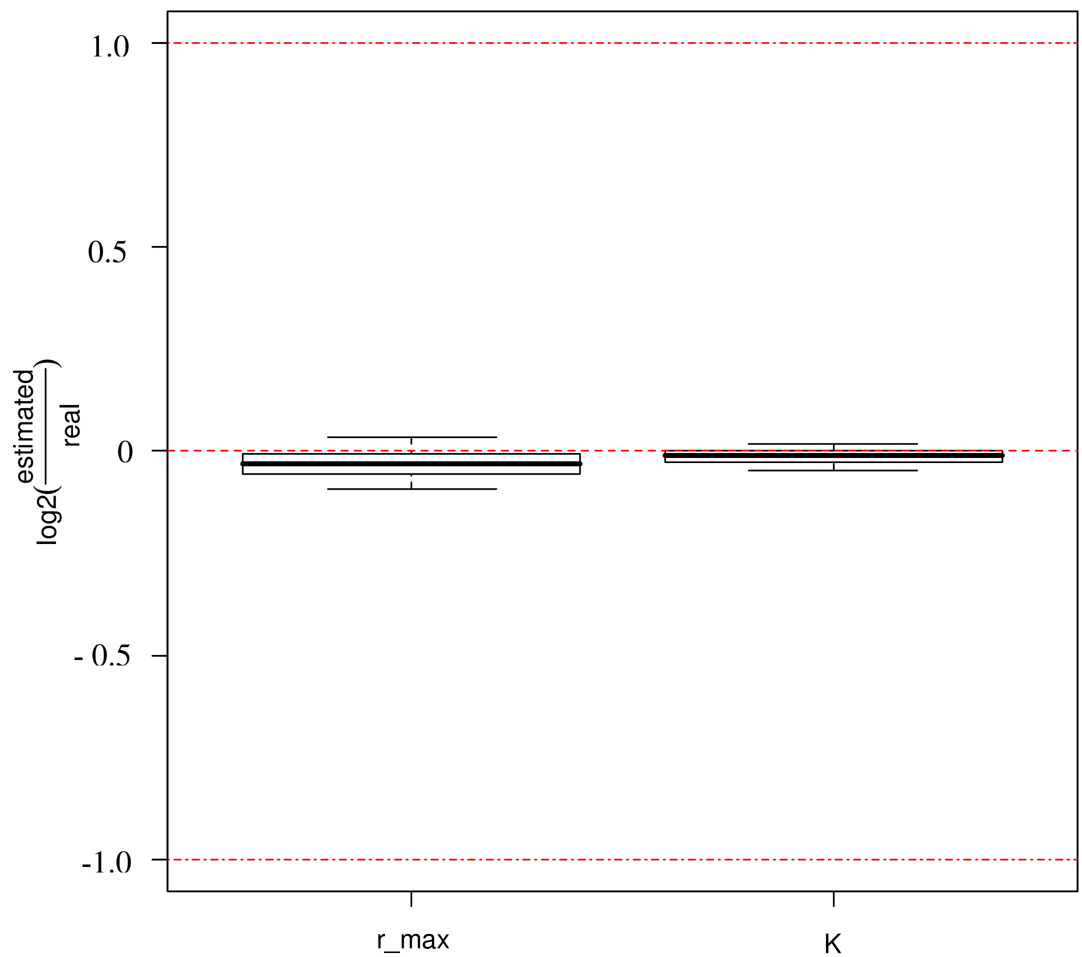


Figure 1: There is no bias in the sample model for the r_{max} and K parameters, set at 0.04 and 160,000 when assuming no observation error and a prior on the rmax parameter with mean = 0.04 and standard deviation = 0.04. NOTE: A median of 0 indicates no bias; a value of +/- 1 indicates an over/underestimate by a factor of 2.

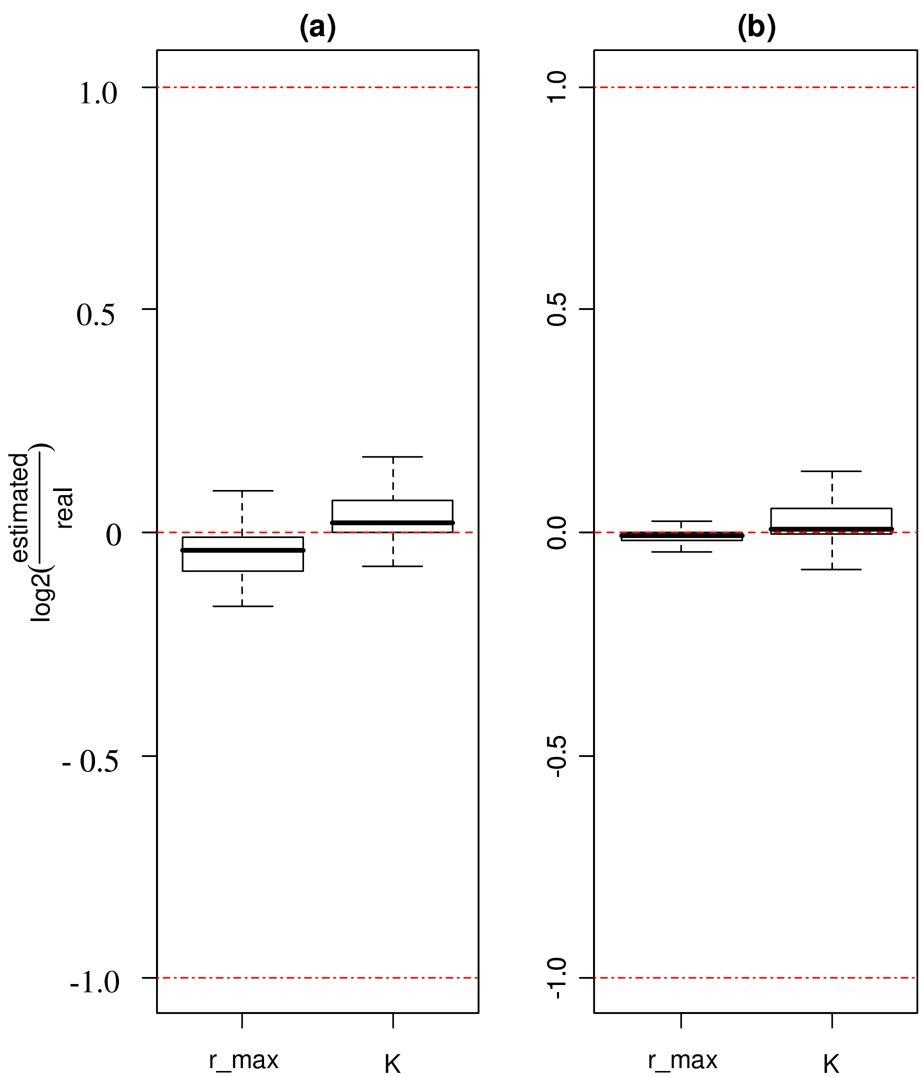


Figure 2: (a) There is a slight bias in the sample model for the r_{max} (set at 0.04) and K (set at 160,000) parameters when assuming both observation and process errors. The r_{max} parameter is slightly underestimated (with a prior on r_{max} with mean 0.04 and standard deviation = 0.04) and the K parameter is slightly overestimated. (b) the bias disappears when the prior on r_{max} is narrowed to mean = 0.04 and standard deviation 0.02. The solids line in the boxes represent the median bias.

The estimate of a parameter will always lie between its true value and the prior placed on it when using Bayesian statistics. Consequently, I found that when I used slightly higher or lower estimates for r_{max}, I got negative or positive biases, respectively, in the r_{max} parameter, and an ensuing bias in the K parameter (Figure 3).

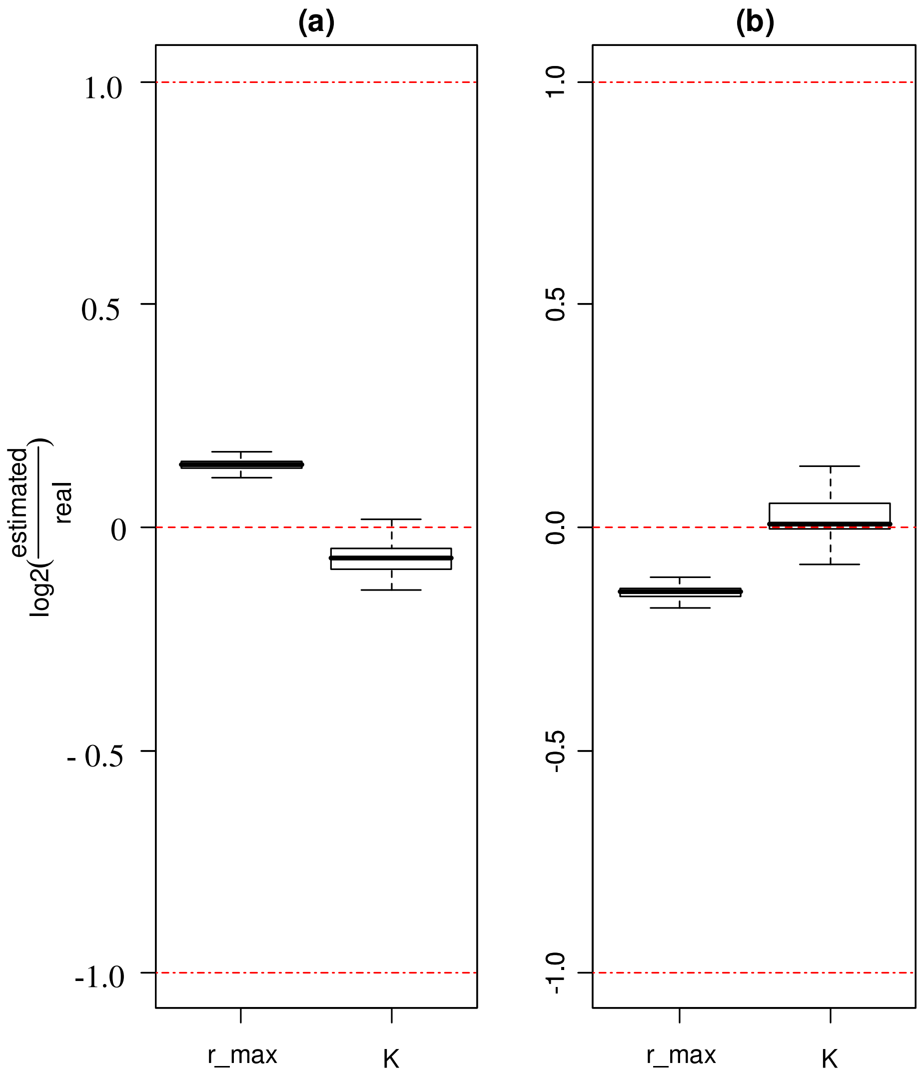
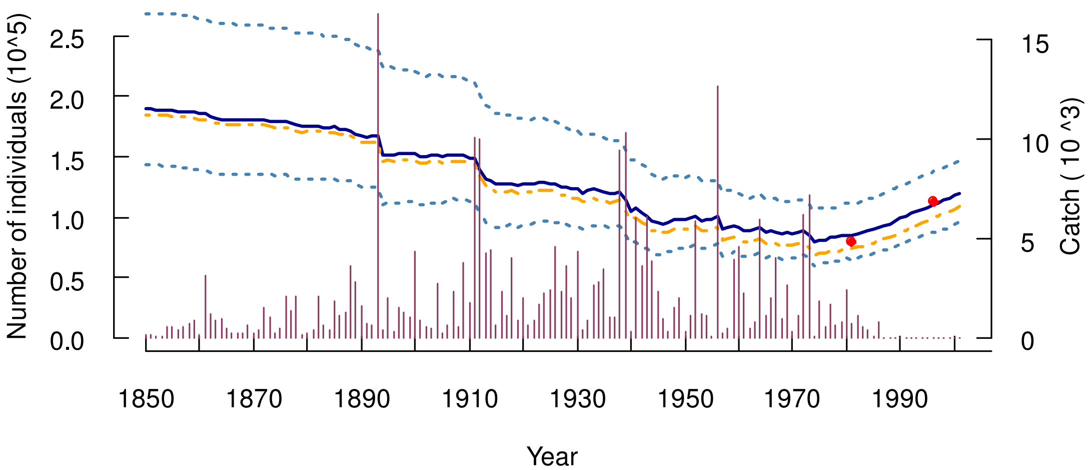


Figure 3: Bias estimates for the r_{max} and K parameters with K = 160,000 and (a) r_{max} = 0.036 and (b) r_{max} = 0.044. The estimates are (a) positively and (b) negatively biased because the estimates for r_{max} fall between the real r_{max} and the prior on r_{max} (mean = 0.04, standard deviation 0.04).

Estimating parameters – single stock

I set up the simulation-estimation model and ran it 100 times. The model was run with true values of K = 185,000 and r_{max} = 0.042 κ = 0.1, of which 30% is attributed to observation error and 70% to process error, i.e., $\sigma_y = \sqrt{0.1*0.3}$ and $\tau_w = \sqrt{0.1*0.7}$ to simulate the catch and observed abundance estimates using a logistic model equivalent to the one provided above assuming both process and observation errors present. The result of each simulation-estimation process was an estimated r_{max} and K value and an associated population trajectory. The result of the entire simulation estimation process is a distribution over the most likely estimates for the net growth (r_{max}) and carrying capacity/pre-exploitation numbers (K) parameters. A sample simulation estimation result is seen in Figure 4 for each of the two scenarios, i.e., with some and no/limited recovery. The box-plots indicating relative bias in the for r_{max} and K parameter estimates, for the 'some recovery' scenario, are shown in Figure 5. They indicate that there is negative bias (-0.1) in the r_{max} parameter as expected because it is higher than the mean, and consequently we also see a positive bias (0.07) in the K parameter.

(a)



(b)

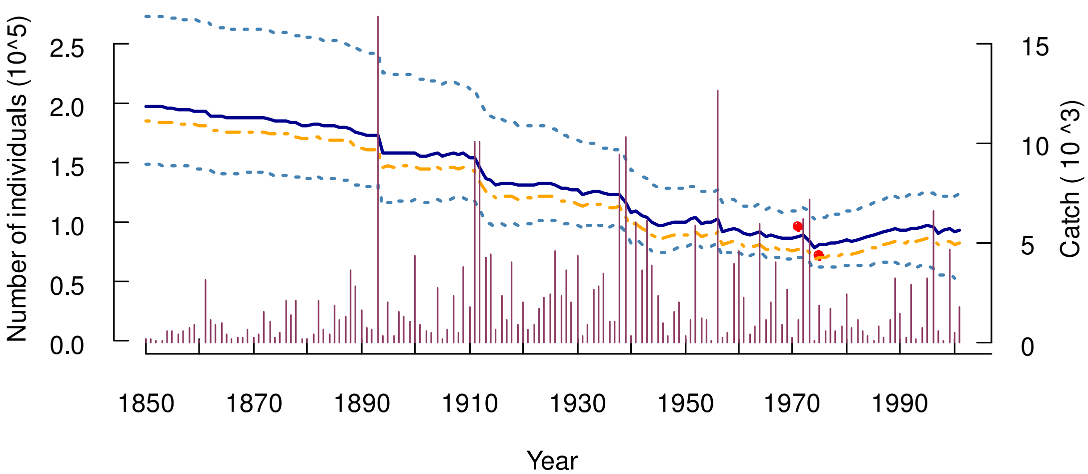


Figure 4. Simulated and estimated population trajectories with a) some recovery and b) no/limited recovery. The solid line represents the most likely estimate for the species population trajectory, the dotted lines represents the 95% credible interval around that trajectory, and the dots are the abundance estimates used to estimate model parameters. The dot-dash line is the 'real' simulated population trajectory, and the vertical lines are the catch data the population was subjected to.

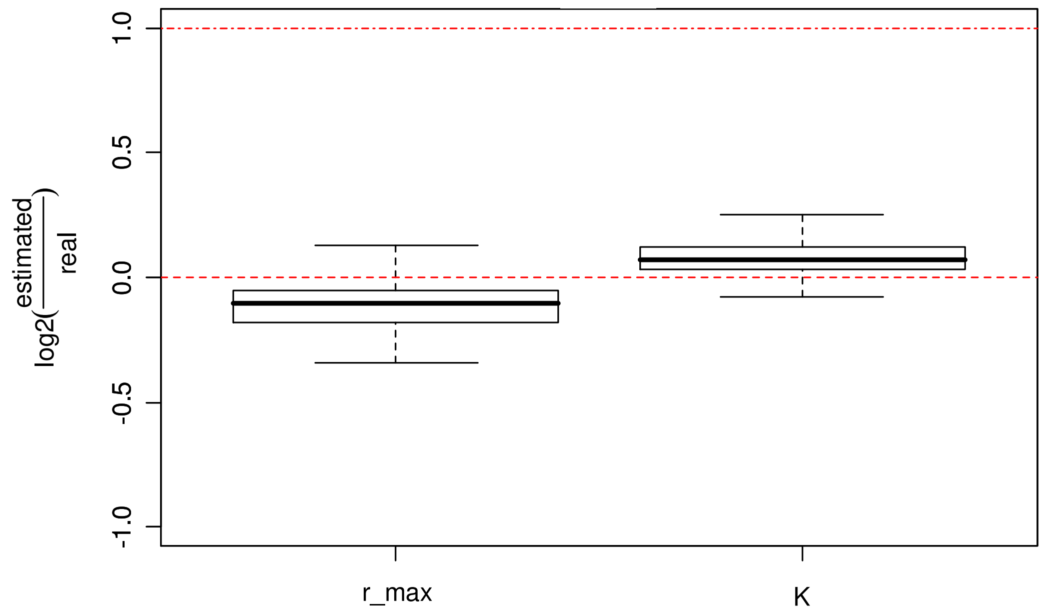


Figure 5. Boxplots for the bias ratios for r_{max} (0.042) and K (185,000) estimated for a single stock. r_{max} is negatively biased because of the effects of the prior pulling the estimated r_{max} parameter towards the prior on r_{max} that has mean = 0.04 and standard deviation = 0.04. As a result, the K parameter is positively biased.

Estimating parameters – aggregated stocks

The second robustness issue we need to address is how the model functions when data from several stocks are aggregated (both in terms of catches and abundance numbers) into a single entity on which we perform our assessment. This is done in most of this report, because of the lack of geographic information, beyond ocean basins, for most of the catches. To evaluate this, I again used the production model and set up three separate stocks and gave each of them catch histories and ran them to produce 3 abundance estimates. The simulation-estimation model was run 100 times, with the r_{max} parameter for the three stocks set at 0.038, 0.036, and 0.044 respectively, with carrying capacities of 15,000, 130,000 and 40,000 respectively, κ = 0.1, of which 30% is attributed to observation error and 70% to process error, i.e., $\sigma_y = \sqrt{0.1*0.3}$ and $\tau_w = \sqrt{0.1*0.7}$. A sample simulation-estimation result is seen in Figure 6 for each of the two scenarios, i.e., with some and no/limited recovery. The box-plots indicating relative bias in the for r_{max} and K parameter estimates, for the 'some recovery' scenario, are shown in Figure 7. The bias plot indicates that when compared to a mean of 0.036 (the r_{max} parameter for the largest stock), the estimated r_{max} parameter positively biased (0.1) because the prior pushes the estimate toward 0.04. The K parameter estimate, however, is unbiased.

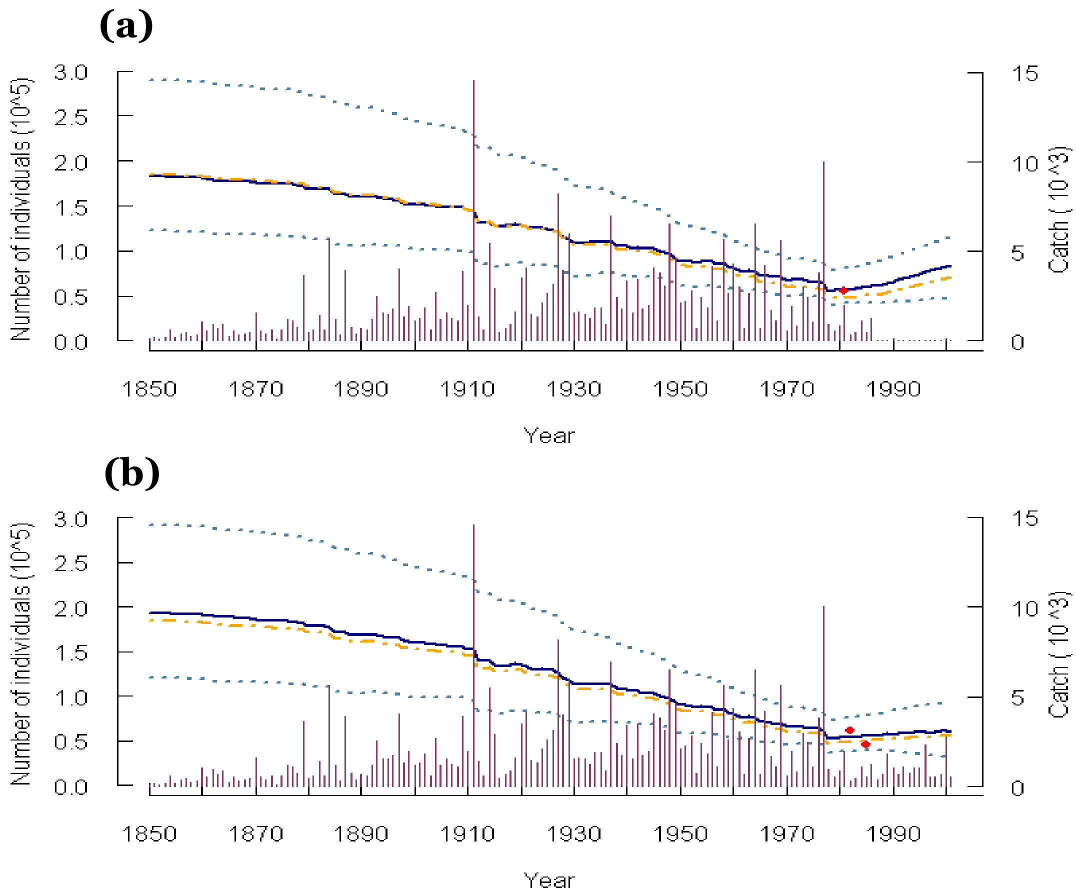


Figure 6. Simulated and estimated population trajectories for the aggregated populations with a) some recovery and b) no/limited recovery. The solid line represents the most likely estimate for the species population trajectory, the dotted lines represents the 95% credible interval around that trajectory, and the red dots are the abundance estimates used to hone in the estimates. The dot-dash line is the 'real' simulated population trajectory, and the vertical lines are the catch data the population was subjected to.

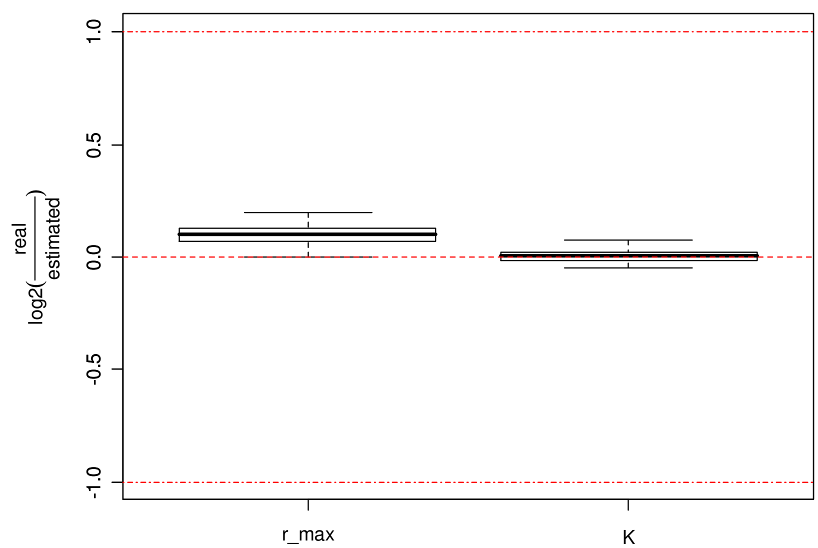


Figure 7. Boxplots for the bias ratios for r_{max} (0.038, 0.036, 0.044) and K (15,000, 130,000, 40,000) for the aggregated populations. The r_{max} parameter is biased slightly upward (0.1) when compared to the 'real' value 0.036 (the r_{max} value for the largest population), because the prior on r_{max} (mean = 0.04, standard deviation = 0.04) drives it upwards. The K parameter, however, is unbiased.

Struck-but-loss ratios

During water-based hunting for marine mammals, an animal is often struck, e.g., with a harpoon or shot on an ice-floe, but may be lost, e.g., it may be wounded but manage to swim away, or the boat might sink. Of these animals, the ones that end up dying because of the actions of hunters should be counted in our analyses. They are, however, often not accounted for. Especially in earlier catch records such rates are rarely, if ever, seen. They are now being collected at least for the ongoing regulated subsistence whaling hunts. The rate at which this happens is called the struck-but-loss rate. It has been speculated to be as high as 35% for many of the great whaling enterprises. Whitehead (2002) used a correction factor of 1.5 on early sperm whale catches, to account for amongst others oil/whale ratio, whales caught but not processed and wrecked ships (Whitehead, 2002). The IWC used a struck-but-loss rate of 35% in their comprehensive assessment of southern right whale (IWC, 2001; Baker and Clapham, 2004).

Adding a struck-but-loss rate increases the estimates of K proportionally to that rate (Baker and Clapham, 2004). In Figure 8 I ran a simulation model to check this and we clearly see that the observed and predicted increase in K virtually mirror each other, indicating that an increase in catches of a certain percentage will produce an increase in K of the same percentage if struck-but-loss rates are constant over time

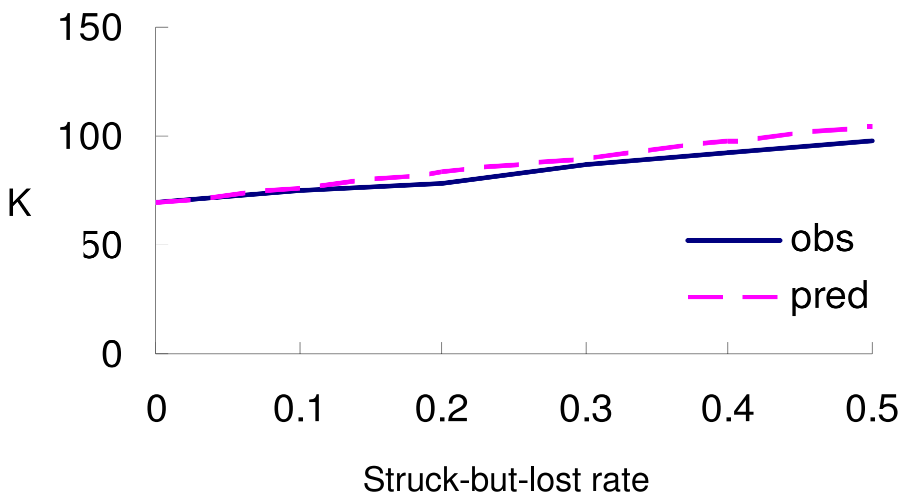


Figure 8. The effect of struck-but-loss rates on estimating K; the solid line (obs) represents an increase in K by the struck-but-loss rate, i.e., the observed values, and the dashed line (pred) shows the increase in K found by running a simulation with the struck-but-loss rate applied to catches, i.e., the predicted values.

I decided not to include a default struck-but-loss rate for this report because I am looking to find the documented, and thus minimum, decline that has occurred. The true decline is likely much larger due to a confluence of factors, struck-but-loss rates, non-, under- and mis-reporting. This is especially true for the subsistence hunts for which struck-but-loss rates are likely high, but for which there rarely exist good data; in fact most often there are no data at all for these hunts.

RESULTS

The following section presents the results of the stochastic stock reduction analysis (SSRA) for marine mammal populations for which I have documented catch numbers and where absolute abundance information was available. The results are presented in two ways, first in a table showing the year in which catching began, the initial and current population sizes and the percent decline (if any) in the population. Secondly, in a figure such as Figure 9, which has years from the onset of catches up to 2001 as its x-axis, and population numbers as the y-axis. The figure shows: (1) the most likely estimate of the population trajectory for the stock represented by the solid dark line; (2) the 95% credible intervals on this trajectory represented by the dotted light lines; (3) the available absolute abundance estimates represented by the dots, and (4) catches in vertical bars with their associated scale on the secondary y-axis. Information on sizes, sources and confidence in the abundance points can be found in Appendix IV. For each population, the stock's initial size, the year that estimate applies to (the year of onset of catches), the 2001 population size and the level of $depletion = \frac{K - N_{2001}}{K} * 100\%$ are given in a table. Lastly, for all populations κ, the total error, was assumed to be 0.1, with the proportion associated with observation errors determined as shown in Table 2. Information on all abundance numbers used as input to the model and their associated CID's can be found in Appendix IV. If more than one abundance estimate exists for the species, I use the highest associated CID.

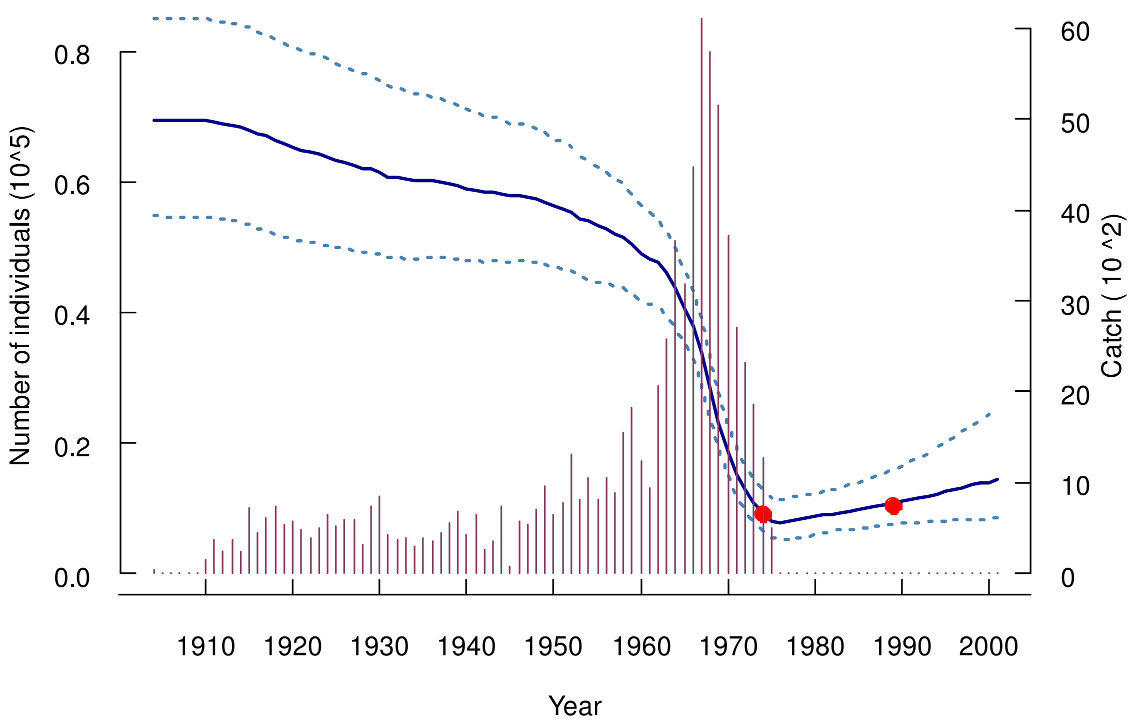


Figure 9. Sample population trajectory. The solid line indicates the most likely population trajectory (the median of the posterior), the stippled lines the 95% credible interval, the vertical lines the catches applied, and the dots the abundance estimates to which the analyses are tuned.

Table 2: Definition of confidence ID's, their meanings and associated proportion of κ attributed to observation error

Confidence ID	Meaning	Proportion of κ
1	Dedicated marine mammal survey with known survey area (map or clearly defined area) and information about uncertainties (CV, SD)	0.3
2	Dedicated marine mammal survey, without definite area description or map and information about uncertainties (CV,SD)	0.4
3	Survey without area description or time period, but giving range (i.e., min to max estimate)	0.4
4	Very general estimate, no specific time period or area, no uncertainties (mostly secondary references)	0.5
5	Outdated general estimates, guesstimates or inferred from other species and unknown.	0.5

POPULATION TRAJECTORIES OF EXPLOITED CETACEANS

The global results referred to in this section are presented in Table 8, which is a summary of the numbers of exploited sub-populations presented in Table 3, Table 4, and Table 5, and of unexploited sub-populations presented in Appendix I. Note that the 95% credible intervals for the unexploited sub-populations are not true credible intervals, but rather estimates.

Great whales

The results presented in this section are all listed in Table 3, which lists the species name, the ocean basin referencing the sub-population, the year of the beginning of documented hunting, the initial, pre-exploitation numbers with associated 95% credible interval, the 2001 numbers with associated 95% credible interval, and the level of depletion of the sub-population.

Table 3: Population sizes of great whales

Species	Ocean Basin	Start of doc. hunts	Initial numbers (Mean, 95% CI)	2001 numbers (Mean, 95% CI)	Depleted by (%)
Sei whale	North Atlantic	1885	10,600 (7,420 – 18,800)	6,990 (5,240 – 9,240)	34
	North Pacific	1904	68,400 (54,600 – 85,600)	14,700 (8,040 – 25,100)	79
	Southern Hemisphere	1904	167,000 (157,000 – 190,000)	27,400 (14,500 – 41,400)	84
Southern Right whale	Southern Hemisphere	1785	86,100 (73,400 – 98,300)	6,740 (4,580 – 11,100)	92
Sperm whale	Global	1800	957,000 (751,000 – 1,350,000)	376,000 (296,000 – 476,000)	61
Fin whale	North Atlantic	1876	72,900 (54,900 – 111,000)	55,700 (42,200 – 68,200)	24
	North Pacific	1903	64,500 (49,600 – 88,000)	30,600 (15,300 – 43,900)	53
	Southern Hemisphere	1904	625,000 (469,000 – 737,000)	23,300 (14,700 – 49,100)	96
Gray whale	Northeast Pacific (Hypothesis 1) Northeast Pacific (Hypothesis 2)	1600	21,200 (18,700 – 25,500)	15,800 (14,600 - 17,800)	25
	Northwest Pacific	1890	3,400 (2,880 – 3,580)	136 (97 - 187)	96
Blue whale	North Atlantic	1868	7,430 (5,920 – 8,480)	367 (263 - 551)	95
	North Pacific	1903	5,850 (4,590 – 8,640)	3,180 (2,230 – 4,140)	46
	Southern Hemisphere	1904	327,000 (298,000 – 359,000)	1,180 (885 – 1,490)	99.6
Bowhead whale	Arctic	1650	89,000 (67,000 – 114,000)	9,450 (7,500 – 10,800)	89
Eden/Bryde's and Bryde's whale	North Atlantic	1925	No information	No information	No info
	North Pacific	1946	52,200 (41,800 – 64,800)	41,100 (30,900 – 53,500)	21
	Southern Hemisphere	1909	94,100 (69,800 – 126,000)	91,300 (66,700 – 123,000)	3
Humpback whale	North Atlantic	1664	16,200 (11,300 – 33,300)	12,400 (9,950 – 15,300)	23
	North Pacific	1900	16,500 (10,500 – 24,100)	7,170 (5,260 – 9,700)	57
	Southern Hemisphere	1904	199,000 (144,000 – 228,000)	22,500 (16,300 – 34,000)	89
Common minke whale	North Atlantic	1926	211,000 (159,000 – 284,000)	157,000 (118,000 – 210,000)	26
	North Pacific	1940	47,000 (36,700 – 60,300)	31,900 (23,900 – 41,400)	32
Antarctic minke whale	Southern Hemisphere	1921	379,000 (300,000 – 478,000)	318,000 (250,000 – 404,000)	16
North Atlantic right whale	North Atlantic	1530	14,100 (10,100 – 27,800)	368 (257 – 469)	97
North Pacific right whale	North Atlantic	1530	14,100 (10,100 – 27,800)	368 (257 – 469)	97

Sei whale, *Balaenoptera borealis*

The sei whale can be found in all the world's oceans, preferring subpolar-tropical water temperatures (Kawamura, 1974; Horwood, 1987; COSEWIC, 2003; Kaschner, 2004). Sei whale hunting is documented from 1885 in the North Atlantic, and from 1904 in the North Pacific and Southern Hemispheres (Table 3). As the stocks of blue and fin whales were depleted, the sei whale became the main target of whalers in the Antarctic (Reeves *et al.*, 2003). All three stocks of sei whales are depleted, the North Atlantic stock by 34% (Table 3, Figure 10), the North Pacific stock by 79% (Table 3, Figure 11), and the Southern Hemisphere stock by 84% (Table 3, Figure 12). Overall, this represents a global decline by 80% for the sei whale population (Table 8).

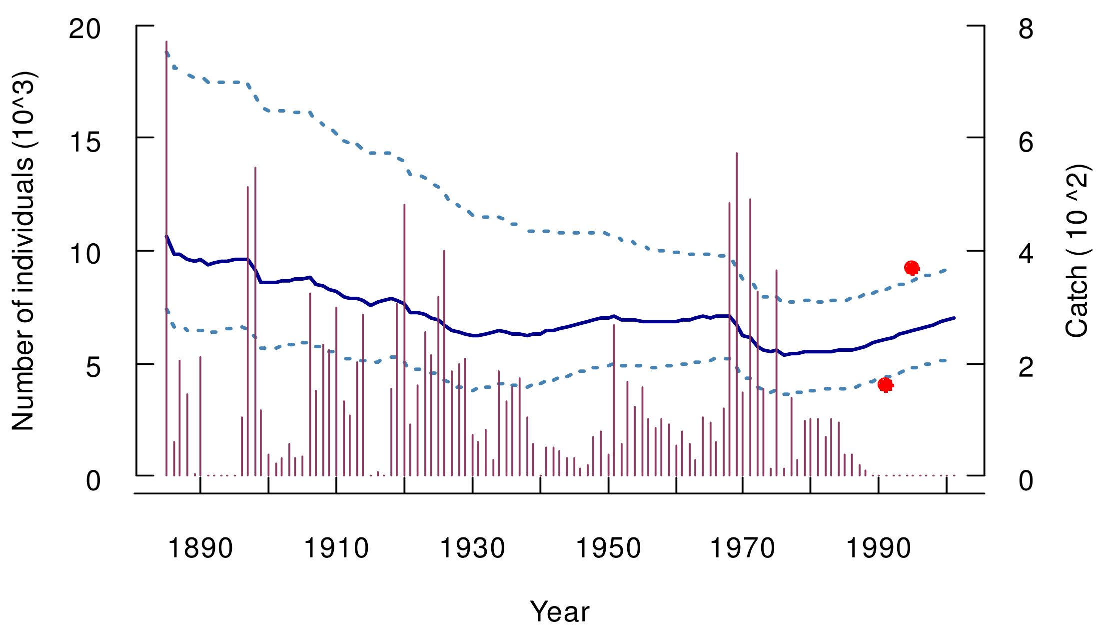


Figure 10. Population trajectories for North Atlantic sei whales

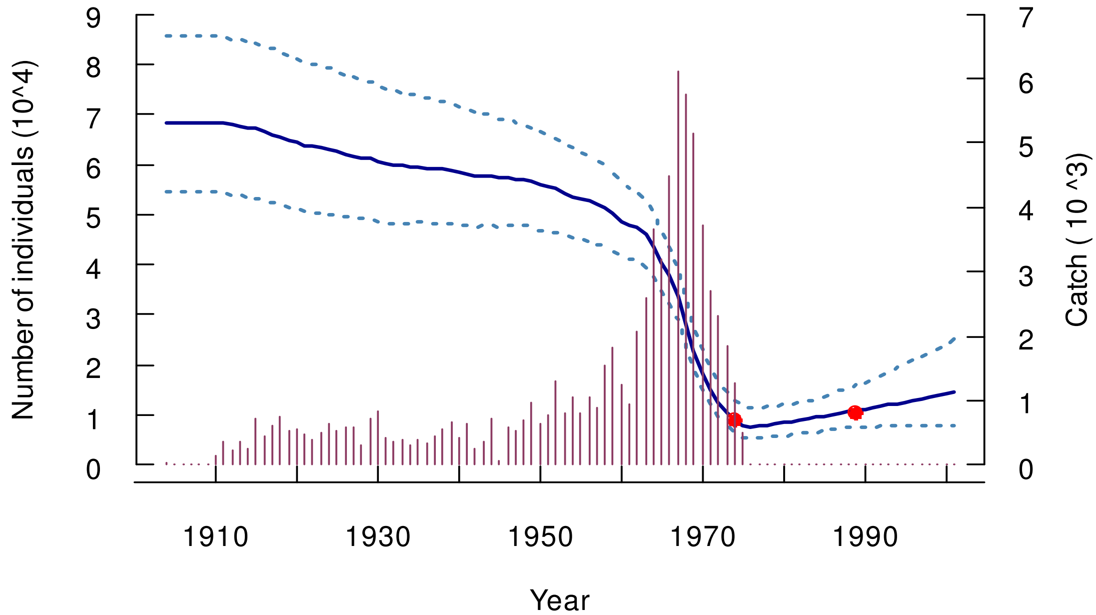


Figure 11. Population trajectories for North Pacific sei whales

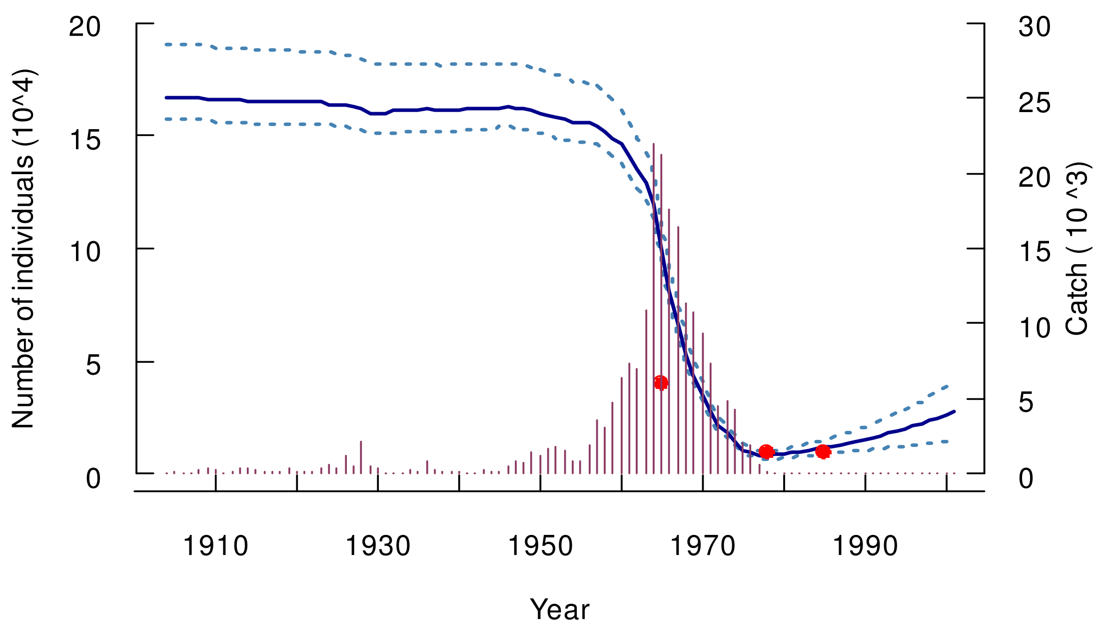


Figure 12. Population trajectories for Southern Hemisphere sei whales

<u>Southern Right whale, *Eubalaena australis*</u>

The Southern right whale inhabits the Southern Hemisphere, preferring polar-subtropical temperature ranges (Ohsumi and Kasamatsu, 1983; Hamner *et al.*, 1988; Kaschner, 2004). The stock has been depleted by 92%, numbering over 86,000 whales in 1785 and falling to its current level of approximately 6,700 individuals (Table 3, Figure 13). There is some evidence of recovery in this right whale stock (Figure 13) (Bannister, 2001; Reeves *et al.*, 2003).

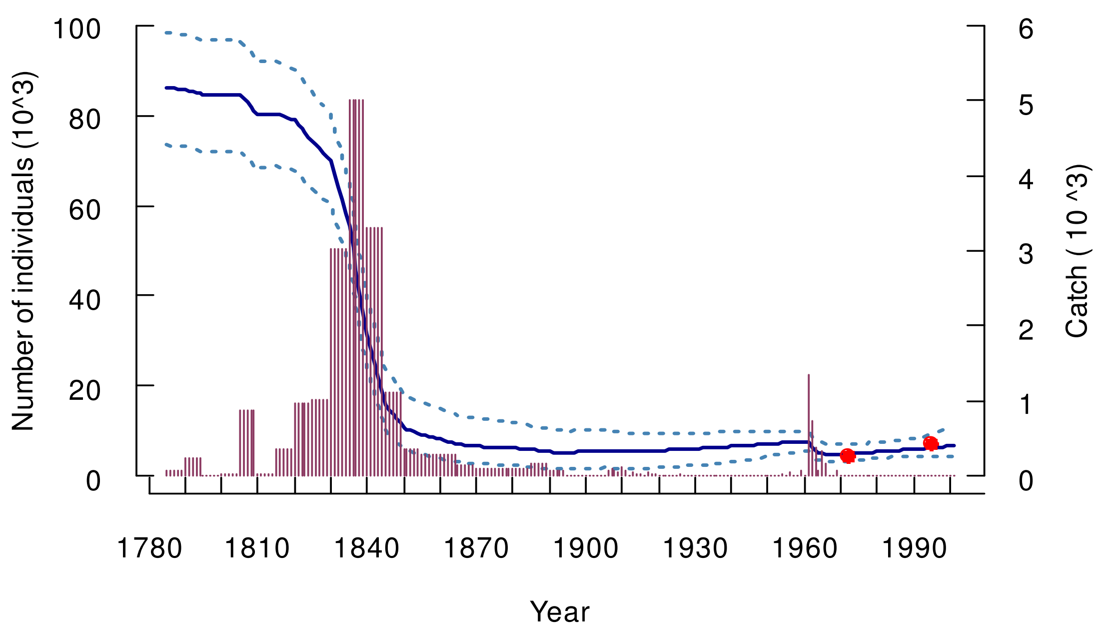


Figure 13. Population trajectory for Southern right whales

Sperm whale, *Physeter catodon*

The sperm whale ranges throughout the world's oceans, in polar to tropical water (Kasuya and Miyashita, 1988; Davis *et al.*, 1998; Jaquet and Gendron, 2002). The population has declined by 61%, from an estimated 1 million to 376,000 individuals globally since exploitation began in 1800 (Table 3, Figure 14). Sperm whales remain a species highly valued for their meat in Japan (Reeves *et al.*, 2003).

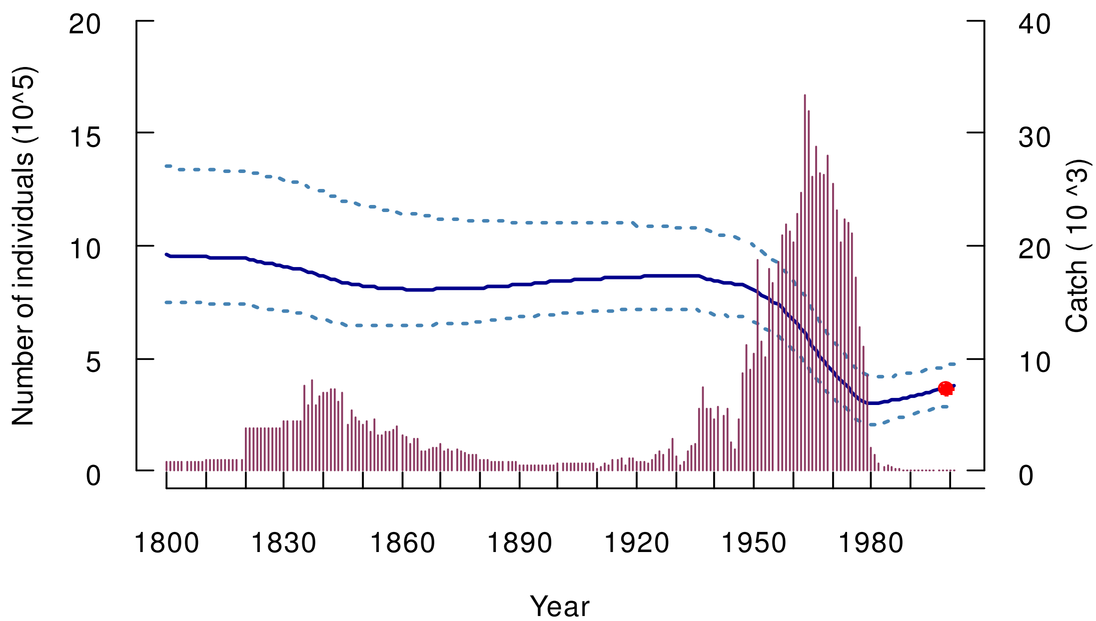


Figure 14. Population trajectories for sperm whales

Fin whale, *Balaenoptera physalus*

Fin whales are endemic to all the world's oceans and range from polar to tropical waters (Zerbini *et al.*, 1997; Rice, 1998; Kasamatsu *et al.*, 2000; Aguilar, 2002; Kaschner, 2004). They have declined by approximately 24% in the North Atlantic (Table 3, Figure 15), 53% in the North Pacific (Table 3, Figure 15, Figure 16), and 96% in the Southern Hemisphere (Table 3, Figure 17), where they are a rare sight today (Reeves *et al.*, 2003). Globally, they have declined by 86% since 1876 (Table 8).

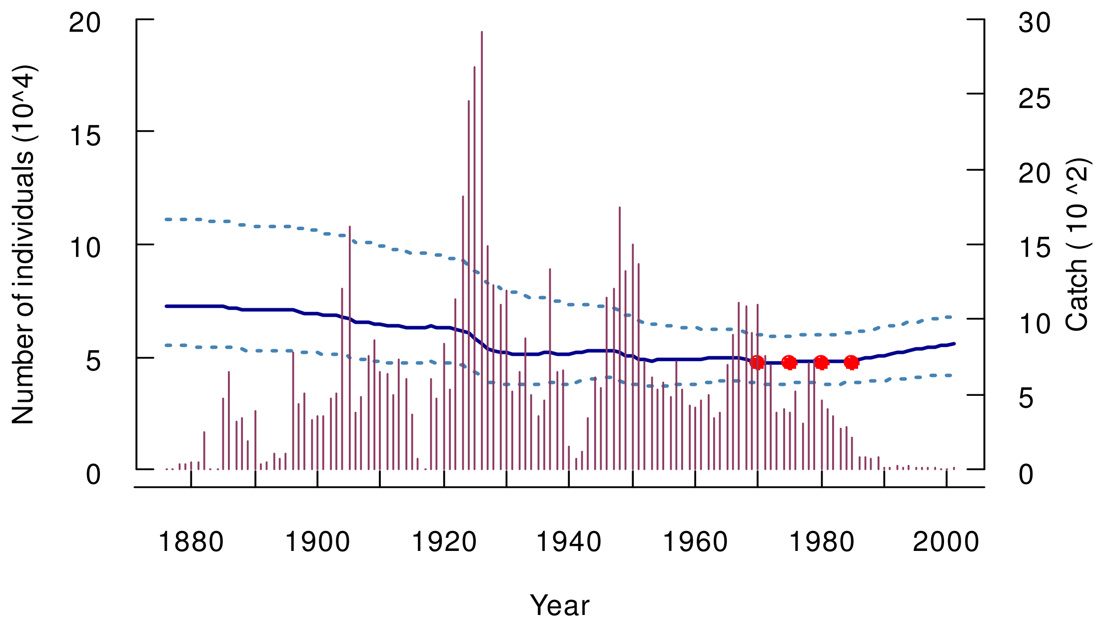


Figure 15. Population trajectories for North Atlantic fin whales

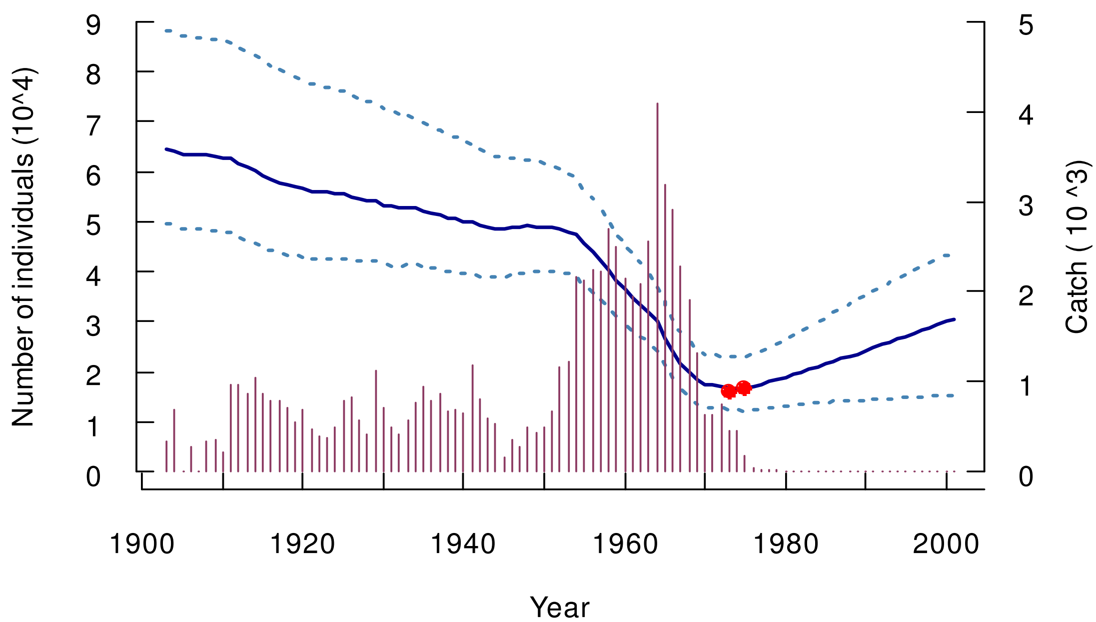


Figure 16. Population trajectories for North Pacific fin whales

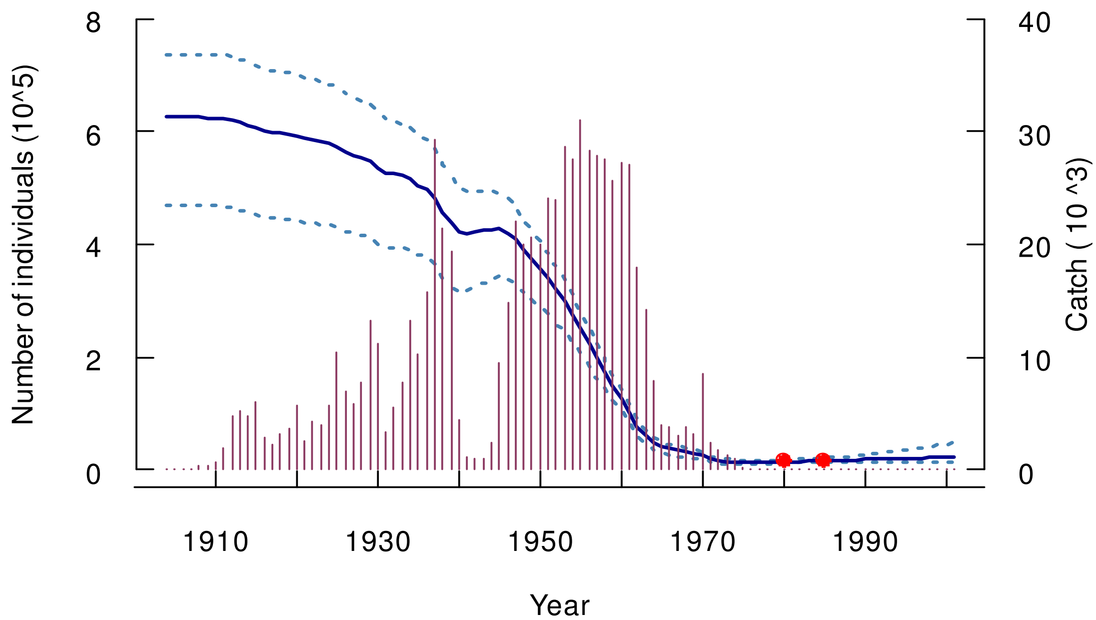


Figure 17. Population trajectories for Southern Hemisphere fin whales

<u>Gray whale, *Eschrichtius robustus*</u>

In the last 300 – 400 years, the North Atlantic gray whale went extinct (Reeves *et al.*, 2003). However, I do not have catch information so I can not reconstruct the historical abundance of that population. In the North Pacific, two separate stocks of gray whales are recognized. Both stocks range from subpolar to subtropical waters (Gardner and Chavez-Rosales, 2000; Jones and Swartz, 2002; Weller *et al.*, 2002; Deecke, 2004; Kaschner, 2004), but behaving quite differently in terms of abundance. The north eastern Pacific stock is recovering from the exploitation that began back in 1600, with the current population only 25% below the estimate of carrying capacity (Table 3, Figure 18). The rapid growth in the last 1990s (Figure 18) cannot be replicated in the model, indicating that either immigration is occurring, or the carrying capacity of the species and/or the maximum intrinsic rate of growth have increased. The abundance estimates themselves do not appear to be suspect, having been estimated from a shore-based station near Monterey, California, in a consistent manner. The Northwestern Pacific stock is not faring so well; exploitation began in 1890 and at current the stock is depleted by 96%. It currently numbers only a few hundreds (Table 3, Figure 18, Figure 19). Questions of genetic bottlenecks must be considered (Swartz *et al.*, 2006). Globally, gray whales have declined by 35%.

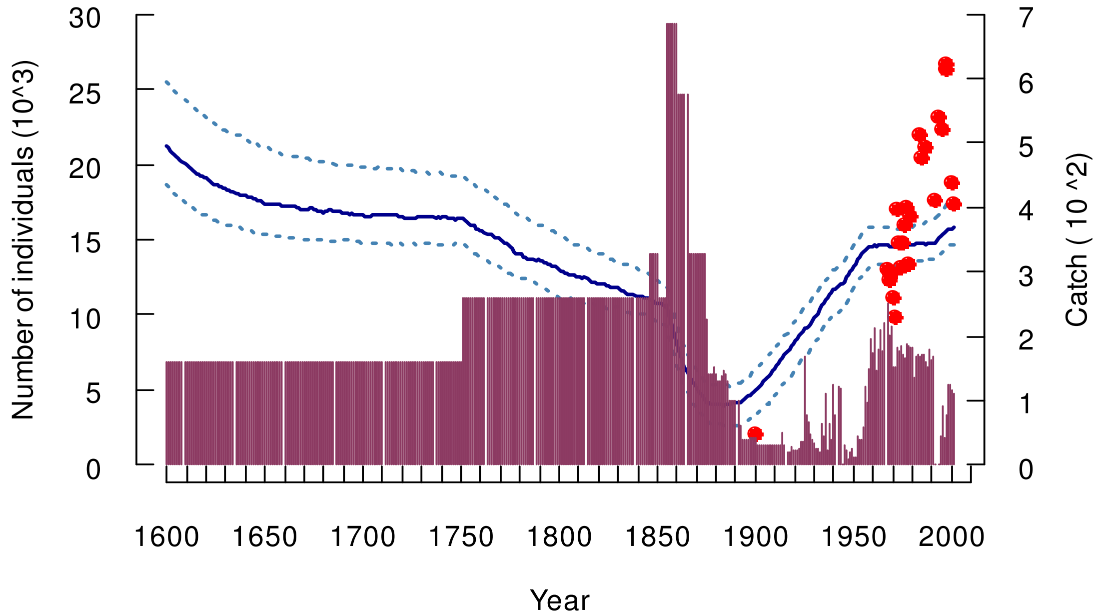


Figure 18. Population trajectories for Northeastern Pacific gray whales

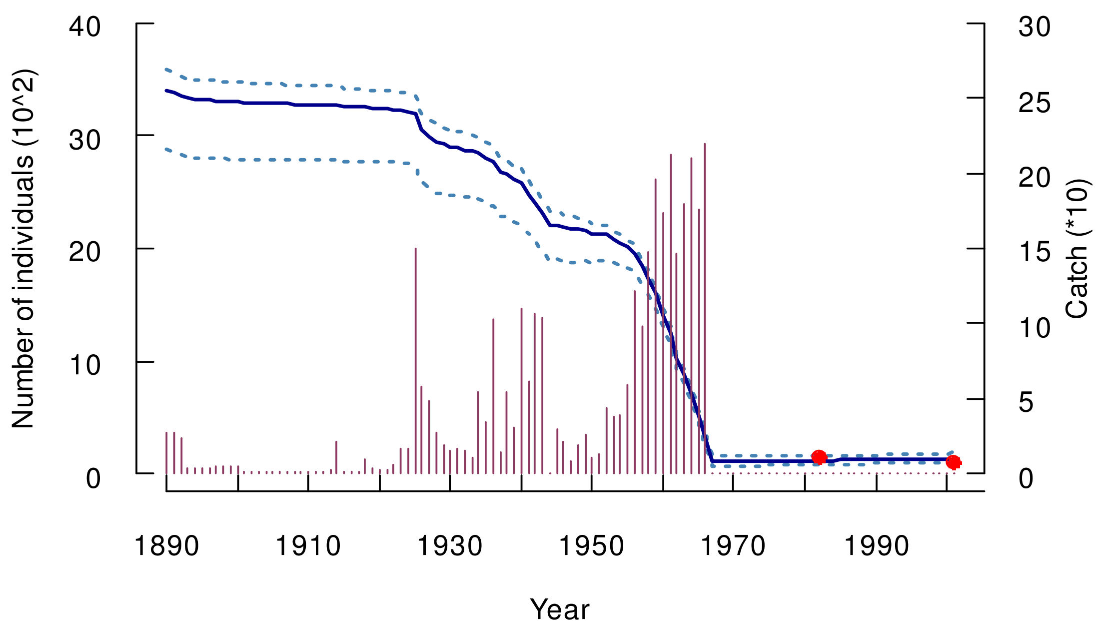


Figure 19. Population trajectories for Northwestern Pacific gray whales

Blue whale, *Balaenoptera musculus*

Blue whales roam the world's oceans, ranging from polar to tropical waters (Zerbini *et al.*, 1997; Perry *et al.*, 1999; Kaschner, 2004). In the North Atlantic, hunting began in 1868, and it has reduced the population size by 95% (Table 3, Figure 20). In the North Pacific, hunting commenced in 1903, but stocks have recovered to 46% of their estimated carrying capacity (Table 3, Figure 21). In the Southern Hemisphere, a bleak picture emerges: whaling began in 1904, and in 2001 the population was estimated to be less than 1% of its original size (Table 3, Figure 22) and likely not recovering. Globally, this amounts to a depletion level of 99% for the blue whales (Table 8).

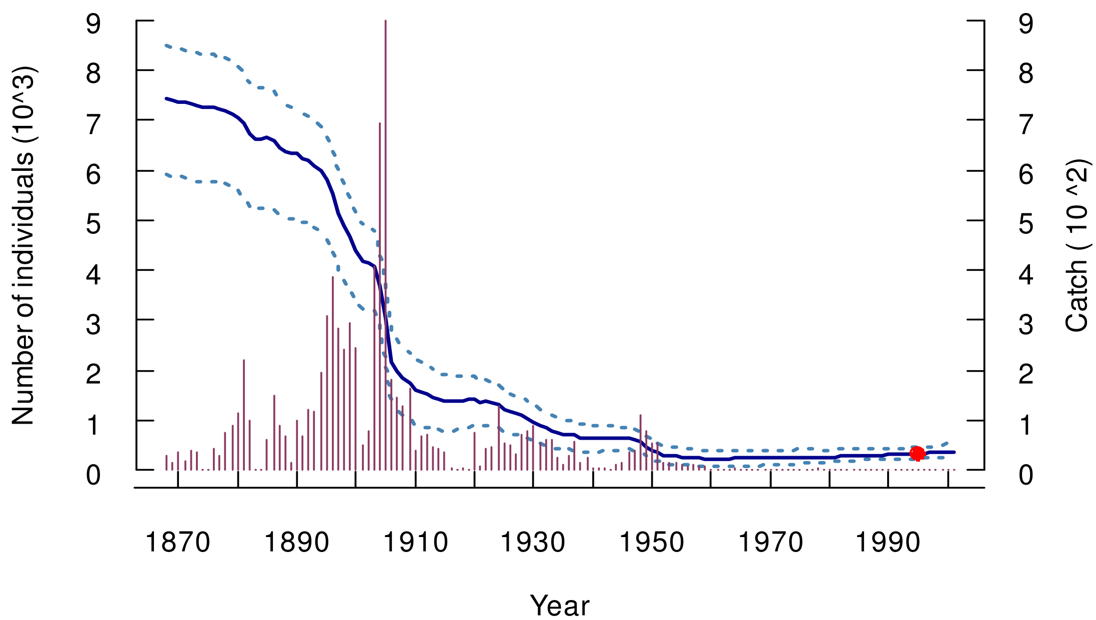


Figure 20. Population trajectory for North Atlantic blue whales

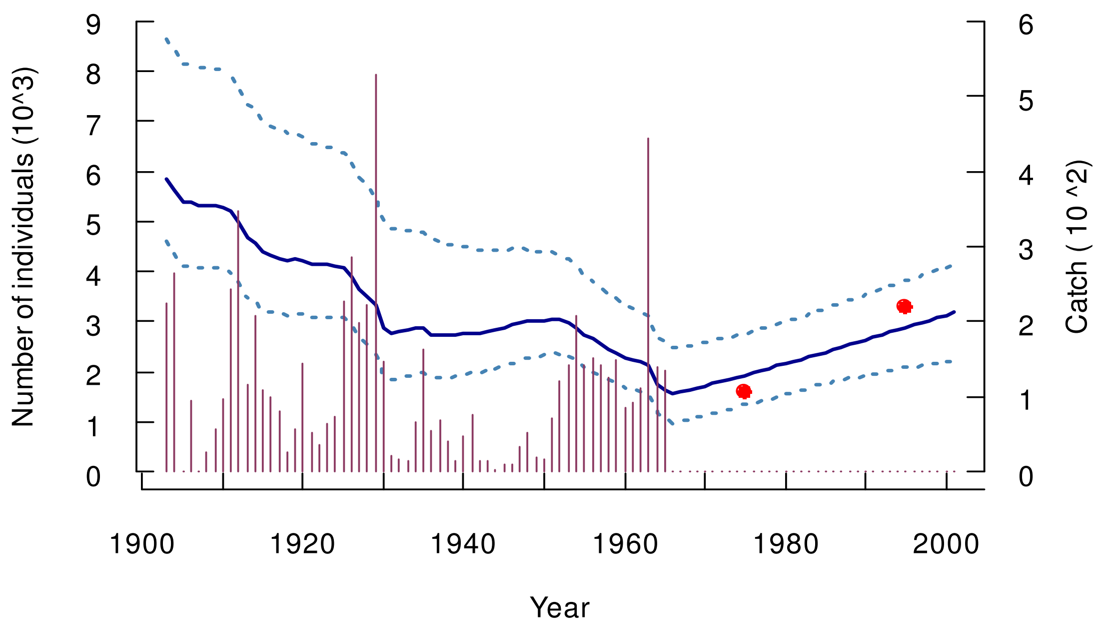


Figure 21. Population trajectory for North Pacific blue whales

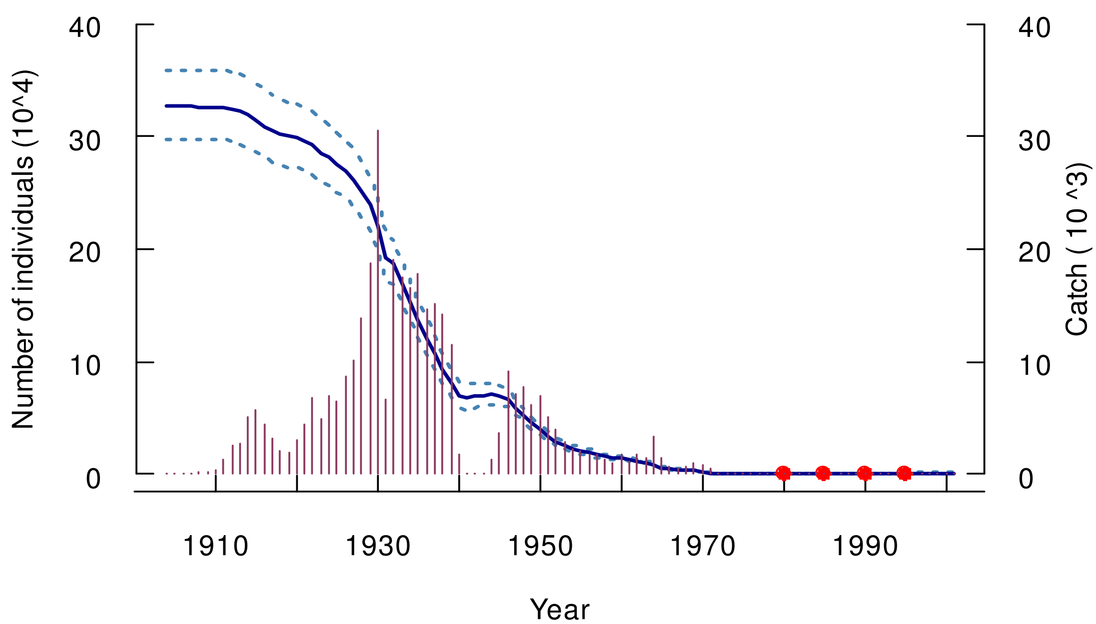


Figure 22. Population trajectory for Southern Hemisphere blue whales

<u>Bowhead whale, *Balaena mysticetus*</u>

Bowhead whales occur only in the Northern Hemisphere, where they are limited to polar waters (Klinowska, 1991; Jefferson *et al.*, 1993; Kaschner, 2004). According to the IWC, five stocks, which were all hunted heavily, comprise this population (Reeves *et al.*, 2003). I estimate that the aggregate population has declined by 89%, although it is displaying some recent recovery (Table 3, Figure 23).

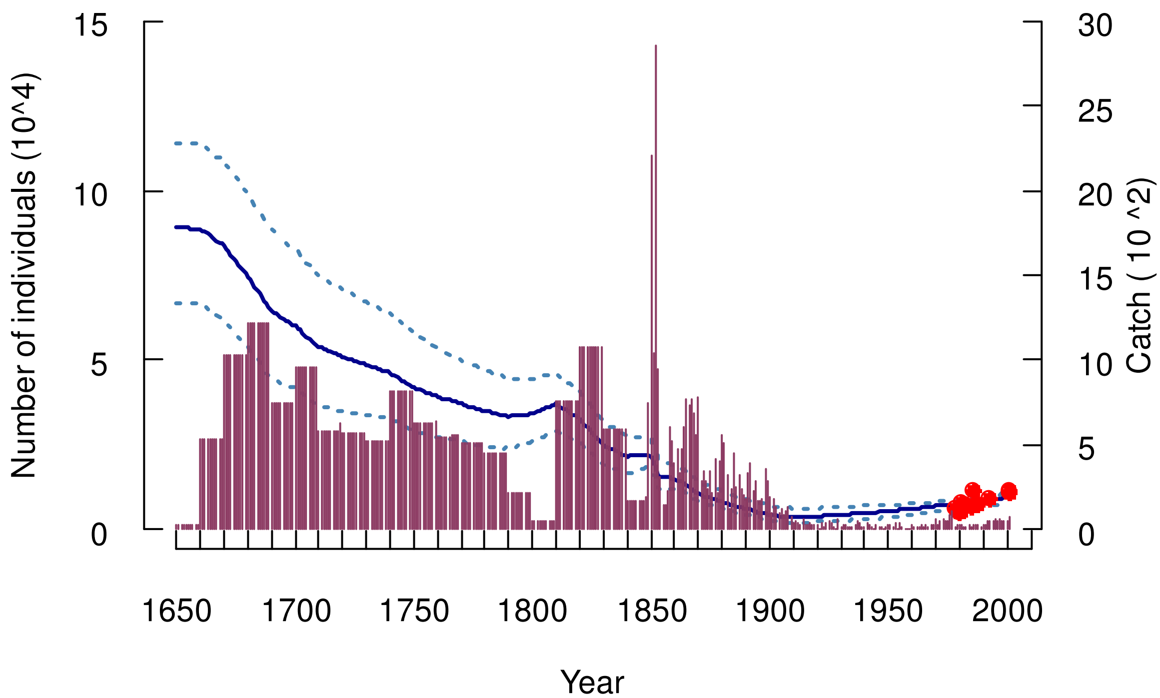


Figure 23. Population trajectory for Arctic bowhead whales

<u>Eden/Bryde's and Bryde's whale, *Balaenoptera edeni* and *Balaenoptera brydei*</u>

These whales are also globally distributed, and prefer subtropical – full tropical water (Nemoto, 1959; Ohsumi, 1977; Cummings, 1985; Klinowska, 1991; Kaschner, 2004). In the North Atlantic, catches of Eden/Bryde whales are documented starting in 1925, but a complete absence of abundance data makes assessment impossible. In fact the species is listed as data-deficient on the IUCN red list. The resemblance of this species to the sei whale has also caused some confusion in reporting, in addition to misreporting by whalers from the former Soviet Union. The numbers I do have, however, indicate the following: in the North Pacific, hunting started in 1946 and it has depleted the population by 21% (Table 3, Figure 24). In the Southern Hemisphere, the estimated decline from the whaling initiated in 1909 is only 3% (Table 3, Figure 25). Globally this gives a decline of 10% (Table 8).

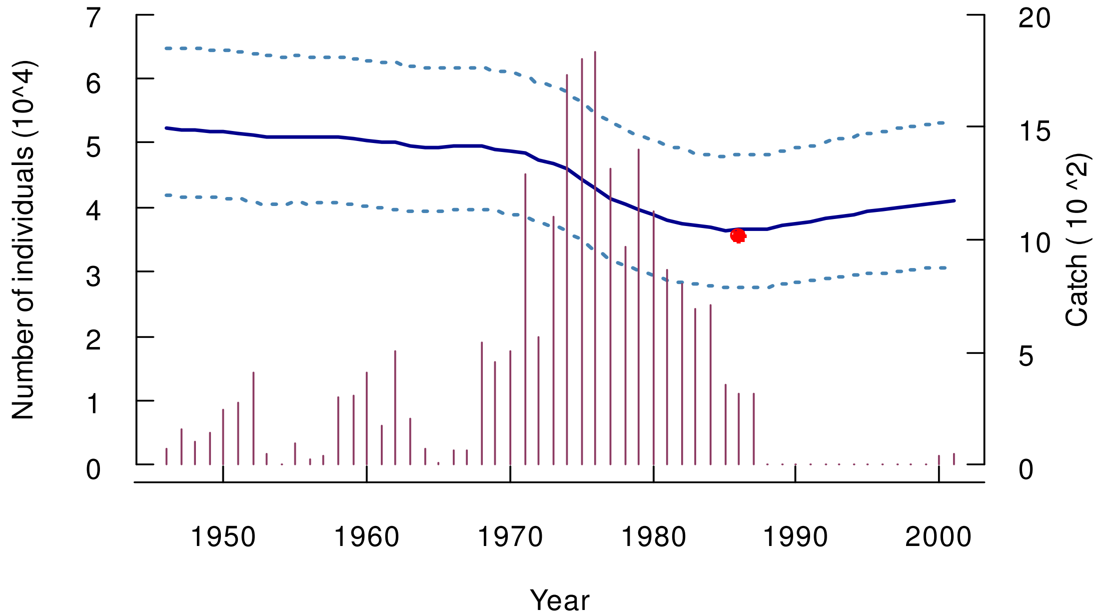


Figure 24. Population trajectory for the North Pacific Eden/Bryde whale complex

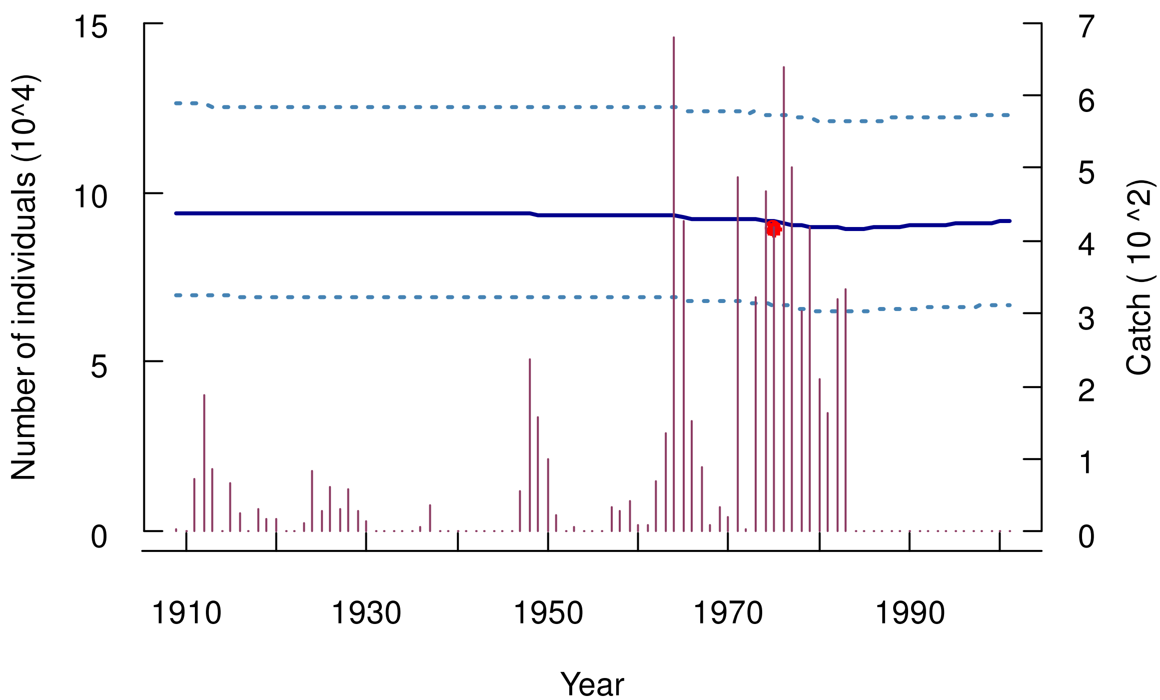


Figure 25. Population trajectory for the Southern Hemisphere Eden/Bryde whale complex

Humpback whale, *Megaptera novaengliae*

Humpback whales range from polar to tropical waters globally (Winn and Reichley, 1985; Clapham, 2002; Hamazaki, 2002; Kaschner, 2004). Although the stocks were intensively hunted, they are all showing signs of recovery (Figure 26, Figure 27, Figure 28). The North Atlantic population is depleted by 23%, and the North Pacific population by 57%, and in the Southern Hemisphere humpbacks are down 89% (Table 3). Globally, this amounts to a 82% depletion (Table 8).

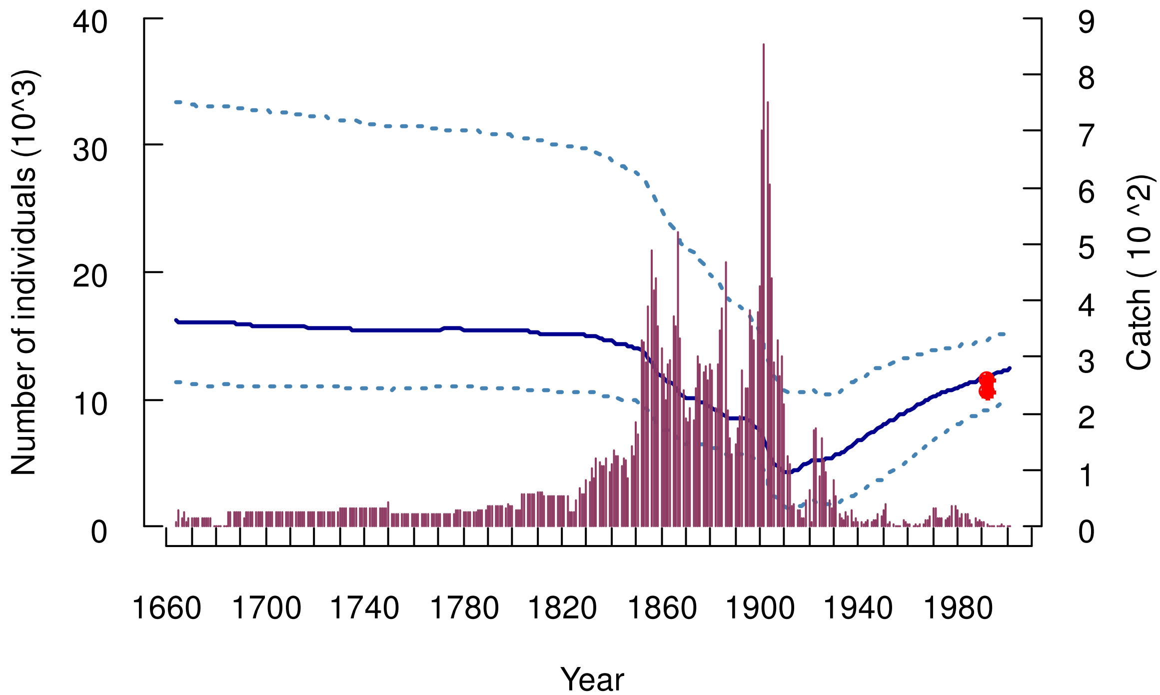


Figure 26. Population trajectory for North Atlantic humpback whales

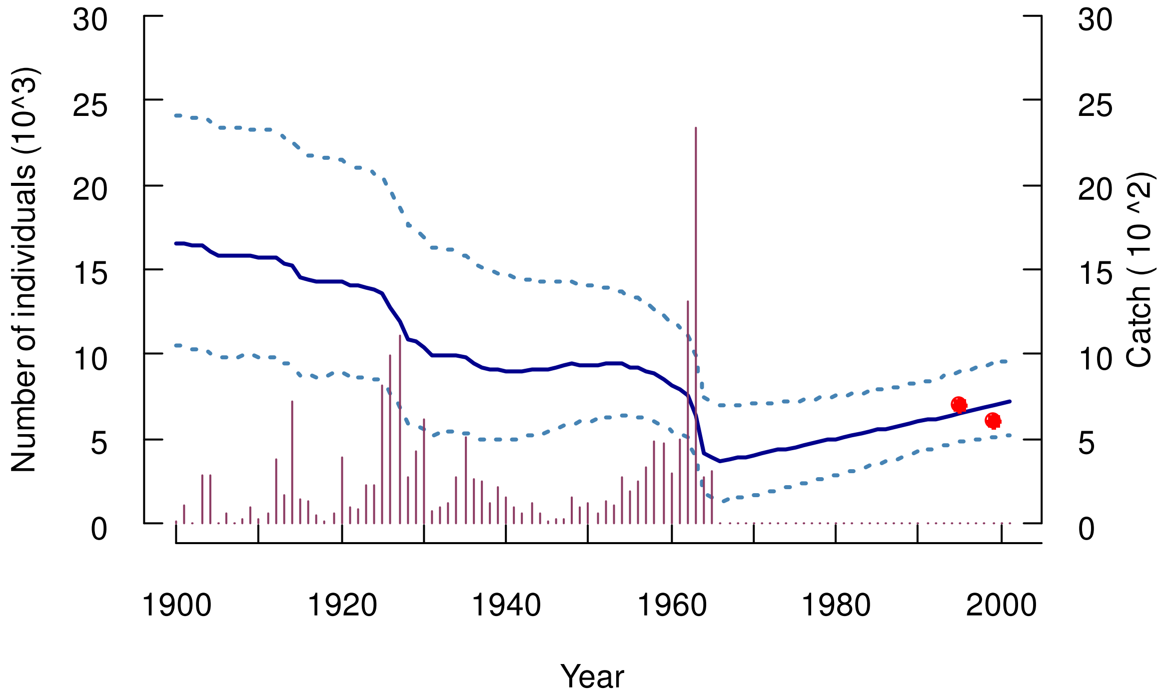


Figure 27. Population trajectory for North Pacific humpback whales

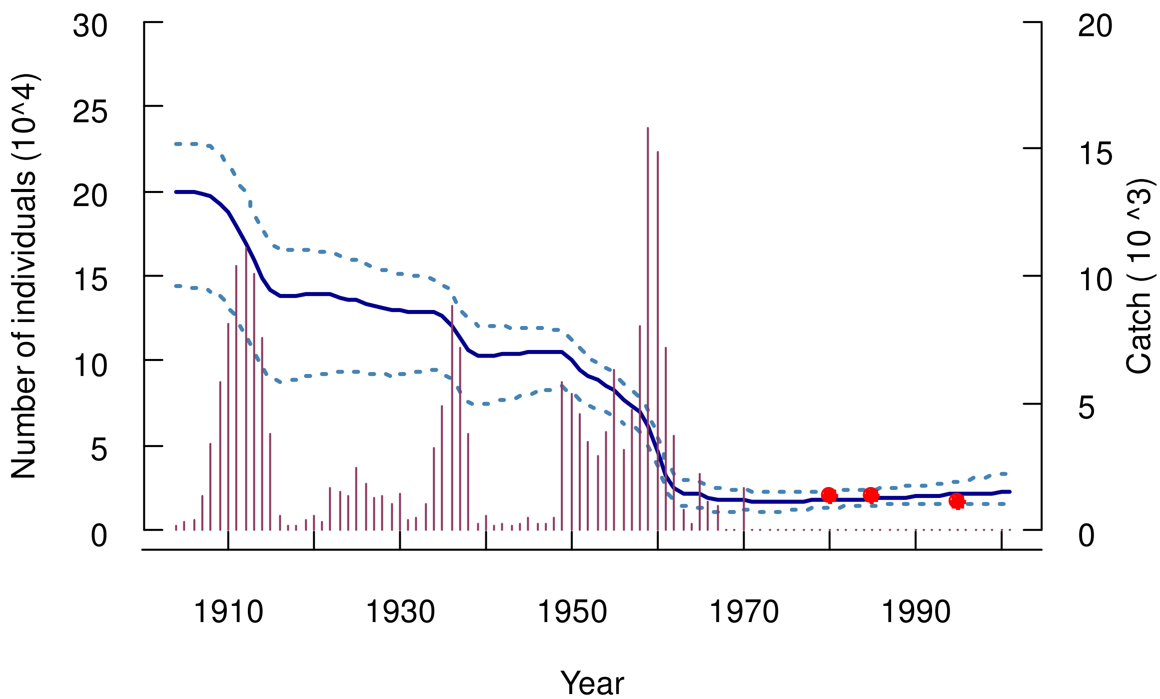


Figure 28. Population trajectory for Southern Hemisphere humpback whales

<u>Common minke whale, *Balaenoptera acutorostrata*</u>

The common minke whale occurs in the Northern Hemisphere (North Atlantic and Pacific stocks), and in the Indian Ocean, part of the Southern Ocean (dwarf stock) (Reeves *et al.*, 2003). I do not have numbers for the latter stock. The hunt for minke whales began relatively late, in 1926 in the North Atlantic and in 1940 in the North Pacific (Table 3). My estimates show that both populations have shown signs of recovery, with the North Atlantic stock depleted by 26% and the North Pacific stock by 32% (Table 3, Figure 29, Figure 30). Minke whales are currently hunted from Norway, Iceland and Greenland in the North Atlantic, and in the North Pacific by the Japanese. Globally, the common minke whales have been depleted by 27% (Table 8).

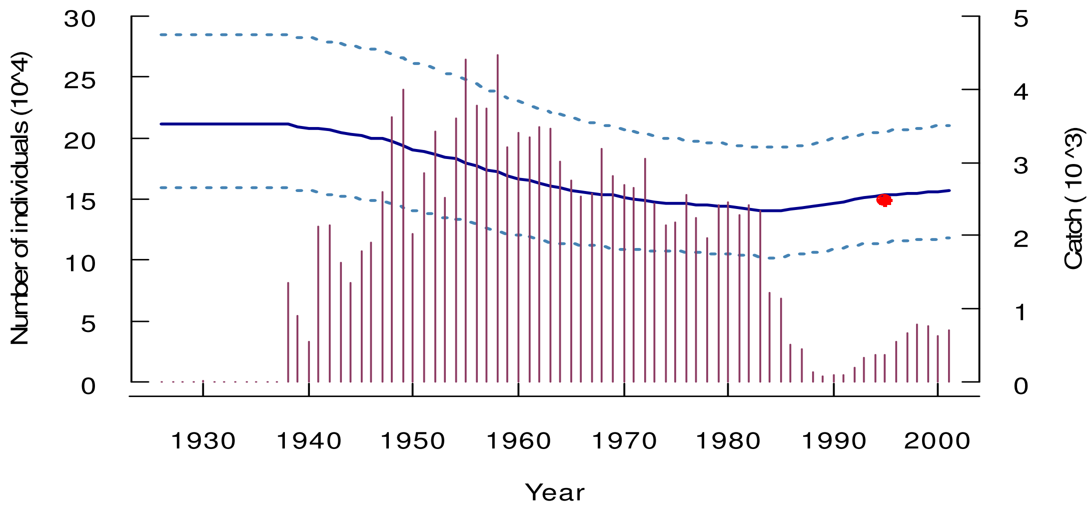


Figure 29. Population trajectory for North Atlantic minke whales

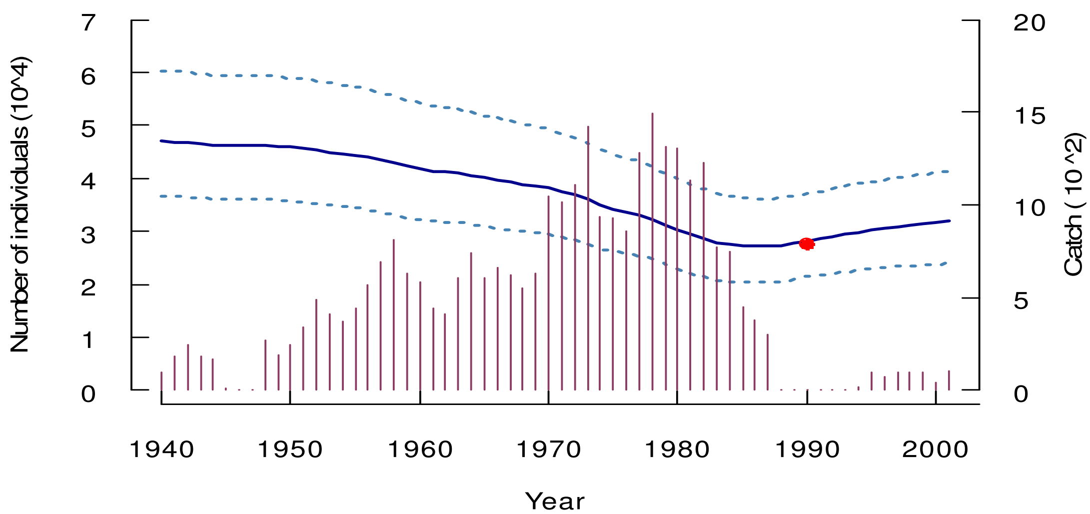


Figure 30. Population trajectory for North Pacific minke whales

Antarctic minke whale, *Balaenoptera bonaerensis*

It has only been within the last decade that the distinctness between the common and Antarctic minke whale has been recognized (Reeves *et al.*, 2003). The Antarctic minke whale ranges from polar to tropical waters in the Southern hemisphere (Ribic *et al.*, 1991; Rice, 1998; Murase *et al.*, 2002; Kaschner, 2004). Whaling for minkes was only initiated in 1921 (Table 3), after the larger species of baleen whales had begun to collapse. While they were hunted intensively, they still have a very large population and have begun recovering, although they are still hunted in the Antarctic by the Japanese, resulting in a depletion of 16% (Reeves *et al.*, 2003) (Table 3, Figure 31).

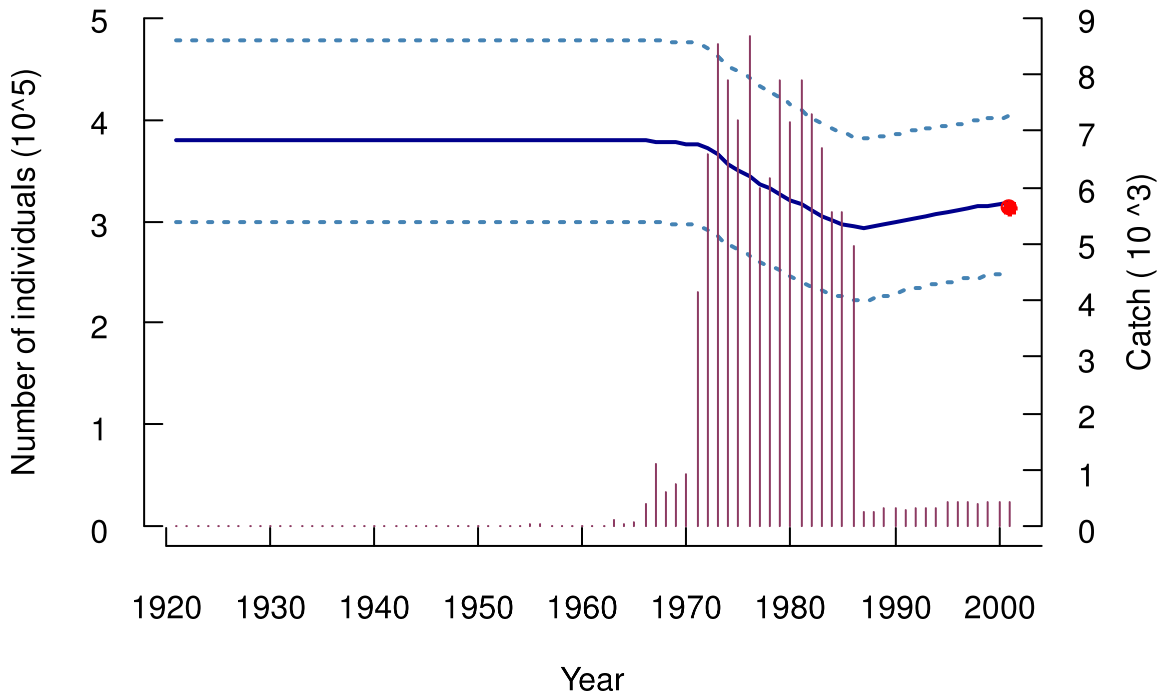


Figure 31. Population trajectory for Antarctic minke whales

North Atlantic right whale, *Eubalaena glacialis*

The North Atlantic right whale ranges from subpolar to tropical waters (Mitchell *et al.*, 1983, Gaskin, 1991, Kenney, 2002, Kaschner, 2004). The species may be nearing extinction, having been hunted since 1530 with a current population size in the low hundreds, about 3% of pre-exploitation numbers (Table 3, Figure 32).

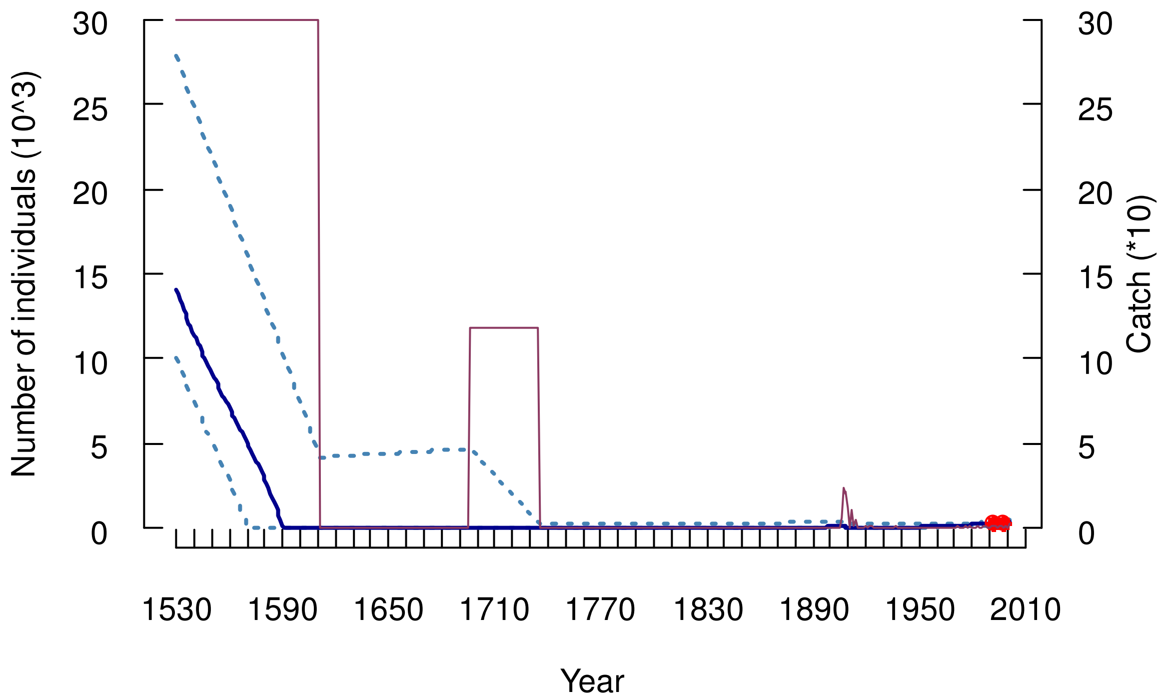


Figure 32. Population trajectory for North Atlantic right whales. NOTE: catches are plotted as a line instead of histograms for visual ease.

<u>North Pacific right whale, *Eubalaena japonica*</u>

The North Pacific right whale ranges from subpolar to subtropical waters (Jefferson *et al.*, 1993, Tynan *et al.*, 2001, Kenney, 2002, Kaschner, 2004). This species is faring slightly better than its North Atlantic cousins, with current population numbers of about 1300, and depleted by 86% since hunting began in 1835 (Table 3, Figure 33).

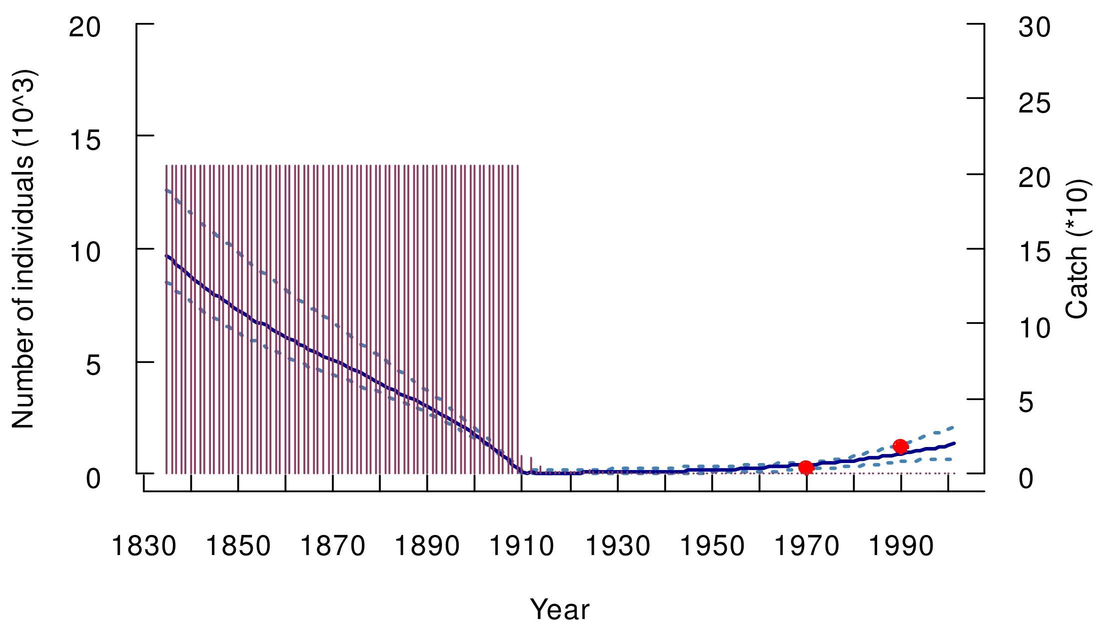


Figure 33. Population trajectory of North Pacific right whales

Smaller whales and large dolphins

The results presented in this section are all listed in Table 4, which lists the species name, the ocean basin referencing the sub-population, the year of the beginning of documented hunting, the initial, pre-exploitation numbers with associated 95% credible interval, the 2001 numbers with associated 95% credible interval, and the level of depletion of the sub-population.

Table 4: Population sizes of smaller whales and large dolphins

Species	Ocean Basin	Start of doc. hunts	Initial numbers (Mean, 95% CI)	2001 numbers (Mean, 95% CI)	Depleted by (%)
Short-finned pilot whale	Japan	1948	56,400 (46,700 – 67,100)	54,700 (45,300 – 65,200)	3
Baird's beaked whale	Japan	1907	9,010 (7,080 – 11,800)	6,450 (5,010 – 8,230)	28
Beluga	Global	1862	170,000 (115,000 – 289,000)	96,500 (71,200 – 132,000)	43
Killer whale	North Atlantic	1954	9,990 (7,550 – 13,300)	9,210 (6,840 – 12,400)	8
	North Pacific	1935	5,140 (3,720 – 7,090)	4,340 (3,230 – 5,850)	16
	Southern Hemisphere	1953	26,400 (19,600 – 35,800)	25,700 (18,900 – 35,000)	3
Long-finned pilot whale	Faroe Islands - Central and Eastern North Atlantic	1709	813,000 (710,000 - 895,000)	773,000 (668,000 – 864,000)	5
	Northwest Atlantic (Newfoundland)	1947	57,800 (50,800 – 67,100)	22,400 (12,900 – 33,900)	61
Northern bottlenose whale	North Atlantic	1584	57,800 (44,200 – 84,700)	48,800 (37,600 – 64,300)	16
False killer whale	Japan	1965	17,100 (13,600 – 21,600)	16,600 (13100 – 21000)	3
Narwhal	Baffin Bay Canada	1977	48,000 (38,600 – 59,800)	43,000 (33,500 – 54,800)	10
	Hudson Bay	1977	10,500 (8,920 – 12,400)	3,580 (2,640 – 4,910)	66
	Baffin Bay Greenland	1977	17,800 (15,200 – 21,000)	6,820 (5,010 – 9,310)	62

<u>Short-finned pilot whale, *Globicephala macrorhynchus*</u>

The short-finned pilot whale is found throughout the world's oceans, and ranges from polar to warm temperate waters (Smith *et al.*, 1986; Payne and Heinemann, 1993; Wade and Gerrodette, 1993; Davis *et al.*, 1998; Reeves *et al.*, 2003; Kaschner, 2004). Catches are not well-documented in Japan, and are much smaller than the estimated population size and so no significant decrease in abundance is estimated (Table 4, Figure 34).

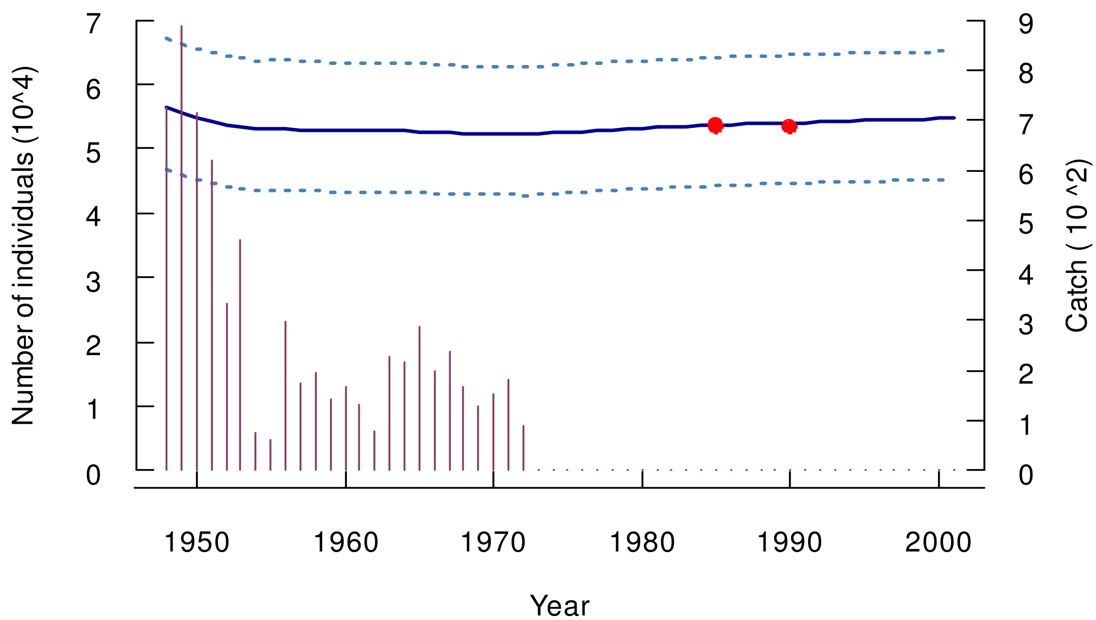


Figure 34. Population trajectory for Japanese short-finned pilot whales

<u>Baird’s beaked whale, *Berardius bairdii*</u>

Baird’s beaked whale is found in the North Pacific, and it inhabits polar to subtropical waters (Reeves and Mitchell, 1993; Kasuya, 2002; D’Amico *et al.*, 2003; Kaschner, 2004). The Japanese stock of Baird’s beaked whale has been hunted since 1907 and is showing a decline of 28% in numbers (Table 4, Figure 35); the global stock is down 26% (Table 8).

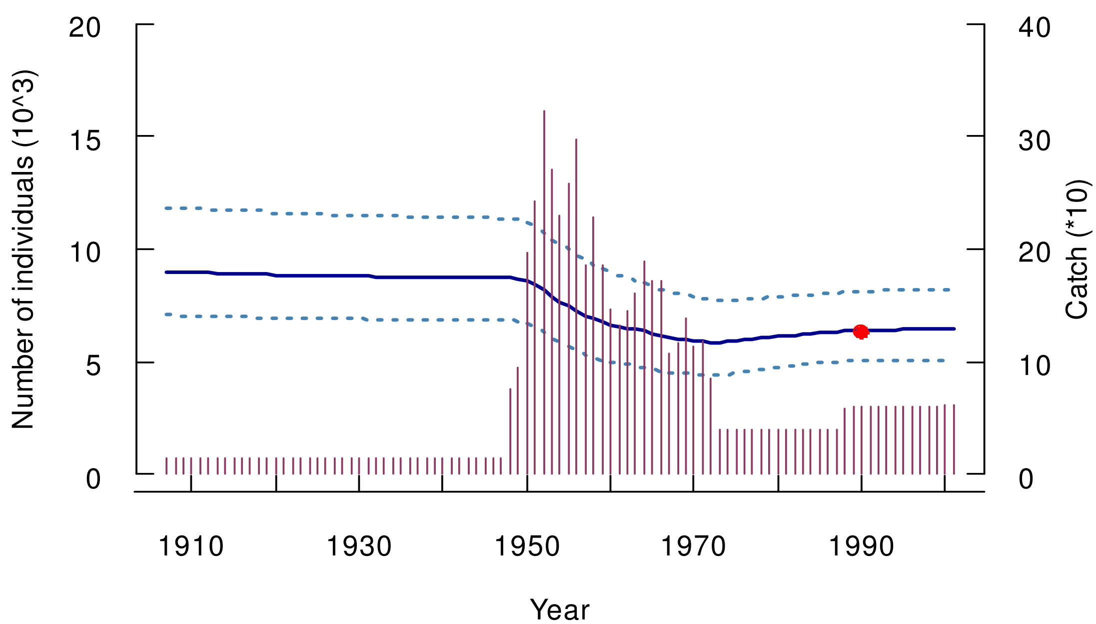


Figure 35. Population trajectory for Japanese Baird's beaked whales

Beluga, *Delphinapterus leucas*

The beluga whale's distribution is circumpolar in the Northern Hemisphere (Watts *et al.*, 1991; Rice, 1998; O'Corry-Crowe, 2002; Kaschner, 2004). The IWC currently recognizes 29 beluga stocks. However, for this assessment I have added up the catches and assessed the belugas as a single stock. This means that, while local depletion of isolated populations is evident, for example in Cook Inlet and Ungava Bay, the stock as a whole, which experienced a significant decline, currently has a steady population level (Table 4, Figure 36). For the west Greenlandic stock, catch data exist stretching back to 1862, although with some holes. As recommended by Heide-Jørgensen and Rosing-Avid (2002), who compiled and summarized the west Greenlandic catch data, I have interpolated numbers to fill such gaps, because: "for population modeling it will be necessary to interpolate years without reported catches, to spread out the average figures over the years involved and to assume some level of catching before 1862" (Heide-Jørgensen and Rosing-Asvid, 2002). However, I decided to begin the catches in 1862 as no indication of previous substantial hunts exists.

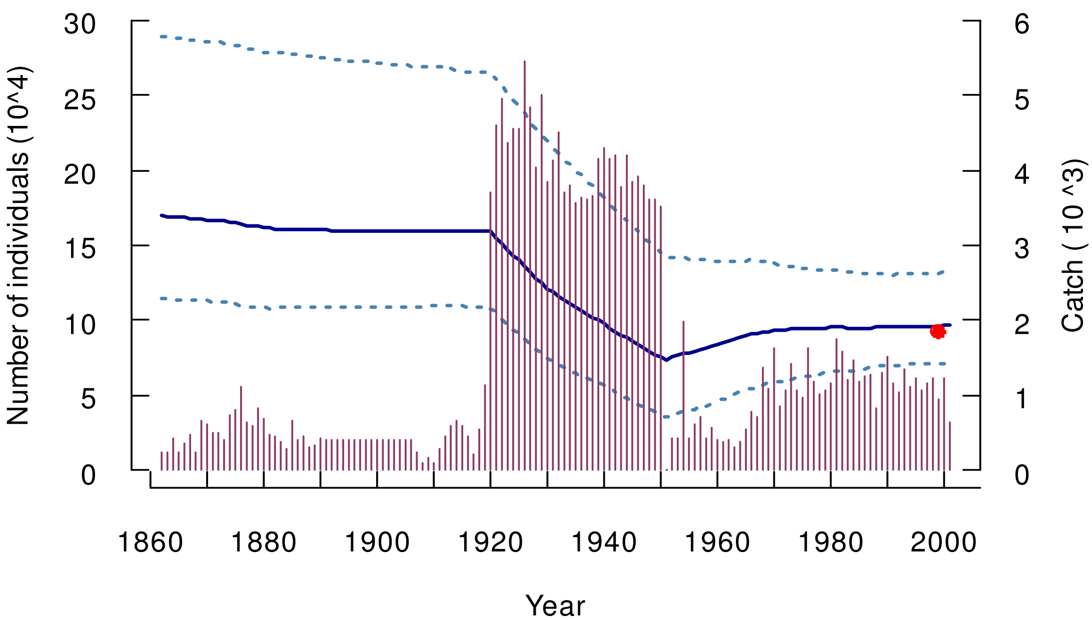


Figure 36. Population trajectory for beluga whales

Killer whale, *Orcinus orca*

Killer whales have a circumglobal distribution, and range from polar to tropical waters (Jefferson *et al.*, 1993; Kasamatsu *et al.*, 2000; IWC/BIWS, 2001; Ford, 2002; Kaschner, 2004). While some populations are hunted, the species appears to be doing fine. In the North Atlantic hunting started in 1954, and current numbers are only reduced by 8% remaining right around the 10,000 individuals (Table 4, Figure 37). In the North Pacific and Southern Hemisphere, where hunting started in 1935 and 1953, respectively, the populations are depleted at 16 and 2% respectively (Table 4, Figure 38, Figure 39). Globally, this represents a decline of 5% for killer whales (Table 8).

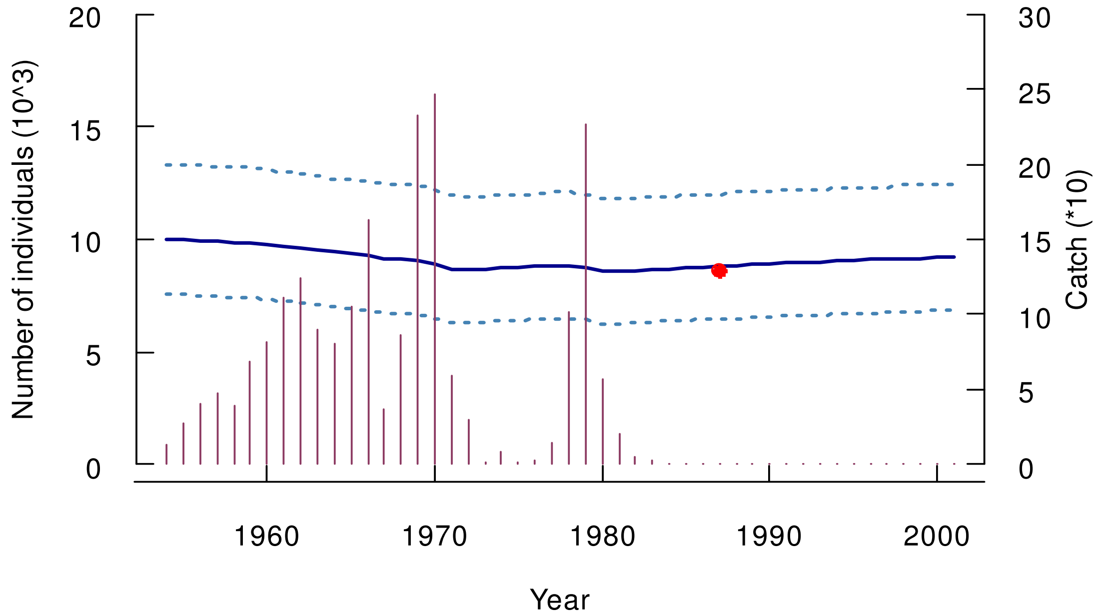


Figure 37. Population trajectory for North Atlantic killer whales

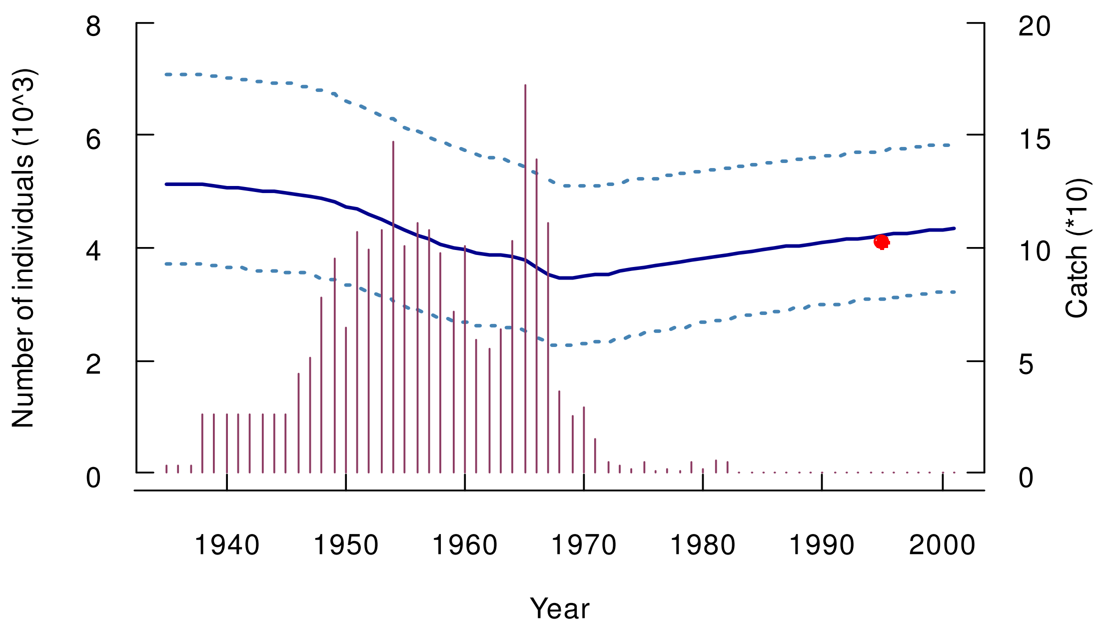


Figure 38. Population trajectory for North Pacific killer whales

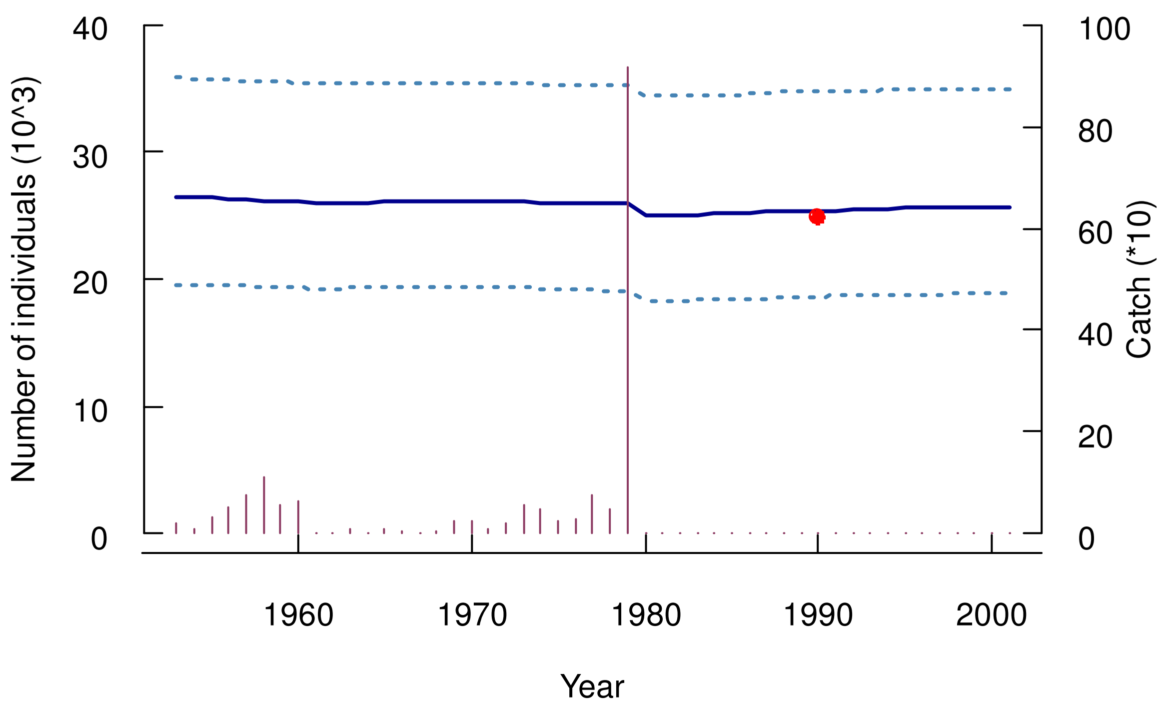


Figure 39. Population trajectory for Southern Hemisphere killer whales

<u>Long-finned pilot whale, *Globicephala melas*</u>

The long-finned pilot whale has a global distribution, from polar to warm temperate waters (Findlay *et al.*, 1992; Jefferson *et al.*, 1993; Kasamatsu and Joyce, 1995; Kaschner, 2004). The Faroe Island population, which has a long traditional catch history beginning in 1709, is only slightly depleted at 5%, indicating that this hunt must be sustainable (Table 4, Figure 40). Off Newfoundland, however, the population seems to be significantly depleted, having dropped 61% in numbers (Table 4, Figure 41). Globally, this represents a decline of 7% for long-finned pilot whales (Table 8).

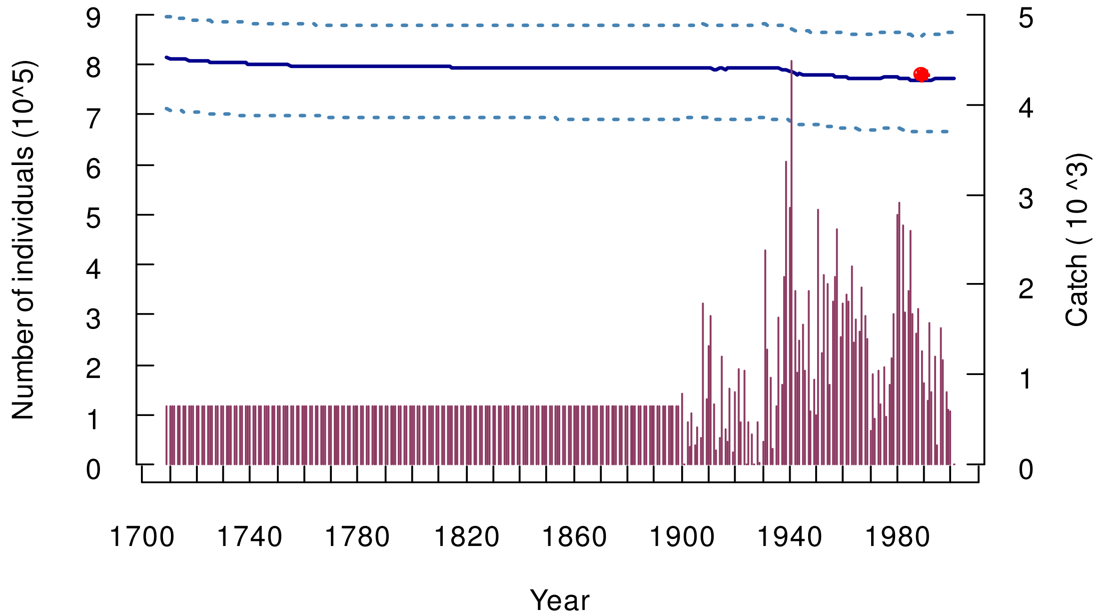


Figure 40. Population trajectory for Faroe Island long-finned pilot whales

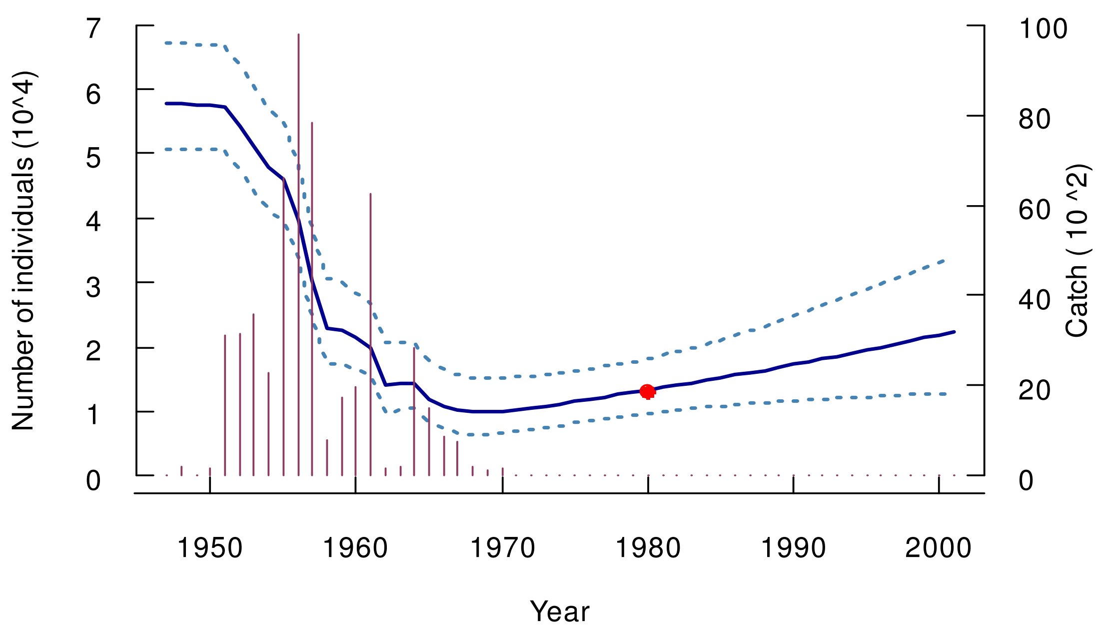


Figure 41. Population trajectory for Northwest Atlantic (Newfoundland) pilot whales

<u>Northern bottlenose whale, *Hyperoodon ampullatus*</u>

The northern bottlenose whale is only found in the North Atlantic, in warm temperate to polar waters (Benjaminsen and Christensen, 1979; Jefferson *et al.*, 1993; D'Amico *et al.*, 2003; Kaschner, 2004). The stock, which has recorded catches all the way back to 1584, is depleted by 16%, and currently number just under 50,000 individuals (Table 4, Figure 42).

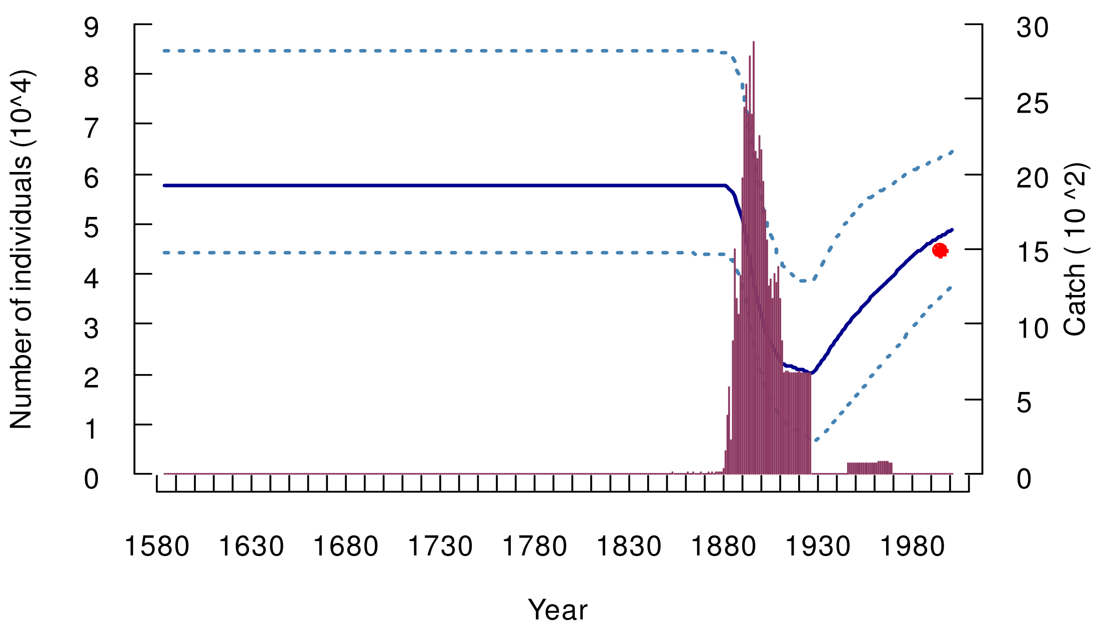


Figure 42. Population trajectory for northern bottlenose whales

False killer whale, *Pseudorca crassidens*

The false killer whale is at home in all the world's oceans, in warm temperate to tropical waters (Miyazaki and Wada, 1978; Wade and Gerrodette, 1993; Stacey *et al.*, 1994; de Boer and Simmonds, 2003; Kaschner, 2004). The Japanese sub-population is the only stock for which I have catch data. Documented hunting here commenced in 1965, and has had only a slight impact on the stock, with current numbers depleted by 6% (Table 4, Figure 43). However, this may be a vast underestimate as the stock is likely still hunted. Globally, the population is depleted by 1% (Table 8).

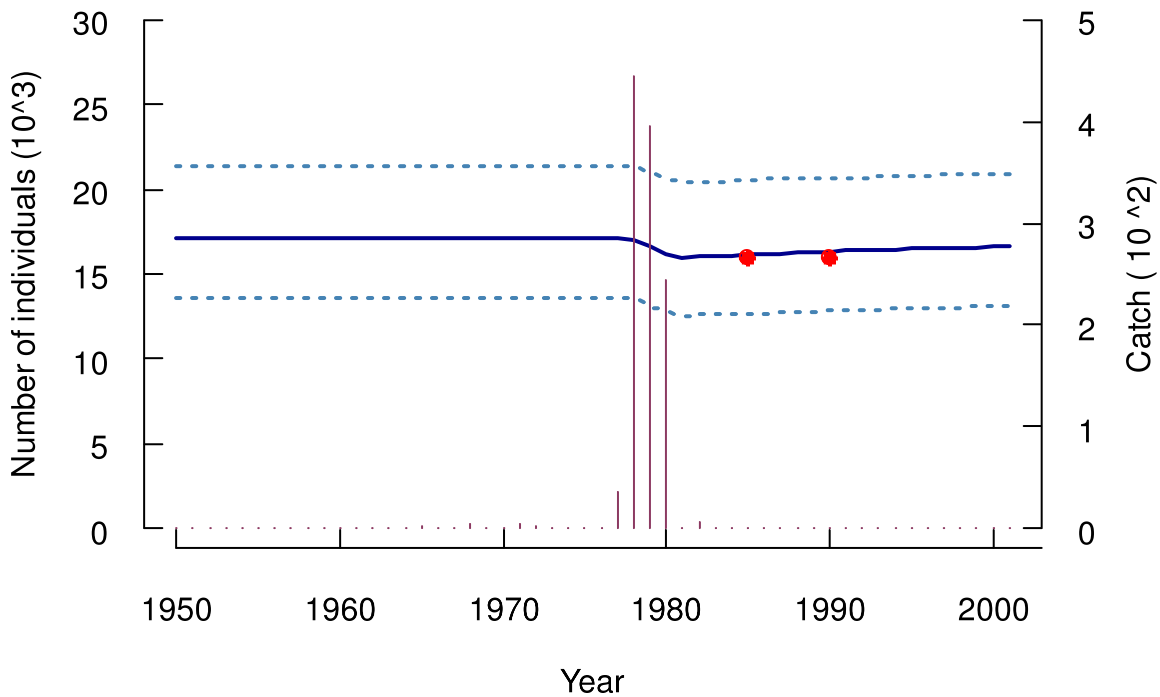


Figure 43. Population trajectory for Japanese false killer whales

Narwhal, *Monodon monoceros*

The narwhal is endemic to the Northern Hemisphere, and occurs in polar water (Jefferson *et al.*, 1993; Heide-Jørgensen, 2002; Kaschner, 2004). Narwhals have been hunted extensively for hundreds or thousands of years. The Northeast Atlantic population of Norway (Svalbard) is largely extinct (Hrynyshyn, 2004), the species hunted by the Vikings for their long unicorn-like horns that made these creatures seem almost mythical (Pluskowski, 2004). The Canadian Baffin Bay stock, hunted since 1977, is depleted by 10% (Table 4, Figure 44). The Greenlandic Baffin Bay stock is faring much worse, at only 38% of its population size in 1977 (Table 4, Figure 46). The Hudson Bay stock does not look much better, with a depletion level of 66% since documented hunting began in 1977 (Table 4, Figure 45). Each of these stocks is still being hunted, and are facing continuous decline. Globally, the stocks have decreased by 24% since 1977 (Table 8).

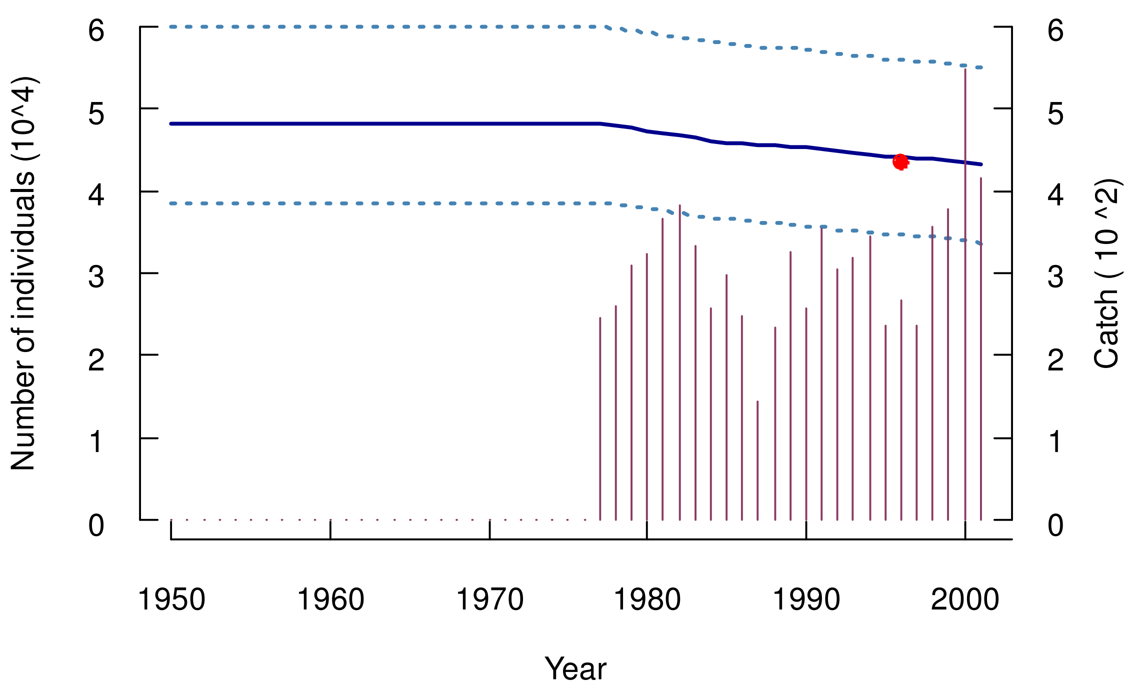


Figure 44. Population trajectory for Canadian Baffin Bay narwhals

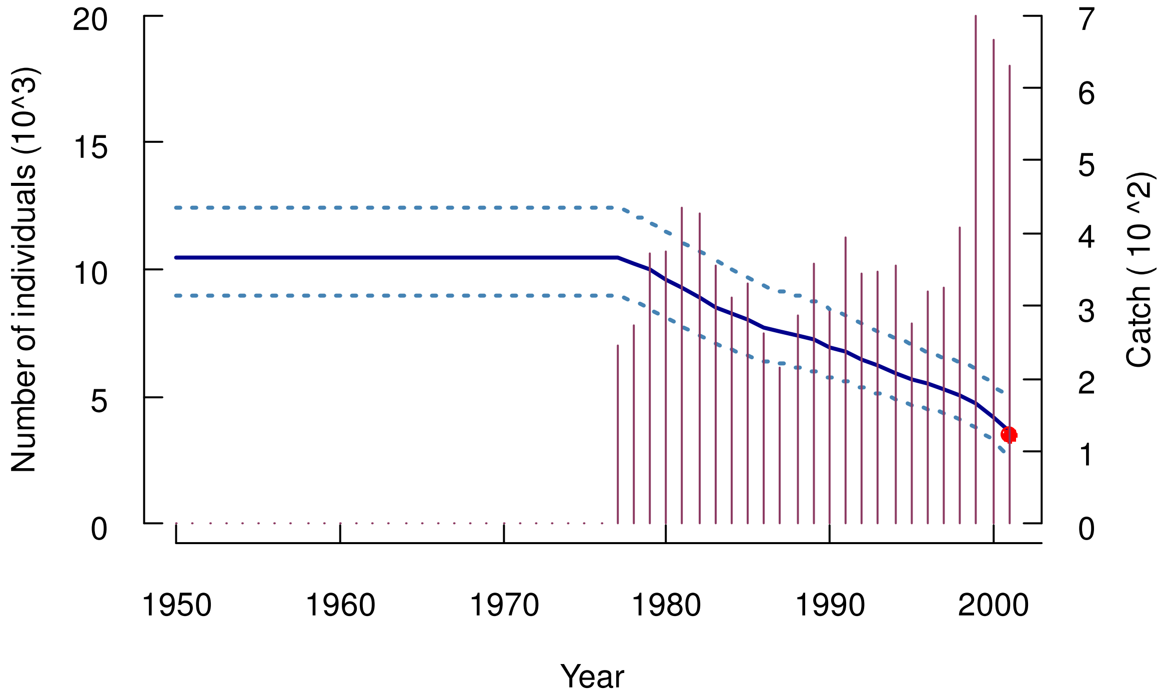


Figure 45. Population trajectory for Hudson Bay narwhals

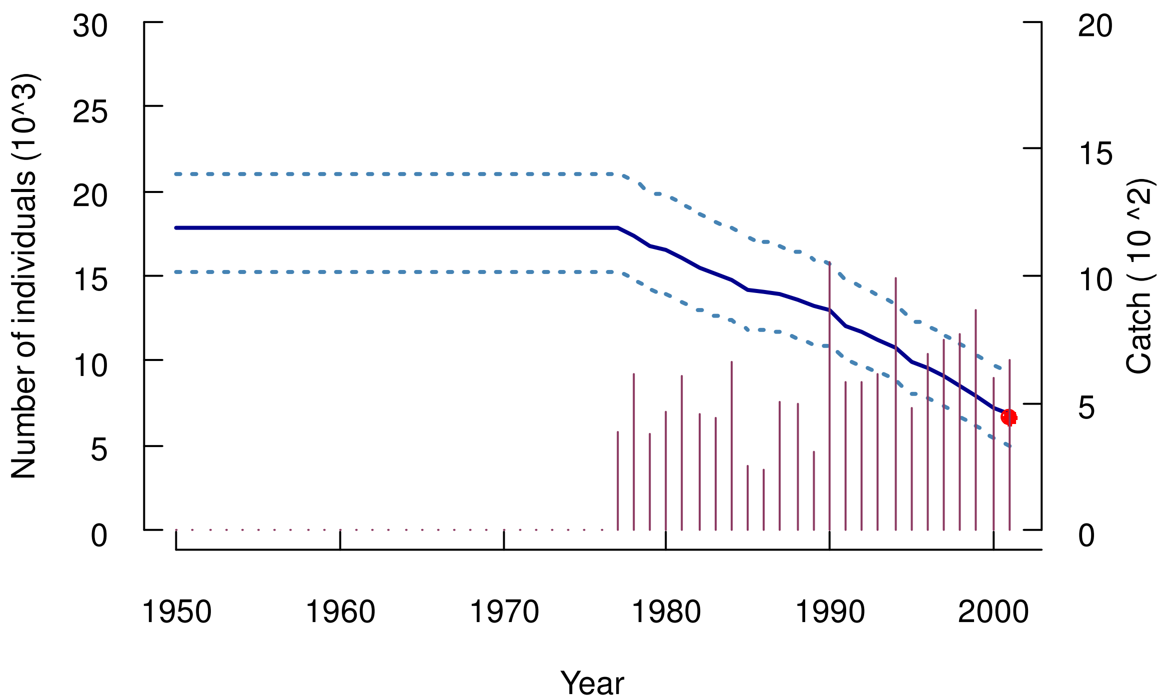


Figure 46. Population trajectory for Greenlandic Baffin Bay narwhals

Smaller Dolphins and Porpoises

The results presented in this section are all given in Table 5, which lists the species name, the ocean basin referencing the sub-population, the year of the beginning of documented hunting, the initial, pre-exploitation numbers with associated 95% credible interval, the 2001 numbers with associated 95% credible interval, and the level of depletion of the sub-population.

Table 5: Population sizes of smaller dolphins and porpoises

Species	Ocean Basin	Start of doc. hunts	Initial numbers (Mean, 95% CI)	2001 numbers (Mean, 95% CI)	Depleted by (%)
Pantropical spotted dolphin	Eastern Tropical Pacific	1959	4,590,000 (3,740,000 – 5,740,000)	1,730,000 (1,350,000 – 2,190,000)	62
	Japan	1970	455,000 (368,000 – 574,000)	449,000 (362,000 – 568,000)	1
Spinner dolphin	Eastern Tropical Pacific	1959	2,630,000 (2,130,000 – 3,260,000)	1,880,000 (1,480,000 – 23,50,000)	29
Short beaked common dolphin	Eastern Tropical Pacific	1959	3,290,000 (2,630,000 – 3,910,000)	3,160,000 (2,510,000 – 3,780,000)	4
	Northwest Atlantic	1989	40,800 (32,600 – 51,100)	37,900 (29,800 – 48,200)	7
Dall's porpoise	Japan	1963	724,000 (593,000 – 899,000)	378,000 (236,000 – 561,000)	48
Bottlenose dolphin	Northwest Atlantic	1950	32,000 (25,500 – 40,500)	30,400 (23,800 - 38800)	5
	Japan	1966	176,000 (139,000 – 222,000)	173,000 (136,000 – 219,000)	2
Northern right whale dolphin	North Pacific	1978	408,000 (345,000 – 491,000)	277,000 (203,000 – 369,000)	32
Harbour Porpoise	Greenland	1900	47,700 (35,300 – 710,00)	5,090 (0 – 11,800)	89
	North Sea	1950	324,000 (263,000 – 401,000)	257,000 (195,000 – 335,000)	21
	Baltic	1716	78,400 (40,500 – 146,000)	40,500 (30,800 – 50,200)	48
	Western North Atlantic	1989	127,000 (978,00 – 166,000)	106,000 (76,800 – 145,000)	17
Atlantic white-sided dolphin	Northwest Atlantic - USA	1950	21,000 (15,300 – 28,600)	20,100 (14,400 – 27,700)	4

Pantropical spotted dolphin, *Stenella attenuata*

The pantropical spotted dolphin, true to its name, ranges over the tropical waters of the world's oceans (Miyazaki *et al*., 1974; Fiedler and Reilly, 1994; Hamazaki, 2002; Kaschner, 2004). The eastern tropical stock, caught as by-catch in the tuna fisheries of the Eastern Tropical Pacific and documented since 1959, is depleted and at only 38% of its original population size (Table 5, Figure 47). In Japan, where the species is caught commercially, with catch data going back to 1970, the population seems steady (Table 5, Figure 11). This could again be an issue of the Japanese limiting data availability, as indications are this hunt is ongoing. Finding reliable documentation has, however, proved difficult. Globally, the stock is depleted by 57% (Table 8).

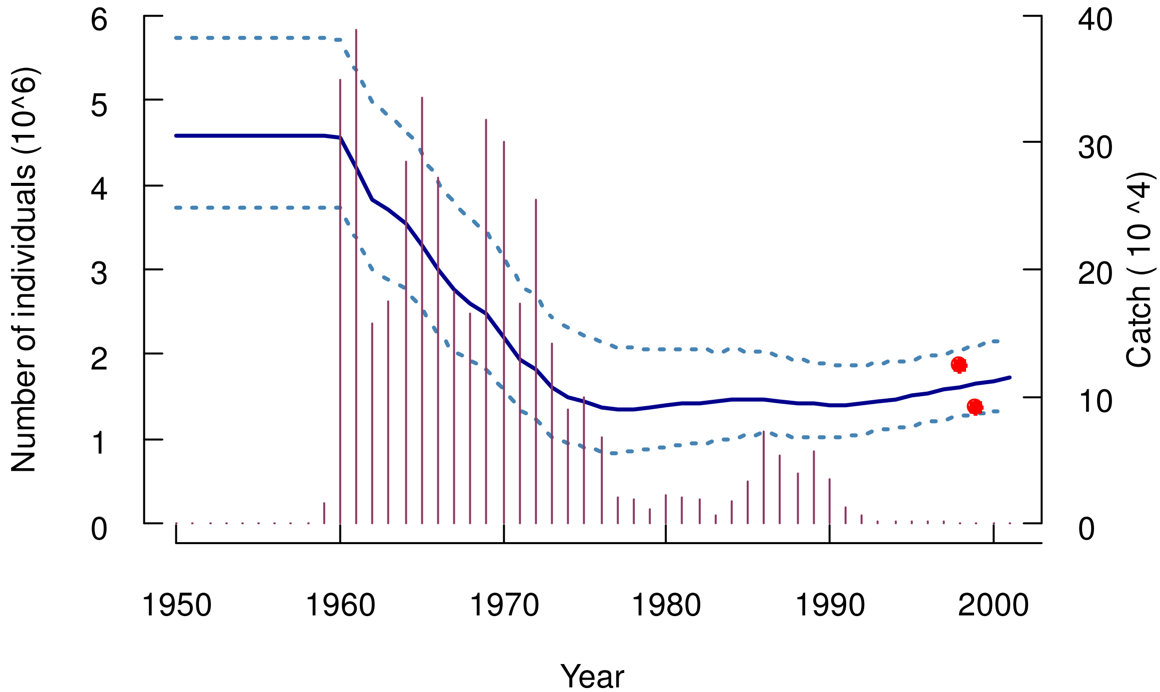


Figure 47. Population trajectory for Eastern Tropical Pacific pantropical spotted dolphins

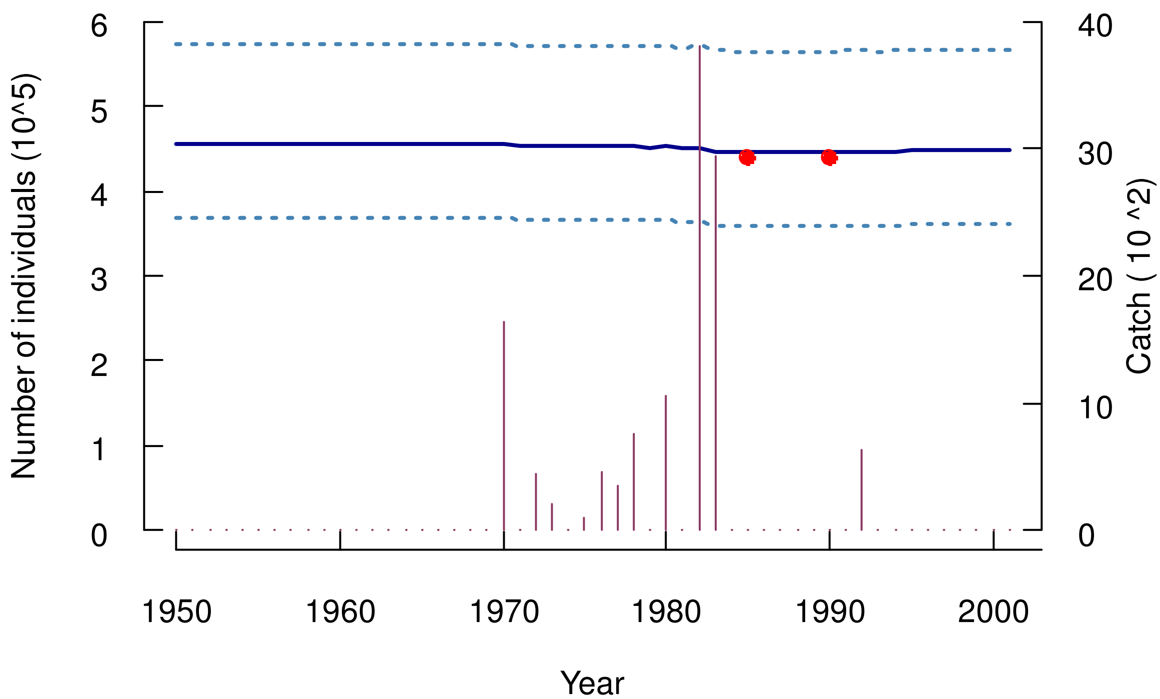


Figure 48. Population trajectory for Japanese pantropical spotted dolphins

Spinner dolphin, *Stenella longirostris*

The spinner dolphin occurs in tropical waters of the oceans (Miyazaki and Wada, 1978; Davis *et al.*, 1998; De Boer, 2000; Perrin, 2002; Kaschner, 2004). The spinner dolphin is caught as incidental by-catch in the tuna fishery in the Eastern Tropical Pacific. Since 1959, this has resulted in a 29% drop in population numbers (Table 5, Figure 49). Globally, the decline is 28% (Table 8).

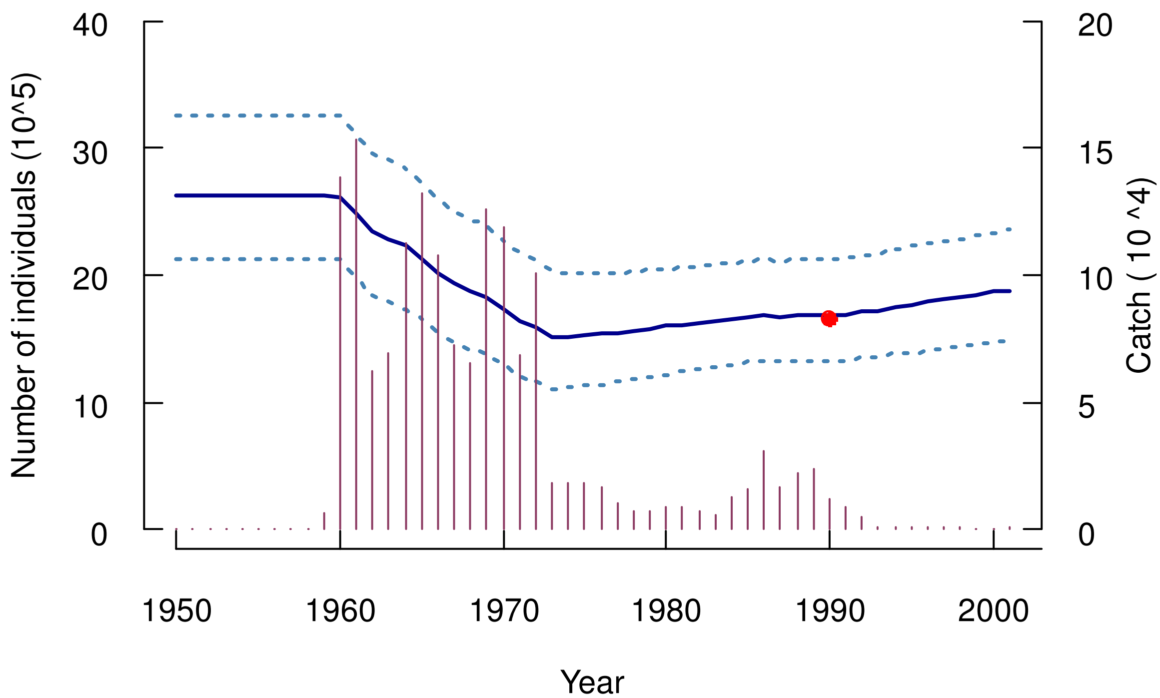


Figure 49. Population trajectory for Eastern Tropical Pacific spinner dolphins

Short beaked common dolphin, *Delphinus delphis*

The short beaked common dolphin is found all the world's oceans, from cold temperate to tropical waters (Selzer and Payne, 1988; Rice, 1998; Perrin, 2002; Kaschner, 2004). They are taken as by-catch in the Eastern Tropical Pacific, although at documented levels the population has only decreased by 4% since 1959 (Table 5, Figure 50). In Japanese waters, the dolphin is killed incidentally as by-catch of various fisheries, but a commercial hunt also exists. Since 1989, this has caused a 7% drop in population levels (Table 5, Figure 51). Again, finding reliable catch data from Japanese waters has been a struggle, and the decline is probably larger. Globally, the population has decreased by 3% (Table 8).

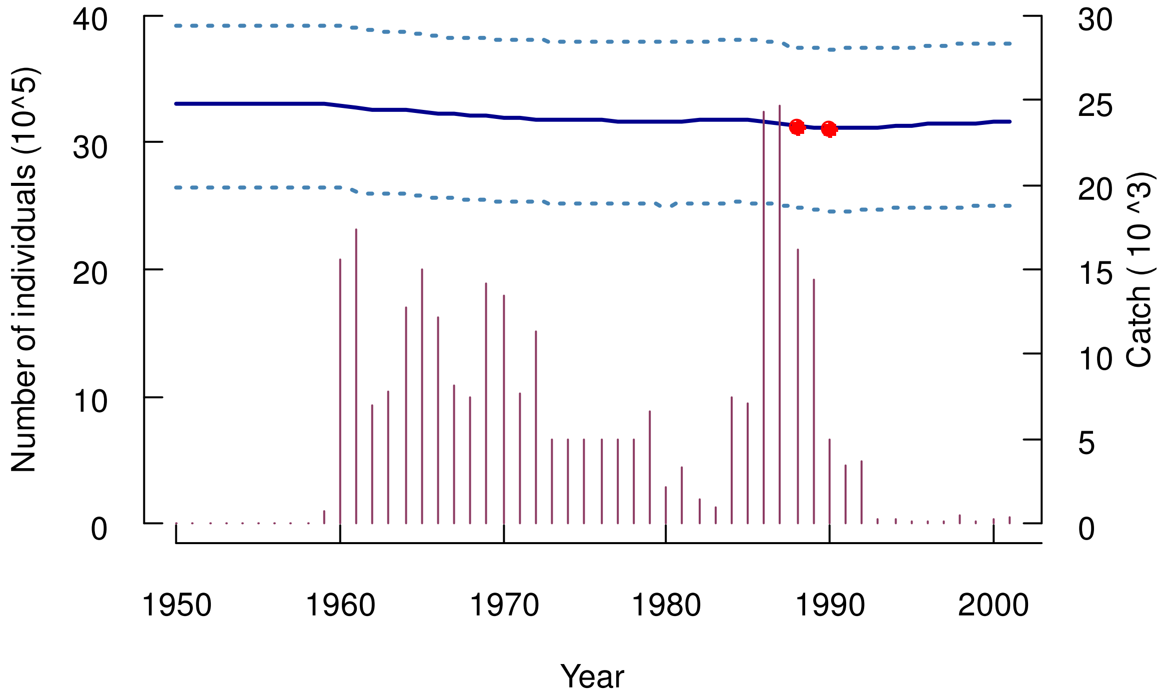


Figure 50. Population trajectory for Eastern Tropical Pacific short beaked common dolphins

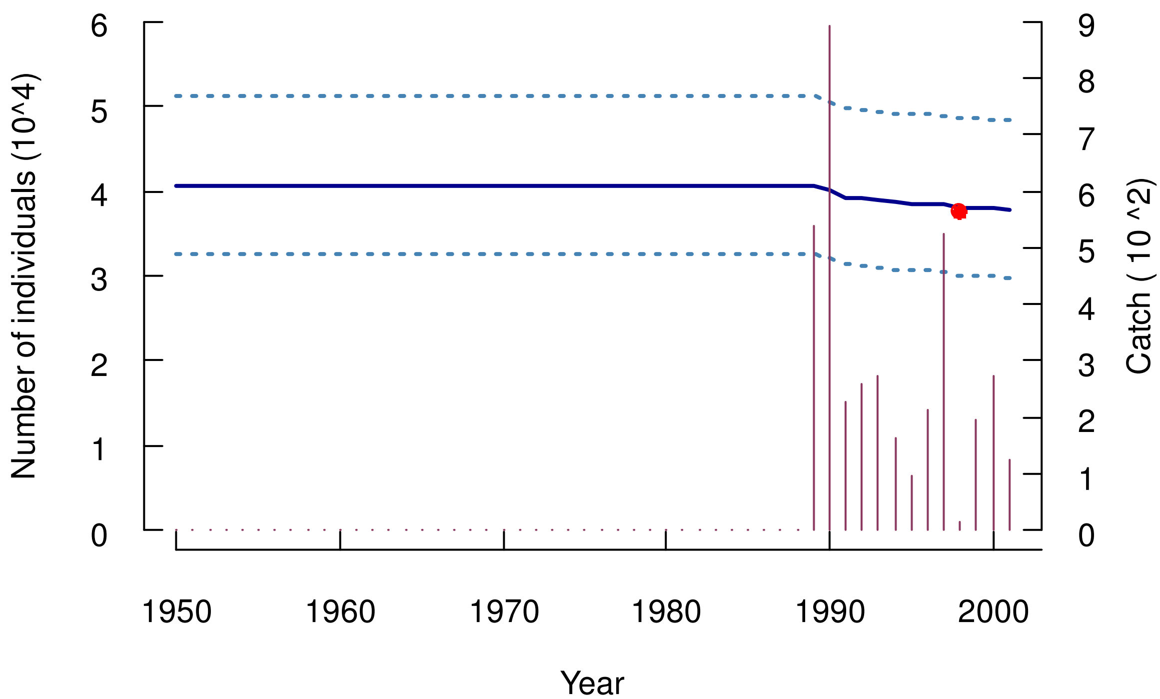


Figure 51. Population trajectory for Northwest Atlantic short beaked common dolphins

Dall's porpoise, *Phocoenoides dalli*

Dall's porpoises are found in the North Pacific, from subpolar to warm temperate waters (Jones *et al.*, 1987; Jefferson, 1988; Miyashita and Kasuya, 1988; Kaschner, 2004). This porpoise is mainly taken as a commercial catch, but by-catch is also a significant source of mortality. The Dall's porpoise in Japan is depleted by some 48% since hunting commenced in 1963 (Table 5, Figure 52). This is a stock for which good catch data are available from Japan. On a global scale, Dall's porpoise populations are depleted by 24% (Table 8).

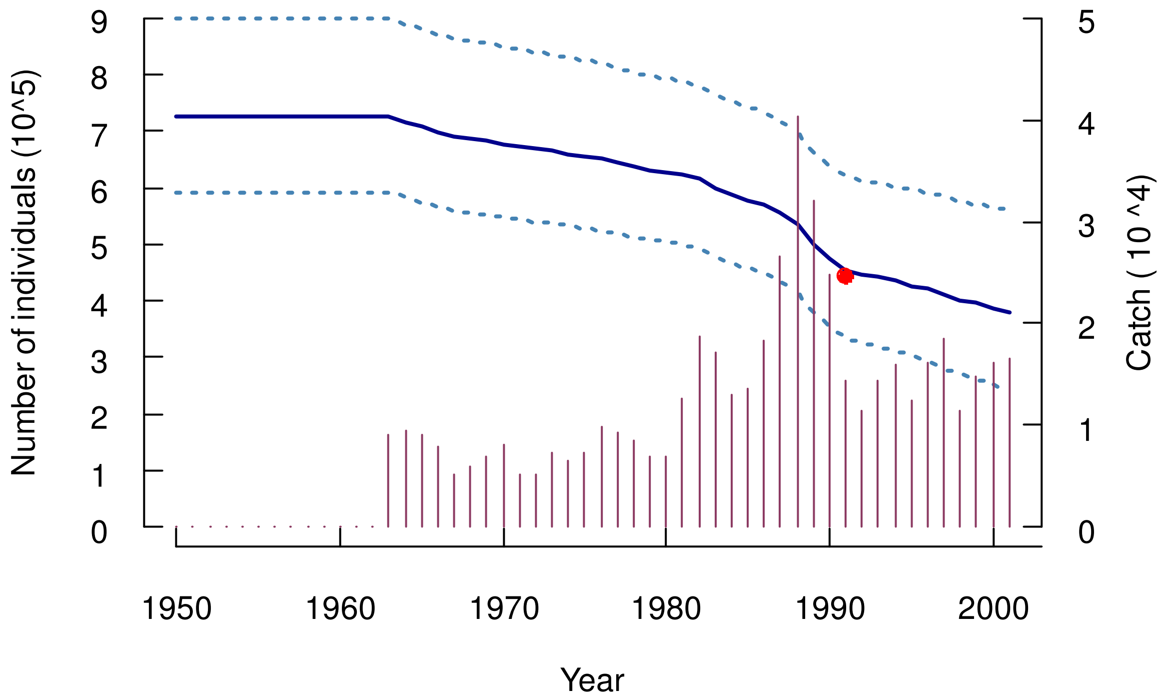


Figure 52. Population trajectory for Japanese Dalls porpoises

Bottlenose dolphin, *Tursiops truncatus*

The bottlenose dolphin ranges throughout the oceans in cold-temperate to full tropical waters (Jefferson *et al.*, 1993; Wells and Scott, 1999; Wells and Scott, 2002; Kaschner, 2004). The bottlenose dolphin has been caught in small quantities off the California coast for live-capture, but is otherwise mostly killed as incidental by-catch although a commercial hunt has gone on in Japan, and most likely continues, although I again have no acess to reliable numbers. In the Northwest Atlantic, the decrease in abundance stands at only 5% since 1950 (Table 5, Figure 53). However the dip is recent, so the stock is declining. In Japan, the decline is rather insignificant, at only 2% since 1966 (Table 5, Figure 54). Globally, the stock has declined by 1% (Table 8).

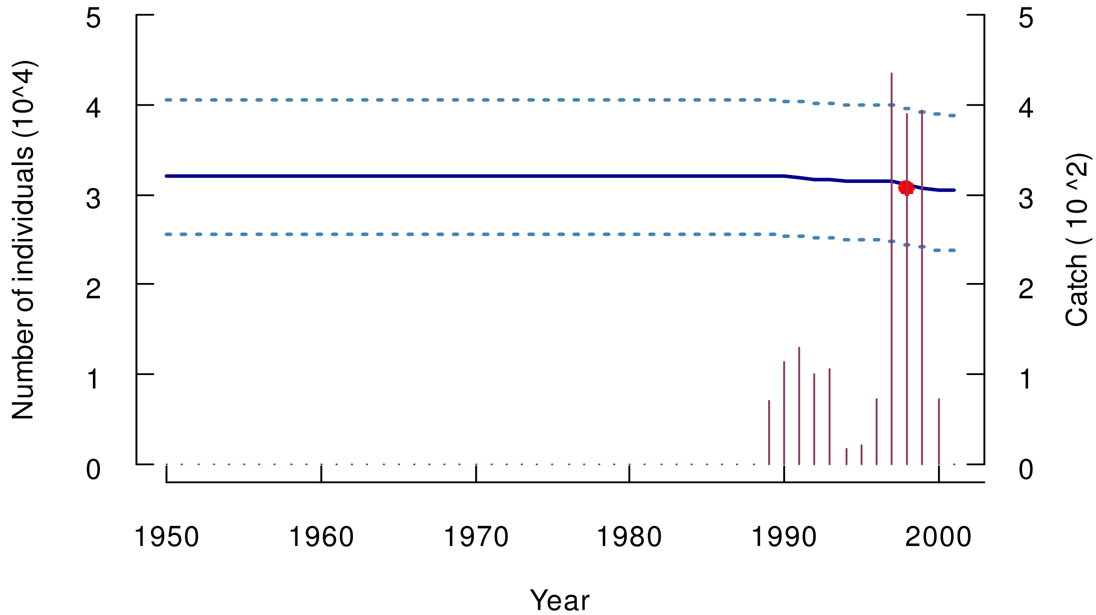


Figure 53. Population trajectory for Northwest Atlantic bottlenose dolphins

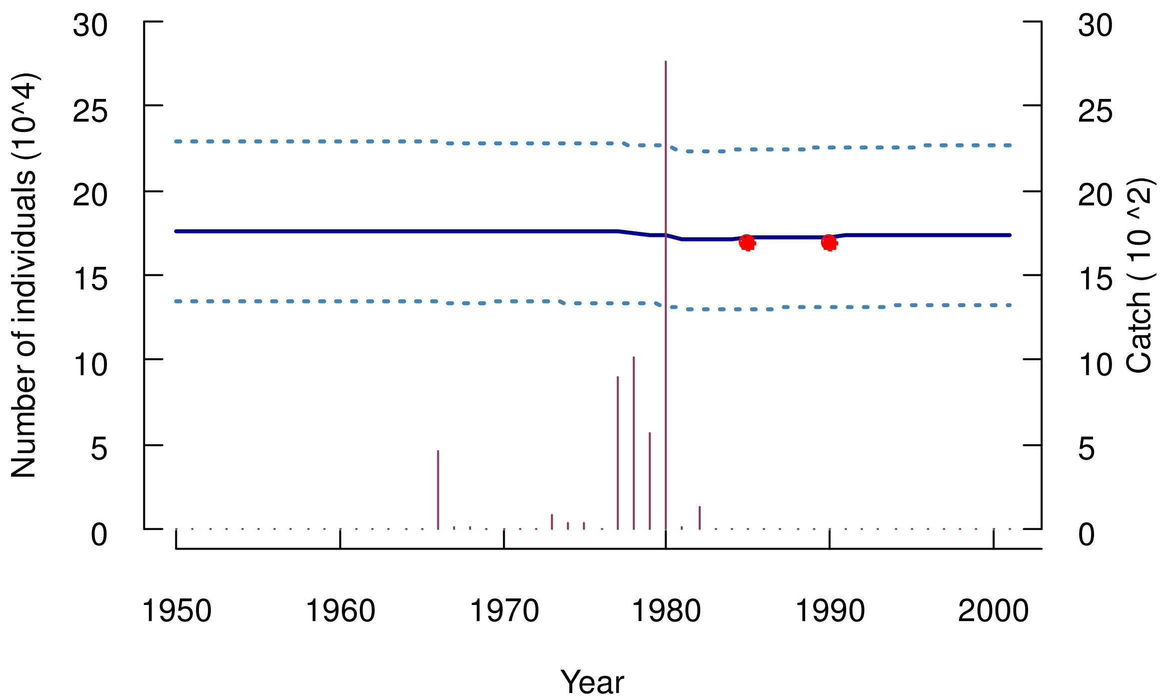


Figure 54. Population trajectory for Japanese bottlenose dolphins

Northern right whale dolphin, *Lissodelphis borealis*

The northern right whale dolphin is found only in the North Pacific, where it lives in subpolar to subtropical waters (Bjørge *et al.*, 1991; Kaschner, 2004). The population is depleted, currently numbering 68% of its 1978 abundance (Table 5, Figure 55).

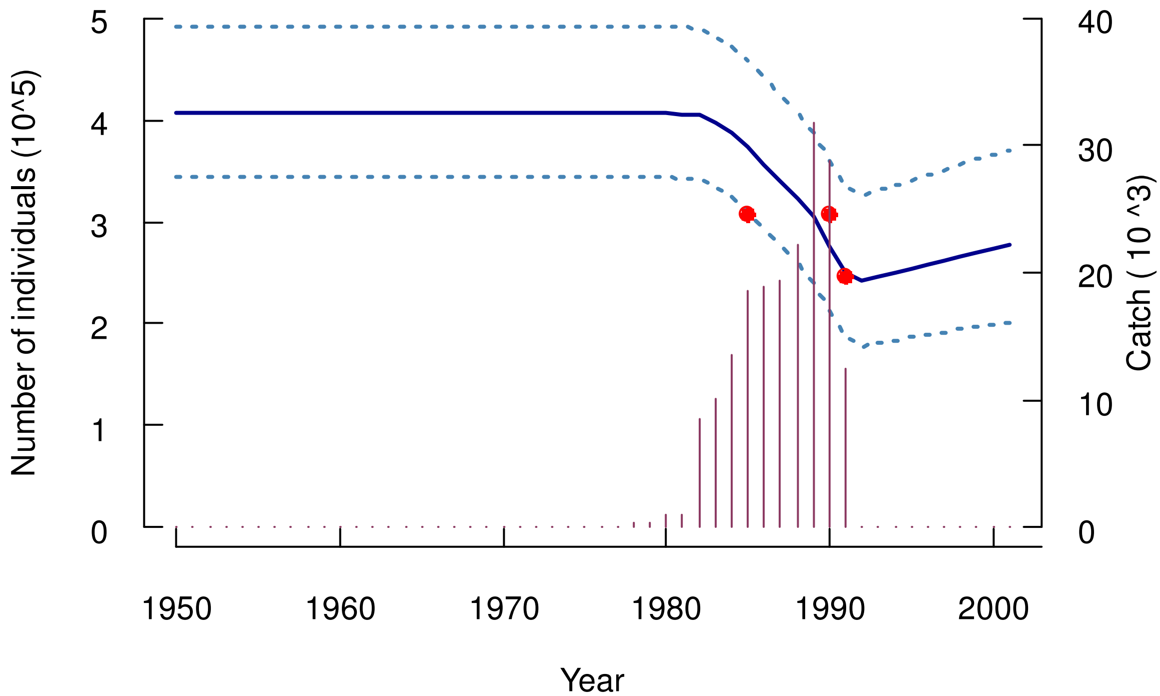


Figure 55. Population trajectory for northern right whale dolphins

Harbour Porpoise, *Phocoena phocoena*

The harbour porpoise is endemic to the Northern Hemisphere, and occur from subpolar to warm temperate waters (Gaskin *et al.*, 1993; Read and Westgate, 1997; Raum-Suryan and Harvey, 1998; Kaschner, 2004). The porpoise is hunted commercially in Greenlandic and Baltic waters, and taken as by-catch in the North Sea and Western North Atlantic. In Greenlandic waters, the population, hunted since 1900, is severely depleted at 89% (Table 5, Figure 56). In the North Sea, the population is declining, having been depleted by 21% since 1950 (Table 5, Figure 57). In the Baltic, the species has been caught since 1716, is showing recovery and is now at 52% of its original population size (Table 5, Figure 58). In the western North Atlantic (Newfoundland and New England), the population has, since 1989, declined by 17% (Table 5, Figure 59). Globally, this means harbour porpoises are depleted by 24% (Table 8).

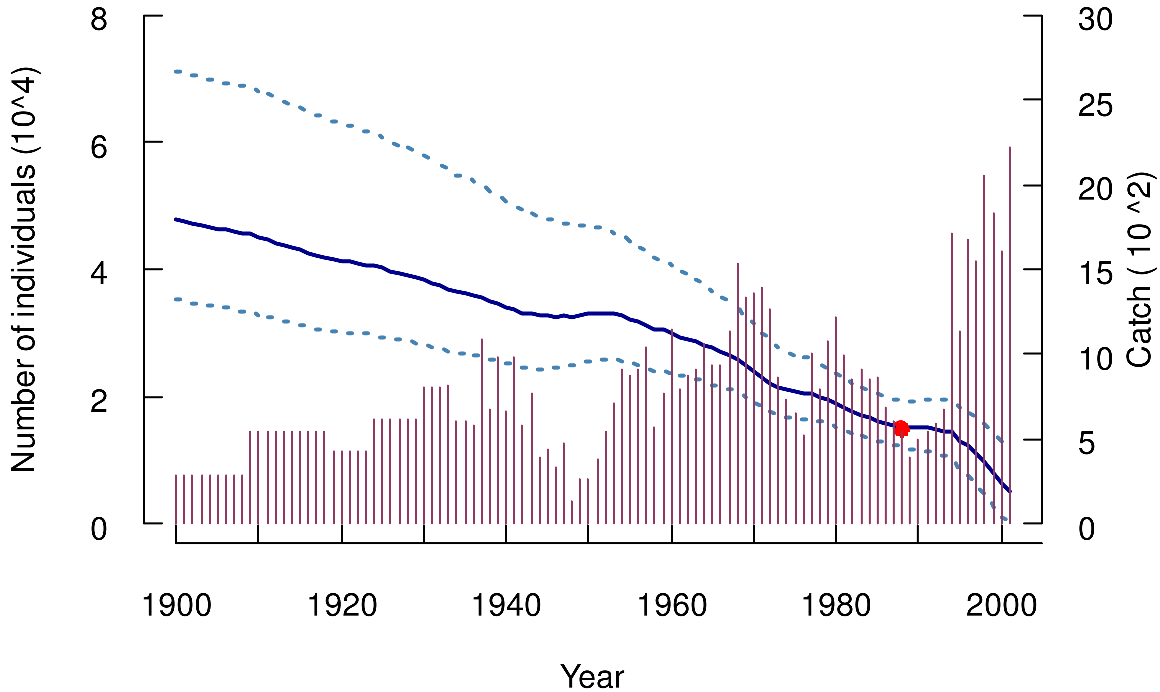


Figure 56. Population trajectory for Greenlandic harbour porpoises

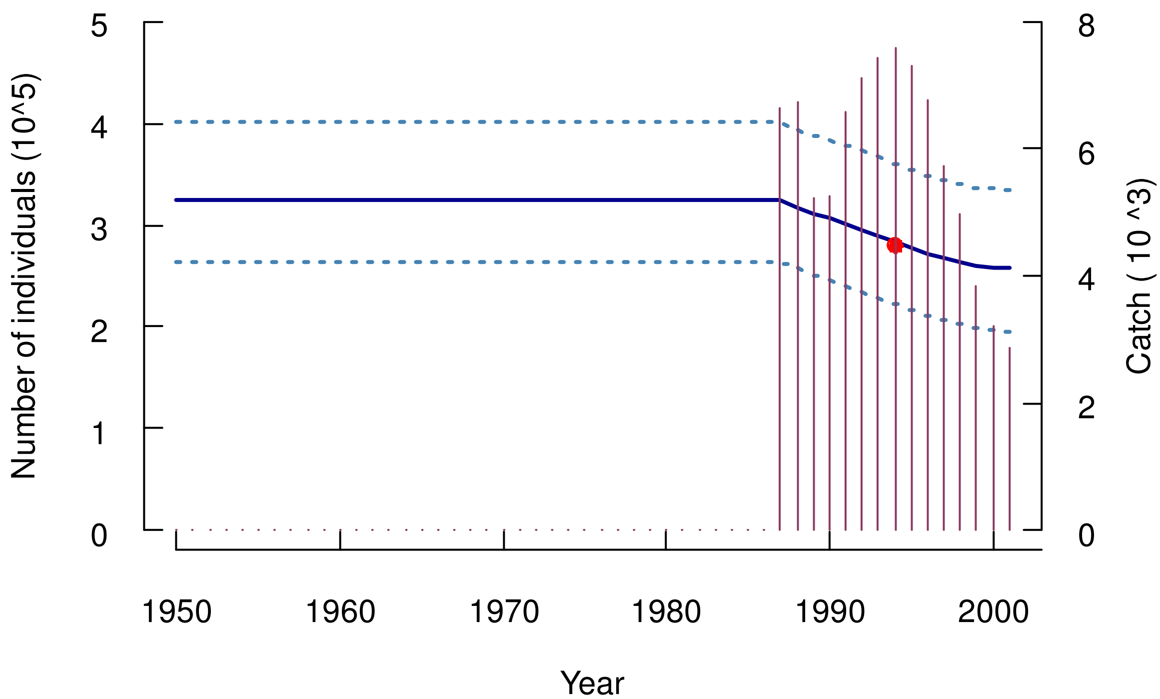


Figure 57. Population trajectory for North Sea harbour porpoises

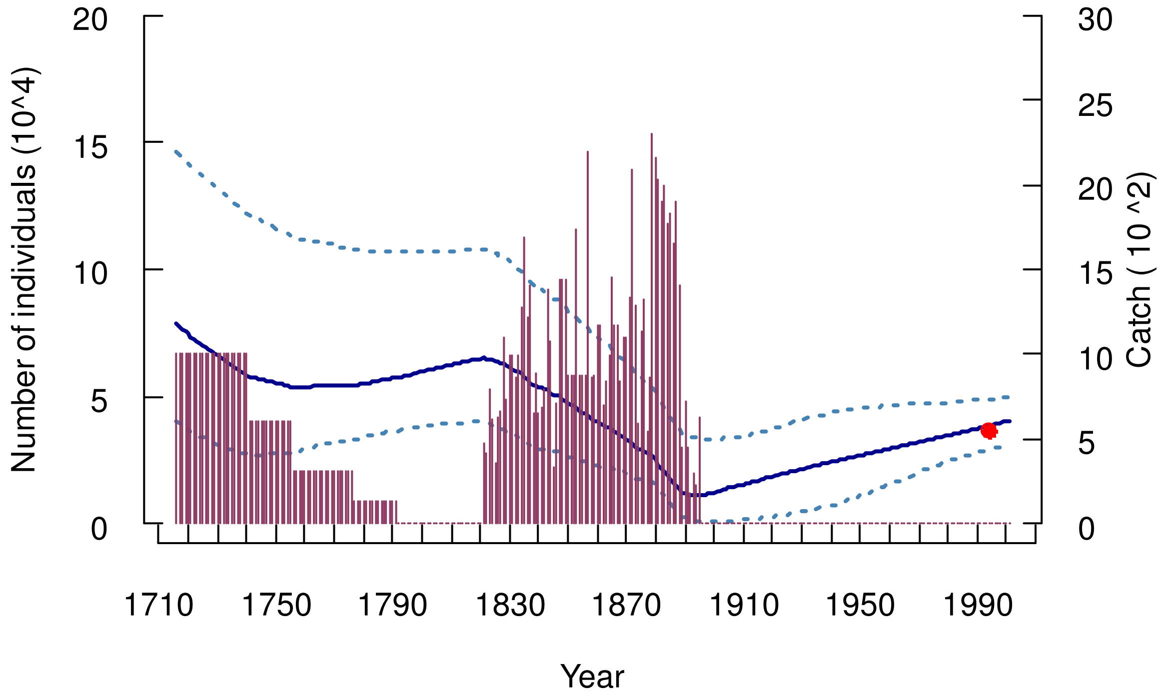


Figure 58. Population trajectory for Baltic harbour porpoises

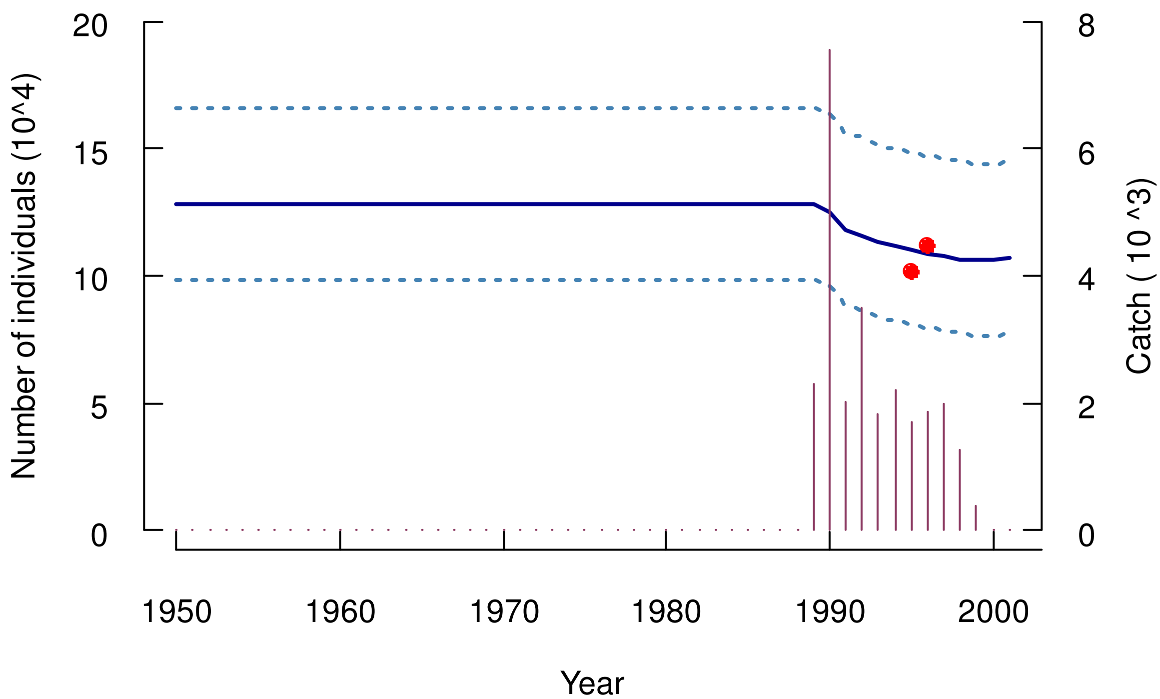


Figure 59. Population trajectory for Western North Atlantic harbour porpoises

<u>Atlantic white-sided dolphin, *Lagenorhynchus acutus*</u>

The Atlantic white-sided dolphin, is as its name indicates found in the North Atlantic, where it inhabits subpolar to warm temperate waters (Sergeant *et al.*, 1980; Selzer and Payne, 1988; Leopold and Couperus, 1995; Hamazaki, 2002; Kaschner, 2004). In northwest Atlantic waters it is depleted by a minimal 4% since 1950 (Table 5, Figure 60). Catch data for the Faroe Islands exist (Appendix VI) but I have yet to come across an abundance estimate for this area. Globally, the decline of Atlantic white-sided dolphins is limited at 1% (Table 8).

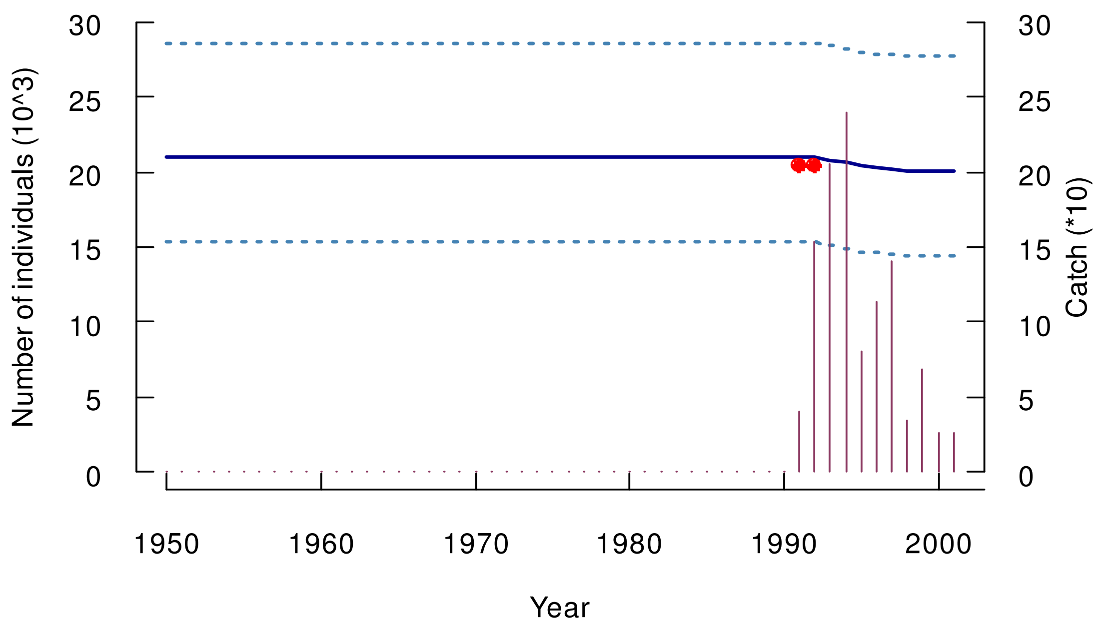


Figure 60. Population trajectory for Northwest Atlantic white-sided dolphins

POPULATION TRAJECTORIES OF EXPLOITED PINNIPEDS

The global results referred to in this section are presented in Table 9, which is a summary of the numbers of exploited sub-populations presented in Table 6 and Table 7 and of unexploited sub-populations presented in Appendix I. Note that the 95% credible intervals for the unexploited sub-populations are not true credible intervals, but rather estimates.

True seals

The results presented in this section are all listed in Table 6, which lists the species name, the ocean basin referencing the sub-population, the year of the beginning of documented hunting, the initial, pre-exploitation numbers with associated 95% credible interval, the 2001 numbers with associated 95% credible interval, and the level of depletion of the sub-population.

Table 6: Population sizes of true seals

Species	Ocean Basin	Start of doc. hunts	Initial numbers (Mean, 95% CI)	2001 numbers (Mean, 95% CI)	Depleted by (%)
Ribbon seal	Bering Sea	1950	13,5000 (113,000 – 164,000)	131,000 (111,000 – 154,000)	3
Ringed seal	North Atlantic/ Arctic	1954	3,810,000 (2,790,000 – 5,570,000)	1,710,000 (72,700 – 2,600,000)	55
	Baltic	1909	150,000 (130,000 – 161,000)	8,150 (4,670 – 11,300)	95
	North Pacific / Arctic	1903	4,610,000 (3,430,000 – 5,820,000)	4,570,000 (3,400,000 – 5,780,000)	1
Southern elephant seal	Southern Hemisphere	1820	739,000 (550,000 – 1,070,000)	733,000 (549,000 – 997,000)	1
Gray seal	Iceland	1950	16,500 (12,600 – 22,000)	5,800 (0 – 12,000)	65
	Scotland	1950	115,000 (84,900 – 156,000)	113,000 (83,000 – 154,000)	2
Harp seal	West Ice (East Greenland)	1946	627,000 (406,000 – 1,110,000)	388,000 (223,000 – 495,000)	38
	Northwest Atlantic (the front and gulf)	1895	6,840,000 (5,060,000 – 11,000,000)	3,930,000 (2,990,000 – 5,160,000)	43
	White Sea	1897	5,570,000 (4,740,000 – 6,430,000)	2,230,000 (1,600,000 – 2,960,000)	60
Hooded seal	Jan Mayen	1940	1,170,000 (788,000 – 1,740,000)	403,000 (147,000 – 689,000)	68
	Northwest Atlantic	1946	607,000 (461,000 – 844,000)	488,000 (364,000 – 627,000)	20
Bearded seal	Bering / Chukchi	1966	298,000 (227,000 – 382,000)	226,000 (121,000 – 321,000)	24
Harbour seal	California	1991	33,500 (26,800 – 41,900)	30,700 (24,100 – 39,000)	8
Largha or spotted seal	Bering Sea	1965	215,000 (166,000 – 281,000)	202,000 (147,000 – 268,000)	6
	Northeast Pacific (Alaska)	1966	80,600 (64,600 – 106,000)	32,800 (11,500 – 54,600)	59
	Sea of Okhotsk	1965	232,000 (178,000 – 303,000)	205,000 (144,000 – 267,000)	12

Ribbon seal, *Histriophoca fasciata*

The ribbon seal is found in the North Pacific, in polar to subpolar waters (Jefferson *et al.*, 1993; Fedoseev, 2002; Mizuno *et al.*, 2002; Kaschner, 2004). Their hunting history includes both commercial and subsistence catch, beginning in 1950. The population declined in numbers in the 1960s, but has since recovered and is now at 97% of the 1950 population size (Table 6, Figure 61). Globally, the ribbon seal population is at 99% of carrying capacity (Table 9).

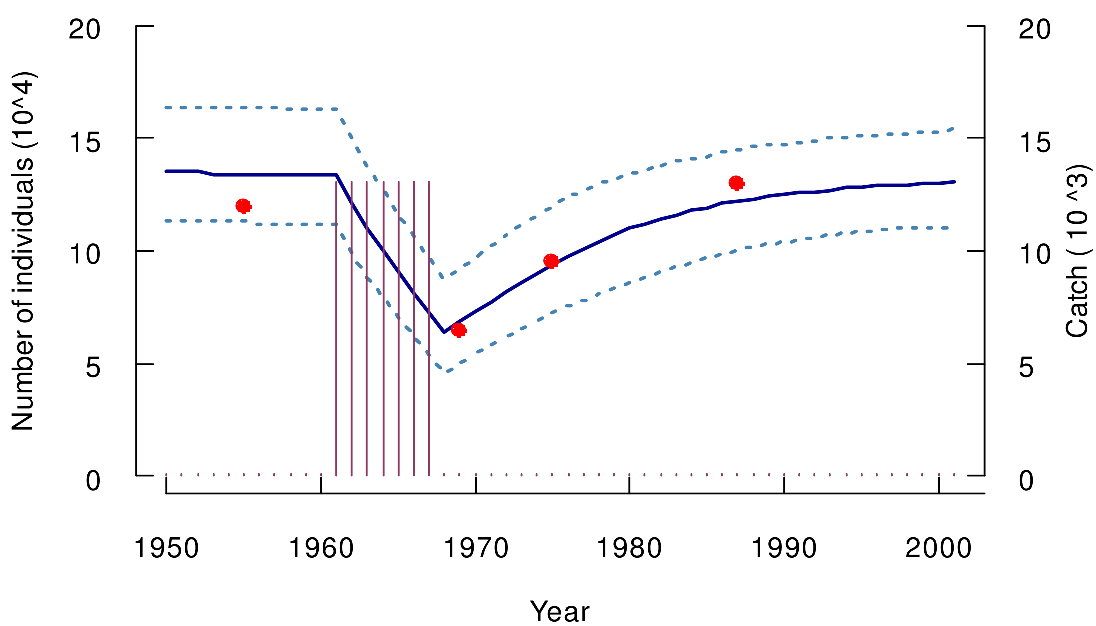


Figure 61. Population trajectory for Bering Sea ribbon seals

Ringed seal, *Pusa hispida*

The ringed seal is found in the Northern Hemisphere, in polar–subpolar waters (Miyazaki, 2002, Kaschner, 2004). The population was hunted on a subsistence basis in the North Pacific, and commercially elsewhere. In the North Atlantic/Arctic the population has declined in abundance by 55% since 1954, and the process of recovery seems to have started (Table 6, Figure 62). In the Baltic, the population is depleted, with current numbers at 5% of the 1909 abundance level (Table 6, Figure 63). I had to run 150,000 simulations, instead of 50,000, because the model was having a hard time reconciling the data. I suspect there are gaps in hunting records, but have no other sources of catch data. In the North Pacific/Arctic, the decline in abundance seems to have been very slight, and the depletion level is only 1% (Table 6, Figure 64). Globally, the decline in ringed seal abundance is 27% (Table 9).

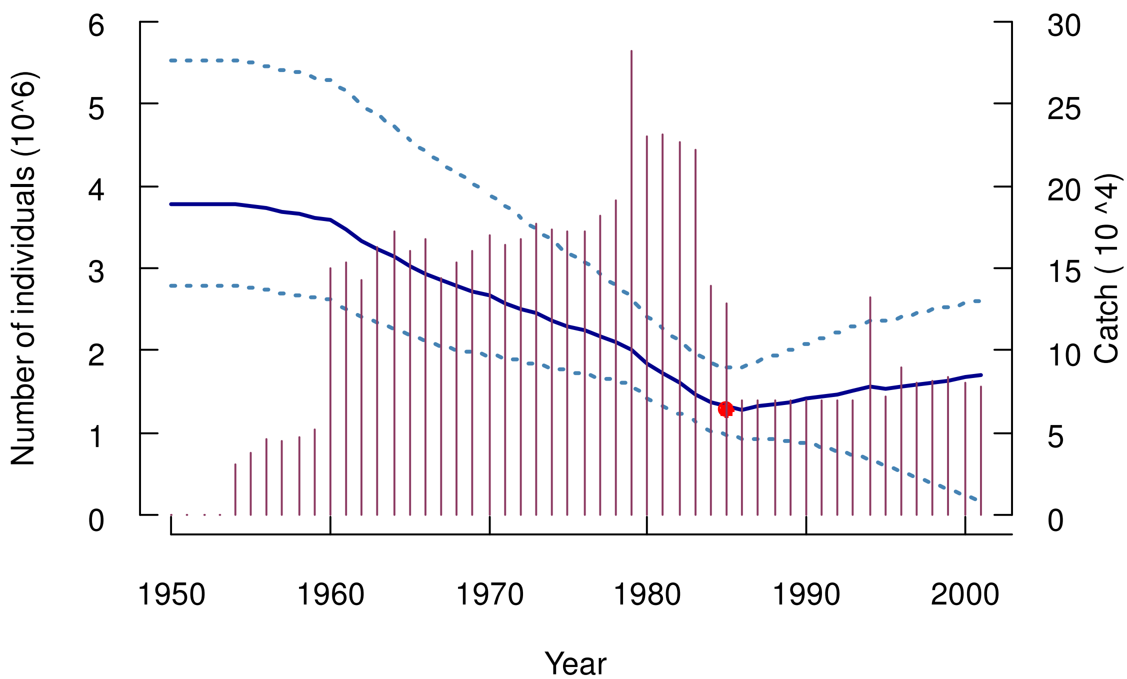


Figure 62. Population trajectory for North Atlantic/Arctic ringed seals

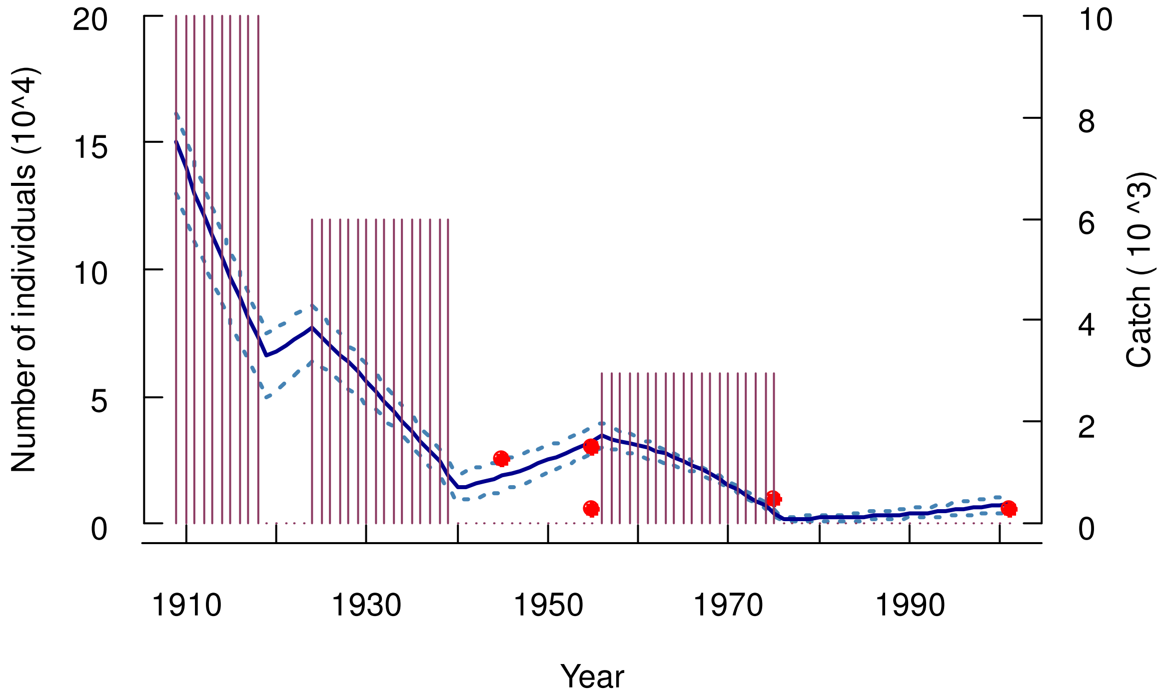


Figure 63. Population trajectory for Baltic ringed seals

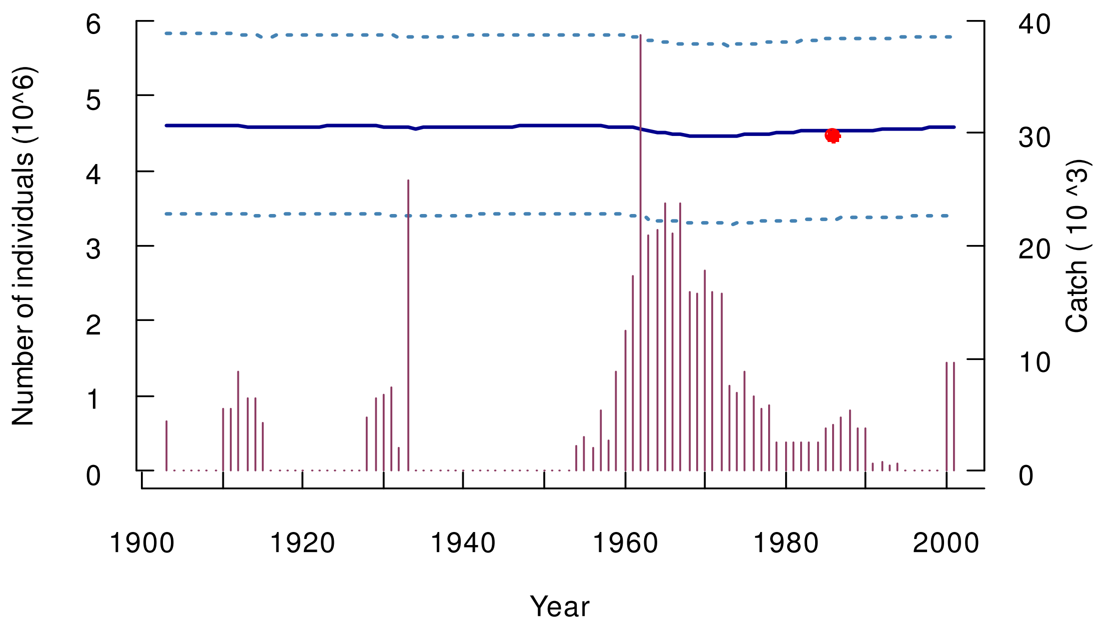


Figure 64. Population trajectory for North Pacific/Arctic ringed seals

<u>Southern elephant seal, *Mirounga leonina*</u>

The southern elephant seal roams the southern oceans, and ranges from polar to tropical waters (Boyd and Arnbom, 1991, Ling and Bryden, 1992, Hindell *et al.*, 1999, Bradshaw *et al.*, 2002, Kaschner, 2004). Population numbers have been relatively steady since 1820, with only a 1% reported decline, although a cumulative total of over 1.2 million animals have been killed (Table 6, Figure 65).

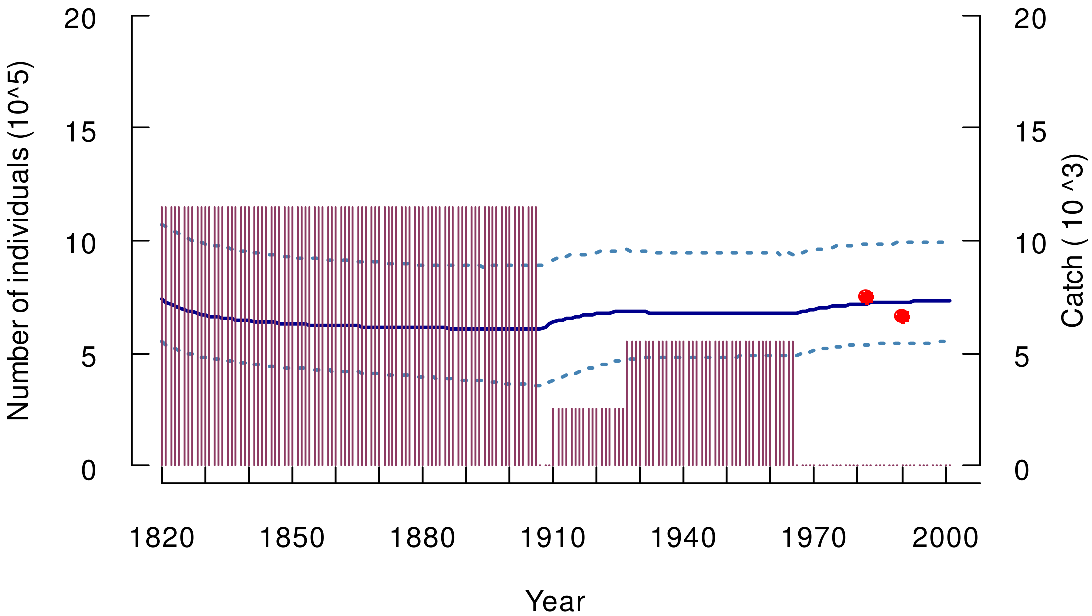


Figure 65. Population trajectory for southern elephant seals

<u>Gray seal, *Halichoerus grypus*</u>

Gray seals occur in the North Atlantic, in subpolar to cold temperate waters (Jefferson *et al.*, 1993; Hall, 2002; Kaschner, 2004). In Icelandic waters, the population has declined 65% from its 1950 levels (Table 6, Figure 66). In Scottish waters, on the other hand, the population was only minimally affected and is at 98% of its 1950 abundance (Table 6, Figure 67). This gives a global decline of only 4% (Table 9).

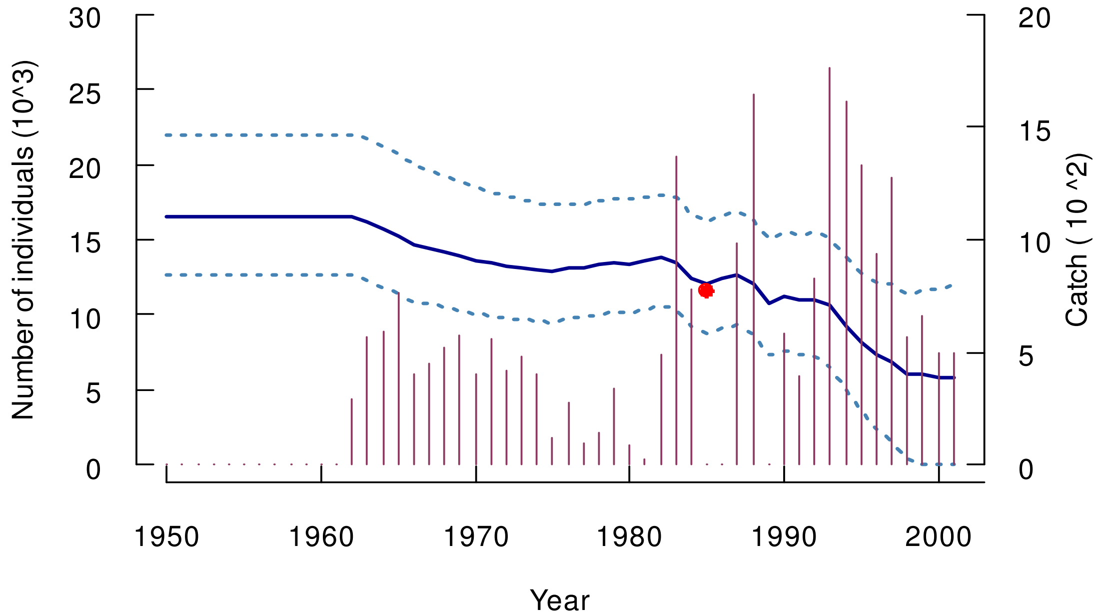


Figure 66. Population trajectory for Icelandic gray seals

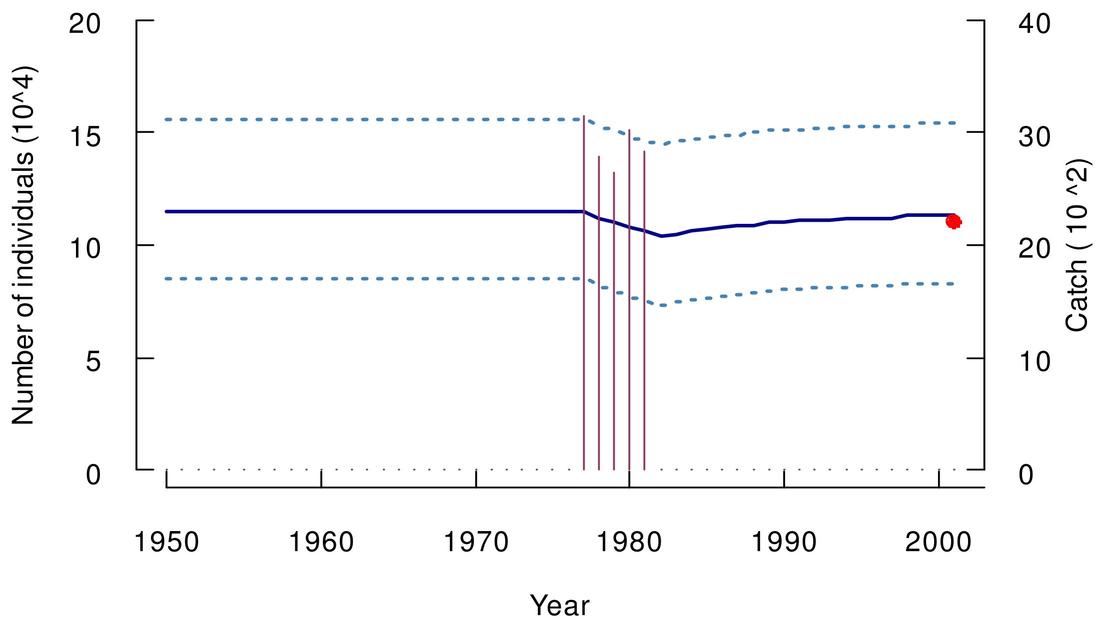


Figure 67. Population trajectory for Scottish gray seals

<u>Harp seal, *Pagophilus groenlandicus*</u>

The harp seal lives in the polar to cold temperate waters of the Northern Hemisphere (Reijnders *et al.*, 1993, Kaschner, 2004). The West Ice stock (East Greenland), while depleted, is showing signs of recovery and is at 62% of its 1946 abundance (Table 6, Figure 68). In the Northwest Atlantic, the population appears to be declining, with current numbers indicating a 43% decline since 1895 (Table 6, Figure 69). The White Sea stock has been depleted by 60% since 1897, but is showing signs of recovery (Table 6, Figure 70). Globally, this corresponds to a decline of 36% (Table 9).

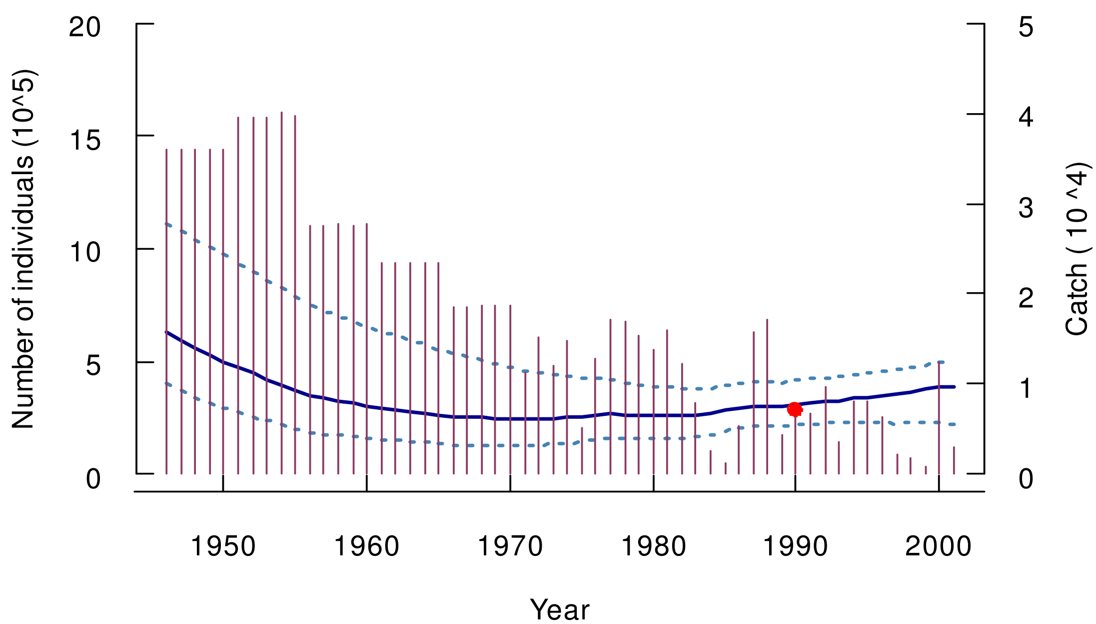


Figure 68. Population trajectory for West Ice (East Greenland) harp seals

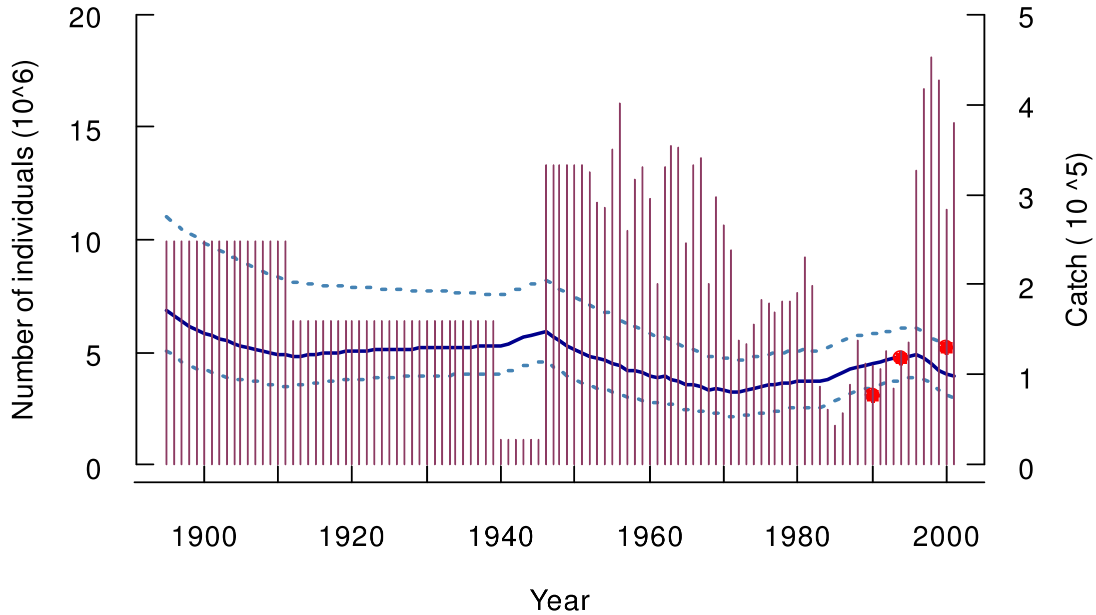


Figure 69. Population trajectory for Northwest Atlantic harp seals

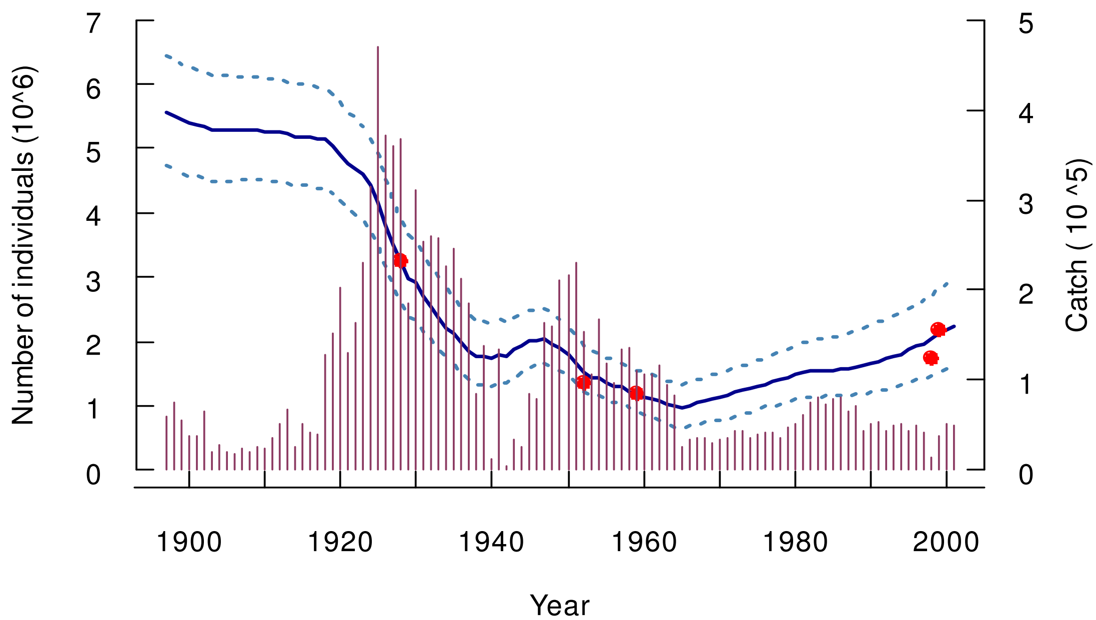


Figure 70. Population trajectory for White Sea harp seals

Hooded seal, *Cystophora cristata*

Hooded seals live in the North Atlantic Ocean, in polar to cold temperate water (Kovacs and Lavigne, 1986; Reijnders *et al.*, 1993; Kaschner, 2004). The Jan Mayen stock has been depleted by 68% since 1940, but has begun to show signs of recovery (Table 6, Figure 71). The Northwest Atlantic stock is depleted by 20%, and recovering from a hunt that began in 1946 (Table 6, Figure 72). Globally, the hooded seal is depleted by 50% (Table 9).

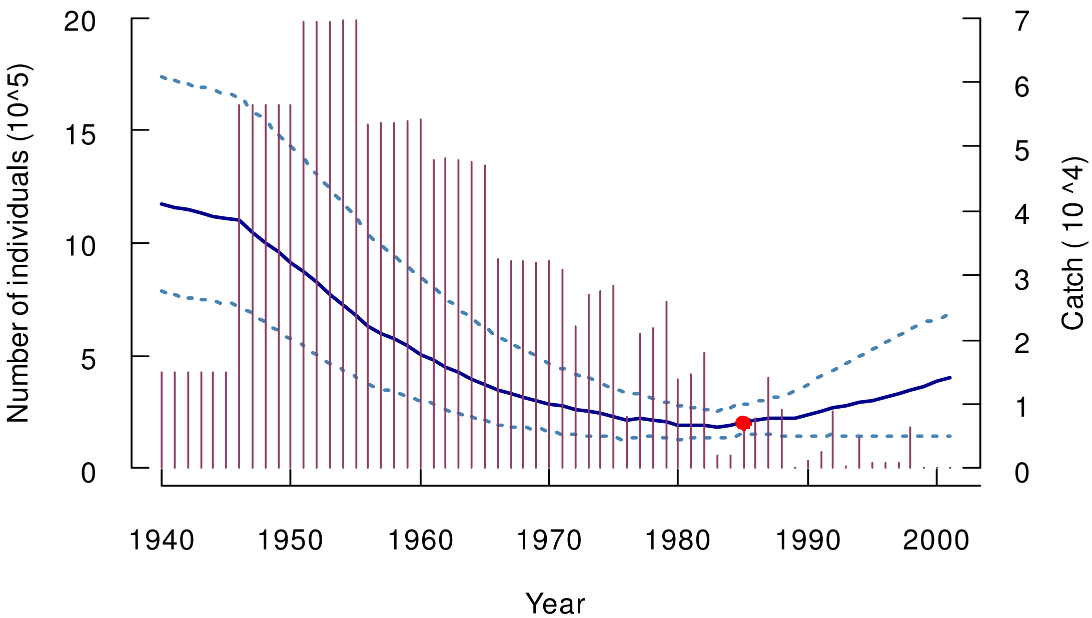


Figure 71. Population trajectory for Jan Mayen hooded seals

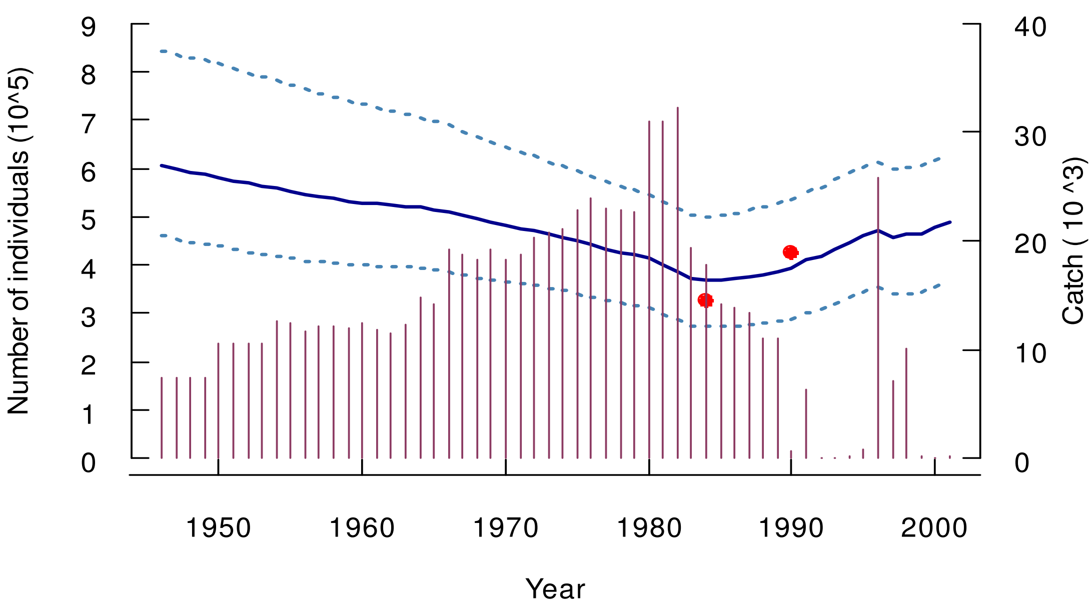


Figure 72. Population trajectory for Northwest Altantic hooded seals

<u>Bearded seal, *Erignathus barbatus*</u>

The bearded seal is found in the Northern hemisphere, in polar–subpolar waters (Reijnders *et al.*, 1993, Kovacs, 2002, Kaschner, 2004). In the Bering/Chukchi Sea, where it is caught in a subsistence hunt, the bearded seal population has been declining since 1966 and is currently depleted by 24% (Table 6, Figure 73). Globally, this means that the bearded seal is depleted by 11% (Table 9).

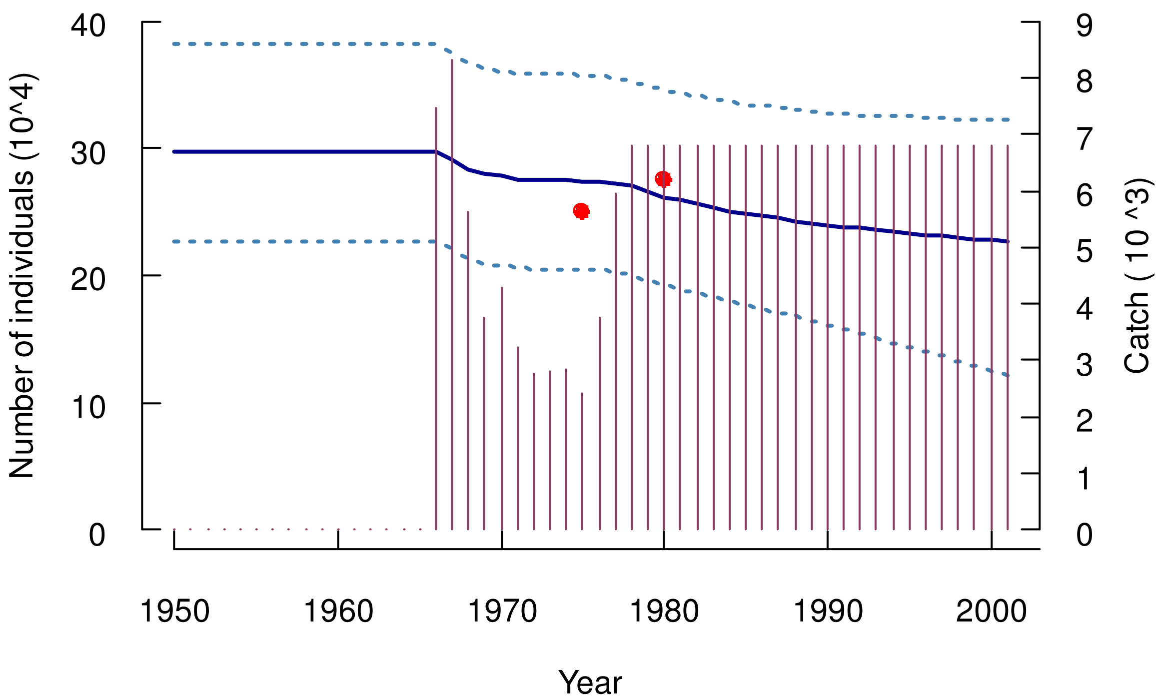


Figure 73. Population trajectory for Bering/Chukchi bearded seals

Harbour seal, *Phoca vitulina*

The harbour seals ranges from subpolar to warm temperate waters in the Northern Hemisphere (Burns, 2002, Kaschner, 2004). The California stock has been depleted by 8% (Table 6, Figure 74); however, the global population is at 99% of carrying capacity (Table 9).

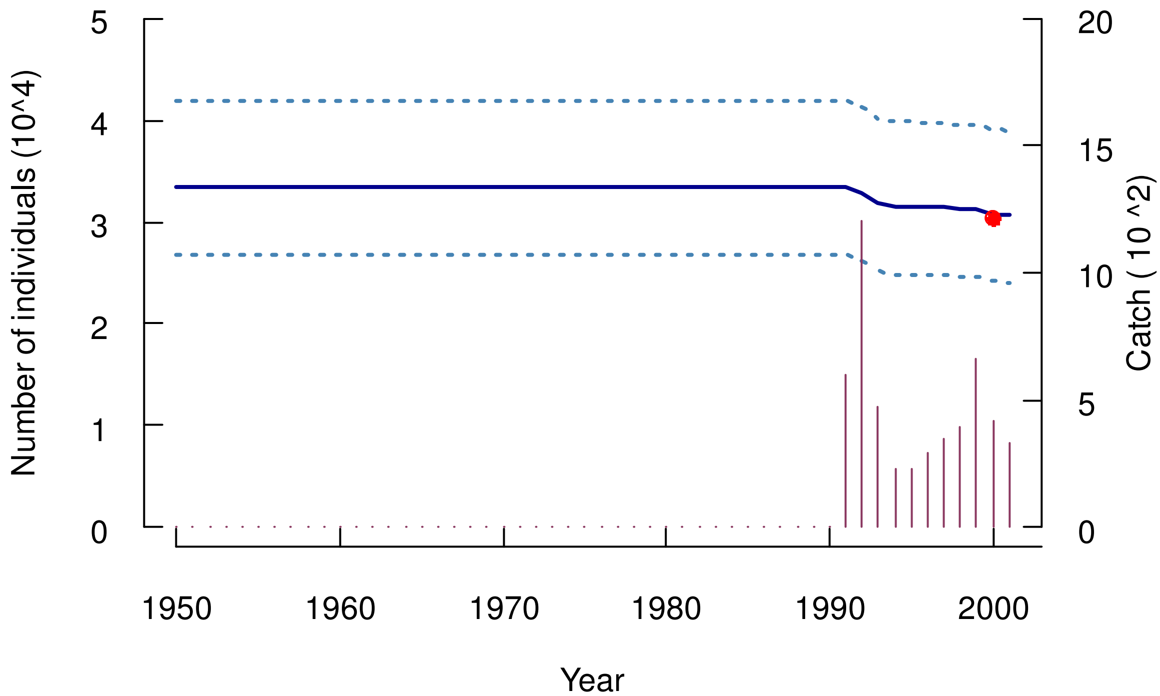


Figure 74. Population trajectory for California harbour seals

Largha or spotted seal, *Phoca largha*

The largha or spotted seal ranges from polar to warm temperate waters in the North Pacific (Burns, 2002, Kaschner, 2004). The Bering Sea population showed a decline due to hunting, but has recovered to 94% of its 1965 abundance (Table 6, Figure 75). In the Northeast Pacific waters off Alaska, the population, which is subjected to a subsistence hunt with documented catches since 1966, is depleted by 60% (Table 6, Figure 76). The Sea of Okhotsk population shows a similar trend to the Bering Sea population, with documented hunting also commencing in 1965, including a period of decline followed by recovery, leaving the population at only a 6% decline (Table 6, Figure 77).

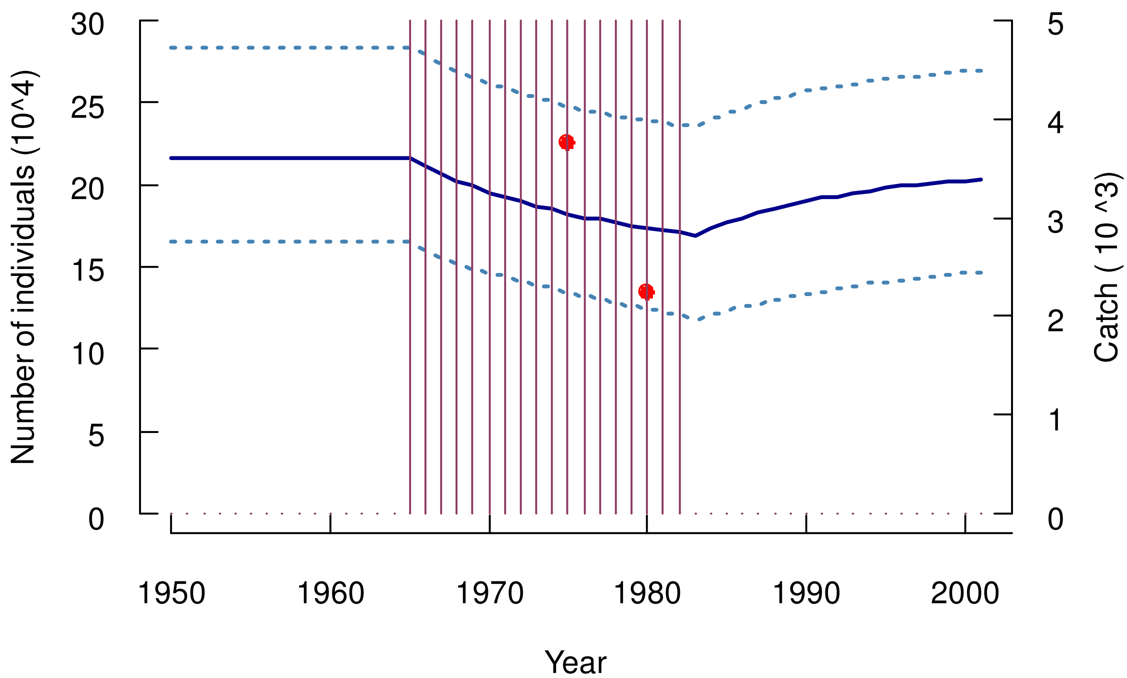


Figure 75. Population trajectory for Bering largha/spotted seals

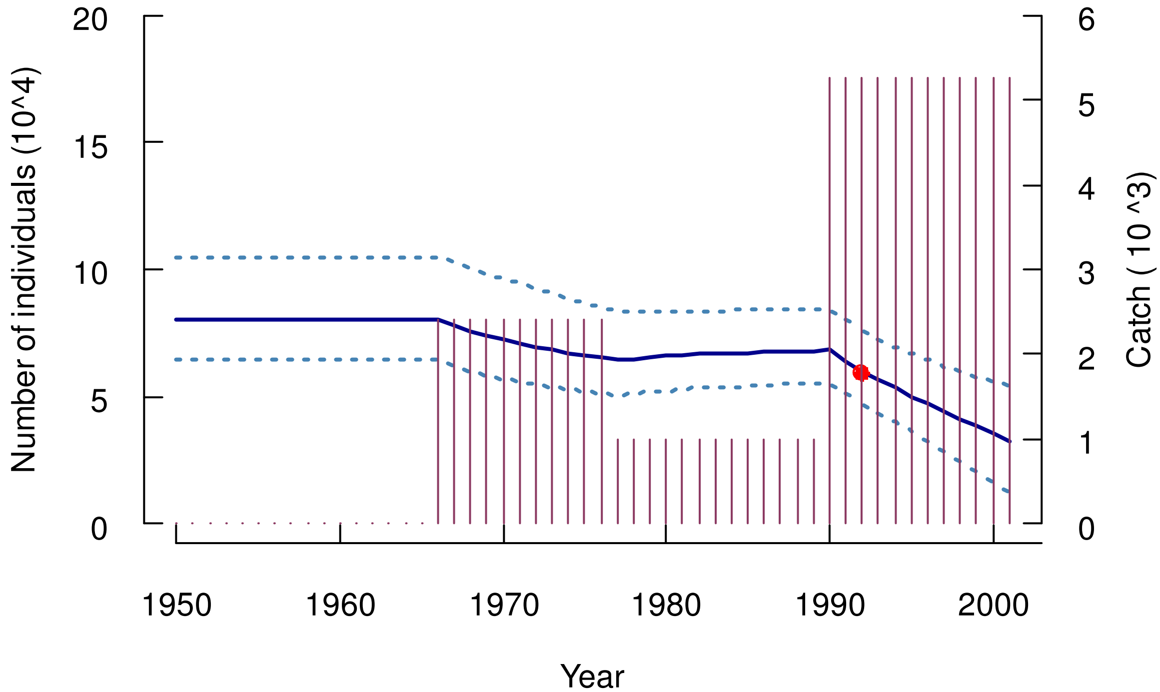


Figure 76. Population trajectory for Northeast Pacific largha/spotted seals

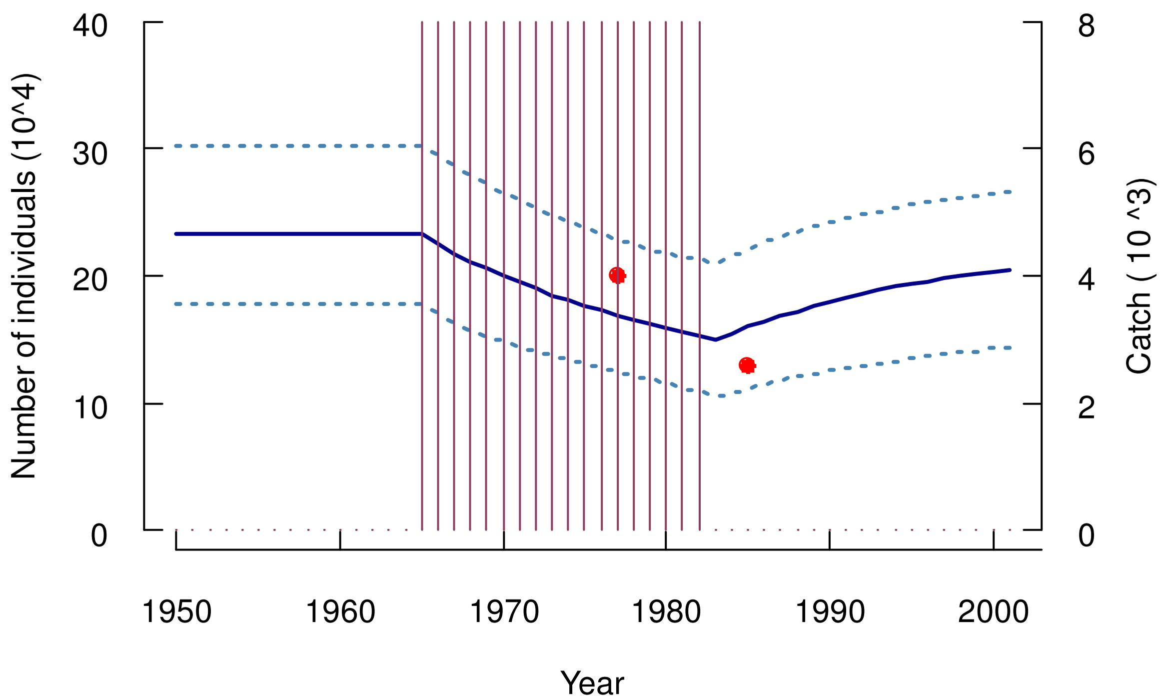


Figure 77. Population trajectory for Okhotsk Sea largha/spotted seals

Eared seals

The results presented in this section are all given in Table 7, which lists the species name, the ocean basin referencing the sub-population, the year of the beginning of documented hunting, the initial, pre-exploitation numbers with associated 95% credible interval, the 2001 numbers with associated 95% credible interval, and the level of depletion of the sub-population.

Table 7: Population sizes of eared seals and walrus

Species	Ocean Basin	Start of doc. hunts	Initial numbers (Mean, 95% CI)	2001 numbers (Mean, 95% CI)	Depleted by (%)
Antarctic fur seal	Southern Hemisphere	1790	1,580,000 (1,010,000 – 1,970,000)	1,270,000 (901,000 – 1,680,000)	20
South African and Australian fur seal	South Africa	1900	1,740,000 (1,380,000 – 2,270,000)	1,580,000 (1,270,000 – 1,970,000)	9
Northern fur seal	Pribilof	1786	1,390,000 (1,290,000 – 2,300,000)	1,290,000 (1,530,000 – 1,680,000)	1
South American sea lion	North Patagonia (Falklands)	1930	110,000 (86,200 – 141,000)	52,200 (32,600 – 95,400)	53
California sea lion	California	1980	176,000 (123,000 – 194,000)	165,000 (113,000 – 183,000)	6
Steller's sea lion	Eastern Alaska	1912	33,000 (26,700 – 63,500)	31,900 (26,300 – 38,600)	3
	Western Alaska	1959	95,300 (87,700 – 101,000)	34,000 (28,900 – 40,300)	64
Walrus	Chukchi-Bering	1869	265,000 (204,000 – 408,000)	181,000 (112,000 – 247,000)	32
	East Greenland	1950	1,090 (813 – 1,470)	1,030 (753 – 1,440)	6
	Northwater	1950	4,380 (2,980 – 7,680)	1,760 (1,360 – 2,290)	60
	Spitsbergen & Franz Josef Land	1660	82,100 (53,900 – 90,300)	2,080 (1,760 – 3,070)	98
	West Greenland	1900	11,100 (7,040 – 16,400)	1,040 (758 – 1,410)	91

<u>Antarctic fur seal, *Arctocephalus gazella*</u>

The Antarctic fur seal lives in polar and subpolar waters in the Southern Hemisphere (Ribic *et al.*, 1991; Reijnders *et al.*, 1993; Kaschner, 2004). The population has recovered remarkably from its most depleted levels in the 1830s. However, this population is a bit of a problem case: documented catches start in 1790 and end by 1830, but almost 100 years elapsed before the population began recovering at a significant rate. However, when this recovery began, the population exploded. The model compensates for the 100 year low recovery by setting the r_{max} parameter low which means I may be overestimating K. Moreover, I cannot reproduce the strong increase seen in recent decades (Table 7, Figure 78).

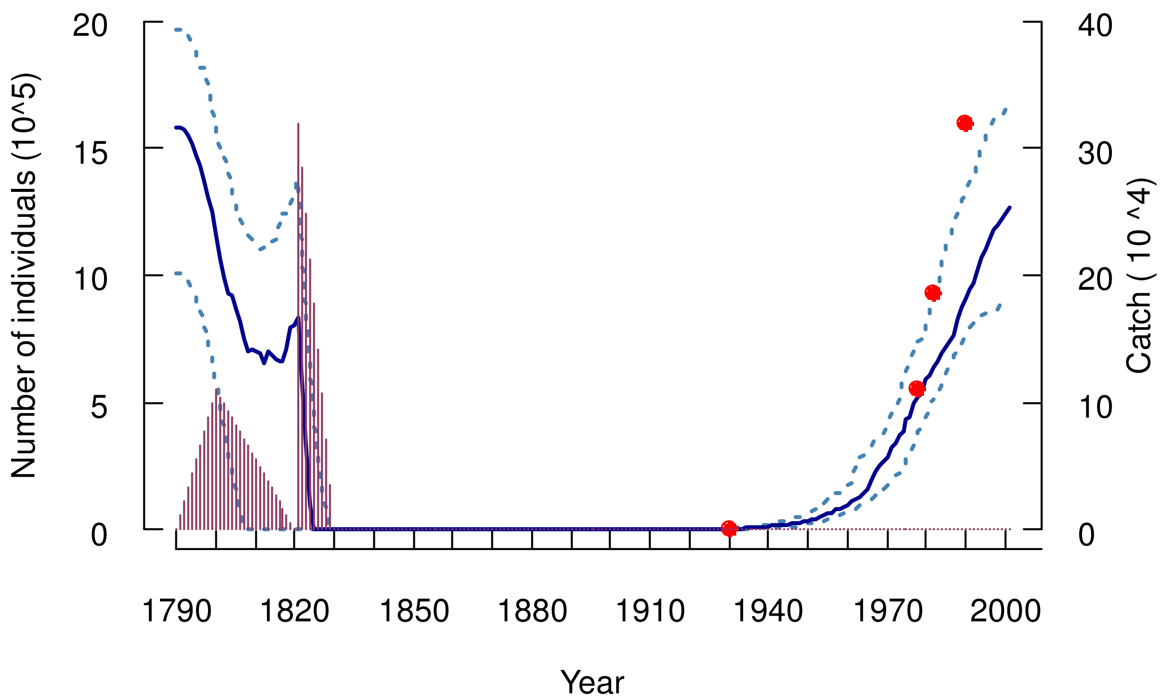


Figure 78. Population trajectory for Antarctic fur seals

South African and Australian fur seal, *Arctocephalus pusillus*

The South African and Australian fur seal occurs in warm temperate to subtropical waters in the Southern Hemisphere (Reijnders *et al.*, 1993, Kaschner, 2004). The species showed some decline, but seems to be well on its way to full recovery, with a current population size of 91% of the 1900 abundance level (Table 7, Figure 79). Globally, this species has been depleted by 9% (Table 9).

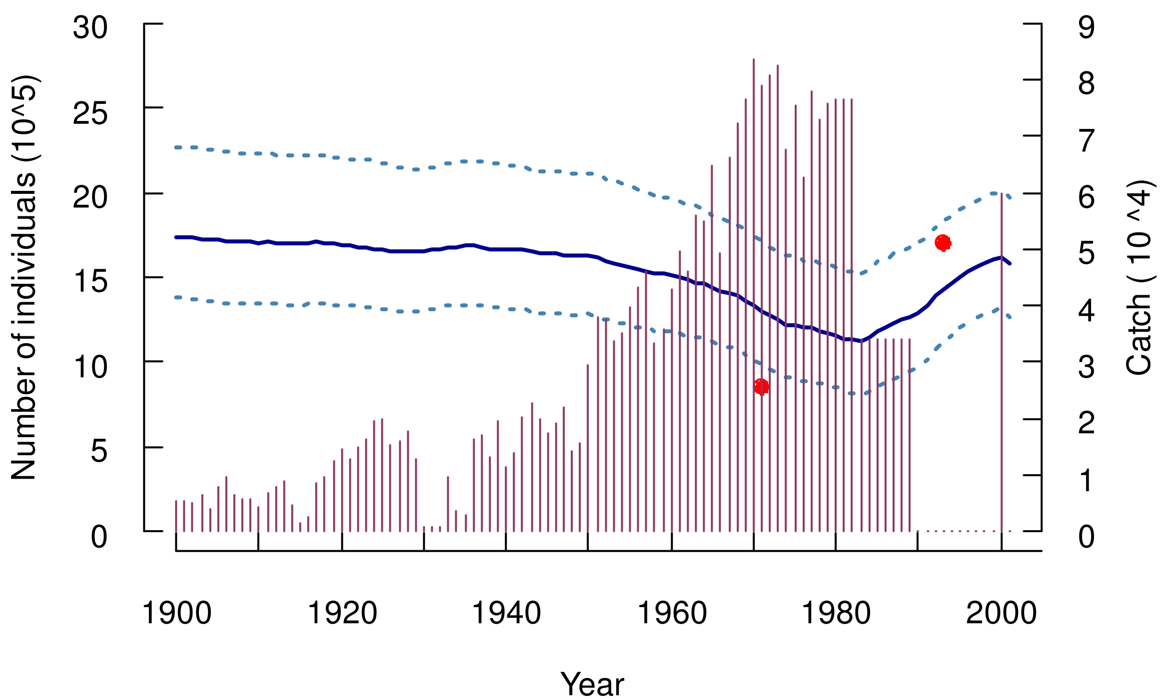


Figure 79. Population trajectory for the South African fur seal

Northern fur seal, *Callorhinus ursinus*

The Northern fur seal lives in the subpolar to cold temperate waters of the North Pacific (Gentry, 1981; Baba *et al.*, 2000; Gentry, 2002; Kaschner, 2004). The Pribilof population, which accounts for the majority of the species, saw a precipitous decline in the late 1800s, but since had time to recover. The current population is depleted by 1% from its 1786 pre-exploitation level (Table 7, Figure 80). Globally, the species is also depleted by 1% (Table 9). The Pribilof population accounts for the majority of the total numbers for the species, with separate population found on the Commander, Kuril, Robben and San Miguel Islands (Appendix I).

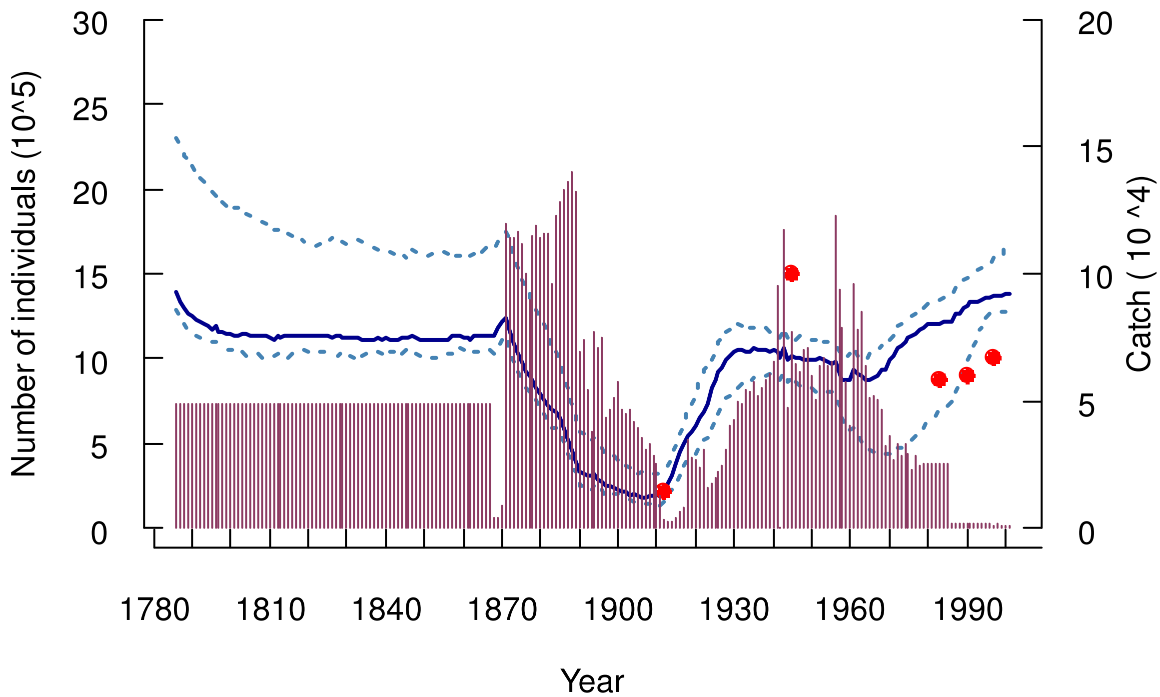


Figure 80. Population trajectory for Northern fur seals

South American sea lion, *Otaria flavenscens*

The South American sea lion occurs in polar to subtropical waters in the Southern Hemisphere (Jefferson *et al.*, 1993; Reijnders *et al.*, 1993; Kaschner, 2004). The North Patagonian/Falklands population faced a huge decline in numbers after hunting began in 1930, but has seen limited recovery since then and is now at 49% of its original size (Table 7, Figure 81).

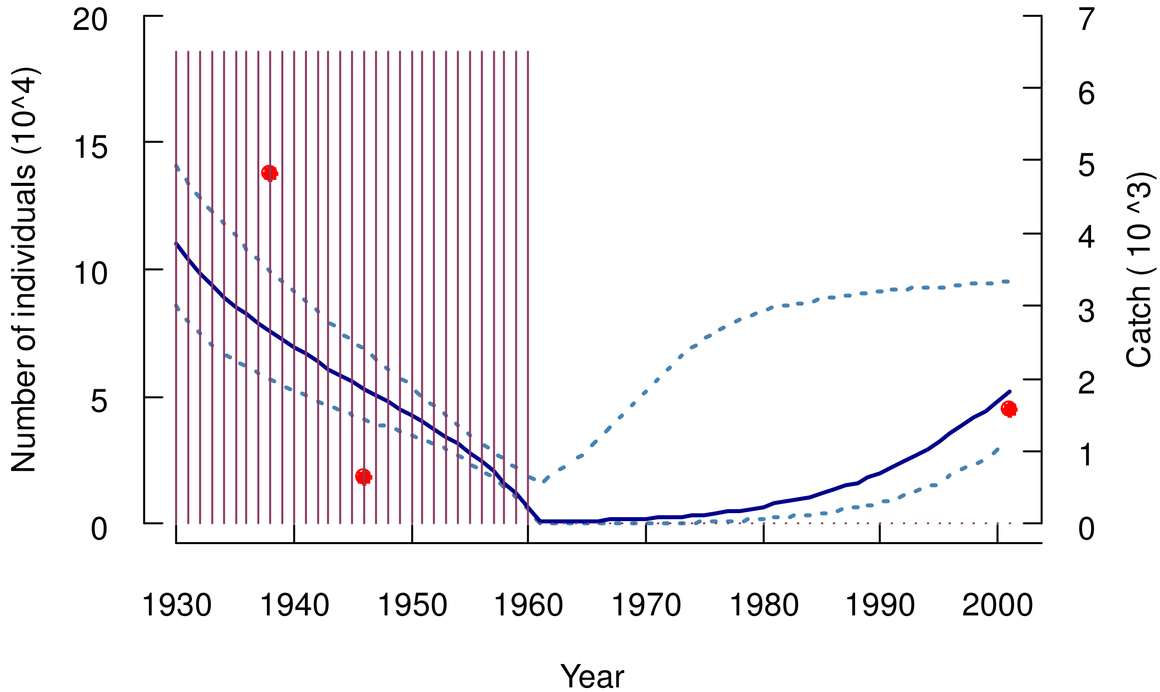


Figure 81. Population trajectory for South American sea lions

<u>New Zealand fur seal, *Arctocephalus forsteri*</u>

The New Zealand fur seals occupies subpolar to warm temperate waters, around New Zealand and South Australia (Jefferson *et al.*, 1993; Kaschner, 2004). As documented, the exploitation history of this species is remarkable. In New Zealand, 340,000 fur seals were thought to have been killed between 1804 and 1813 (Matlin, 1998). After this there are no documented catches until 1991-1996 where 6,416 fur seals were reported killed as by-catch in the hoki fishery (Manly *et al.*, 2002). This has to be reconciled with an abundance estimate of 40,000 fur seals in New Zealand in the early 1980s (Reijnders *et al.*, 1993), although this estimate is considered out of date and the population may be somewhat higher (60,000+) (Matlin, 1998). I cannot reconstruct this population trajectory. I find that the population should have recovered to much higher levels if they were at a population level where they could have sustained a hunt of 340,000 individuals. Historical population size for the New Zealand fur seal population has been estimated at 1,250,000 (Richards, 1994, Matlin, 1998). However, I cannot reproduce this number and end up with a population of 40,000 individuals given their documented exploitation history. There are two possible explanations for this: (1) either the catches are not well documented or (2) there has been a massive change in carrying capacity for the species. The catch history seems plausible, though given the history of fur seal hunting in the Antarctic (Hart, 2004), I believe it more likely that there was a change in carrying capacity, likely due to interspecific competition and biological changes in the ecosystem.

<u>California sea lion, *Zalophus californianus*</u>

The California sea lion is endemic to North Pacific waters, and occurs in warm temperate and tropical waters (Heath, 2002, Kaschner, 2004). The California stock has seen a 6% decline, a result of the species being taken as by-catch in a number of fisheries (Table 7, Figure 82). Globally, this accounts for 5% depletion in the species (Table 9).

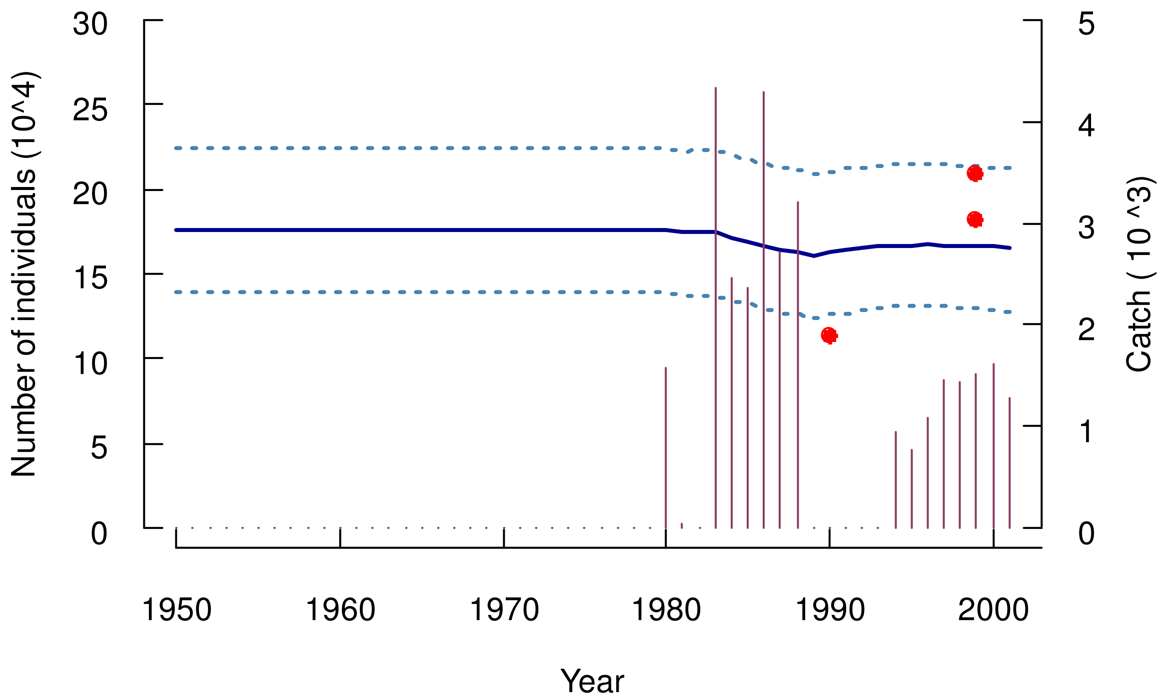


Figure 82. Population trajectory for California sea lion

<u>Steller sea lion, *Eumetopias jubatus*</u>

The Steller sea lion inhabits the subpolar and cold temperate waters of the North Pacific (Rice, 1998; Baba *et al.*, 2000; Kaschner, 2004). The Eastern Alaska stock is doing quite well, with limited depletion of only 3% since 1912. This is very different for the Western Alaska stock, which has been depleted by 64% since 1959 (Table 7, Figure 83, Figure 84). Globally, Steller sea lions have declined by 43% from 1800 to 2001 (Table 9). This estimate also includes the Russian and the California/Oregon/Washington populations (Appendix I). See Discussion section for a review of the Western Alaska population trends.

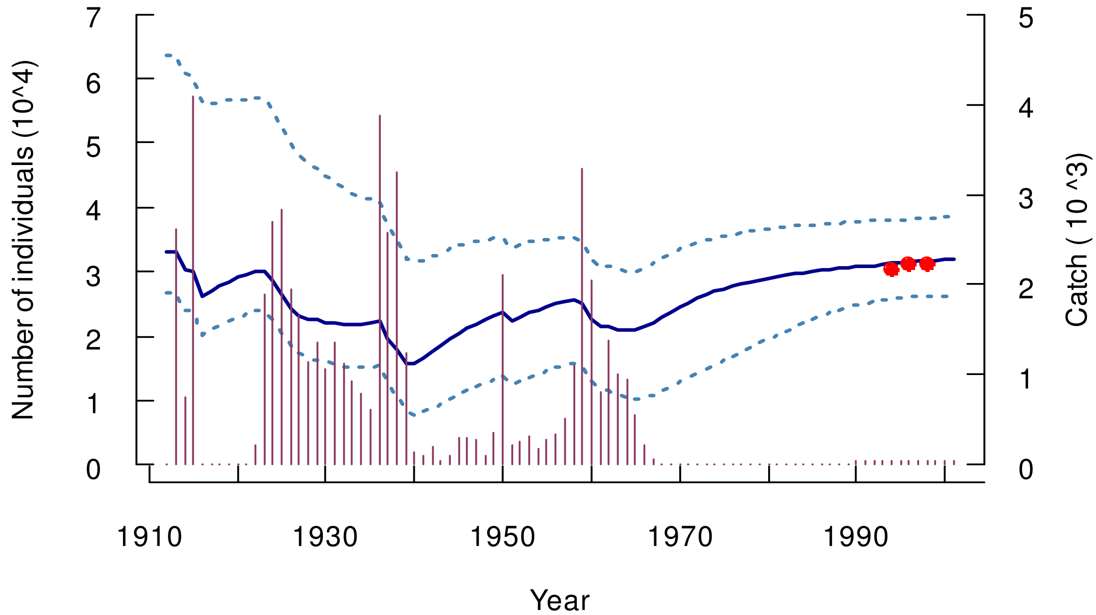


Figure 83. Population trajectory for Eastern Alaska Steller sea lions

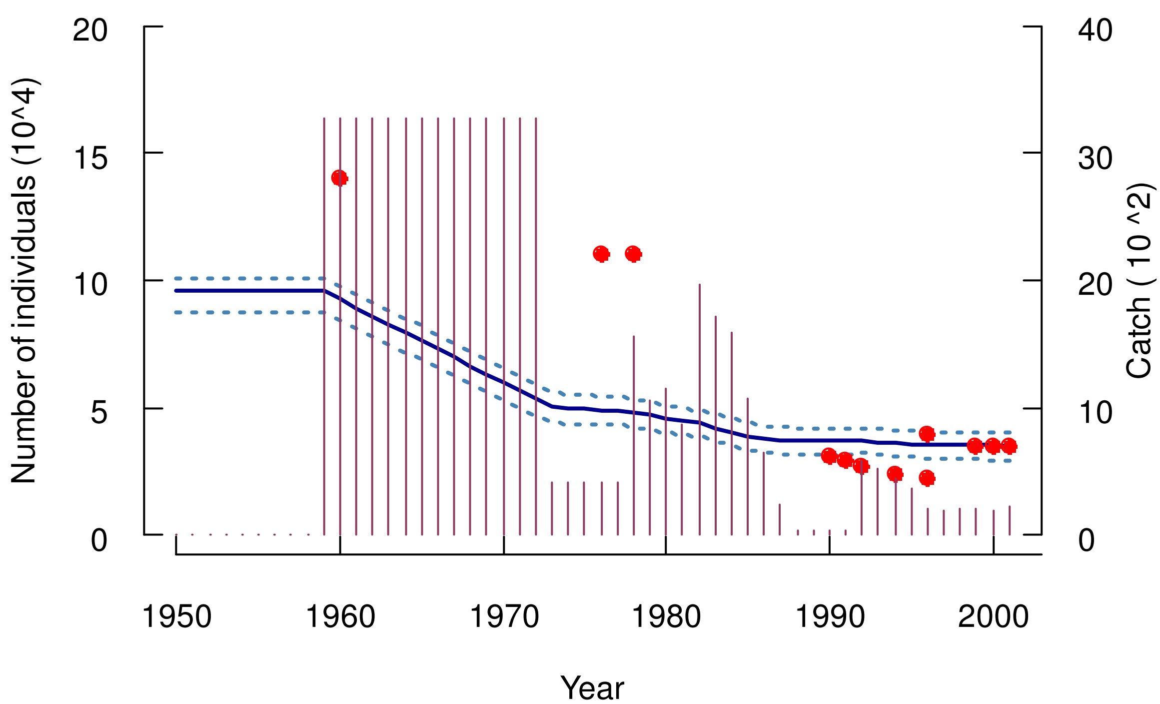


Figure 84. Population trajectory for Western Alaska Steller sea lions

Walrus

<u>Walrus, *Odobenus rosmarus*</u>

The walrus is endemic to the polar waters of the Northern Hemisphere (Rice, 1998, Kastelein, 2002, Kaschner, 2004). The Spitsbergen and Franz Josef Land population is depleted by 98%, while the West Greenlandic stock is depleted by 91% of its 1900 abundance, and the Northwater population is at 60% of its 1950 population (Table 7, Figure 88, Figure 89, Figure 87). The Chukchi/Bering Sea population is at 68% of its 1869 level, and the East Greenlandic population is at 94% of its 1950 level (Table 7, Figure 85, Figure 86). Globally, the species is depleted by 47% (Table 9); this estimate includes the Northwest Atlantic and Laptev Sea population (Appendix I).

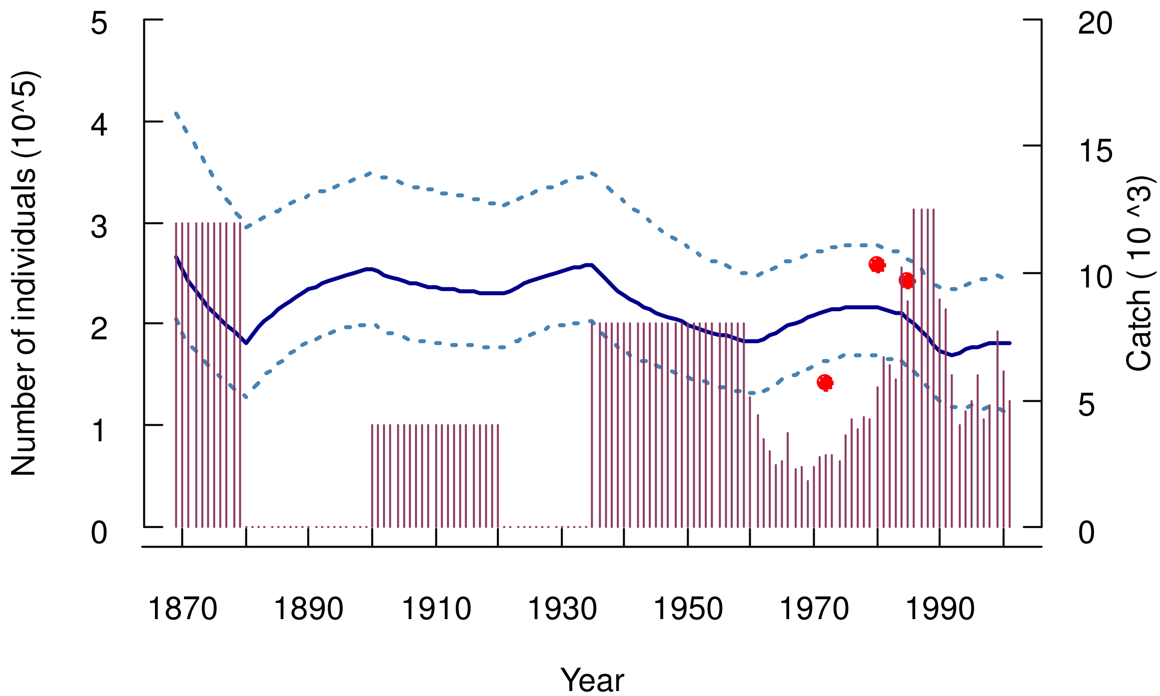


Figure 85. Population trajectory for Chukchi / Bering Sea walruses

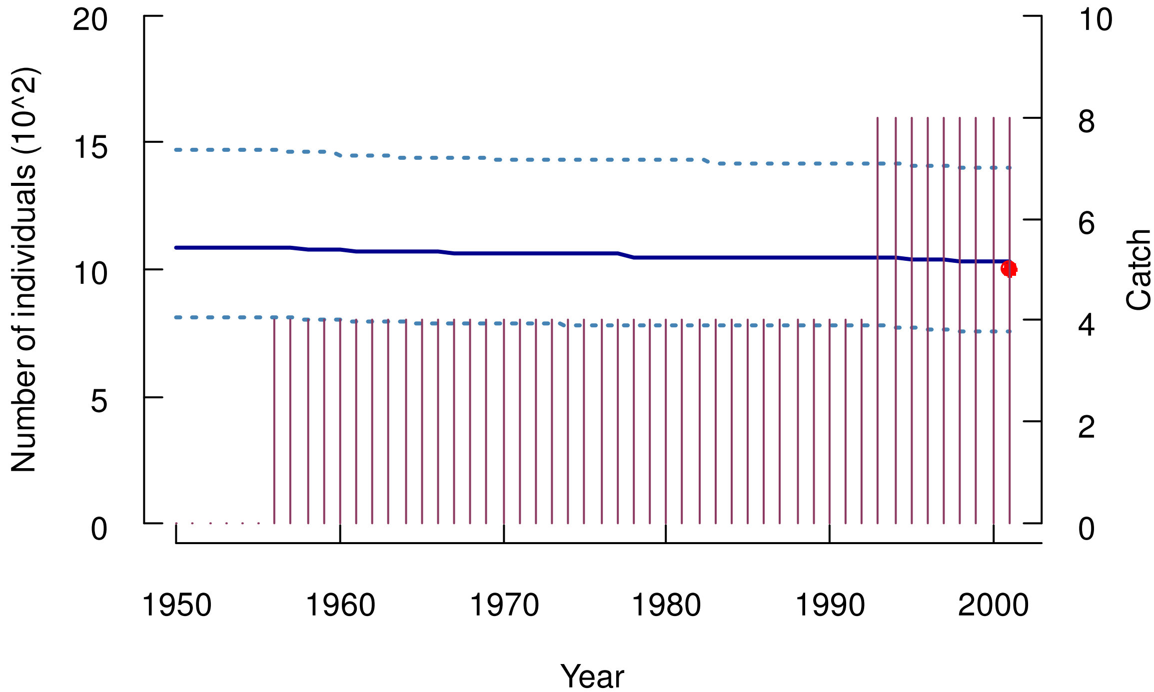


Figure 86. Population tracjectory for East Greenlandic walruses

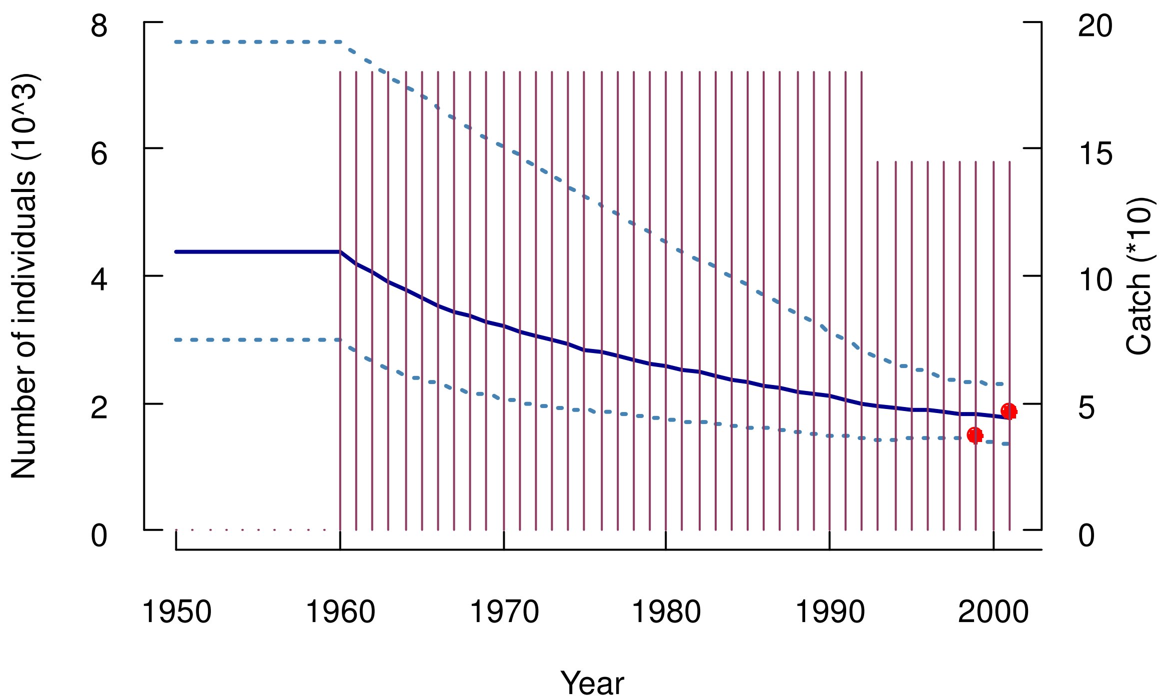


Figure 87. Population trajectory for Northwater walruses

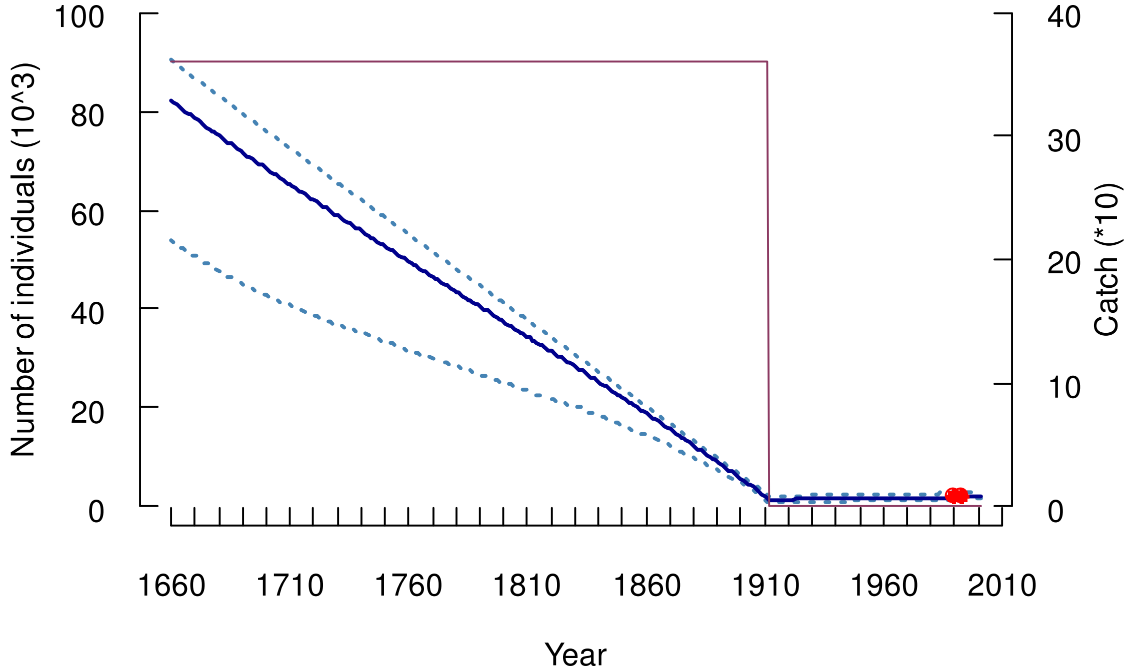


Figure 88. Population trajectory for Spitsbergen walruses

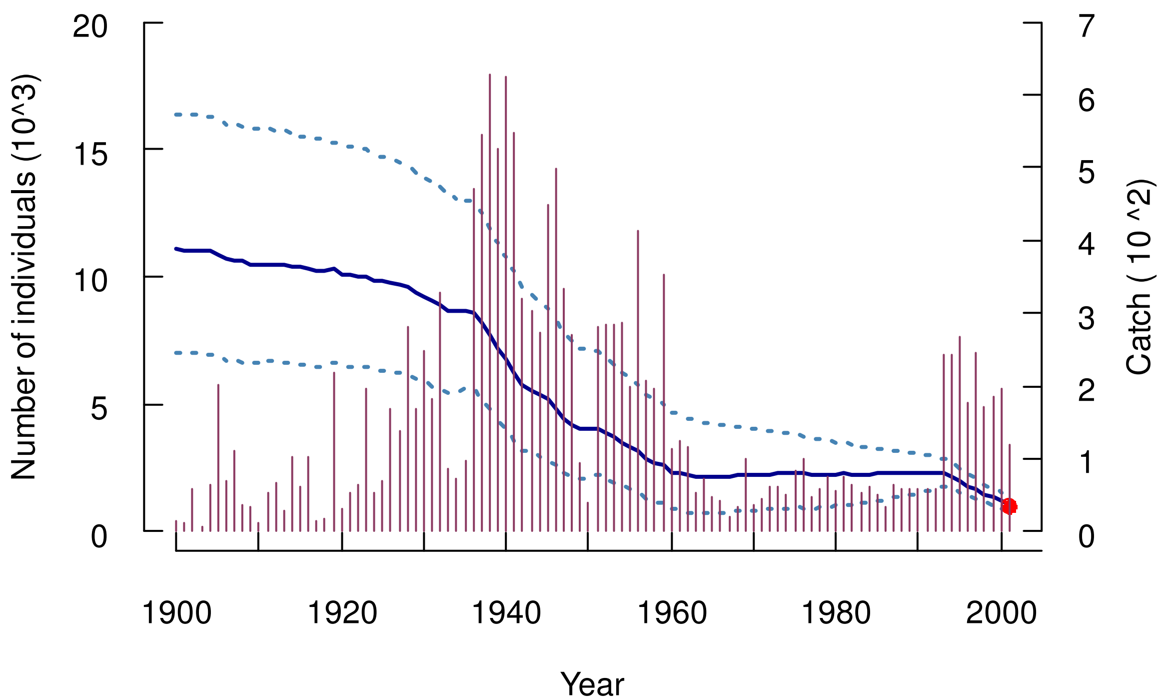


Figure 89. Population trajectory for West Greenlandic walruses

THE BIG PICTURE

Population trajectories were generated for all marine mammals with documented exploitation histories. This represents 45 of the 115 marine mammal species globally. Table 8 presents the results for exploited cetaceans and Table 9 the results for exploited pinnipeds, aggregated by exploited and unexploited sub-populations for each species. Figure 90 shows a summary of the results of the analysis. Marine mammal abundance has declined 22% (0-62%) in numbers, and 76% (58-86%) in biomass from 1800 to 2001. Cumulative catches over the same time period totaled 74.5 million in numbers, corresponding to 135.6 million tonnes (t) in biomass. The world catch of fish in the 1970s was between 60 and 64 million t/year, increasing to around 80 million t/year between 1985 and 1995 (Christensen, 2006). In 1930 and 1937, marine mammal landings totaled over 4 and 3.7 million t respectively. This illustrates how huge these hunts were, especially when compared to the fisheries catches, which, during that early period, would have been much smaller than now. Marine mammal abundance in 1800 was 125 million t, which is a small fraction of the overall estimate of fish biomass, estimated at 800 billion t (S. Jennings, CEFAS, pers. comm to V. Christensen, 2006) and even up to 2 trillion t (V. Christensen, Fisheries Centre, UBC, pers. comm, 2006).

Table 8: Total population sizes of exploited cetaceans

Species	Start of doc. hunts	Initial numbers (Mean, 95% CI)	2001 numbers (Mean, 95% CI)	Depleted by (%)
Sei whale	1885	246,000 (227,000 – 294,000)	49,090 (41,300 – 75,700)	80
Southern Right whale	1785	86,100 (73,400 – 98,300)	6,740 (4,580 – 11,100)	92
Sperm whale	1800	957,000 (751,000 – 1,350,000)	376,000 (296,000 476,000)	61
Fin whale	1876	762,000 (574,000 – 936,000)	109,600 (72,200 – 161,000)	86
Gray whale (Hypothesis 1)	1600	24,600 (21,600 – 29,100)	15,936 (14,700 – 18,000)	35
Gray whale (Hypothesis 2)				
Blue whale	1868	340,000 (309,000 – 376,000)	4,730 (3,378 – 6,180)	99
Bowhead whale	1650	89,000 (67,000 – 114,000)	9,450 (7,500 – 10,800)	89
Eden/Bryde's and Bryde's whale	1909	146,000 (112,000 – 191,000)	132,000 (97,600 – 177,000)	10
Humpback whale	1664	232,000 (166,000 – 285,000)	42,070 (31,500 – 59,000)	82
Common minke whale	1926	258,000 (196,000 – 344,000)	189,000 (142,000 – 251,000)	27
Antarctic minke whale	1921	379,000 (300,000 – 478,000)	318,000 (250,000 – 404,000)	16
North Atlantic right whale	1530	14,100 (10,100 – 27,800)	368 (257 - 469)	97
North Pacific right whale	1835	9,720 (8,540 – 12,600)	1,340 (679 – 2,070)	86
Short-finned pilot whale	1948	226,400 (163,000 – 507,000)	225,000 (161,000 – 505,000)	1
Baird's beaked whale	1907	9,670 (7,410 – 12,800)	7110 (5340 – 9,200)	26
Beluga	1862	170,000 (115,000 – 289,000)	96,500 (71,200 – 132,000)	43
Killer whale	1935	50,000 (35,600 – 72,100)	47,800 (33,700 – 69,200)	5
Long-finned pilot whale	1709	1,070,000 (824,000 – 1,300,000)	995,000 (744,000 – 1,230,000)	7
Northern bottlenose whale	1584	57,800 (44,200 – 84,700)	48,800 (37,600 – 64,300)	16
False killer whale	1965	57,600 (25,400 – 242,000)	57,100 (24,900 – 241,000)	1

Table 8: Total population sizes of exploited cetaceans (cont ...)

Species	Start of doc. hunts	Initial numbers (Mean, 95% CI)	2001 numbers (Mean, 95% CI)	Depleted by (%)
Narwhal	1977	94,600 (77,500 – 115,000)	71,700 (56,000 – 90,800)	24
Pantropical spotted dolphin	1959	5,060,000 (4,110,000 – 6,410,000)	2,200,000 (1,720,000 – 2,850,000)	57
Spinner dolphin	1959	2,660,000 (2,150,000 – 3,360,000)	1,910,000 (1,500,000 – 2,450,000)	28
Short beaked common dolphin	1959	3,940,000 (3,030,000 – 5,660,000)	3,800,000 (2,910,000 – 5,530,000)	3
Dall's porpoise	1963	1,440,000 (941,000 – 1,660,000)	1,090,000 (584,000 – 1,320,000)	24
Bottlenose dolphin	1950	524,000 (405,000 – 779,000)	519,000 (400,000 – 774,000)	1
Northern right whale dolphin	1978	408,000 (345,000 – 491,000)	277,000 (203,000 – 369,000)	32
Harbour Porpoise	1716	704,000 (479,000 – 997,000)	535,000 (345000 - 755000)	24
Atlantic white-sided dolphin	1950	103,000 (52,300 – 217,000)	102,000 (51,400 – 216,000)	1

Table 9: Total population sizes of exploited pinnipeds

Species	Start of doc. hunts	Initial numbers (Mean, 95% CI)	2001 numbers (Mean, 95% CI)	Depleted by (%)
Ribbon seal	1950	505,000 (363,000 – 664,000)	501,000 (361,000 – 654,000)	1
Ringed seal	1903	8,570,000 (6,350,000 – 11,600,000)	6,290,000 (3,480,000 – 8,390,000)	27
Southern elephant seal	1820	739,000 (550,000 – 1,070,000)	733,000 (549,000 – 997,000)	1
Gray seal	1950	299,000 (226,000 – 393,000)	286,000 (211,000 – 381,000)	4
Harp seal	1895	17,800,000 (14,300,000 – 23,500,000)	11,300,000 (8,910,000 – 13,600,000)	36
Hooded seal	1940	1,780,000 (1,250,000 – 2,580,000)	891,000 (511,000 – 1,320,000)	50
Bearded seal	1966	668,000 (357,000 – 642,000)	596,000 (251,000 – 581,000)	11
Harbour seal	1991	384,000 (377,000 – 422,000)	381,000 (374,000 – 419,000)	1
Largha or spotted seal	1965	532,000 (413,000 – 695,000)	444,000 (307,000 – 594,000)	17
Antarctic fur seal	1790	1,580,000 (1,010,000 – 1,970,000)	1,270,000 (901,000 – 1,680,000)	20
South African and Australian fur seal	1900	1,780,000 (1,410,000 – 2,320,000)	1,620,000 (1,300,000 – 2,020,000)	9
Northern fur seal	1786	1,730,000 (1,620,000 – 2,650,000)	1,630,000 (1,860,000 – 2,030,000)	1
South American sea lion	1930	290,000 (226,000 – 381,000)	232,000 (173,000 – 335,000)	20
California sea lion	1980	225,000 (1560,00 – 247,000)	214,000 (146,000 – 236,000)	5
Steller sea lion	1912	143,000 (129,000 – 180,000)	81,400 (70,700 – 94,400)	43
Walrus	1660	378,000 (268,000 – 527,000)	201,000 (131,000 – 271,000)	47

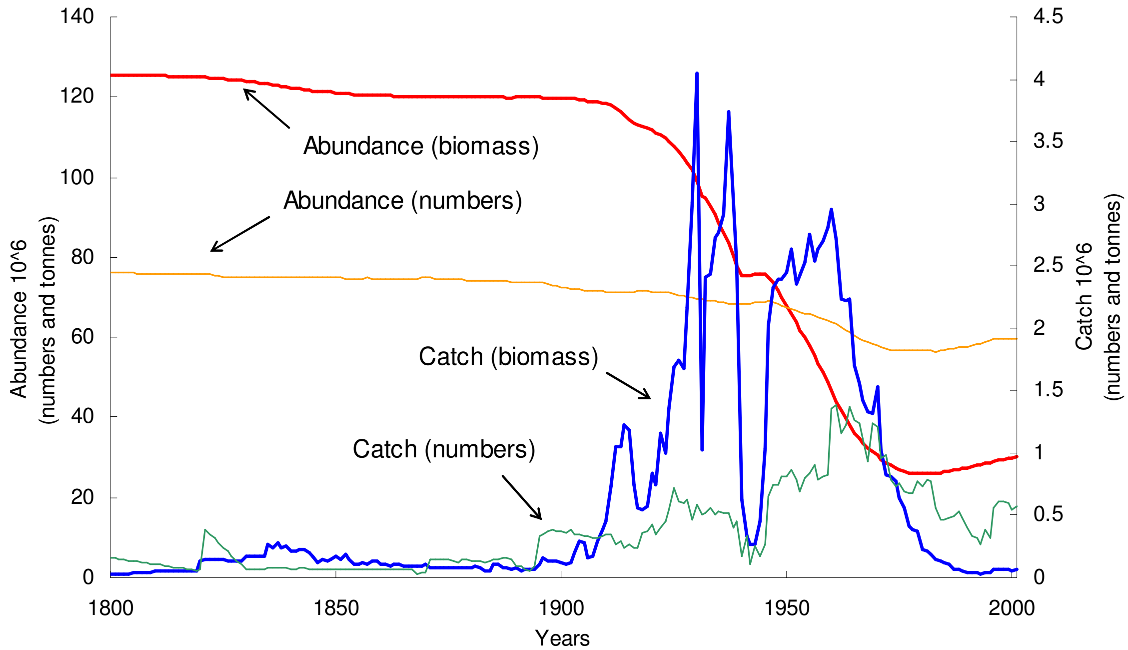


Figure 90. Trends in marine mammal biomass and abundance from 1800 - 2001. The thick line shows abundance in biomass, the stippled line shows abundance in numbers over time. The thin line shows catch in biomass and the medium line shows catch in numbers over time.

Marine mammal catches

The earliest documented catch I have acquired is for the year 1530, when 300 North Atlantic right whales were estimated to have been caught (Aguilar, 1986; Reeves, 1999). However, it is not until the late 1700s that the size of marine mammal hunts becomes significant (Figure 91). The total number of documented marine mammals caught since 1530 is 74,537,339 (135,641,639 t) of which 73,042,166 (131,239,231 t) were caught after 1800. The average weight of individuals caught (biomass/numbers) is very high up until the late 1700s, when a drastic decline occurred, due to the onset of fur seal catches which strongly increased numbers caught, but only slightly increased the catch in weight (Figure 92). From the late 1700s to the early 1900s, catch in both numbers and biomass were relatively low, albeit with some fluctuations. This likely only identifies the start of reporting for a number of hunted stocks. The spike beginning in 1821 is important, however, as it represents a drastic increase in the catch of Antarctic fur seals coupled with the beginning of the Southern elephant seal hunt. The next interesting feature of this graph is the development that happened from the early 1900s until the Second World War, where biomass increases disproportionably to numbers caught. This, or course, is because great whales increasingly figure in catches. In particular, it is due to catch of the biggest and heaviest of the species, the blue whale.

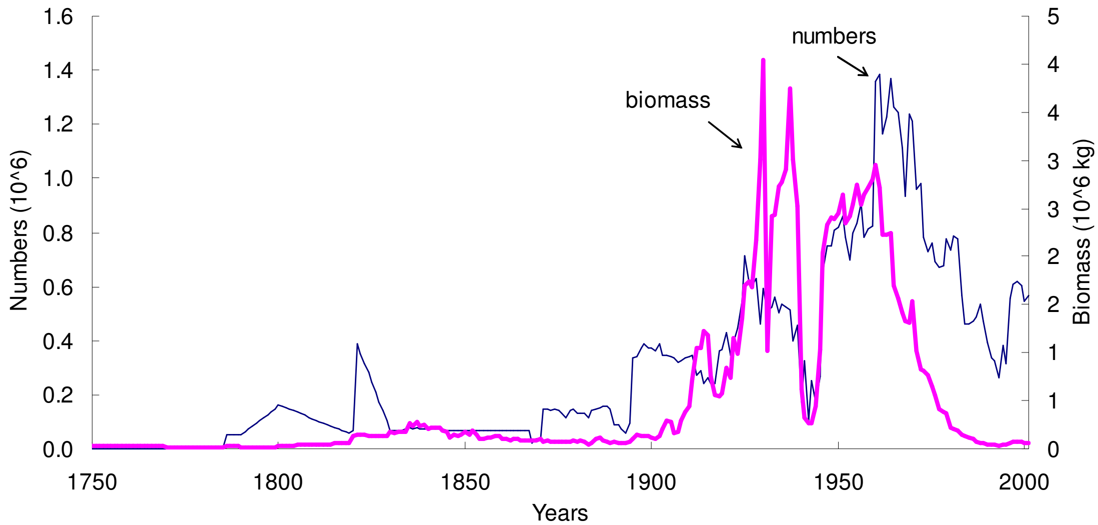


Figure 91. World catch of marine mammals, in numbers (thin line) and biomass (thick line) from 1750 to 2001. The decline in catch by weight clearly precedes the decline by numbers.

Figure 92. Average weight of marine mammals caught during 1530 – 2001, calculated as a moving average over 31 years. The average weight is estimated from the tonnage of mammals caught relative to numbers caught.

A drop is noted in catch in weight and by numbers under the First World War, and again in 1931, although only by weight (Figure 91). In 1930, the second-largest annual catch of blue whales (the 1937 season holds the record) virtually flooded the market, leading to a crisis that saw vastly reduced catches (Tønnessen, 1982). During the Second World War, catches dropped again as a large portion of the whaling fleet was converted to tankers and transport ships (Tønnessen, 1982). The only great whale species that did not experience a large decline in catches was the sperm whale; in fact, in 1943, it made up 38% of the world's marine mammal catch by biomass. The decline in catches was not so precipitous for the smaller marine mammals, many of which were caught for subsistence. After WWII, catches increased both by numbers and weight, although more so by numbers, indicating that the greatest whales were already depleted, and the whaling fleets were forced to target the smaller species.

The total biomass caught declines rapidly in the 1960s, followed by a collapse in catch by numbers. This collapse is much bigger in terms of biomass than numbers, indicating depletion of the great whales. In 1986, when the IWC moratorium on whaling came into force, catch by weight is severely reduced, while numbers caught begins increasing again, indicating increased catches of smaller mammals, and/or perhaps better documentation of smaller mammal catches. Figure 93 clearly shows the build-up in average weight of the catch as the great whales were hunted in great numbers especially in the Southern Hemisphere. This was followed by a declining trend, indicating that these large mammals made up a declining proportion of the total catch.

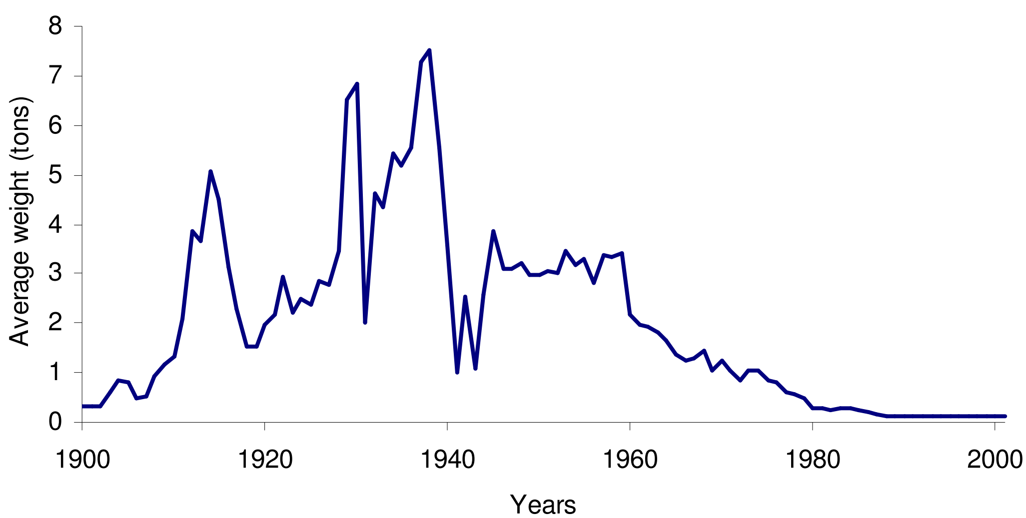


Figure 93. Average weight of marine mammals caught during 1900 – 2001, estimated from total weight of mammals caught relative to numbers caught.

Marine mammal numbers

Figure 94 shows the abundance of marine mammals in numbers from 1800 – 2001. Abundance levels have been declining steadily, with a total decline of 22% (0-62%) between 1800 and 2001. In terms of numbers, the total population went from 76 (58-115) to 60 (44-93) million. The 2001 abundance marks a bit of an increase from the 1983 numbers of 56.4 million, which corresponds to a 28% depletion since 1800.

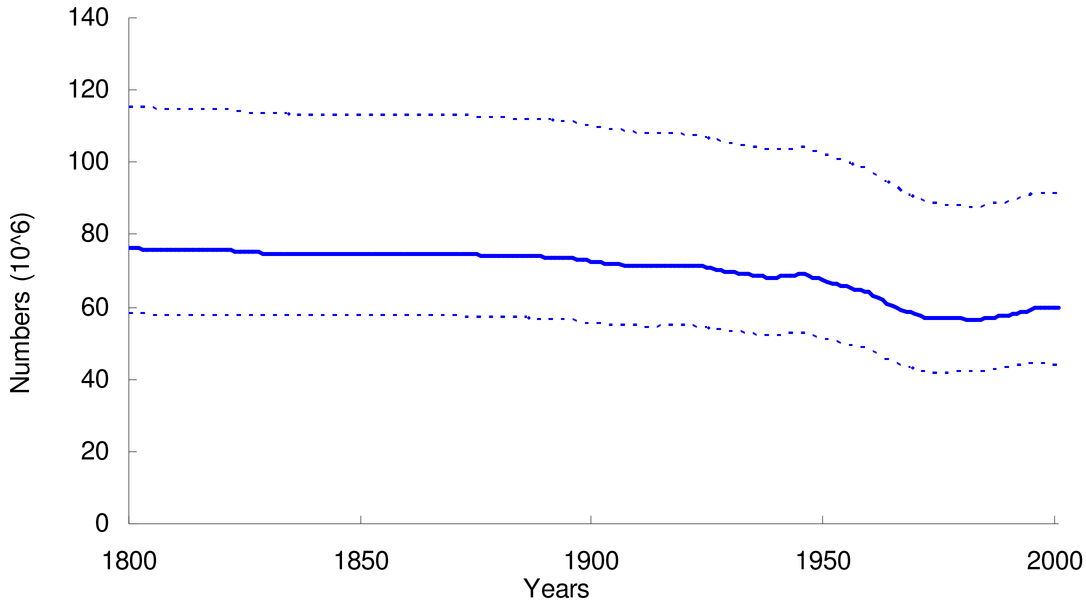


Figure 94. Decline in numbers of marine mammals from 1800 to 2001. The solid line is the median, and the dotted lines represent the 95% credible intervals.

The decline in the groups that make up the marine mammal populations is shown in Figure 95. True seals constitute the greatest proportion of marine mammal numbers, decreasing from 1900 to the 1980s, but increasing in abundance since. The smaller dolphins and porpoises have declined since the 1960s. The eared seals and walrus declined up until about 1900; since then they have shown signs of recovery. The abundance trend for the smaller whales and larger dolphins seems steady, while the great whales have decreased since the early 1900s.

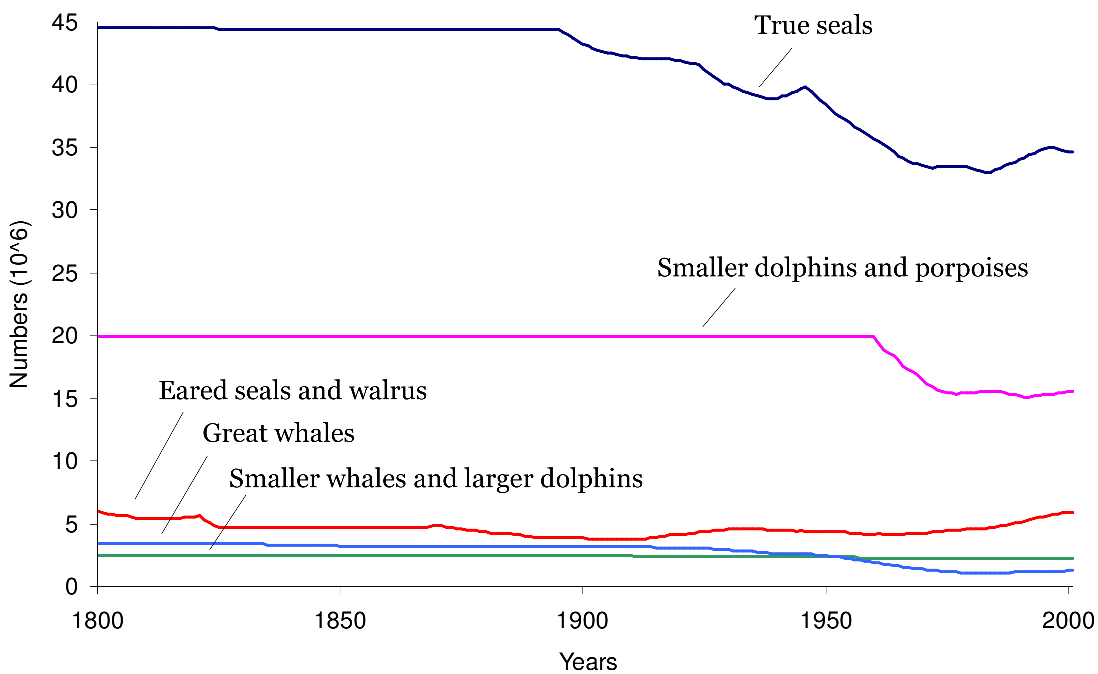


Figure 95. Marine mammal global abundance in numbers.

Figure 96 shows abundance for cetaceans and pinnipeds. The pinnipeds clearly decline earlier than the cetaceans, leveling off in the 1970s, and increasing again from the 1980s on. The cetaceans show a remarkable trend consistent with rapid over-exploitation; their abundance was reduced from 24.5 million animals in 1958 to 18.8 million in 1977, which is a 22% decline in 20 years. The cetacean population seems to have leveled off since the late 1970s, and has even increased slightly in recent years.

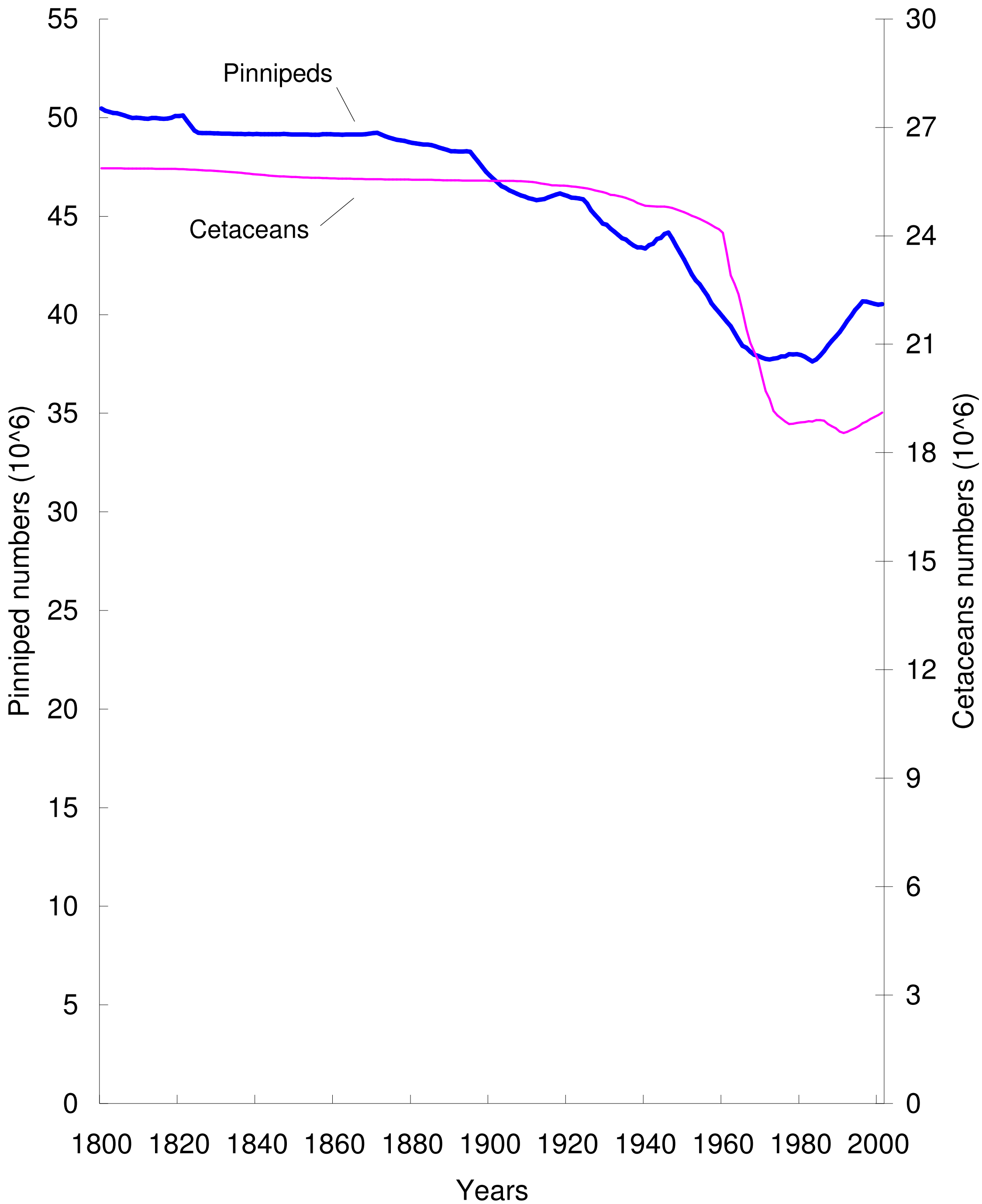


Figure 96. Global aggregated abundance of cetaceans and pinnipeds (in numbers) from 1800 to 2001.

Marine mammal biomass

This section examines what happened to marine mammal abundance in terms of biomass. The graphs are like the above except for the change in units. This lets us appreciate the true dominance of the great whales in the ecosystems. Figure 97 shows the decline in biomass of 76% (58-86%) for aggregated marine mammal population from 1800 to 2001. It is evident that the great whales, although accounting for only 5% of the total numbers of marine mammals in 1800, accounted for the vast majority, 92%, of the total marine mammal biomass The decline is staggering, with current great whale biomass making up 72% of the total biomass and 2% of the total numbers.

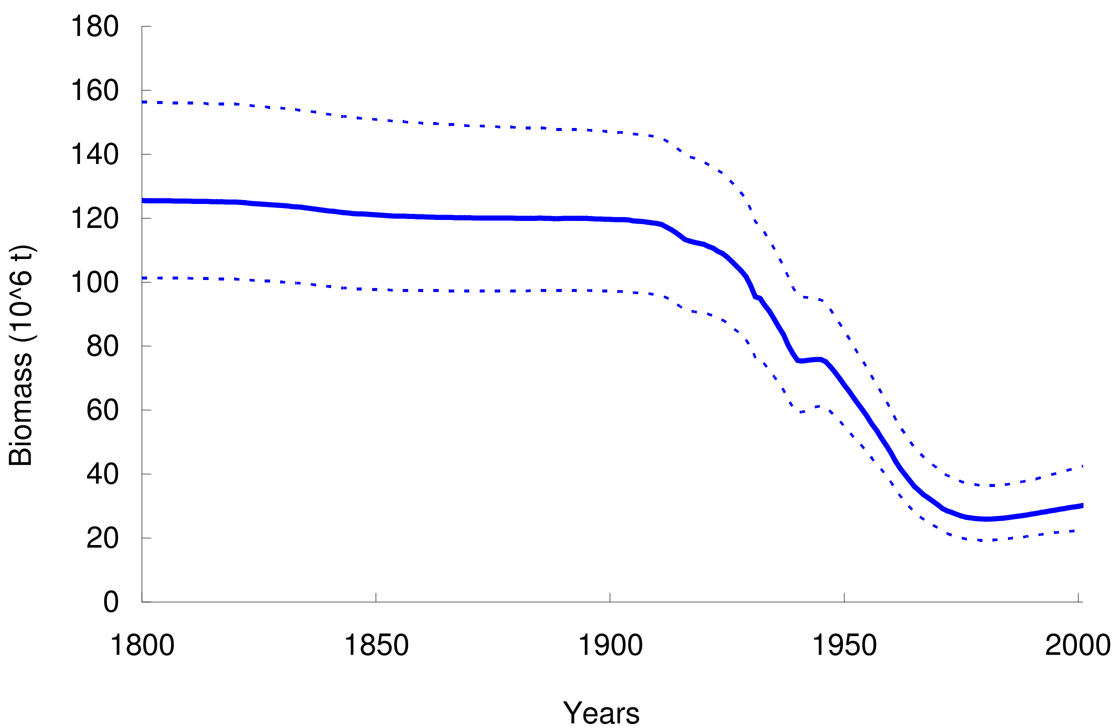


Figure 97. Decline in the biomass of marine mammals. The solid line is the median, and the dotted lines represent the 95% credible interval.

Figure 98 shows the decline by marine mammal groups from 1800 to 2001. The great whales contribute most to marine mammal abundance by weight. Although the decline by numbers for this group did not look remarkable (Figure 95), the decline in biomass was very pronounced (Figure 98, and see next section). True seal and smaller dolphin and porpoise biomass has declined in accordance to their respective abundance in numbers. The smaller whales and larger dolphin biomass and the eared seals and walrus are slowly declining over time (Figure 98).

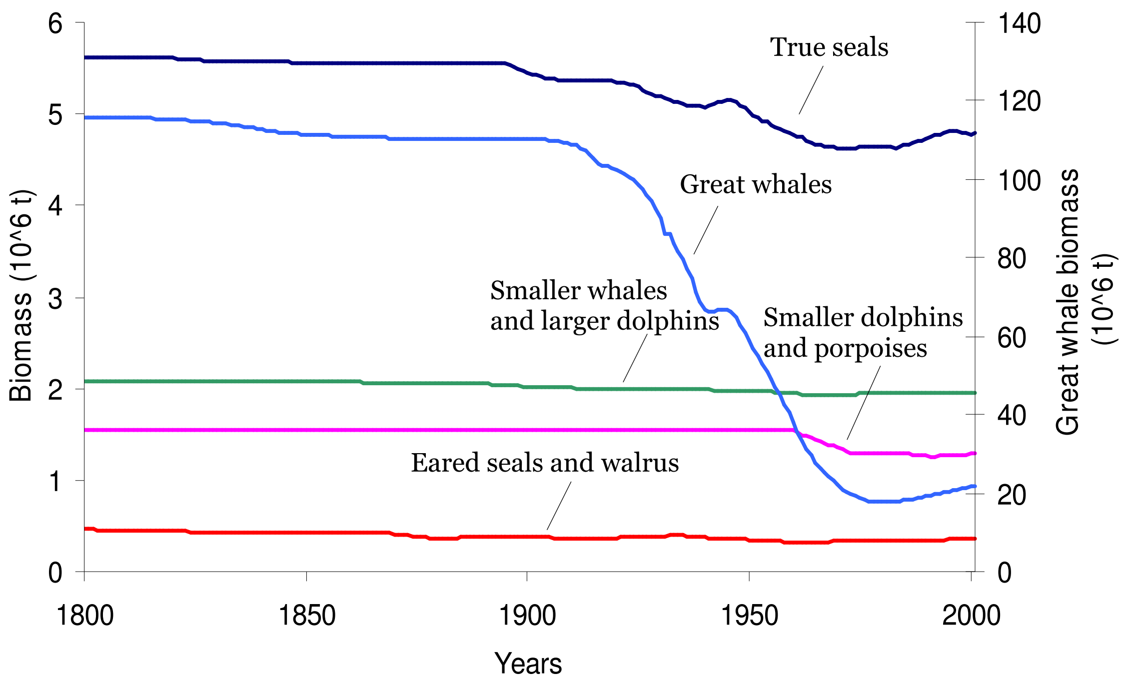


Figure 98. Marine mammal global abundance in biomass aggregated by groups from 1800 to 2001

Figure 99 shows the decline in biomass for pinnipeds and cetaceans. It is apparent that the bulk of the decline is occurring in the cetacean population. The pinnipeds, while also declining, have done so at a much lesser rate.

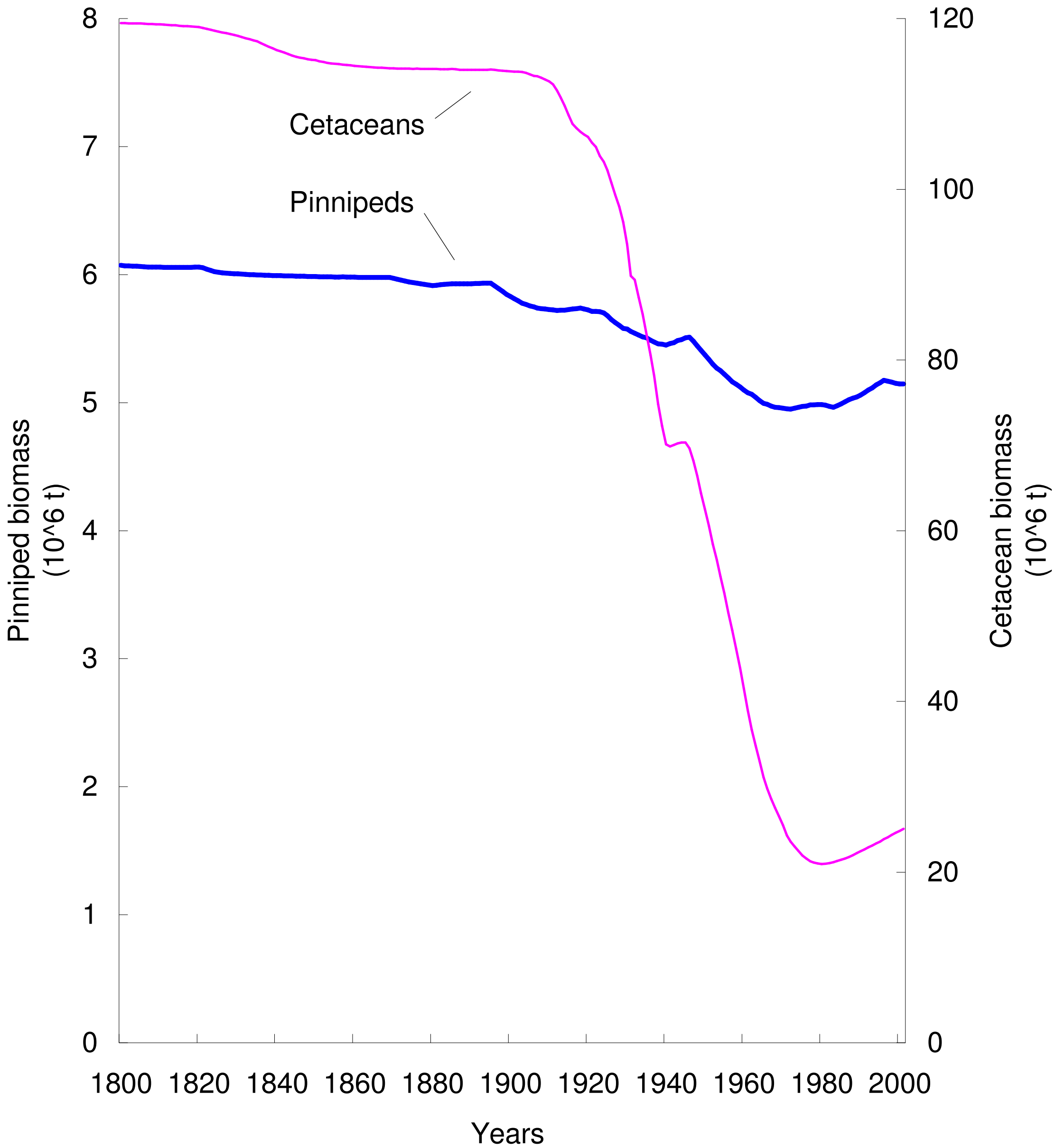


Figure 99. Marine mammal global abundance by cetaceans and pinnipeds, from 1800-2001.

The great whales

The sections above should have made it clear that the great whales make up the majority of marine mammal biomass and have experienced the greatest rate and magnitude of depletion. Figure 100 shows the scale of decline: great whale biomass declined at a greater rate and to a greater extent than the corresponding numbers from 1800 to 2001, indicating that the largest whales were hunted first.

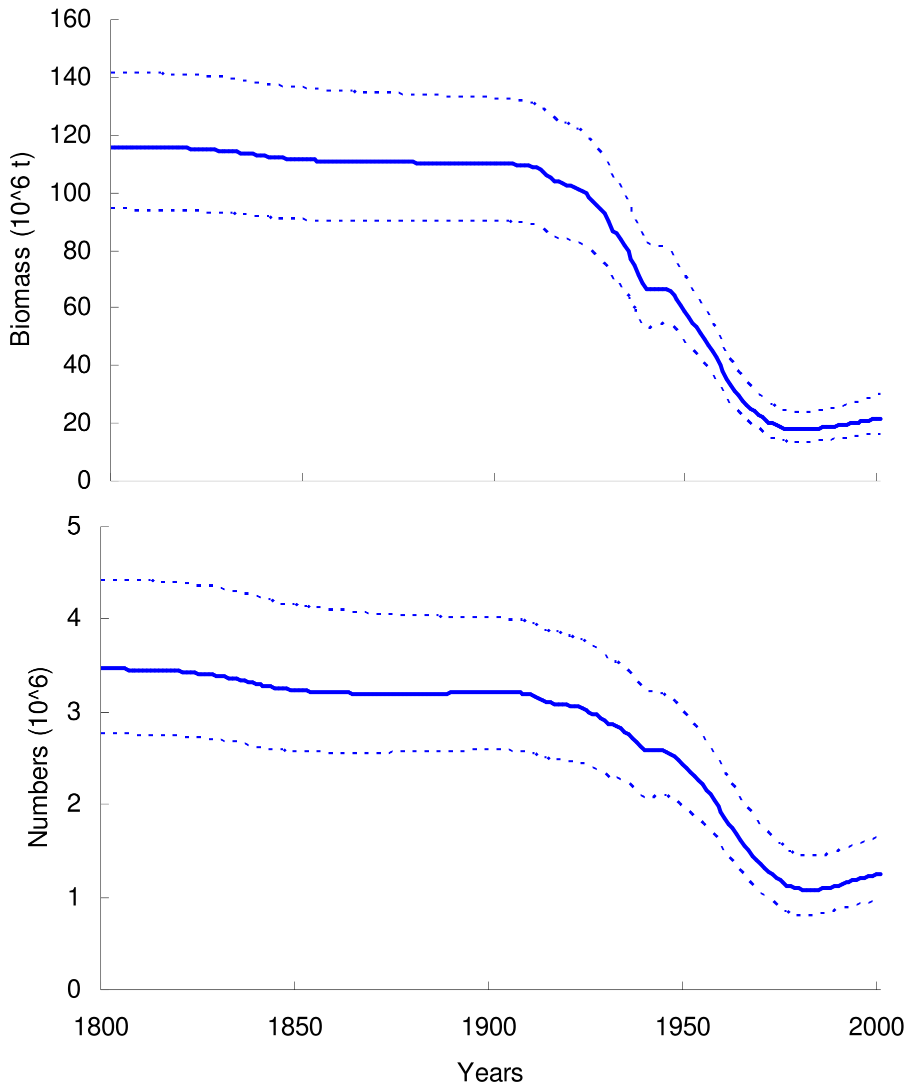


Figure 100. Decline in great whales numbers and biomass from 1800 to 2001. The solid lines are the medians and the dotted lines the 95% credible intervals.

The total number of whales caught since 1800 by species are listed in Table 10. In Figure 101 I have plotted the catches of the five species that were caught in the greatest amounts since 1900. It is evident that sequential depletion of the great whales has occurred. First to go were the blue whales, followed by the fin, sperm and sei whale. The species which peaked last was the minke whale, which only started to be caught in large quantities in the 1970s, and whose catch dropped to near zero when the moratorium came into effect, although the catch can be seen to be increasing again. The solid line in Figure 3-93 is the average weight of the whales caught, which saw an increase up until the 1930s as blue whales comprised larger and larger portions of the catch. Since then, the average weight of whales caught has declined, with a precipitous trough during the Second World War. There is a slight increase in average weight in 1987-89, when fin whales accounted for a relatively larger portion of the limited reported catch.

Table 10: Catch by species since 1800

Species	Catches since 1800	Species	Catches since 1800
Sperm whale	1,014,449	Minke whale	280,341
Fin whale	872,524	Humpback whale	253,080
Blue whale	373,870	Right whale	107,052
Sei whale	295,885	Bowhead whale	55,293

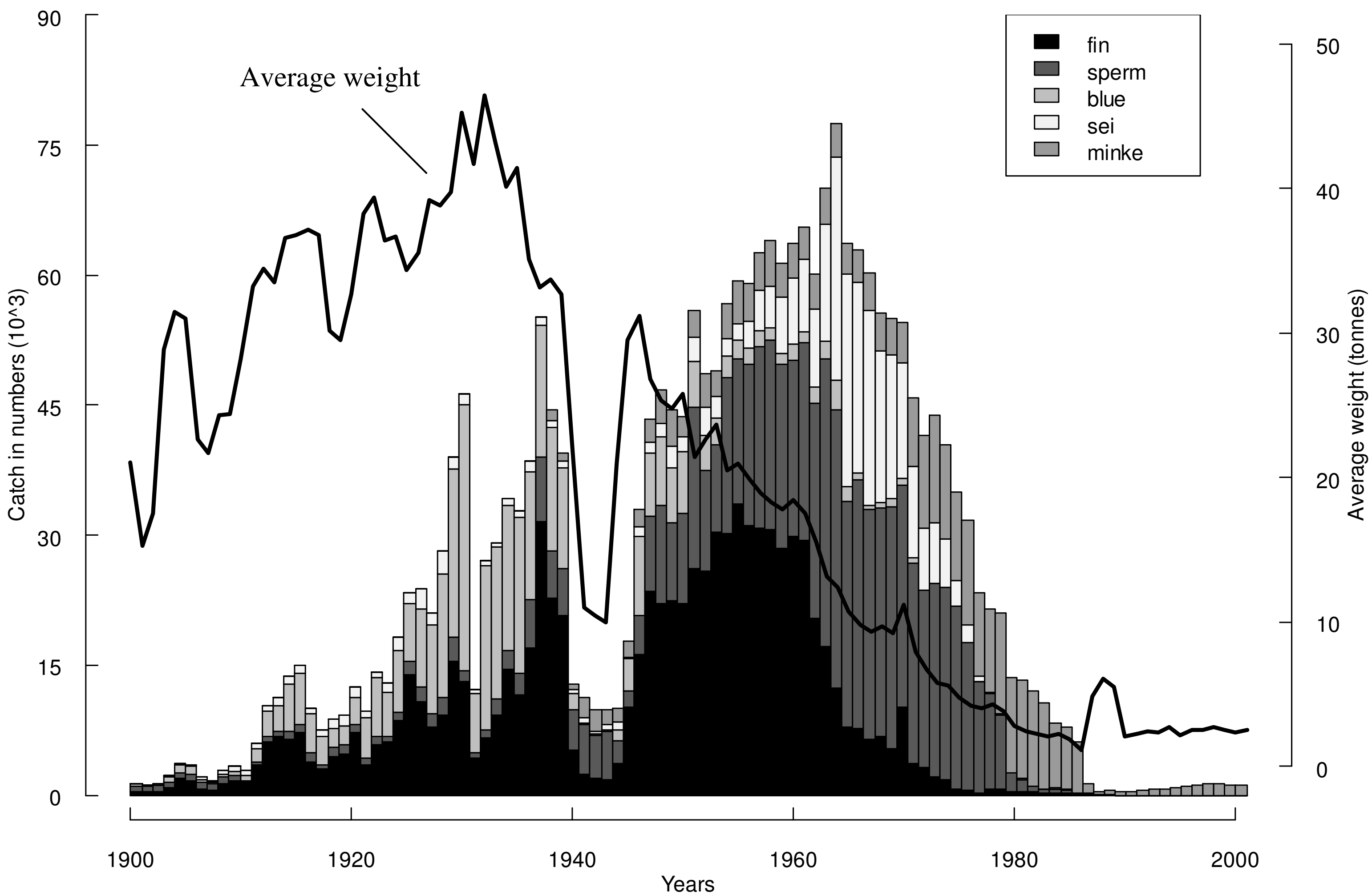


Figure 101. Sequential depletion of the great whale and average body weight of landed animal

DISCUSSION

This section is divided into three sections to discuss the data, methodology and results, respectively. The overriding message in this section is that the results are only as good as the data, and the data are often incomplete. They are the best available documentation of the history of marine mammal populations. However, the data are too sparse to investigate finer details of the historical changes in abundance associated with natural and anthropogenic affect.

DATA

The primary limitations I encountered in conducting the analyses in this thesis had to do with data availability and reliability. The early hunts were not documented, and much of the history of sealing remains a mystery. In this section, I will explore the causes and explanations for some of the obstacles that have presented themselves.

Regarding availability of abundance data, one of the species for which there were major problems was the Antarctic minke whales. There have been significant problems with the estimation of their stock size due to conflicting trends in the data collected. The International Decade of Cetacean Research (IDRC), now the Southern Ocean Whale and Ecosystem Research (SOWER), circumpolar cruises, 1982/83-1988/89 led to the IWC Science Committee agreeing that the best estimate of minke whale abundance in the Antarctic was 761,000 (95% CL: 510,000 – 1,140,000) in 1991 (IWC, 1991; Tamura and Ohsumi, 2000). Branch (2001) estimated that from the 1878/79-1982/83 and 1985/86-1990/91 IDRC/SOWER surveys the best estimates of abundance were 608,000 (c.v. 0.130) and 766,000 (c.v. 0.091) respectively (Branch and Butterworth, 2001). The 1991/92-1997/98 SOWER third circumpolar cruises resulted in an estimate of abundance of 268,000 (c.v. 0.093), although the survey is considered incomplete (Branch and Butterworth, 2001; IWC, 2002). The updated estimate for the 1991/92-2000/01 was reported at 312,000 (IWC, 2003). Erring on the side of caution, I chose to use the 312,000 estimate in my analysis. The Scientific Committee, however, while acknowledging a decline in minke abundance estimates, is not concluding that minke whale abundance in the Southern Hemisphere is actually declining (IWC, 2003). A number of hypotheses for the differences have been suggested, the two most important of which were: 1) open areas sighting rates decreasing because an increased proportion of minke whales within pack-ice, which is affected by climatological connections, and 2) distributional changes in minke whale stocks due to shifts in sea ice extent (Branch, 2006, IWC, 2006). For my SSRA, the implications of having uncertain estimates will affect the estimate of total biomass of this species, but given the limited catches (Figure 31, Appendix VI), the population trend, while variable in magnitude dependent on the absolute size of the population, would follow the same trend (i.e., my results will not be significantly altered).

The problem I faced when attempting to assess the North Atlantic Bryde's whales, for which catch data exist beginning in 1925 (Table 3, Appendix VI), was that no abundance estimate is available for this stock. This meant that the probability of a population trajectory could not be calculated for the species in this region. This means that any change in numbers over time for this stock is not reflected in the estimated global trend, and also the estimated absolute size of all marine mammal abundances does not include the North Atlantic Bryde's whale.

The California sea lion has been hunted for subsistence for almost 5,000 years. However, there is only a very limited amount of historical catch records (NMFS, 2003). In fact, catch data are only available from 1980 on (Figure 82, Appendix VI). This means that the trend generated by the U.S. pup count index which has been increasing since the late 1970s (NMFS, 2003) cannot be reproduced by my SSRA. As well, it seems that El Niño drastically reduced pup production in three years since 1980 (DeLong *et al.*, 1991; NMFS, 2003). However, there is not enough trend information on abundances for the SSRA, which would otherwise be able to capture this trend, to pick it up. Again, the 'real' trend for this species will not be reflected in my SSRA. However, the relative size of this population to the aggregate mammal group means that the importance of missing this information is limited.

Given the nature of water-based mammal hunts, where animals are readily lost from sight, occurrences of struck-but-lost animals are unavoidable. It is most likely that the magnitude of struck-but-loss rates has declined over time. The rates likely decreased as the efficiency of hunting methods and technology improved, and reporting systems became increasingly organized. In terms of our model predictions, the carrying capacity (K) would be underestimated and there will be downward bias on recovery goals, because a larger number of mammals has been removed from the stock than documented. Conversely, the intrinsic rate of growth (r_{max}), would tend to be overestimated. This is a structural problem, because of the way the logistic equation is set up. The addition to a year's population depends on the term $r_{max}(1-\frac{N_t}{K})$ for population size N_t in year t. If K is underestimated the ratio of N_t to K will bias the density dependence term downward, and the r_{max} parameter will be artificially inflated.

Thus struck-but-loss rates could have profound effects on the results in this model. To add these effects, I would have had to either estimate the rates based on very limited information (if any) on these rates over time, i.e., employ guesswork, or I would have had to increase the number of parameters estimated. However, the already limited information that this data set contains led me to steer away from this path. My estimates can, however, in their current form, be seen as approximating a minimum rate of decline for marine mammal populations, which is likely to be larger because of undocumented exploitation and issues like the struck-but-loss rate. This is my main motivation for not including struck-but-loss ratios in the SSRA

METHODOLOGY

To assemble the population reconstructions I employed a production model that assumed logistic growth. The method was chosen because of its limited data requirements (catch information and indices of absolute abundance, both in numbers). Although effort data exist for many hunts, problems with the influence of technological development and the lull in catches during the Second World War make these very unreliable indices (i.e., capture probabilities have presumably increased over time, biasing catch rate indices) and so I have chosen not to use them. In addition, for many of the species, no indication of age or sex are given for catch numbers, which means that I can not use age- or sex-structured models.

The major problems I ran into are the effects of working with data describing trajectories that are essentially 'one-way trips', i.e., the population trends are determined by decline, with no subsequent recovery. Thus, several explanations may exist for the observed data, all consistent with the maximum net growth and carrying capacity trade-off (i.e., the catches could be taken from a large slow-growing population or from a small fast-growing population). Fortunately, I had some auxiliary data for likely net recruitment rates in both cetaceans and pinnipeds, and thus could somewhat constrain the estimates in the form of a prior on r_{max}. There are some species where recovery has occurred (e.g. North Pacific and Southern Hemisphere sei whales and Being Sea ribbon seal), and in these cases the time series do provide information about r_{max} and K. However, some species (such as the blue whale) have shown no recovery over the last 20 years under the moratorium, and yet there have been no documented catches. If illegal catching is going on (Baker and Palumbi, 1994) then it could be that the hunt is impeding the recovery, and estimated model parameters will be biased downwards in net recruitment and upward carrying capacity.

The IWC's catch limit algorithm (CLA) is based on a surplus production model, much like the SSRA, set up as $P_t = P_{t-1} + r(1-\frac{P_{t-1}}{K})^2 - C_{t-1}$, where P_t is the population in year t, C_t is the catch in year t, r is the productivity parameter, and K = P_0 (Cooke, 1999). According to Cooke (1999), adding age-structure or a time-lag (either to age at fishing or reproduction), as well as the exponent of 2 in the equation, does not significantly impact the performance or behaviour of the model. The CLA performs well for management purposes, for which it uses a control law which sets the total allowable catch at $TAC = brP_t(\frac{P_t}{K} - a)$,
where '*a*' and '*b*' are intercept and slope parameters of the plot of P_t vs. TAC (Cooke, 1999). The IWC has set the '*a*' parameter at 54% of K, as a safety measure to ensure that the population does not drop below its most productive level due to scientific error in estimating relative stock size. Thus, if the size of the stock reaches 54% or less of its K, hunting is banned to allow recovery.

Stock reduction analysis (SRA) and its extension, stochastic stock reduction analysis (SSRA), as methods, were described by Walters *et al.* (2006), who applied the models to Fraser River white sturgeon and Georgia Strait lingcod. Similarly, M.K. McAllister assessed the Gulf of Mexico snapper for the Southeast Fisheries Science Centre's Southeast Data, Assessment and Review (SEDAR) workshop on the Gulf of Mexico Red Snapper (SEDAR 07) and found high density-dependence, a surprising insight, in juvenile mortality rates, a critical step to assessing the effects of the shrimp fishery by-catch (Walters *et al.*, 2006). In fact, Walters *et al.* (2006) state that "SRA should be a required assessment component rather than a methodology for use only in data-poor situations", adding to confidence in my SSRA framework. However, there were some situations, related to non-stationary effects where the structural assumptions of the SSRA led to an inability to replicate documented observations of and trends in abundance.

A first example of the consequences of the omission of non-stationary effects, (i.e., systematic changes in r_{max} and K) is provided by the assessment of the Western Alaska Steller sea lion population. These mammals have been studied in depth, and their population numbers have been estimated since 1956 (Trites and Larkin, 1996; A.W. Trites, Fisheries Centre, UBC, pers. comm., 2006). These sea lions are known to have increased from the late 1950s up until the early 1970s, after which they went into a precipitous decline (Figure 102). Given the documented catch history (Figure 84, Appendix VI), I have been unable to reproduce the population trajectory reported by Trites and Larkin (1996) (Figure 102). There are a number of hypotheses as to the explanation for the declining abundance of the stock, including the nutritional stress hypothesis that pins the decline on changes in prey availability and consequent changes in diet to include less 'healthy' food (Trites and Larkin, 1996; Rosen and Trites, 2000; Trites and Donnelly, 2003). Other hypotheses include incidental take, legal and illegal shooting, changes in carrying capacity due to environmental variation (e.g., climate change) and other changes in productivity, as well as disease and predation. Guénette *et al.* (in press) suggest that the decline is best explained by a combination of effects including fishing, predation, competition, and ocean productivity. While there is controversy as to the relative merits of the hypotheses, the decline is agreed on. This represents a case that my SSRA is unable to reproduce, and more complex modeling is required to model the non-stationary effects.

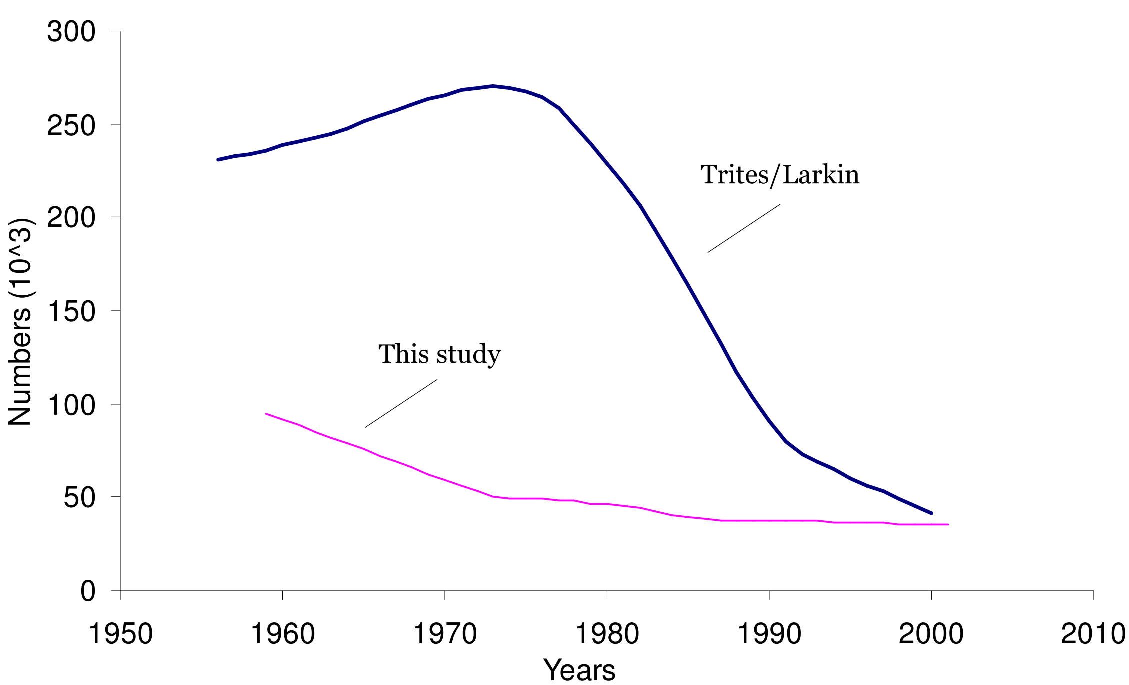


Figure 102. Population trajectories for the Western Alaska population of Steller sea lions, with the solid line representing estimates from Trites and Larkin (1996) and A.W. Trites (Fisheries Centre, UBC, pers. comm., 2006), and the stippled line representing this study.

Another situation in which non-stationary effects perplex historical assessments occurs for the Northeast Pacific gray whale, whose population trends are very well documented. The history of exploitation and recovery for this species is bewildering. The whale has a very long catch history, which begins in 1660 and is still ongoing, with a cumulative total of over 73,000 whales caught (Table 3, Appendix VI). The problem for the eastern North Pacific gray whale is that recent abundance information suggests a high intrinsic rate of growth. However, given the decline in catches 100 years ago, there is a lag, with recovery happening slowly, which is not consistent with that hypothesis (Punt *et al.*, 2004).

The problem with this stock is that it is violating the assumptions of the production model I employ, i.e., there are likely systematic changes in K and/or r_{max}. Similar conclusions have been drawn by other authors, and it is generally accepted that a density-dependent population trajectory models cannot explain the abundance trends (Lankester and Beddington, 1986; Butterworth *et al.*, 2002; Punt *et al.*, 2004). To resolve these disparities, it is necessary for either the 1988 carrying capacity to be twice that in 1846, or 1846 to 1900 commercial catches must be overestimated by a factor of 2.5, or estimated subsistence catches prior to 1846 must be underestimated by a factor of 3 (Butterworth *et al.*, 2002). Perhaps more plausible are some explanations for why these models have been unable to reconcile catch histories and abundance information, including changes in carrying capacity over time and the presence of cyclic population dynamics (Butterworth *et al.*, 2002; Witting, 2003; Punt *et al.*, 2004).

Gray whale assessments have been conducted in two ways. The first method involves shortening the modeled time period: Wade (2002) constrained analysis to the 1967-1996 time period, Punt *et al.* (2004) began their models in either 1930 or 1968, and used Bayesian statistics to assess the likelihood of different trajectories (Punt and Butterworth, 2002; Wade, 2002; Punt *et al.*, 2004). This hinges on the age-structure of the populations being stable at the starting year. Given the low catches in this time period this is a reasonable assumption, and the robustness of the models under varying starting years further backs this up (Punt and Butterworth, 2002; Punt *et al.*, 2004).

The methodology of the second form of assessments involves inertial dynamics as described by Witting (2003). Here, the dynamic equations of the assessment model are altered, such that life history traits become density-dependent and specific to whales at time of birth. That is, each whale has its own set of intrinsic values (determined by the state of the population at its time of birth relative to a reference level), which remains constant over time but differs between animals, allowing for cyclical patterns in abundance (Witting, 2003, Punt *et al.*, 2004). The resulting population estimations were able to reconcile the catch histories and recent abundance information (Witting, 2003). The main differences in the models pertain to the assessment time frame and to future predictions, where either a decline (Witting, 2003) or a steady-state is predicted (Punt *et al.*, 2004).

Again, this is a case for which my SSRA becomes too simplistic, and the necessity of more complex models or differently-structured models is evident. The implications of the discrepancies for the global model are, however, limited given overall consistency with a trend that indicates the population is well on its way to full recovery.

The problem with non-stationary effects in model parameters can also be seen when looking at carrying capacity estimates generated by DNA analyses. Roman and Palumbi (2003) use this method to generate a pre-exploitation estimate of 360,000 fin whales in the North Atlantic. To generate such numbers in SSRA, the reported catches would have to have been consistently underestimated by a factor of 10. There could be a number of reasons for the apparent discrepancies. Traditional knowledge offers some indications that marine mammal abundances may have varied by orders of magnitude over relatively short periods in time (Maschner *et al.*, in review). The concept of the existence of a single carrying capacity may thus be overly simplistic as we have seen in this section. If this is indeed the case, the framework on which most management objectives are based will have to be reconsidered. However, there is, in most cases, not enough information in available data to read such a conclusion. This does raise an interesting question of whether all the estimates of carrying capacity I am generating could occur simultaneously given the varying onsets of exploitation.

RESULTS

To validate my results, I compared the estimates of carrying capacity from this study with published estimates (Table 11). Of the 24 species/stock/area combinations with published carrying capacity estimates, 16 have estimates that fall within the 95% confidence limits I generated for the equivalent species/stock combination. These are Southern Hemisphere sei whales, North Pacific sei whales, Southern right whales, sperm whales, Southern Hemisphere fin whales, North Atlantic fin whales, Northern Hemisphere humpback whales, North Pacific humpback whales, North Pacific right whales, Newfoundland's long finned pilot whales, Northern bottlenose whales, Pantropical spotted dolphins in the Eastern Tropical Pacific, Bering Sea ribbon seals, the Falkland stock of South American sea lions in North Patagonia, Californian California sea lions, and the Spitsbergen stock of walrus. Of the remaining 8, 3 come very close. These are the North Pacific fin whales, the Eastern Tropical Pacific spinner dolphins and the Okhotsk sea largha seals.

I estimate the North Pacific fin whale carrying capacity to be 64,500 (49,600 - 88,000). This can be compared to the historical abundance estimated by Ohsumi and Wada (1974), set at 42,000 to 45,000 whales based on a population model incorporating catch and abundance data (Ohsumi and Wada, 1974; Carretta *et al.*, 2004). That estimate falls just below the lower confidence bound of my estimate, 49,600.

For the Eastern Tropical Pacific spinner dolphin, my pre-exploitation estimate is 2,630,000 (2,130,000 – 3,260,000), which differs only marginally from a published estimate of 2,008,000 (Smith, 1983). The differences may be due to problems with estimating the size of by-catch and allocating dolphin by-catch to spinner or spotted dolphins. Given the level of uncertainty, this estimate is close.

For the largha seal in the Sea of Okhotsk, I estimated a carrying capacity of 232,000 (178,000 – 303,000). Fedoseev's (1970) estimate of 170,000 is just below my lower 95% credible interval, 178,000. The estimate of 170,000 is based on late 1960s aerial surveys of the area, which I consider an estimate of carrying capacity because hunting in the Okhotsk Sea is documented as beginning only in 1965. Perhaps the slightly smaller estimate of Fedoseev (1970) is due to its pertaining to a period after the onset of the hunt.

The remaining 5 species warrant some explanation. We begin with the gray whale, for which my total estimate for the Northern Hemisphere is 24,600 (15,900 - 29,000), while the published estimate is 45,000 (Nowak and Walker, 1991). The discrepancy here is due to the data violating the structural model assumptions of the SSRA, i.e., there are likely systematic changes in K and/or r_{max} (see section 4.2), and I expect to underestimate the size of this population.

For blue whales, my Northern Hemisphere estimate was 14,500 (10,510 - 17,120), which is to be compared with a published estimate of 20,100 (Nowak and Walker, 1991). However, Nowak's (1991) estimates are from a general reference book 'Walker's mammals of the world', citing another mammal handbook (Yochem and Leatherwood, 1985). However, I can not make the numbers cited there add to 20,100. I find that, given the number of estimates listed, the total would be 9,100-10,600, which falls within our 95% credible interval. In the Southern Hemisphere population, my estimate is 327,000 (298,000 - 359,000) and Nowak's (1991) is 200,000, which is again cited from Yochem (1985). Yochem (1985) also refers to an estimate of "more than 200,000" by Rice (1978), and also mentions that Gambell (1976) examined 5 sources to give an estimate of 150,000-210,000. The discrepancy may be due to the non-recovery of the stock, which in the absence of hunting is suggesting a very low intrinsic rate of growth for these animals. If this rate is negatively biased, the result would be a positive bias in the carrying capacity parameter. In the Southern Hemisphere, my SSRA predicts that at least some recovery should be occurring given the ban on hunting blue whales. However, continued hunting is likely still threatening the species (Baker and Palumbi, 1994). According to my SSRA, the annual human-induced mortality required to circumvent recovery of the Antarctic blue whales would be equal to $N_t r_{\max} (1 - \frac{N_t}{K})$, which for the current population would be (N_t = 1180, r_{max} = 0.01, K = 327,000), between 11 and 12 whales per year. Anything higher than this level would result in stock declines. So the question becomes: is the annual human induced mortality, including ship strikes, entanglement, hunting, etc., this high, or is the intrinsic rate of growth just very low, or are we seeing a combination of effects?

Table 11: Available published and predicted carrying capacities/pre-exploitation abundances

Species – Ocean basin (SH = Southern hemisphere, NH = Northern hemisphere, ETP = Eastern Tropical Pacific)	Onset of recorded catch (year)	Predicted pre-exploitation numbers (95% Confidence level)	Published Carrying capacities (P = Pacific)
Sei whale – SH	1904	167,000 (157,000 - 190,000)	200,000[i]
Sei whale – NP	1904	68,400 (54,600 - 85,600)	70,000[ii] (P), 42,000[iii] (NP), 58-62,000[iiib](NP)
Southern right whale	1785	86,100 (73,400 - 98,300)	80,000[iiic]
Sperm whale	1800	957,000 (751,000 - 1,350,000)	1,100,000[ix]
Fin whale – SH	1904	625,000 (469,000 - 737,000)	600,000[i]
Fin whale – NA	1876	72,900 (54,900 - 111,000)	30,000 - 50,000[xviii], 50,000 – 100,000[xviv]
Fin whale – NP	1903	64,500 (49,600 - 88,000)	42,000 – 45,000[v]
Gray whale	1600	24,600 (15,900 - 29,000)	45,000[i]
Blue whale – SH	1904	327,000 (298,000 - 359,000)	200,000[i] , 200,000[xvc], 150,000-210,000[xvd,xvc]
Blue whale – NH	1868	14,500 (10,510 - 17,120)	20,100[i] , 9,100-10,600[xvc]
Bowhead whale	1650	89,000 (67,000 - 114,000)	50,000[vii], 74,000[viii], 43,000[i]
Humpback whale - SH	1904	199,000 (144,000 - 228,000)	100,000[i]
Humpback whale - NH	1664	32,700 (21,800 - 57,400)	50,000[i]
Humpback whale - NP	1664	16,500 (10,500 - 24,100) NP	15,000[vi] (North P)
North Pacific right whale	1835	9,720 (8,540 – 12,600)	11,000+ [iv] (Northeast P)
Long-finned pilot whale – Newfoundland	1947	57,800 (50,800 – 67,100)	60,000[x] (Newfoundland)
Northern Bottlenose whale - NA	1584	57800 (44200 - 84700)	40,000 – 100,000 (Eastern NA)[xvb]
Pantropical spotted dolphin - ETP	1959	4,590,000 (3,740,000 – 5,740,000)	5,590,000[xi] (Eastern Tropical Pacific)
Spinner dolphin - ETP	1959	2,630,000 (2,130,000 – 3,260,000)	2,008,000[xi] (Eastern Tropical Pacific)
Ribbon seal - Bering sea	1950	135,000 (113,000 – 164,000)	120,000[xii] (Bering sea)
Largha - Okhotsk	1965	232,000 (178,000 – 303,000)	170,000[xiii] (Okhotsk)
South American sea lion - Falklands	1930	110,000 (86,200 – 141,000)	137,000[xiv] (Falklands)
California sea lion - California	1980	155,000 (123,000 – 194,000)	145,000[xv] (USA and Mexico Pacific coast), 67,000[xvi] (US Stock)
Walrus - Spitsbergen	1660	82,100 (53,900 – 90,300)	25,000[xvii] (Spitsbergen)

i = (Nowak and Walker, 1991), ii = (Horwood, 2002), iii = (Tillman, 1977) and (Carretta *et al.*, 2003), iiib = (Ohsumi and Wada, 1974), iiic = (Baker and Clapham, 2004), iv = (NMFS, 1991) and (Angliss and Lodge, 2003), v = (Ohsumi and Wada, 1974) and (Carretta *et al.*, 2004), vi = (Rice, 1978) and (Calambokidis *et al.*, 1997), vii = (Woodby and Botkin, 1993) and (Finley, 2001), viii = (Hacquebord and Leinenga, 1994), (Weslawski *et al.*, 2000), (Woodby and Botkin, 1993), (Angliss *et al.*, 2001), (Mitchell and Reeves, 1981), (Finley, 2001) and (Rugh *et al.*, 2003), ix = (Whitehead, 2002), x = (Mercer, 1975), xi = (Smith, 1983), xii = (Burns, 1994), xiii = (Mizuno *et al.*, 2002) and (Fedoseev, 1970), xiv = (Dans *et al.*, 2004) (Godoy, 1963), xv = (Le Boeuf *et al.*, 1983, Reijnders *et al.*, 1993), xvi = (Carretta *et al.*, 2003), xvii = (Weslawski *et al.*, 2000), xviii = (Sergeant, 1977), xviv = (Sigurjónsson, 1995). xvb =(Nowak and Walker, 1991), (Benjaminsen and Christensen, 1979), xvc = (Yochem and Leatherwood, 1985), xvd = (Gambell, 1976).

The next species for which a divergence between this model and published estimates exists, is the Southern Hemisphere humpback whale. I estimate the carrying capacity of this species to be 199,000 (144,000 - 228,000), while the published estimate is 100,000 (Nowak and Walker, 1991). This was taken from Johnson and Wolman (1982), who state that the original Southern Hemisphere humpback whale size was “about 100,000”. However, no reference is given for how this was calculated.

The last stock for which my estimates of historical stock size differ is for the Spitsbergen stock of walrus. My carrying capacity estimate was 82,100 (53,900 – 90,300), while the published estimate by Weslawski *et al.* (2000) is 25,000. However, the authors of that estimate mention that walrus hunting was ill documented, and their estimate is considered a guesstimate based on the population size of Franz Joseph Land relative to the size of that area. My estimate covers both Franz Joseph Land and Spitsbergen, but is based on the assumption that the total catch of 90,740 animals, which does not include subsistence catch (Ross, 1993), was split evenly in the time period 1660-1911. There is a lot of uncertainty in these estimates, which likely explains the quite significant differences.

In conclusion, Table 11 serves as a good validation of the model, and given the uncertainties (section 4.1 and 4.2) inherent in this kind of analysis on a global scale, I am confident the method is contextually appropriate and may be used with due consideration of uncertainty in catch and abundance estimates. Recall that these estimates are not generated for management purposes, but for the purposes of looking at the overall trends in marine mammal abundance.

Tamura and Ohsumi (2003) work attempted to estimate prey consumption for cetaceans, to quantify competition with commercial fisheries. Their report has been heavily criticised by Holt (2006), who identifies a number of unjustified assumptions and leaps of faith and alleges that they are over inflating their estimates to scale up the problem. This takes us back to the context of management. At this years IWC meeting, the St. Kitts and Nevis declaration was passed, including this segment:

"...ACCEPTING that scientific research has shown that whales consume huge quantities of fish making the issue a matter of food security for coastal nations and requiring that the issue of management of whale stocks must be considered in a broader context of ecosystem management since eco-system management has now become an international standard ..."

\- St. Kitts and Nevis Declaration, IWC Meeting 58

This is exactly the argument that Tamura and Ohsumi (2003) make. This argument has led to a number of papers by Kaschner and colleagues on overlap between mammals and fisheries (Kaschner and Pauly, 2004; Kaschner *et al.*, in press), and most recently to a paper looking at this issue historically with the abundance trends presented in this paper (Kaschner *et al.*, 2006). Kaschner and Pauly (2004) conclude that spatial overlap of marine mammals and commercial fishery operations is low, and find no evidence of competition on a global scale. In Kaschner *et al.* (2006), we conclude that marine mammals are being replaced by fisheries as top consumers in almost all of the areas where they intersect. This stands in stark contrast to the report by Tamura (2003) and the St. Kitts and Nevis declaration. It is my hope that this thesis will lead to more of this kind of work, where marine mammals are seen in the context of their histories and biology.

Conclusion

In this report I have determined that globally aggregated information on all marine mammal populations indicate a decline of 22% (0-62%) in numbers, and 76% (58-86%) in biomass. The decline has been greatest for the great whales, which were exposed to sequential declines dependent on animal size and speed. Globally, the aggregated great whale populations have declined by 64% (40-79%) by numbers, and 81% (69-89%) in terms of biomass. These estimates are consistent with published estimates of carrying capacities.

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This work is dedicated to my relatives; the fishermen and their wives who have lived with the North Sea in their homes. My great-grandparents Jørgen Christian (Krænfus) and Anne Marie Christensen, my grandparents Martin (Maggefus, Magge Frænde) and Gudrun Christensen, my uncle Jørgen and father Villy Christensen.

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APPENDICES

APPENDIX I: ESTIMATED POPULATION SIZES FOR UNEXPLOITED PORTIONS OF EXPLOITED MARINE MAMMAL POPULATIONS

The numbers used in this Appendix and in Appendix II are all taken from Kristin Kaschner's PhD thesis (2004). I am making the assumption that the mean value mirrors the actual population size and that the minimum and maximum values approximate a 95% credible interval.

Species	Ocean Basin	Min	Mean	Max
Short-finned pilot whale	North East Atlantic, Northern Gulf Mexico, Hawaii, Eastern Tropical Pacific (ETP), US West Coast	116,000	170,000	440,000
Baird's beaked whale	Sea of Okhotsk	330	660	990
Killer whale	ETP	4,700	8,500	15,900
Long-finned pilot whale	Southern Hemisphere	63,000	200,000	337,000
False killer whale	ETP, Gulf of Mexico, Hawaii	11,800	40,520	220,000
Narwhal	Canadian High Arctic, Scoresby	14,800	18,300	21,800
Pantropical spotted dolphin	Hawaii, Malaysia, US East Coast	6,050	19,500	95,600
Spinner dolphin	Sulu Sea, Hawaii	16,000	33,200	101,000
Short beaked common dolphin	California, Black Sea, Bay of Biscay, Celtic Sea	370,000	607,000	1,700,000
Dall's porpoise	Everywhere but Japan	348,000	713,000	762,000
Bottlenose dolphin	ETP, Hawaii, Coastal California, Gulf of Mexico, ICES area, Black Sea, Mediterranean, South Africa	240,000	316,000	516,000
Harbour Porpoise	Black Sea, US West Coast, Canada West Coast, Alaksa	42,000	126,800	212,500
Atlantic white-sided dolphin	Gulf of St. Lawrence, North Sea, West of Ireland	37,000	82,300	188,500
Gray seal	Sable Island, Gulf of St. Lawrence, Finnmark, Murmansk, Nordland, Baltic Sea	128,000	167,000	215,000
Harp seal	Eastern North Atlantic	4,100,000	4,750,000	5,000,000
Bearded seal	Canadian Arctic, US Alaskan Waters	130,000	195,000	260,000
Harbour seal	Baltic Sea, Wadden Sea, Britain, Iceland, North West Atlantic, British Columbia, Alaska	350,000	350,000	380,000
Largha or spotted seal	China	4,500	4,500	4,500
South African and Australian fur seal	South Australia	30,000	40,000	50,000
Northern fur seal*	Kuril Islands, Robben Island, San Miguel Island, Commander Islands	334,000	344,000	354,000
South American sea lion	Chile, Argentina, Uruguay, Peru	140,000	180,000	240,000
California sea lion	Gulf of Mexico, Gulf of California	33,000	49,000	53,000
Steller sea lion*#	Russia, California/Oregon/Washington	15,464	15,464	15,464
Walrus	North West Atlantic, Laptev Sea	14,000	14,500	15,000

*Reijnders, 1993. #Angliss, 2002.

APPENDIX II: TOTAL POPULATION SIZES OF UNEXPLOITED MARINE MAMMAL POPULATIONS

Species	min	mean	max
Subantarctic fur seal	310,000	350,000	400,000
Crabeater seal	10,000,000	12,500,000	20,000,000
Juan Fernandez fur seal	15,000	18,000	30,000
Leopard seal	220,000	296,454	440,000
Northern elephant seal	61,000	101,000	150,000
Weddell seal	200,000	400,000	1,000,000
Pacific white-sided dolphin	200,000	990,000	4,200,000
Risso's dolphin	170,000	308,000	1,000,000
Southern bottlenose whale	450,000	560,000	700,000
Striped dolphin	1,960,000	2,700,000	7,000,000
Ross seal	100,000	130,000	400,000
Rough-toothed dolphin	90,000	150,000	500,000
Southern right whale dolphin	50,000	270,000	1,000,000
Fraser's dolphin	150,000	300,000	1,000,000
Atlantic spotted dolphin	40,000	80,000	400,000
Hooker's or New Zealand sea lion	11,100	12,500	14,000
Hourglass dolphin	100,000	145,000	200,000
Melon headed whale	39,000	51,000	200,000
White-beaked dolphin	16,000	26,000	60,000
Guadalupe fur seal	3,000	7,400	10,000
Pygmy killer whale	20,000	40,000	100,000
Pygmy right whale	1,000	3,000	10,000
Pygmy sperm whale	3,200	5,300	15,000
Dwarf sperm whale	8,000	12,500	36,000
Finless porpoise	10,000	20,000	40,000
Hawaiian monk seal	1,437	1,463	1,500
Clymene dolphin	12,000	18,000	56,000
Mediterranean monk seal	300	380	470
Long-beaked common dolphin	20,000	32,000	87,000
South American fur lion	235,000	285,000	320,000
New Zealand fur seal	135,000	150,000	200,000
Galapagos fur seal	30,000	40,000	50,000
Pygmy beaked whale	1,000	2,500	5,000
Sowerby's beaked whale	1,000	1,500	3,000
Stejneger's beaked whale	1,000	1,500	3,000
Strap-toothed whale	1,000	1,500	3,000
Gervais' beaked whale	1,000	1,500	3,000
Ginkgo-toothed beaked whale	1,000	1,500	3,000
Gray's beaked whale	1,000	1,500	3,000
Hector's beaked whale	1,000	1,500	3,000
Andrews' beaked whale	1,000	1,500	3,000
Arnoux's beaked whale	1,000	1,500	3,000
Blainville's beaked whale	10,000	15,000	30,000
Cuvier's beaked whale	21,700	28,000	70,000
Hubb's beaked whale	1,000	1,500	3,000
Tasman or Shepherd's beaked whale	1,000	1,500	3,000
True's beaked whale	1,000	1,500	3,000
Longman's beaked whale	1,000	5,000	10,000
Spade-toothed beaked whale	1,000	1,500	3,000
Perrin's beaked whale	1,000	1,500	3,000
Peale's dolphin	1,000	3,000	10,000
Dusky dolphin	4,039	10,000	20,000
Franciscana	4,000	20,000	60,000
Heaviside's dolphin	1,000	3,000	5,000
Hector's dolphin	5,300	7,300	10,000
Atlantic hump-backed dolphin	120	500	1,000
Australian sea lion	9,300	10,500	11,700
Black dolphin	1,000	1,500	3,000
Burmeister's porpoise	5,000	10,000	50,000
Commerson's dolphin	800	1,300	5,000
Pacific hump-backed dolphin	2,600	1,300	1,100
Irrawaddy dolphin	2,600	1,300	1,000
Tucuxi	1,000	3,000	10,000
Vaquita	77	567	1,073
Galapagos sea lion	10,000	14,000	25,000
Indian hump-backed dolphin	600	1,200	2,400
Indian Ocean bottlenose dolphin	1,500	5,000	7,500
Arabian common dolphin	5,000	10,000	15,000
Spectacled porpoise	1,000	3,000	10,000

APPENDIX III: SPECIES LIST

This is a list of the marine mammal species including their common and scientific names, information on whether exploitation data exists, a Male:Female ratio (expressed as % of the population that is female) and the average weights for females and males in t. Data for the three latter columns are taken from Trites and Pauly (1998).

Common name (Scientific name)	Exploited	Male:Female ratio (% ♀)	Mean weight female (t)	Mean weight male (t)
Sei whale (*B. borealis*)	Y	0.5	17.3869	16.2347
Southern right whale (*E. australis*)	Y	0.5	19.576	16.5743
Sperm whale (*P. catodon*)	Y	0.5	10.0976	26.9387
Fin whale (*B. physalus*)	Y	0.5	59.8189	51.3614
Gray whale (*E. robustus*)	Y	0.5	15.6528	15.0904
Blue whale (*B. musculus*)	Y	0.5	110.1258	95.3471
Bowhead whale (*B. mysticetus*)	Y	0.5	30.7448	31.4056
Eden/Bryde's whale (*B. edeni*)	Y	0.5	16.9047	15.3808
Humpback whale (*M. novaeangliae*)	Y	0.5	32.493	28.3234
Dwarf minke whale (*B. acutorostrata*)	Y	0.5	7.0111	6.1213
North Atlantic right whale (*E. glacialis*)	Y	0.5	24.9599	21.8054
Antarctic minke whale (*B. bonaerensis*)	Y	0.5	7.0111	6.1213
Bryde's whale (*B. brydei*)	Assessed with *B. edeni*			
North Pacific right whale (*E. japonica*)	Y	0.5	24.9599	21.8054
Ribbon seal (*H. fasciata*)	Y	0.5	0.0714	0.0715
Ringed seal (*P. hispida*)	Y	0.5	0.0407	0.0443
Southern elephant seal (*M. leonina*)	Y	0.5	0.3267	0.5428
Subantarctic fur seal (*A. tropicalis*)	N	0.6	0.0246	0.0301
Gray seal (*H. grypus*)	Y	0.5	0.1519	0.1683
Harp seal (*P. groenlandicus*)	Y	0.5	0.0922	0.0922
Crabeater seal (*L. carcinophagus*)		0.5	0.2162	0.196
Hooded seal (*C. cristata*)	Y	0.5	0.1402	0.1086
Juan Fernandez fur seal (*A. philippii*)	N	0.6	0.031	0.0402
Leopard seal (*H. leptonyx*)	N	0.5	0.5462	0.3823
Northern elephant seal (*M. angustirostris*)	N	0.5	0.3303	0.4117
Walrus (*O. rosmarus*)	Y	0.5	0.5302	0.6425
Weddell seal (*L. weddellii*)	N	0.5	0.1625	0.1541
Bearded seal (*E. barbatus*)	Y	0.5	0.1998	0.1998
Antarctic fur seal (*A. gazella*)	Y	0.6	0.0227	0.0307
South African and Australian fur seal (*A. pusillus*)	Y	0.6	0.059	0.054
Northern fur seal (*C. ursinus*)	Y	0.6	0.0253	0.0302
Pacific white-sided dolphin (*L. obliquidens*)	N	0.5	0.0727	0.0836
Pantropical spotted dolphin (*S. attenuata*)	Y	0.5	0.0591	0.0717
Risso's dolphin (*G. griseus*)	N	0.5	0.2113	0.2359
Short-finned pilot whale (*G. macrorhynchus*)	Y	0.5	0.467	0.8189
Southern bottlenose whale (*H. planifrons*)	N	0.5	1.3306	0.8268
Spinner dolphin (*S. longirostris*)	Y	0.5	0.0395	0.0431
Striped dolphin (*S. coeruleoalba*)	N	0.5	0.1145	0.1167
Baird's beaked whale (*B. bairdii*)	Y	0.5	3.7936	2.4787
Beluga or white whale (*D. leucas*)	Y	0.5	0.2885	0.3375
short beaked common dolphin (*D. delphis*)	Y	0.5	0.0683	0.092
Dall's porpoise (*P. dalli*)	Y	0.5	0.0613	0.0613
Killer whale (*O. orca*)	Y	0.5	1.9738	2.5871

Species list (cont …)				
Common name	Exploited	Male:Female ratio (% ♀)	Mean weight female (t)	Mean weight male (t)
Long-finned pilot whale (*G. melas*)	Y	0.5	0.6721	1.0285
Northern bottlenose whale (*H. ampullatus*)	Y	0.5	1.6399	1.7382
Bottlenose dolphin (*T. truncatus*)	Y	0.5	0.1719	0.2032
Northern right whale dolphin (*L. borealis*)	Y	0.5	0.0683	0.1411
Ross seal (*O. rossii*)	N	0.5	0.163	0.1285
Rough-toothed dolphin (*S. bredanensis*)	N	0.5	0.0877	0.0963
South American sea lion (*O. flavescens*)	Y	0.6	0.1198	0.1026
Southern right whale dolphin (*L. peronii*)	N	0.5	0.0683	0.0547
False killer whale (*P. crassidens*)	Y	0.5	0.4645	0.6916
Fraser's dolphin (*L. hosei*)	N	0.5	0.0954	0.0954
Harbour porpoise (*P. phocoena*)	Y	0.5	0.0326	0.0295
Harbour seal (*P. vitulina*)	Y	0.5	0.0584	0.0688
Atlantic spotted dolphin (*S. frontalis*)	N	0.5	0.0675	0.0654
Atlantic white-sided dolphin (*L. acutus*)	Y	0.5	0.078	0.1054
California sea lion (*Z. californianus*)	Y	0.6	0.0856	0.0621
Hooker's or New Zealand sea lion (*P. hookeri*)	N	0.6	0.0856	0.1752
Hourglass dolphin (*L. cruciger*)	N	0.5	0.0391	0.0295
Largha or spotted seal (*P. largha*)	Y	0.5	0.0389	0.05
Melon-headed whale (*P. electra*)	N	0.5	0.1054	0.1036
Narwhal (*M. monoceros*)	Y	0.5	0.2622	0.3881
White-beaked dolphin (*L. albirostris*)	N	0.5	0.1356	0.1467
Guadalupe fur seal (*A. townsendi*)	N	0.6	0.0243	0.029
Pygmy killer whale (*F. attenuate*)	N	0.5	0.078	0.1169
Pygmy right whale (*C. marginata*)	N	0.5	2.1602	1.9694
Pygmy sperm whale (*K. breviceps*)	N	0.5	0.1766	0.1766
Steller sea lion (*E. jubatus*)	Y	0.6	0.1864	0.2136
Dwarf sperm whale (*K. simus*)	N	0.5	0.1008	0.1008
Finless porpoise (*N. phocaenoides*)	N	0.5	0.0381	0.0429
Hawaiian monk seal (*M. schauinslandi*)	N	0.5	0.163	0.0986
Clymene dolphin (*S. clymene*)	N	0.5	0.0468	0.0468
Mediterranean monk seal (*M. monachus*)	N	0.5	0.2809	0.2488
long-beaked common dolphin (*D. capensis*)	N	0.5	0.0683	0.092
South American fur seal (*A. australis*)	N	0.6	0.031	0.029
New Zealand fur seal (*A. forsteri*)	N	0.6	0.031	0.0343
Galapagos fur seal (*A. galapagoensis*)	N	0.6	0.0187	0.0166
Pygmy beaked whale (*M. peruvianus*)	N	0.5	0.1921	0.1768
Sowerby's beaked whale (*M. bidens*)	N	0.5	0.4622	0.4482
Stejneger's beaked whale (*M. stejnegeri*)	N	0.5	0.508	0.4018
Strap-toothed whale (*M. layardii*)	N	0.5	0.7464	0.5159
Gervais' beaked whale (*M. europaeus*)	N	0.5	0.4963	0.2887
Ginkgo-toothed beaked whale (*M. ginkgodens*)	N	0.5	0.4295	0.3209
Gray's beaked whale (*M. grayi*)	N	0.5	0.527	0.4754
Hector's beaked whale (*M. hectori*)	N	0.5	0.3361	0.2515
Andrews' beaked whale (*M. bowdoini*)	N	0.5	0.3625	0.3053
Arnoux's beaked whale (*B. arnuxii*)	N	0.5	1.809	1.6561
Blainville's beaked whale (*M. densirostris*)	N	0.5	0.3901	0.5076
Cuvier's beaked whale (*Z. cavirostris*)	N	0.5	0.8863	0.7708
Hubb's beaked whale (*M. carlhubbsi*)	N	0.5	0.5246	0.4145

Species list (cont …)				
Common name	Exploited	Male:Female ratio (% ♀)	Mean weight female (t)	Mean weight male (t)
Tasman or Shepherd's beaked whale (*T. shepherdi*)	N	0.5	0.8863	0.7892
True's beaked whale (*M. mirus*)	N	0.5	0.4734	0.4163
Longman's beaked whale (*I. pacificus*)	N	0.5	1.2095	0.9279
Spade-toothed beaked whale (*M. traversii*)	N	0.5	0.454017	0.376908
Perrin's beaked whale (*M. perrini*)	N	0.5	0.454017	0.376908
Peale's dolphin (*L. australis*)	N	0.5	0.0586	0.0586
Dusky dolphin (*L. obscurus*)	N	0.5	0.0446	0.0553
Franciscana (*P. blainvillei*)	N	0.5	0.0313	0.0223
Heaviside's dolphin (*C. heavisidii*)	N	0.5	0.0327	0.0327
Hector's dolphin (*C. hectori*)	N	0.5	0.0367	0.0298
Atlantic hump-backed dolphin (*S. teuszii*)	N	0.5	0.0719	0.082
Australian sea lion (*N. cinerea*)	N	0.6	0.059	0.0709
Black dolphin (*C. eutropia*)	N	0.5	0.0304	0.0313
Burmeister's porpoise (*P. spinipinnis*)	N	0.5	0.0423	0.0423
Commerson's dolphin (*C. commersonii*)	N	0.5	0.0295	0.0274
Pacific hump-backed dolphin (*S. chinensis*)	N	0.5	0.0788	0.1524
Irrawaddy dolphin (*O. brevirostris*)	N	0.5	0.0697	0.1054
Tucuxi (*S. fluviatilis*)	N	0.5	0.0386	0.0386
Vaquita (*P. sinus*)	N	0.5	0.0241	0.0204
Galapagos sea lion (*Z. wollebaeki*)	N	0.5	0.0856	0.0621
Indian hump-backed dolphin (*S. plumbea*)	N	0.5	0.0719	0.082
Indian Ocean bottlenose dolphin (*T. aduncus*)	N	0.5	0.1719	0.2032
Arabian common dolphin (*D. tropicalis*)	N	0.5	0.0683	0.092
Spectacled porpoise (*P. dioptrica*)	N	0.5	0.051	0.064

APPENDIX IV: MODEL INPUT

Species – Area (NA = North Atlantic, NP = North Pacific, SH = Southern Hemisphere, G = Global, A = Arctic, NEP = Northeast Pacific, NWP = Northwest Pacific, NWA = Northwest Atlantic)	Carrying Capacity uniform prior (lower bound – upper bound)	CID	Abundance points the models are fit to for each species (year, number)	Sources
Sei whale - NA	5,000-20,000	5	1991, 4,000 1995, 9,250	(Braham, 1991), (Perry *et al.*, 1999), (NAAMCO, 1997)
Sei whale - NP	5,000-150,000	3	1974, 9,110 1989, 10,300	(Tillman, 1977),(Carretta *et al.*, 2001), http://luna.pos.to/whale/iwc_chair92_11.html
Sei whale - SH	150,000-300,000	1	1965, 40,000	(Borchers *et al.*, 1990), (Klinowska, 1991), (IWC, 1996), (Perry *et al.*, 1999)
Right whale - SH	80,000-150,000	4	1972, 4300	(Masaki, 1972), (Cummings, 1985), (IWC, 1998), (Perry *et al.*, 1999)
Sperm whale - G	500,000-1,500,000	5	1999, 361,400	(Whitehead, 2002)
Fin whale – NA	40,000-100,000	5	1969-1989, 47,300	(IWC, 1992), (Tamura and Ohsumi, 2000), (IWC, 2004)
Fin whale - NP	50,000-100,000	3	1973, 16,150 1975, 16,625	[2] (Braham, 1991), (Perry *et al.*, 1999)
Fin whale - SH	500,000-1,000,000	1	1978-1988, 15,178	(IWC, 1996, Perry *et al.*, 1999)
Gray whale - NEP	20,000-30 ,000	3	1900, 1967-2001, several 1900, 160 1967, 13,012 1968, 12,244 1969, 12,777 1970, 11,170 1971, 9,841 1972, 16,962 1973, 14,817 1974, 13,134 1975, 14,811 1976, 15,950 1977, 17,127 1978, 13,300 1979, 16,581 1984, 21,942 1985, 20,450 1987, 21,113 1992, 17,647 1993, 23,109 1995, 22,263 1997, 26,300 1997, 26,635 2001, 18,761	(Buckland *et al.*, 1993), (Butterworth *et al.*, 2002), (Hobbs and Rugh, 1999), (Tamura and Ohsumi, 2000) (Townsend, 1886), (Buckland *et al.*, 1993), (Butterworth *et al.*, 2002), (IWC, 1989), (Laake *et al.*, 1994), , (Hobbs *et al.*, 1996), (Buckland and Breiwick, 2002), , (Tamura and Ohsumi, 2000), (Hobbs and Rugh, 1999),(Angliss and Lodge, 2003), (IWC, 2003), (Deecke, 2004)

[2] http://www.nmfs.noaa.gov/pr/PR2/Stock_Assessment_Program/Cetaceans/Fin_Whale_(CA-OR-WA)/p003finwhalecaorwa.pdf

Species – Area	K	CID	Abund pts	Sources
Model input cont …				
Gray whale - NWP	3,000-5,000	4	1982, 150	(Yablokov and Bogoslovskaya, 1984), (Klinowska, 1991), (Jones and Swartz, 2002)
Blue whale – NA	6,000-12,000	3	1995, 330 (NWA only)	(Perry *et al.*, 1999)
Blue whale - NP	4,000-8,000	5	1975, 1600 1995, 3300	(Perry *et al.*, 1999), (Gambell, 1976)
Blue whale - SH	340,000-480,000	3	1980-2000, 900 1995, 1260	(IWC, 2004), (IWC, 1996), (Perry *et al.*, 1999)
Bowhead whale - A	70,000-100,000	4	1978, 5189 1980, 4998 1981, 5756 1982, 7874 1983, 7547 1985, 6839 1986, 11100 1988, 7379 1993, 9000 2001, 11270 2001, 10660	(Woodby and Botkin, 1993), (Angliss *et al.*, 2001), (Finley, 2001), (Mitchell and Reeves, 1981), (Vladimirov, 1994, Shelden and Rugh, 1995), (Mitchell and Reeves, 1982), (Finley *et al.*, 1990), (Cosens *et al.*, 1997), (Clapham *et al.*, 1999), (Rugh and Shelden, 2002), (Zeh *et al.*, 1993), (Tamura and Ohsumi, 2000), (Rugh *et al.*, 2003), (Tillman, 1984), (Reeves and Leatherwood, 1985), (Trites *et al.*, 1997), (Angliss and Lodge, 2003), (Raftery *et al.*, 1995), (da Silva *et al.*, 2000), (Angliss *et al.*, 2001), (Tamura and Ohsumi, 2000), (Weslawski *et al.*, 2000), (Raftery and Zeh, 1991), (Zeh *et al.*, 1995), (Zeh *et al.*, 1994), (George *et al.*, 2002), (George *et al.*, 2004)
Bryde's whale – NP	20,000-80,000	2	1986, 35,639	(Miyashita, 1986, Grass *et al.*, 1993, Kato, 2002)
Bryde's whale - SH	40,000-140,000	3	1975, 89,000	(Ohsumi, 1981, Tamura and Ohsumi, 2000)
Humpback whale – NA	13,000-19,000	1	1992, 11,570 1992, 10,600	(Stevick *et al.*, 2003), (Waring *et al.*, 2002), (Smith *et al.*, 1999), (Perry *et al.*, 1999)
Humpback whale – NP	10,000-25,000	5	1995, 7000 1999, 6000	(Calambokidis *et al.*, 2001), (Perry *et al.*, 1999), (Calambokidis *et al.*, 1997)
Humpback whale – SH	100,000-300,000	5	1980, 19,851 1985, 20,000 1995, 17,000	(Butterworth *et al.*, 1995), (IWC, 1996), (Laws and Hofman, 1977), (Tamura and Ohsumi, 1999), (Perry *et al.*, 1999)
Commmon minke whale – NA	100,000-250,000	3	1995, 149,000	(IWC, 2004), (Tamura and Ohsumi, 2000)
Common minke whale - NP	40,000-60,000	2	1990, 27570	(Moore *et al.*, 2000), (Barlow, 1997), (Carretta *et al.*, 2001), (Buckland *et al.*, 1992), (IWC, 2004), (Tamura and Ohsumi, 2000)
Antarctic minke whale - SH	250,000-450,000	1	1995, 312,000	(IWC, 2003)
Right whale - NA	30,000 – 40,000	3	1992, 295 1995, 291	(Knowlton *et al.*, 1994), (Perry *et al.*, 1999), (Kraus *et al.*, 2001), (Waring *et al.*, 2002)
Right whale – NP	8,000 – 15,000	4	1970, 225 1990, 1200 1995, 7000 1978 – 1987, 9,718	(Wada, 1971, Klinowska, 1991), (IWC, 1998), (Perry *et al.*, 1999), (Tamura and Ohsumi, 2000)
Short-finned pilot whale - Japan	40,000-70,000	1	1985, 53,,608 1985, 53,347 1990, 53,347	(IWC, 1987, Miyashita, 1993, Stacey and Baird, 1993)
Baird's beaked whale - Japan	5,000-15,000	1	1990, 6289	(Kasuya and Miyashita, 1997, Kasuya, 2002)
Beluga whale - Arctic	50,000 – 400,000	5	1999, 92,500	(Frost *et al.*, 1993, R. Hobbs Beluga abundance in Bering Sea. pers. comm. to Angliss, R. P. National Marine Mammal Laboratory, Seattle, 2000, Hobbs *et al.*, 2000, IWC, 2000, Angliss and Lodge, 2002)
Killer whale – NA	2,000-20,000	5	1987, 8600	(Christensen, 1988, Gunnlaugsson and Sigurjónsson, 1990, Sigurjónsson and Víkingsson, 1997, Dahlheim and Heyning, 1999)
Killer whale – NP	1,000-10,000	5	1995, 4,000	(Kaschner, 2004)

Species – Area	K	CID	Abund pts	Sources
Model input cont …				
Killer whale – SH	10,000-60,000	5	1990, 24,800	(Branch and Butterworth, 2001)
Long-finned pilot whale – Faroe Islands	700,000-900,000	1	1989, 780000	(Buckland *et al.*, 1993)
Long-finned pilot whale – Newfoundland	10,000-100,000	5	1980, 13000	(Hay, 1982, Buckland *et al.*, 1993)
Northern bottlenose whale - NA	20,000-90,000	5	1994, 44,500	(Kaschner, 2004)
False killer whale - Japan	10,000-30,000	1	1985, 16000 1990, 16000	(Miyashita, 1993)
Narwhal – Baffin Bay Canada	20,000-80,000	1	1996, 43358	(Innes *et al.*, 2002, COSEWIC, 2004)
Narwhal – Hudson Bay	5,000-20,000	3	2001, 3500	(COSEWIC, 2004)
Narwhal – Baffin Bay Greenland	10,000-25,000	5	2001, 6650	(WWF, 2005)
Pantropical spotted dolphin - ETP	3,000,000-7,000,000	1	1998, 1862559 1999, 1377082	(Gerrodette, 1999, Gerrodette, 2000, Culik, 2002)
Pantropical spotted dolphin - Japan	3,000,000-7,500,000	1	1985, 438064 1990, 438064	(Miyashita, 1993)
Spinner dolphin - ETP	1,500,000-3,500,000	1	1990, 1651000	(Wade and Gerrodette, 1993)
Short beaked common dolphin - ETP	2,000,000-4,000,000	1	1988, 3112300 1990, 3093300	(Holt and Sexton, 1990, Wade and Gerrodette, 1993, Evans, 1994)
Short beaked common dolphin - NWA	20,000-60,000	1	1998, 37509	(Waring *et al.*, 2002, Palka *et al.*, in review)
Dall's porpoise - Japan	400,000-1,200,000	5	1991, 443000	(Bass, 2005)
Bottlenose dolphin – NWA	10,000-50,000	1	1998, 30633	(Waring *et al.*, 2002)
Bottlenose dolphin - Japan	100,000-250,000	2	1985, 168792 1990, 168792	(Miyashita, 1993)
Northern right whale dolphin - NP	200,000-600,000	3	1985, 307784 1990 , 307784 1991, 247000	(Miyashita, 1991, Hobbs and Jones, 1993, Mangel, 1993, Miyashita, 1993)
Harbour porpoise – Greenland	20,000-80,000	4	1988, 15000	(Klinowska, 1991)
Harbour porpoise – North Sea	150,000-500,000	1	1994, 279367	(IWC, 1996, Read, 1999)
Harbour porpoise - Baltic	5,000-100,000	1	1994, 36046	(IWC, 1996, Read, 1999)
Harbour porpoise - NWA	60,000-190,000	3	1995, 101700 1996, 111400	(Kingsley and Reeves, 1998, Palka, 2000, Waring *et al.*, 2002)
Atlantic white-sided dolphin – NWA/US	500-40,000	5	1991, 20400 1992, 20400	(Palka, 1995, Palka *et al.*, 1997)
Ribbon seal – Bering sea	40,000-200,000	5	1955, 120000 1969, 65000 1975, 95000 1987, 130,000	(Burns, 1981, Burns, 1994, Angliss and Lodge, 2002, Fedoseev, 2002)
Ringed seal – NA & Arctic	2,000,000-6,000,000	3	1985, 1289000	(Lunn *et al.*, 1997, Born *et al.*, 1998, Kingsley, 1998, Reeves, 1998)
Ringed seal – Baltic	120,000-180,000	4	1945, 25000 1955, 6000 1975, 10000 2001, 5500	(Härkönen *et al.*, 1998, Anon., 2001)

Species – Area	K	CID	Abund pts	Sources
Model input cont …				
Ringed seal – NP & Arctic	3,000,000-6,000,000	5	1986, 4470560	(Popov, 1982, Frost *et al.*, 1988, Reijnders *et al.*, 1993, Reeves, 1998, Angliss and Lodge, 2002)
Southern elephant seal - SH	500,000-1,500,000	5	1982, 750,000 1990, 664,000	(Laws, 1984, Knox, 1994, Laws, 1994, Le Boeuf and Laws, 1994)
Gray seal – Iceland	3,000-30,000	5	1985, 11600	(Hauksson, 1987, Reijnders *et al.*, 1993)
Gray seal - Scotland	50,000-200,000	4	2001, 110500	(Duck, 2005)
Harp seal – West Ice	100,000-1,200,000	5	1990, 286000	(ICES, 1994, Lavigne, 2002)
Harp seal - NWA	300,000-12,000,000	5	1990, 3100000 1994, 4751000 2000, 5200000	(Shelton *et al.*, 1996, Warren *et al.*, 1997, Healey and Stenson, 2000, Waring *et al.*, 2002, Hammill and Stenson, 2003)
Harp seal – White Sea	3,000,000-8,000,000	5	1928, 3250000 1952, 1350000 1959, 1200000 1998, 1750000 1999, 2180000	(Dorofeev, 1956, Surkov, 1957, Surkov, 1957, ICES, 1999, Nilssen *et al.*, 2000, Lavigne, 2002)
Hooded seal – Jan Mayen	400,000-1,800,000	4	1985, 2000000	(ICES, 1991, Reijnders *et al.*, 1993)
Hooded seal - NWA	400,000-900,000	4	1984, 325000 1990, 425000	(Bowen *et al.*, 1987, Reijnders *et al.*, 1993) (Stenson, 1994, Waring *et al.*, 2002)
Bearded seal – Bering / Chukchi Sea	200,000-400,000	5	1975, 250000 1980, 275000	(Popov, 1976, Reijnders *et al.*, 1993, Angliss and Lodge, 2002)
Harbour seal - California	20,000-50,000	1	2000, 30293	(Carretta *et al.*, 2002)
Largha or spotted seal, Bering Sea	100,000-350,000	5	1975, 225000 1980, 135000	(Popov, 1982, Reijnders *et al.*, 1993, Burns, 2002)
Largha or spotted seal, Northeast Pacific (Alaska)	30,000-150,000	1	1992, 59214	(Rugh *et al.*, 1995, Angliss and Lodge, 2002)
Largha or spotted seal, Sea of Okhotsk	100,000-350,000	5	1977, 200000 1985, 130000	(Reijnders *et al.*, 1993, Mizuno *et al.*, 2002)
Antarctic Fur seal	2,500,000-3,500,000	5	1930, 100 1978, 554,000 1982, 930,000 1990, 1,600,000 1999, 100	(Bonner, 1981), (Laws, 1984). (Knox, 1994), (Arnould, 2002)
South African and Australian fur seal	800,000-3,000,000	5	1971, 850000 1993, 1700000	(Shaughnessy, 1982, Arnould, 2002)
Northern fur seal	1,000,000-2,500,000	4	1912, 216000 1945, 1500000 1983, 877000 1990, 900000 1997, 1002516	(Kenyon *et al.*, 1954, Briggs and Fowler, 1984, Trites, 1992, Reijnders *et al.*, 1993, Antonelis *et al.*, 1996, Hill *et al.*, 1998, Angliss and Lodge, 2003, Anon., 2004)
South American sea lion, North Patagonia (Falklands)	80,000-180,000	5	1938, 137500 1946, 18000 2001, 44842	(Carrara, 1952, Godoy, 1963, Dans *et al.*, 2004)

Species – Area	K	CID	Abund pts	Sources
Model input cont …				
New Zealand fur seal, New Zealand	400,000-500,000	5	1991, 40000	(Reijnders *et al.*, 1993)
California sea lion, California	100,000-500,000	5	1990, 113000 1999, 182000 1999, 209000	(Carretta *et al.*, 2002, Heath, 2002) (Stewart *et al.*, 1990, Reijnders *et al.*, 1993)
Steller sea lion - Northeast Alaska	10,000-100,000	1	1994, 30403 1996, 31208 1998, 31208	(Hill *et al.*, 1998, Sease *et al.*, 2001, Angliss and Lodge, 2002)
Steller sea lion - Northwest Alaska	50,000-300,000	3	1960, 140000 1976, 109800 1978, 109800 1990, 30525 1991, 29405 1992, 27299 1994, 24136 1996, 22210 1999, 34595 2000, 34595 2001, 34779	(Merrick *et al.*, 1987, Sease *et al.*, 2001, Angliss and Lodge, 2002, Sease and Gudmundson, 2002, Angliss and Lodge, 2003)
Walrus – Chukchi/Bering Sea	100,000-600,000	3	1972, 142200 1980, 256900 1985, 242600	(Fay *et al.*, 1997)
Walrus – East Greenland	500-2,000	5	2001, 1000	(Born, 2005)
Walrus – Northwater	500-10,000	5	1999, 1500 2001, 1850	(Born *et al.*, 1995, Born, 2005)
Walrus – Spitsbergen & Franz Josef Land	10,000-80,000	2	1990, 2000 1993, 2000	(Gjertz and Wiig, 1995)
Walrus – West Greenland	5,000-20,000	5	2001, 1000	(Born, 2005)

APPENDIX V: R CODE

```
#*****************************************************************************************
#          Programmer:       Line Bang Christensen
#          Project Name:     Reconstructing historical marine mammal biomass at the global scale
#                            mmsra.dat (Marine Mammal Stock Reduction Analysis)
#          Date:             2005/2006
#          Version: many
#          Comments:         RMES 499 - masters thesis
#*****************************************************************************************
graphics.off()
memory.size(4095)
seed = round(runif(1,1,1000))
set.seed(seed)

spec  = scan("mmsra.dat",skip=2,what='character',sep='\n',nlines=1)     # specie
area  = scan("mmsra.dat",skip=4,what='character',nlines=1)              # area
meanr = scan("mmsra.dat",skip=6,nmax=1)                                 # mean r
sdr   = scan("mmsra.dat",skip=8,nmax=1)                                 # std r
kap   = scan("mmsra.dat",skip=10,nmax=1)                                # total error term
cid   = scan("mmsra.dat",skip=12,nmax=1)                                # confidence id, used to set prop
minK  = scan("mmsra.dat",skip=14,nmax=1)                          # minimum carrying capacity
maxK  = scan("mmsra.dat",skip=16,nmax=1)                          # maximum carrying capacity
byr   = scan("mmsra.dat",skip=18,nmax=1)                                # begin year
nyr   = scan("mmsra.dat",skip=20,nmax=1)                                # end year
syr   = scan("mmsra.dat",skip=22,nlines=1)                              # survey year
yt    = scan("mmsra.dat",skip=24,nlines=1)                              # survey - abundance estimates
ct    = scan("mmsra.dat",skip=26)                                       # catch data

prop = 0.5                             #proportion of error attributed to observation errors
if (cid == 1) {prop = 0.3}
if (cid == 2) {prop = 0.4}
if (cid == 3) {prop = 0.5}
if (cid == 4) {prop = 0.5}

sig = sqrt(prop)*sqrt(kap)             # std in the residuals for yt (observation error)
tau = sqrt(1-prop)*sqrt(kap)           # process errors
yr=byr:nyr
n=length(yr)
iyr = syr-min(yr)+1
ci=matrix(nrow=n,ncol=3)
meanEst = vector(length=n)

##-----------------------------------------------
"popdy"=function(theta, niter=1, tau=0)      #tau here represent process errors.
{
          r=theta[1,]; k=theta[2,]
          Nt= matrix(0,nrow=n,ncol=niter); Nt[1,]=k
          wt=matrix(rnorm(n*niter)*tau,nrow=n,ncol=niter)
          like=vector(mode="numeric",length=niter)
          for(i in 1:(n-1))
          {
                    aa=r*(1-Nt[i,]/k)*exp(wt[i,])
                    Nt[i+1,]=Nt[i,]+Nt[i,]*aa-ct[i]
                    Nt[i+1,Nt[i+1,]<0]=0
          }

          #now calculate liklelihood
          zt = 0
          zt=log(Nt[iyr,])-log(yt)      #residuals
          zbar=0                        # i.e., absolute abundance estimates
```

```
        if(niter ==1) like=sum(dnorm(zt,zbar,sig,log=T))
        if(niter > 1) like = rowSums(apply(zt,1,dnorm,mean=zbar,sd=sig,log=T))
        like[Nt[n,]<=0]=0; like=like-min(like); like[Nt[n,]<=0]=-1e70

        prior=dnorm(r,mean=meanr,sd=sdr,log=T)
        pop=list(); pop$Nt=Nt[1:n,]; pop$like=like+prior;
        pop$wt=exp(wt);return(pop)
}

"fitmodel"=function()  #This gets the maximum likelihood estimates of k and r.
{
        fun=function(theta) popdy(matrix(theta))$like
        fit=optim(theta,fun,control=list(fnscale=-1, maxit=2000, method="BFGS"))
        return(fit)
}

"calcY"=function(Nmax)
{
        b=integer
        a=1; exponent=0
        while(Nmax/a>99){ a = a*10;exponent=exponent+1}
        b=Nmax/a; b = ceiling(b);

        while(b%%10!=0){b=b+1}
        if(b==10){b=b/10;exponent = exponent+1}
        if(b==50|| b==60 || b==70 ||b== 80 ||b== 90){b=b/10;exponent = exponent+1}
byval = c(20,10,5,2,1); i = 3
        if (b%%byval[5]==0 && b/byval[5]>=4) {i=5}
        if (b%%byval[4]==0 && b/byval[4]>=4) {i=4}
        if (b%%byval[3]==0 && b/byval[3]>=4) {i=3}
        if (b%%byval[2]==0 && b/byval[2]>=4) {i=2}
        if (b%%byval[1]==0 && b/byval[1]>=4) {i=1}
        vals = seq(0,b,by=byval[i])

        yaxis=list(); yaxis$vals=vals; yaxis$exponent=exponent; return(yaxis);
}

"sir"=function(niter=1000)
{
        rtry=runif(niter,0,(meanr*2))
        ktry=runif(niter,minK,maxK)
        theta=rbind(rtry,ktry)

        sir=popdy(theta,niter,tau)#generate samples

        #importance weights
        p=sir$like; maxp=max(na.omit(p))  #importance weight
        p=exp(p-maxp);                    #Must divide by the probability density function for each Ro.
        p[p=="NA"]=0

        ix=sample(1:niter,niter,replace=T,prob=p)
        a = seq(1500,2010,by=10);b=a[a>=(byr-9)]

        dd = calcY(max(ct))
        if(dd$exponent==0) ylabel2="Catch"

        else if(dd$exponent==1) ylabel2 = "Catch (*10)"
        else ylabel2 = paste("Catch ( 10 ^",dd$exponent,")",sep="")

        for(i in 1:n)
```

```
        ci[i,] = signif(quantile(sir$Nt[i,ix],c(0.025,0.5,0.975)),3)

ninit=ci[1,2]
nend=ci[n,2]

d=calcY(ci[1,3])
if(d$exponent==0) ylabel="Number of individuals"
else if(d$exponent==1) ylabel = "Number of individuals (*10)"
else ylabel = paste("Number of individuals (10^",d$exponent,")",sep="")


write (ci[1,1],file=paste(spec,area,"popCImin.txt"))
for(i in 2:n)
        write (ci[i,1],file=paste(spec,area,"popCImin.txt"),append=T)
write ("\n#Depleted by",file=paste(spec,area,"popCImin.txt"),append=T)
depmin = (ci[1,1]-ci[n,1])/ci[1,1]*100
if(depmin>90)depmin=signif(depmin,3) else depmin=signif(depmin,2)
write (depmin,file=paste(spec,area,"popCImin.txt"),append=T)

write (ci[1,3],file=paste(spec,area,"popCImax.txt"))
for(i in 2:n)
        write (ci[i,3],file=paste(spec,area,"popCImax.txt"),append=T)
write ("\n#Depleted by",file=paste(spec,area,"popCImax.txt"),append=T)
depmax = (ci[1,3]-ci[n,3])/ci[1,3]*100
if(depmax>90)depmax=signif(depmax,3) else depmax=signif(depmax,2)
write (depmax,file=paste(spec,area,"popCImax.txt"),append=T)


#plot confidence intervals
x11(height=4,width=6)
par(mar=c(5,4,2,4))
plot(yr,ci[,3]/(10^d$exponent),ylim=c(0,max(d$vals)),xlab="Year",
        ylab="",type='n',yaxt="n",xaxt="n",frame=F,axes=F)
axis(side=1,at=b,las=1,tcl=0.5)
axis(side=2,tcl=0.5,las=1, at=d$vals);mtext(ylabel,2,line=3)
lines(byr:nyr, ci[,3]/(10^d$exponent), col="steelblue",lty=3,lwd=2)
lines(byr:nyr, ci[,1]/(10^d$exponent),col="steelblue",lty=3,lwd=2)
lines(byr:nyr, ci[,2]/(10^d$exponent),col="darkblue",lwd=2)
points(syr,yt/(10^d$exponent),pch=20,cex=1.8,col="red")
par(new=TRUE)
plot(yr,ct/(10^dd$exponent),xaxt="n",yaxt="n",xlab="",ylab="",type='h',lty=1,col='hotpink4',fram
        e=F,axes=F,ylim=c(0,max(dd$vals)))
axis(side=4,tcl=0.5,las=1,at=dd$vals); mtext(ylabel2,4,line=2);

savePlot(filename=paste(spec,area,"popSimplePlot"), type="wmf",device=dev.cur())

write(ci[1,2],file=paste(spec,area,"pop.txt"))
for(i in 2:n)
{
        write(ci[i,2],file=paste(spec,area,"pop.txt"),append=T)
}

dep = (ninit-nend)/ninit *100
if(dep>90)dep=signif(dep,3) else dep=signif(dep,2)
write("\n#Depleted by",file=paste(spec,area,"pop.txt"),append=T)
write(dep,file=paste(spec,area,"pop.txt"),append=T
rm(ci)

x11()
plot(ktry[ix],rtry[ix],pch=20)
savePlot(filename=paste(spec,area,"Posterior"), type="jpg",device=dev.cur())
```

```
	windows()
	split.screen(c(2,1))
	split.screen(c(1,2),2)
	screen(1); plot(rtry[ix],type="l",ylab="Intrinsic rate of growth (r)",las=1,main="(a)")
	screen(3); hist(rtry[ix],xlab="Intrinsic rate of growth (r)",main="(b)",breaks=50)
	yy=density(rtry[ix],adjust=2,from =0, to =meanr*2)
	screen(4);plot(yy,xlab="Intrinsic rate of growth (r)",main="(c)")
		lines(c(0,0,0.1,0.1),c(0,1,1,0),lty=2)		#uniform prior distribution
		xx=seq(0,0.1,by=0.001)
		yy=dnorm(xx,mean=meanr,sd=sdr)
		lines(xx,yy,lty=2,col="red")
	 close.screen(all = TRUE)				# exit split-screen mode
	 savePlot(filename=paste(spec,area,"R"), type="jpg",device=dev.cur())

	#Now plot statistics for carrying capacity K
	windows()
	split.screen(c(2,1))
	split.screen(c(1,2),2)
	screen(1); plot(ktry[ix],type="l",ylab="Carrying capacity",las=1,main="(a)")
	screen(3); hist(ktry[ix],xlab="Carrying capacity(x1000)",main="(b)",breaks=50)
	yy=density(ktry[ix],adjust=2,from = minK, to = maxK)
	screen(4);plot(yy,xlab="Carrying capacity(x1000)",main="(c)")
		lines(c(minK,minK,maxK,maxK),c(0,.01,.01,0),lty=2)  #prior distribution
	close.screen(all = TRUE)
	savePlot(filename=paste(spec,area,"K"), type="jpg",device=dev.cur())
	#-------------------------------------------------------------------------------------------------------------------
--
	return(sir)
}

sir(100000)
```

Appendix VI: Catch data

See Appendix VII for sources.

Catch data table 1 (Right whale NA – Right whale SH)

	Right whale NA	Northern bottlenose whale NA	Gray whale NEP	Bow-head Arctic	Walrus Spits-bergen	Hump-back NA	Long finned pilot Faroe	Harbour porpoise Baltic	Right whale SH
Onset of hunt	1530	1584	1600	1650	1660	1664	1709	1716	1785
1530 - 1583	300/yr								
1584	300	3							
1585-1599	300/yr	0/yr							
1600-1610	300/yr	0/yr	160/yr						
1611-1617	0/yr	0/yr	160/yr						
1618	0	2	160						
1619	0	0	160						
1620	0	0	160						
1621	0	0	160						
1622	0	6	160						
1623	0	0	160						
1624	0	0	160						
1625	0	0	160						
1626	0	1	160						
1627	0	0	160						
1628	0	0	160						
1629	0	0	160						
1630	0	0	160						
1631	0	3	160						
1632	0	0	160						
1633	0	1	160						
1634	0	1	160						
1635	0	0	160						
1636	0	0	160						
1637	0	2	160						
1638-1649	0/yr	0/yr	160/yr						
1650-1659	0/yr	0/yr	160/yr	25/yr					
1660-1663	0/yr	0/yr	160/yr	532/yr	360/yr				
1664	0	0	160	532	360	7			
1665	0	0	160	533	360	30			
1666	0	0	160	533	360	17			
1667	0	0	160	533	360	26			
1668	0	0	160	533	360	7			
1669-1678	0/yr	0/yr	160/yr	533/yr	360/yr	17/yr			
1679-1684	0	0	160	1034	360	0			
1680	0	0	160	1216	360	0			

Catch data table 1 cont ...

	Right whale NA	Northern bottlenose whale NA	Gray whale NEP	Bow-head Arctic	Walrus Spits-bergen	Hump-back NA	Long finned pilot faroe	Harbour porpoise baltic	Right whale SH
1681	0	0	160	1216	360	0			
1682	0	0	160	1216	360	0			
1683	0	0	160	1216	360	0			
1684	0	0	160	1216	360	0			
1685	0	0	160	1216	360	26			
1686	0	0	160	1216	360	26			
1687	0	0	160	1216	360	26			
1688	0	0	160	1215	360	26			
1689	0	0	160	1215	360	26			
1690	0	0	160	748	360	26			
1691	0	0	160	748	360	16			
1692	0	0	160	748	360	26			
1693	0	0	160	748	360	26			
1694	0	0	160	748	360	26			
1695	0	0	160	748	360	26			
1696	118	0	160	747	360	26			
1697	118	0	160	747	360	26			
1698	118	0	160	747	360	26			
1699	118	0	160	747	360	26			
1700	118	0	160	959	360	26			
1701	118	0	160	959	360	26			
1702	118	0	160	959	360	26			
1703	118	0	160	959	360	26			
1704	118	0	160	959	360	26			
1705	118	0	160	959	360	26			
1706	118	0	160	958	360	26			
1707	118	0	160	958	360	26			
1708	118	0	160	958	360	26			
1709	118	5	160	958	360	26	655		
1710	118	0	160	585	360	26	655		
1711	118	4	160	585	360	26	655		
1712	118	0	160	585	360	26	655		
1713	118	1	160	585	360	26	655		
1714	118	0	160	585	360	26	655		
1715	118	3	160	585	360	26	655		
1716	118	3	160	584	360	26	655	1000	
1717	118	2	160	584	360	26	655	1000	
1718	118	0	160	584	360	26	655	1000	
1719	118	7	160	628	360	26	655	1000	
1720	118	5	160	566	360	26	655	1000	
1721	118	3	160	566	360	26	655	1000	
1722	118	2	160	566	360	26	655	1000	
1723	118	6	160	566	360	26	655	1000	
1724	118	1	160	566	360	26	655	1000	
1725	118	2	160	566	360	26	655	1000	
1726	118	4	160	565	360	26	655	1000	
1727	118	0	160	564	360	26	655	1000	

Catch data table 1 cont …

	Right whale NA	Northern bottlenose whale NA	Gray whale NEP	Bow-head Arctic	Walrus Spits-bergen	Hump-back NA	Long finned pilot faroe	Harbour porpoise baltic	Right whale SH
1728	118	4	160	564	360	26	655	1000	
1729	118	2	160	564	360	26	655	1000	
1730	118	0	160	524	360	34	655	1000	
1731	118	0	160	524	360	34	655	1000	
1732	118	3	160	524	360	34	655	1000	
1733	118	0	160	524	360	34	655	1000	
1734	118	3	160	524	360	34	655	1000	
1735	0	1	160	524	360	34	655	1000	
1736	0	0	160	523	360	34	655	1000	
1737	0	3	160	522	360	34	655	1000	
1738	0	3	160	522	360	34	655	1000	
1739	0	0	160	522	360	34	655	1000	
1740	0	0	160	812	360	34	655	1000	
1741	0	1	160	812	360	34	655	605	
1742	0	2	160	812	360	34	655	605	
1743	0	0	160	812	360	34	655	605	
1744	0	0	160	812	360	34	655	605	
1745	0	0	160	812	360	34	655	605	
1746	0	6	160	812	360	34	655	605	
1747	0	0	160	811	360	34	655	605	
1748	0	3	160	812	360	34	655	605	
1749	0	0	160	812	360	34	655	605	
1750	0	1	160	633	360	42	655	605	
1751	0	0	260	633	360	21	655	605	
1752	0	2	260	633	360	21	655	605	
1753	0	0	260	633	360	21	655	605	
1754	0	3	260	633	360	21	655	605	
1755	0	1	260	634	360	21	655	605	
1756	0	0	260	634	360	21	655	306	
1757	0	0	260	634	360	21	655	306	
1758	0	0	260	634	360	21	655	306	
1759	0	0	260	635	360	21	655	306	
1760	0	0	260	550	360	21	655	306	
1761	0	0	260	550	360	21	655	306	
1762	0	0	260	550	360	21	655	306	
1763	0	1	260	550	360	21	655	306	
1764	0	0	260	550	360	21	655	306	
1765	0	0	260	550	360	21	655	306	
1766	0	0	260	552	360	21	655	306	
1767	0	3	260	552	360	21	655	306	
1768	0	0	260	552	360	21	655	306	
1769	0	0	260	552	360	21	655	306	
1770	0	0	260	513	360	21	655	306	
1771	0	1	260	513	360	21	655	306	
1772	0	0	260	513	360	21	655	306	
1773	0	0	260	513	360	21	655	306	
1774	0	0	260	513	360	21	655	306	

Catch data table 1 cont …

	Right whale NA	Northern bottlenose whale NA	Gray whale NEP	Bow-head Arctic	Walrus Spits-bergen	Hump-back NA	Long finned pilot faroe	Harbour porpoise baltic	Right whale SH
1775	0	0	260	513	360	21	655	306	
1776	0	0	260	514	360	21	655	306	
1777	0	1	260	514	360	29	655	135	
1778	0	3	260	513	360	29	655	135	
1779	0	0	260	513	360	29	655	135	
1780	0	0	260	454	360	26	655	135	
1781	0	0	260	454	360	26	655	135	
1782	0	2	260	454	360	26	655	135	
1783	0	0	260	454	360	26	655	135	
1784	0	0	260	454	360	26	655	135	
1785	0	0	260	454	360	26	655	135	74
1786	0	0	260	453	360	29	655	135	74
1787	0	0	260	454	360	29	655	135	74
1788	0	0	260	454	360	29	655	135	74
1789	0	0	260	454	360	29	655	135	74
1790	0	0	260	219	360	38	655	135	236
1791	0	0	260	219	360	38	655	135	236
1792	0	0	260	219	360	38	655	0	236
1793	0	0	260	219	360	38	655	0	236
1794	0	0	260	219	360	38	655	0	235
1795	0	0	260	219	360	38	655	0	19
1796	0	3	260	219	360	38	655	0	19
1797	0	0	260	219	360	33	655	0	19
1798	0	0	260	220	360	40	655	0	18
1799	0	0	260	219	360	38	655	0	18
1800	0	0	260	51	360	38	655	0	30
1801	0	0	260	51	360	29	655	0	30
1802	0	1	260	51	360	29	655	0	30
1803	0	2	260	51	360	29	655	0	30
1804	0	0	260	51	360	57	655	0	30
1805	0	0	260	51	360	57	655	0	884
1806	0	0	260	51	360	57	655	0	884
1807	0	1	260	51	360	57	655	0	884
1808	0	0	260	50	360	57	655	0	884
1809	0	0	260	50	360	57	655	0	884
1810	0	0	260	754	360	61	655	0	30
1811	0	0	260	754	360	61	655	0	30
1812	0	0	260	754	360	61	655	0	30
1813	0	1	260	754	360	55	655	0	29
1814	0	2	260	754	360	55	655	0	29
1815	0	1	260	754	360	55	655	0	365
1816	0	5	260	755	360	55	655	0	365
1817	0	4	260	755	360	55	655	0	365
1818	0	0	260	755	360	55	655	0	365
1819	0	7	260	756	360	55	655	0	366
1820	0	0	260	1072	360	55	655	0	973
1821	0	3	260	1072	360	55	655	480	973

Catch data table 1 cont ...									
	Right whale NA	Northern bottlenose whale NA	Gray whale NEP	Bow-head Arctic	Walrus Spits-bergen	Hump-back NA	Long finned pilot faroe	Harbour porpoise baltic	Right whale SH
1822	0	3	260	1072	360	55	655	414	973
1823	0	0	260	1072	360	27	655	788	972
1824	0	0	260	1072	360	27	655	618	972
1825	0	2	260	1072	360	27	655	359	1026
1826	0	6	260	1072	360	47	655	629	1026
1827	0	0	260	1073	360	70	655	661	1026
1828	0	0	260	1074	360	57	655	1101	1026
1829	0	2	260	1074	360	59	655	738	1026
1830	0	2	260	596	360	81	655	997	3035
1831	0	2	260	596	360	79	655	997	3035
1832	0	0	260	596	360	102	655	859	3035
1833	0	2	260	596	360	87	655	991	3034
1834	0	2	260	596	360	120	655	1277	3034
1835	0	8	260	596	360	113	655	1683	5007
1836	0	2	260	595	360	106	655	1222	5007
1837	0	0	260	595	360	106	655	1408	5007
1838	0	2	260	595	360	120	655	656	5006
1839	0	7	260	596	360	98	655	886	5006
1840	0	0	260	170	360	111	655	650	3307
1841	0	5	260	170	360	134	655	689	3307
1842	0	1	260	170	360	126	655	798	3307
1843	0	4	260	170	360	126	655	1381	3306
1844	0	2	260	170	360	107	655	1073	3306
1845	0	6	260	170	360	121	655	337	1118
1846	0	6	328	170	360	118	655	710	1118
1847	0	4	328	169	360	87	655	1436	1118
1848	0	1	328	187	360	142	655	1436	1118
1849	0	3	328	741	360	124	655	1441	1119
1850	0	5	328	2212	360	184	655	875	359
1851	0	1	258	1043	360	162	655	875	358
1852	0	6	258	2854	360	331	655	875	358
1853	0	14	258	952	360	325	655	1732	358
1854	0	0	258	311	360	291	655	875	359
1855	0	9	686	147	360	391	655	875	300
1856	0	7	686	147	360	489	655	875	300
1857	0	6	686	225	360	419	655	2194	300
1858	0	6	686	608	360	441	655	869	301
1859	0	3	686	519	360	355	655	880	301
1860	0	9	686	395	360	317	655	1166	285
1861	0	12	576	480	360	270	655	1166	285
1862	0	6	576	331	360	223	655	693	285
1863	0	8	576	477	360	289	655	844	285
1864	0	14	576	608	360	293	655	996	286
1865	0	4	576	764	360	374	655	1452	160
1866	0	4	328	729	360	354	655	1166	160
1867	0	2	328	773	360	522	655	1166	160
1868	0	10	328	690	360	335	655	842	160

Catch data table 1 cont ...

	Right whale NA	Northern bottlenose whale NA	Gray whale NEP	Bow-head Arctic	Walrus Spits-bergen	Hump-back NA	Long finned pilot faroe	Harbour porpoise baltic	Right whale SH
1869	0	6	328	557	360	240	655	1100	159
1870	0	6	328	780	360	192	655	1094	97
1871	0	7	329	281	360	186	655	1336	97
1872	0	12	329	343	360	211	655	2089	97
1873	0	2	329	290	360	188	655	1292	97
1874	0	16	329	238	360	244	655	589	96
1875	0	2	225	342	360	300	655	1138	104
1876	0	10	140	217	360	288	655	1319	104
1877	0	17	140	411	360	274	655	545	104
1878	0	12	140	220	360	283	655	869	104
1879	0	17	153	406	360	260	655	2297	105
1880	0	43	141	561	360	287	655	2154	111
1881	0	161	130	516	360	278	655	2033	111
1882	0	387	130	323	360	211	655	1902	111
1883	0	580	138	123	360	289	655	2000	112
1884	0	223	147	241	360	348	655	1775	112
1885	0	886	141	457	360	388	655	1825	169
1886	0	1497	129	250	360	466	655	1649	169
1887	0	1174	99	322	360	206	655	1901	169
1888	0	1062	99	242	360	156	655	1401	169
1889	0	1325	99	209	360	130	655	456	169
1890	0	1971	99	184	360	147	655	720	83
1891	0	2443	99	332	360	174	655	456	83
1892	0	2601	60	394	360	197	655	176	83
1893	0	2394	40	228	360	278	655	302	82
1894	0	2779	40	282	360	245	655	225	82
1895	0	2399	40	165	360	246	655	632	9
1896	0	2883	40	165	360	382	655	0	9
1897	0	2145	41	177	360	355	655	0	9
1898	0	2106	41	357	360	329	655	0	8
1899	0	2255	41	282	360	380	655	0	8
1900	0	2158	41	189	360	426	788	0	13
1901	0	1952	30	96	360	700	0	0	13
1902	0	1754	30	178	360	852	481	0	13
1903	0	1557	30	132	360	751	204	0	12
1904	0	1252	30	102	360	606	566	0	12
1905	0	1295	30	122	360	438	221	0	16
1906	6	1172	30	85	360	290	410	0	87
1907	24	1334	30	112	360	331	302	0	93
1908	20	1278	30	139	360	265	1793	0	67
1909	21	1385	30	77	360	303	734	0	59
1910	12	1172	30	42	360	217	1324	0	132
1911	0	883	30	53	360	124	1650	0	82
1912	11	677	30	43	0	110	669	0	11
1913	2	687	31	27	0	36	168	0	57
1914	5	685	49	65	0	40	291	0	25
1915	0	680	30	25	0	30	1203	0	29

Catch data table 1 cont …									
	Right whale NA	Northern bottlenose whale NA	Gray whale NEP	Bow-head Arctic	Walrus Spits-bergen	Hump-back NA	Long finned pilot faroe	Harbour porpoise baltic	Right whale SH
1916	0	679	20	23	0	31	397	0	17
1917	0	677	20	35	0	15	263	0	53
1918	0	679	28	27	0	16	848	0	20
1919	0	677	22	33	0	46	153	0	20
1920	1	685	22	33	0	65	802	0	0
1921	0	677	22	9	0	7	1076	0	5
1922	1	677	25	39	0	171	473	0	0
1923	2	680	36	12	0	176	1047	0	0
1924	0	678	36	41	0	91	0	0	7
1925	0	678	169	53	0	157	468	0	16
1926	0	681	77	35	0	116	348	0	21
1927	0	1	68	14	0	97	0	0	1
1928	0	2	47	0	0	47	480	0	1
1929	0	2	38	60	0	34	17	0	0
1930	0	2	35	17	0	81	266	0	2
1931	0	4	26	32	0	55	2386	0	0
1932	0	0	25	27	0	24	1282	0	0
1933	0	0	20	21	0	17	959	0	0
1934	0	2	64	21	0	11	178	0	0
1935	0	4	44	15	0	26	652	0	0
1936	0	0	112	24	0	20	1633	0	2
1937	1	5	24	53	0	31	886	0	0
1938	0	0	63	36	0	8	2093	0	14
1939	0	0	39	18	0	17	3362	0	0
1940	0	3	125	20	0	9	2847	0	0
1941	0	0	77	38	0	8	4475	0	0
1942	0	1	121	26	0	4	1931	0	0
1943	0	2	119	14	0	8	1037	0	1
1944	0	0	0	8	0	10	1386	0	0
1945	0	0	30	23	0	8	1555	0	0
1946	0	75	22	20	0	11	1040	0	0
1947	0	74	9	21	0	13	1939	0	0
1948	0	71	19	8	0	23	587	0	0
1949	0	71	26	11	0	19	955	0	0
1950	0	71	11	23	0	28	562	0	0
1951	0	71	13	23	0	40	2836	0	19
1952	0	71	44	11	0	3	1242	0	9
1953	0	73	38	41	0	8	2100	0	11
1954	0	72	39	9	0	6	2010	0	34
1955	0	71	59	36	0	1	885	0	11
1956	0	71	122	11	0	2	1816	0	49
1957	0	71	98	5	0	2	2085	0	19
1958	0	71	148	5	0	12	2619	0	3
1959	0	71	196	2	0	9	1426	0	79
1960	0	71	173	33	0	3	1795	0	4
1961	0	71	212	17	0	5	1892	0	1356
1962	0	85	147	20	0	2	1813	0	727

Catch data table 1 cont ...									
	Right whale NA	Northern bottlenose whale NA	Gray whale NEP	Bow-head Arctic	Walrus Spits-bergen	Hump-back NA	Long finned pilot faroe	Harbour porpoise baltic	Right whale SH
1963	0	89	180	15	0	6	2204	0	374
1964	0	89	210	24	0	2	1364	0	82
1965	0	87	176	14	0	3	1620	0	348
1966	0	91	220	24	0	4	1485	0	161
1967	0	90	250	12	0	10	1973	0	4
1968	0	72	201	27	0	11	1650	0	0
1969	0	72	214	32	0	18	1395	0	78
1970	0	1	151	66	0	32	388	0	0
1971	0	0	153	26	0	32	1015	0	0
1972	0	0	182	45	0	16	511	0	0
1973	0	0	178	57	0	15	1050	0	0
1974	0	4	184	54	0	15	673	0	0
1975	0	0	171	45	0	11	1086	0	0
1976	0	0	165	92	0	15	531	0	0
1977	0	0	187	111	0	19	898	0	0
1978	0	2	184	17	0	36	1192	0	0
1979	0	0	183	27	0	38	1673	0	0
1980	0	0	181	30	0	28	2775	0	0
1981	0	3	136	26	0	16	2909	0	0
1982	0	3	168	19	0	21	2652	0	0
1983	0	0	171	18	0	24	1689	0	0
1984	0	0	169	25	0	24	1921	0	0
1985	0	0	170	17	0	12	2595	0	0
1986	0	0	171	28	0	6	1676	0	0
1987	0	0	159	29	0	14	1450	0	0
1988	0	3	151	23	0	7	1738	0	0
1989	0	2	180	18	0	12	1260	0	0
1990	0	0	162	30	0	9	917	0	0
1991	0	0	169	27	0	9	722	0	0
1992	0	3	0	50	0	3	1572	0	0
1993	0	8	0	52	0	2	808	0	0
1994	0	0	44	46	0	1	1201	0	0
1995	0	0	92	57	0	0	228	0	0
1996	0	0	43	45	0	2	1524	0	0
1997	0	0	79	66	0	0	1162	0	0
1998	0	0	125	55	0	3	815	0	0
1999	0	0	124	48	0	2	608	0	0
2000	0	0	115	48	0	2	588	0	0
2001	0	0	112	76	0	2	0	0	0

Catch data table 2 (Northern fur seal – Fin whale NA)

Species	Northern fur seal	Antarctic fur seal	Sperm	Elephant seal SH	Right whale NP	Beluga	Blue whale NA	Walrus Chukchi -Bering	Fin whale NA
Onset of hunt	1786	1790	1800	1820	1835	1862	1868	1869	1876
1786	48781								
1787	48781								
1788	48781								
1789	48781								
1790	48781	0							
1791	48781	11000							
1792	48781	22000							
1793	48781	33000							
1794	48781	44000							
1795	48781	55000							
1796	48781	66000							
1797	48781	77000							
1798	48781	88000							
1799	48781	99000							
1800	48781	110000	827						
1801	48781	104500	827						
1802	48781	99000	827						
1803	48781	93500	827						
1804	48781	88000	827						
1805	48781	82500	827						
1806	48781	77000	827						
1807	48781	71500	827						
1808	48781	66000	827						
1809	48781	60500	827						
1810	48781	55000	944						
1811	48781	49500	944						
1812	48781	44000	944						
1813	48781	38500	944						
1814	48781	33000	944						
1815	48781	27500	944						
1816	48781	22000	944						
1817	48781	16500	944						
1818	48781	11000	944						
1819	48781	5500	944						
1820	48781	0	3866	11495					
1821	48781	320000	3866	11495					
1822	48781	284444	3866	11495					
1823	48781	248888	3866	11495					
1824	48781	213332	3866	11495					
1825	48781	177776	3866	11495					
1826	48780	142220	3866	11495					
1827	48780	106664	3866	11495					
1828	48780	71108	3866	11495					
1829	48780	35552	3866	11495					
1830	48780	0	4467	11495					

Catch data table 2 cont …									
Species	Northern fur seal	Antarctic fur seal	Sperm	Elephant seal SH	Right whale NP	Beluga	Blue whale NA	Walrus Chukchi -Bering	Fin whale NA
1831	48780	0	4467	11495					
1832	48780	0	4467	11495					
1833	48780	0	4467	11495					
1834	48780	0	4470	11495					
1835	48780	0	7598	11495	205				
1836	48780	0	5814	11495	205				
1837	48780	0	7996	11495	205				
1838	48780	0	5801	11495	205				
1839	48780	0	6600	11495	205				
1840	48780	0	6943	11495	205				
1841	48780	0	7009	11495	205				
1842	48780	0	7288	11494	205				
1843	48780	0	7347	11494	205				
1844	48780	0	6142	11494	205				
1845	48780	0	6949	11494	205				
1846	48780	0	4190	11494	205				
1847	48780	0	5313	11494	205				
1848	48780	0	4751	11494	205				
1849	48780	0	4442	11494	205				
1850	48780	0	4088	11494	205				
1851	48780	0	4382	11494	205				
1852	48780	0	3471	11494	205				
1853	48780	0	4535	11494	205				
1854	48780	0	3243	11494	205				
1855	48780	0	3197	11494	205				
1856	48780	0	3562	11494	205				
1857	48780	0	3452	11494	205				
1858	48780	0	3606	11494	205				
1859	48780	0	4022	11494	205				
1860	48780	0	3243	11494	205				
1861	48780	0	3033	11494	205				
1862	48780	0	2449	11494	205	234			
1863	48780	0	2862	11494	205	237			
1864	48780	0	2833	11494	205	426			
1865	48780	0	1811	11494	205	242			
1866	48780	0	1811	11494	205	369			
1867	48780	0	1911	11494	205	468			
1868	4367	0	2076	11494	205	249	30		
1869	4430	0	2109	11494	205	657	17	12000	
1870	8686	0	2428	11494	205	625	36	12000	
1871	119871	0	1827	11494	205	505	20	12000	
1872	114155	0	1975	11494	205	513	40	12000	
1873	114346	0	1810	11494	205	413	36	12000	
1874	116410	0	1914	11494	205	733	0	12000	
1875	111493	0	1817	11494	205	806	0	12000	
1876	100172	0	1656	11494	205	1115	42	12000	3
1877	89520	0	1470	11494	205	652	28	12000	8

Catch data table 2 cont …									
Species	Northern fur seal	Antarctic fur seal	Sperm	Elephant seal SH	Right whale NP	Beluga	Blue whale NA	Walrus Chukchi -Bering	Fin whale NA
1878	114863	0	1470	11494	205	592	76	12000	40
1879	119068	0	1470	11494	205	832	90	12000	40
1880	114136	0	998	11494	205	694	113	0	50
1881	115445	0	1065	11494	205	487	221	0	52
1882	115393	0	1025	11494	205	446	101	0	250
1883	96096	0	906	11494	205	393	0	0	0
1884	122405	0	906	11494	205	291	0	0	0
1885	128064	0	906	11494	205	672	60	0	475
1886	133015	0	906	11494	205	417	149	0	650
1887	136388	0	906	11494	205	445	90	0	320
1888	139693	0	906	11494	205	317	68	0	346
1889	132475	0	906	11494	205	330	14	0	188
1890	69673	0	562	11494	205	423	101	0	391
1891	73974	0	562	11494	205	400	67	0	43
1892	54151	0	562	11494	205	400	122	0	47
1893	38202	0	562	11494	205	400	116	0	113
1894	76871	0	562	11494	205	400	196	0	79
1895	71137	0	562	11494	205	400	309	0	112
1896	74571	0	562	11494	205	400	385	0	778
1897	43532	0	562	11494	205	400	284	0	436
1898	46599	0	562	11494	205	400	240	0	505
1899	50980	0	562	11494	205	400	294	0	338
1900	57661	0	689	11494	205	400	246	4000	358
1901	46722	0	689	11494	205	400	49	4000	360
1902	45198	0	689	11494	205	400	79	4000	475
1903	46292	0	689	11494	205	400	409	4000	513
1904	42134	0	689	11494	205	400	694	4000	1202
1905	39688	0	689	11494	205	400	900	4000	1623
1906	35712	0	689	11494	205	400	181	4000	380
1907	31000	0	689	0	205	240	146	4000	483
1908	33147	0	689	0	205	109	129	4000	760
1909	28507	0	689	0	205	161	163	4000	867
1910	25697	0	155	2500	12	98	41	4000	653
1911	12671	0	302	2500	0	300	68	4000	637
1912	3764	0	619	2500	11	448	72	4000	494
1913	2406	0	561	2500	2	596	47	4000	739
1914	2735	0	964	2500	5	670	45	4000	601
1915	3947	0	919	2500	1	600	37	4000	366
1916	6468	0	1097	2500	1	450	3	4000	77
1917	8170	0	513	2500	1	210	0	4000	0
1918	34890	0	1092	2500	1	540	3	4000	605
1919	27821	0	1219	2500	1	1140	0	4000	477
1920	26648	0	873	2500	1	3700	77	4000	845
1921	23681	0	796	2500	1	4600	7	0	534
1922	31156	0	912	2500	1	4955	45	0	1139
1923	15920	0	740	2500	2	4374	48	0	1818
1924	17219	0	950	2500	3	4550	129	0	2455

Catch data table 2 cont …									
Species	Northern fur seal	Antarctic fur seal	Sperm	Elephant seal SH	Right whale NP	Beluga	Blue whale NA	Walrus Chukchi -Bering	Fin whale NA
1925	19860	0	1475	2500	1	4550	55	0	2674
1926	22131	0	1775	2500	1	5461	49	0	2917
1927	24942	0	1441	5500	1	4836	34	0	1483
1928	31099	0	1989	5500	1	4036	72	0	1228
1929	40068	0	2852	5500	1	5012	78	0	1098
1930	42500	0	1311	5500	1	3850	91	0	1199
1931	49524	0	597	5500	1	4122	54	0	527
1932	49336	0	903	5500	1	4512	62	0	656
1933	54550	0	1844	5500	0	3703	60	0	874
1934	53468	0	2209	5500	0	3796	25	0	496
1935	57296	0	2481	5500	0	3563	10	8000	358
1936	52446	0	5621	5500	0	3645	31	8000	462
1937	55180	0	7463	5500	1	3623	57	8000	1331
1938	58364	0	5479	5500	0	3668	15	8000	654
1939	60473	0	5511	5500	0	4159	26	8000	665
1940	65263	0	4671	5500	0	4286	3	8000	154
1941	95013	0	5641	5500	0	4166	3	8000	71
1942	150	0	4957	5500	0	4196	5	8000	120
1943	117184	0	5580	5500	0	3774	1	8000	341
1944	47652	0	2614	5500	0	4201	10	8000	612
1945	76964	0	1899	5500	0	3838	14	8000	541
1946	64523	0	4550	5500	0	3914	36	8000	1144
1947	61447	0	8742	5500	0	3797	39	8000	1205
1948	70142	0	11217	5500	0	3623	110	8000	1742
1949	70990	0	9016	5500	0	3615	79	8000	1328
1950	60204	0	10409	5500	0	3525	55	8000	1502
1951	50771	0	18710	5500	1	18	53	8000	1372
1952	63922	0	11558	5500	0	431	15	8000	727
1953	66669	0	10058	5500	0	431	15	8000	614
1954	63882	0	18010	5500	0	1984	16	8000	530
1955	65453	0	16702	5500	0	424	13	8000	586
1956	122826	0	18590	5500	0	619	9	8000	481
1957	93618	0	20911	5500	0	722	11	8000	722
1958	78919	0	21846	5500	0	432	7	8000	528
1959	57810	0	21298	5500	0	568	7	8000	426
1960	40616	0	20344	5500	0	407	0	5166	413
1961	95974	0	22793	5500	0	382	0	4433	463
1962	77915	0	24695	5500	0	408	1	3508	504
1963	85254	0	33321	5500	0	316	0	2974	347
1964	64206	0	31994	5500	0	386	3	2475	385
1965	51020	0	26177	5500	0	538	1	2630	700
1966	52472	0	28752	0	0	792	1	3717	902
1967	50229	0	26424	0	0	707	2	2287	1117
1968	46893	0	26308	0	0	1369	0	2375	1093
1969	32817	0	27934	0	0	1088	1	1847	916
1970	36307	0	25521	0	0	1640	1	2410	1094
1971	27338	0	23115	0	0	855	1	2812	761

Catch data table 2 cont …									
Species	Northern fur seal	Antarctic fur seal	Sperm	Elephant seal SH	Right whale NP	Beluga	Blue whale NA	Walrus Chukchi -Bering	Fin whale NA
1972	33173	0	20370	0	0	1064	0	2843	696
1973	28482	0	22305	0	0	1425	1	2872	381
1974	33027	0	22041	0	0	1066	0	2615	410
1975	29148	0	21045	0	0	964	0	3643	383
1976	23096	0	17134	0	0	1623	1	4260	518
1977	28444	0	12722	0	0	1197	2	3838	308
1978	24885	0	11065	0	0	1031	6	4344	711
1979	25762	0	8536	0	0	1059	0	4271	730
1980	25000	0	2092	0	0	1163	0	5553	468
1981	25000	0	1456	0	0	1754	0	6670	410
1982	25000	0	621	0	0	1580	0	6378	356
1983	25000	0	414	0	0	1205	0	5835	277
1984	25000	0	463	0	0	1468	0	10272	281
1985	25000	0	400	0	0	1178	0	8917	218
1986	1605	0	200	0	0	1267	0	12500	85
1987	1605	0	191	0	0	1284	0	12500	89
1988	1605	0	0	0	0	842	0	12500	77
1989	1605	0	0	0	0	1297	0	12500	82
1990	1605	0	0	0	0	1517	0	9000	19
1991	1605	0	0	0	0	1172	0	8600	18
1992	1605	0	0	0	0	1039	0	6000	22
1993	1605	0	0	0	0	1346	0	4000	14
1994	1605	0	0	0	0	1118	0	4600	22
1995	1605	0	0	0	0	1235	0	5000	12
1996	1605	0	0	0	0	1063	0	6003	19
1997	1380	0	0	0	0	1165	0	4259	13
1998	1558	0	0	0	0	1241	0	4810	11
1999	1193	0	0	0	0	948	0	7757	9
2000	750	0	5	0	0	1237	0	6114	7
2001	781	0	8	0	0	643	0	5000	13

Catch data table 3 (Sei whale NA – Blue whale NP)

Spe-cies	Sei whale NA	Gray whale NWP	Harp seal NWA	Harp seal White sea	Hump-back whale NP	Wal-rus West Green-land	SA/ SAus fur seal	Harbour porpoise Greenland	Fin whale NP	Blue whale NP
Onset of hunt	1885	1890	1895	1897	1900	1900	1900	1900	1903	1903
1885	771									
1886	61									
1887	206									
1888	144									
1889	5									
1890	213	27								
1891	0	27								
1892	0	24								
1893	0	4								
1894	0	4								
1895	0	4	249000							
1896	106	4	249000							
1897	513	5	249000	60089						
1898	547	5	249000	75355						
1899	117	5	249000	55347						
1900	39	5	249000	37246	11	14	5291	285		
1901	22	2	249000	38211	105	11	5303	285		
1902	33	2	249000	65873	0	59	5052	285		
1903	59	2	249000	20124	287	5	6389	285	345	225
1904	31	2	249000	28715	281	65	3890	285	690	264
1905	36	2	249000	20000	0	202	7870	285	0	0
1906	326	2	249000	19209	58	69	9733	285	272	96
1907	151	2	249000	24941	0	110	6575	285	0	0
1908	232	2	249000	20185	24	37	5925	285	345	26
1909	223	2	249000	26872	103	34	5936	550	352	57
1910	299	2	249000	24978	29	11	4498	550	217	97
1911	134	2	249000	36432	60	52	6891	550	974	243
1912	108	2	159000	51699	383	68	7829	550	978	348
1913	203	3	159000	67919	166	27	9032	550	879	116
1914	288	21	159000	26937	725	102	4815	550	1041	208
1915	0	2	159000	51736	141	61	1391	550	870	108
1916	6	2	159000	42218	132	102	2726	550	798	100
1917	0	2	159000	39370	53	15	8691	550	783	82
1918	154	10	159000	128044	20	16	9630	550	720	27
1919	305	4	159000	150940	59	217	12419	430	563	57
1920	481	3	159000	203387	395	32	14545	430	703	145
1921	91	3	159000	129992	101	52	12842	430	470	53
1922	160	6	159000	163375	82	64	15104	430	394	36
1923	255	17	159000	231073	225	195	16306	430	385	64
1924	216	17	159000	314026	227	52	19488	620	490	74
1925	317	150	159000	469447	822	70	19901	620	801	228
1926	399	58	159000	371262	996	168	15417	620	823	286

Catch data table 3 cont …

Spe-cies	Sei whale NA	Gray whale NWP	Harp seal NWA	Harp seal White sea	Hump -back whale NP	Wal-rus West Green -land	SA/ SAus fur seal	Harbour porpoise Greenland	Fin whale NP	Blue whale NP
1927	185	49	159000	360788	1116	138	15960	620	579	198
1928	200	28	159000	368427	278	282	17825	620	418	223
1929	209	19	159000	185390	429	168	12683	620	1128	528
1930	72	16	159000	310295	622	249	928	800	707	148
1931	60	17	159000	254058	73	182	812	800	496	23
1932	82	16	159000	258837	99	328	823	800	413	17
1933	30	11	159000	256942	121	85	9826	820	568	15
1934	187	55	159000	225493	276	71	3624	600	775	67
1935	132	35	159000	245529	505	97	2842	600	941	163
1936	158	103	159000	213130	262	470	16210	580	788	54
1937	173	15	159000	185491	247	545	17150	1090	879	69
1938	106	55	159000	84444	121	629	13063	680	682	41
1939	59	31	159000	138799	215	526	19427	981	703	15
1940	0	110	27500	12965	161	625	11374	660	663	49
1941	51	62	27500	134059	97	547	13900	980	1183	76
1942	52	106	27500	5362	64	319	20126	580	819	15
1943	45	104	27500	34931	116	303	22784	770	594	15
1944	33	0	27500	25409	65	272	20020	390	540	4
1945	33	30	27500	85484	11	448	17522	440	169	10
1946	12	22	332500	79778	29	498	19252	330	350	10
1947	20	9	332500	162735	22	334	22043	470	274	34
1948	69	19	332500	159886	155	270	14387	130	491	53
1949	80	26	332500	210427	98	95	15592	260	441	19
1950	39	11	332500	216164	122	39	29487	265	489	18
1951	267	13	332500	230477	68	280	37833	380	681	72
1952	57	44	325292	154222	128	283	37449	550	1159	122
1953	166	38	291070	106562	115	284	33760	715	1221	142
1954	123	39	285351	166637	279	288	35094	915	2167	207
1955	158	59	350687	118982	194	200	39869	880	2132	142
1956	100	122	402167	97068	253	413	43186	915	2238	151
1957	87	98	260148	134261	328	206	46111	1040	2225	143
1958	102	148	316455	135229	487	195	33164	565	2696	125
1959	93	196	330846	110452	470	353	35823	775	2499	149
1960	55	173	295288	107605	297	114	42842	1145	2140	86
1961	79	212	201646	107617	501	124	49601	795	1954	92
1962	57	147	330273	117163	1312	117	46176	872	2080	112
1963	30	180	353937	95250	2339	54	55842	910	2559	443
1964	104	210	352650	82870	280	73	55059	1065	4084	140
1965	95	176	245326	25678	310	48	64860	930	3183	134
1966	62	220	331980	33317	5	43	49270	940	2907	0
1967	121	0	340382	35237	0	20	66339	1130	2293	0
1968	485	0	201596	35251	0	35	72302	1531	1909	0
1969	573	0	297034	30496	2	99	76413	1340	1320	0
1970	150	0	265548	34379	0	37	83701	1360	625	0
1971	490	0	238322	36292	0	46	78955	1390	637	0
1972	328	0	137661	43573	4	62	80553	1260	761	0

Catch data table 3 cont …										
Spe-cies	Sei whale NA	Gray whale NWP	Harp seal NWA	Harp seal White sea	Hump -back whale NP	Wal-rus West Green -land	SA/ SAus fur seal	Harbour porpoise Greenland	Fin whale NP	Blue whale NP
1973	156	0	134828	43081	0	62	82551	860	467	0
1974	14	0	156564	36883	0	50	67753	740	466	0
1975	366	0	182899	40447	0	82	75306	655	176	0
1976	13	0	178742	42665	0	100	62623	527	43	0
1977	138	0	169793	41707	0	48	77712	1000	26	0
1978	29	0	180490	36344	0	59	73097	795	34	0
1979	98	0	181706	48531	0	74	75624	1075	18	0
1980	103	0	191131	51702	0	55	76400	1220	4	0
1981	100	0	229815	61031	0	76	76400	995	1	0
1982	71	0	198547	75960	0	63	76400	850	0	0
1983	100	0	87555	82089	0	54	34000	910	0	0
1984	95	0	62254	73971	0	60	34000	855	0	0
1985	38	0	44701	80050	0	51	34000	860	1	0
1986	40	0	56914	80149	0	35	34000	690	0	0
1987	20	0	89536	64797	0	63	34000	605	0	0
1988	10	0	137280	70999	0	59	34000	550	0	0
1989	2	0	112105	42877	0	59	34000	395	0	0
1990	0	0	110755	52285	0	58	0	495	0	0
1991	0	0	107196	53308	0	59	0	550	0	0
1992	0	0	126516	44115	0	58	0	595	0	0
1993	0	0	85078	49016	0	242	0	680	0	0
1994	0	0	125944	51572	0	243	0	1716	0	0
1995	0	0	136946	43328	0	268	0	1135	0	0
1996	0	0	326715	50570	0	178	0	1682	0	0
1997	0	0	415931	41418	0	245	0	1550	0	0
1998	0	0	452328	15034	0	171	0	2051	0	0
1999	0	0	427401	37150	0	185	0	1830	0	0
2000	0	0	284252	51127	0	195	60000	1607	0	0
2001	0	0	379713	49516	0	118	0	2216	0	0

Catch data table 4 (Ringed seal – Steller sea lion E Alaska)

Specie s	Ringed seal NP&A	Sei whale NP	Sei whale SH	Fin whale SH	Blue whale SH	Hump -back whale SH	Bairds beaked whale Japan	Bry-de's whale SH	Ring-ed seal Baltic	Steller sea lion E Alaska
Onset of hunt	1903	1904	1904	1904	1904	1904	1907	1909	1909	1912
1903	4512									
1904	0	39	0	4	11	180				
1905	0	0	97	104	51	311				
1906	0	2	0	93	68	441				
1907	0	0	0	122	106	1391	15			
1908	0	0	215	295	245	3407	15			
1909	0	2	346	437	212	5810	15	3	10000	
1910	5527	156	225	694	387	8077	15	0	10000	
1911	5500	375	49	1916	1235	10371	15	73	10000	
1912	8912	236	201	4724	2505	11101	15	188	10000	0
1913	6521	369	351	5211	2774	10103	15	85	10000	2627
1914	6557	243	393	4779	5127	7589	15	0	10000	750
1915	4306	723	218	6076	5636	3760	15	66	10000	4089
1916	0	440	181	2916	4387	577	15	26	10000	0
1917	0	607	199	2213	3173	153	15	0	10000	0
1918	0	743	195	3148	2046	191	15	32	10000	0
1919	0	534	367	3658	2009	393	15	16	0	0
1920	0	569	107	5677	3002	562	15	17	0	0
1921	0	474	150	2563	4521	370	15	0	0	0
1922	0	390	139	4289	6774	1690	15	2	0	220
1923	0	493	390	3909	4918	1556	15	11	0	1885
1924	0	642	672	5654	6966	1362	15	84	6000	2706
1925	0	522	440	10488	6422	2448	15	29	6000	2827
1926	0	587	1255	7017	8665	1846	15	60	6000	1956
1927	0	599	553	5841	10106	1290	15	31	6000	1663
1928	4800	312	2123	7679	13900	1369	15	59	6000	1142
1929	6500	733	465	13234	18726	1026	15	27	6000	1359
1930	6800	842	359	11159	30457	1434	15	14	6000	1068
1931	7450	418	44	3337	6659	420	15	0	6000	1357
1932	2117	372	35	5509	18983	506	15	0	6000	1128
1933	25800	391	26	7823	17432	1079	14	0	6000	923
1934	0	301	324	13205	16612	3277	14	0	6000	786
1935	0	386	186	10289	17870	4901	14	0	6000	623
1936	0	348	804	15759	14598	8806	14	7	6000	3867
1937	0	449	285	29312	15119	7192	14	36	6000	2585
1938	0	553	133	21376	14127	3810	14	0	6000	3249
1939	0	677	138	19303	11518	293	14	0	6000	1245
1940	0	432	128	4387	1754	562	14	0	0	134
1941	0	641	51	1226	51	178	14	0	0	111
1942	0	256	86	980	127	227	14	0	0	208
1943	0	354	231	933	38	174	14	0	0	45
1944	0	736	102	2479	1361	263	14	0	0	97
1945	0	74	119	9430	3646	461	14	0	0	293

Catch data table 4 cont ...										
Species	Ringed seal NP&A	Sei whale NP	Sei whale SH	Fin whale SH	Blue whale SH	Hump -back whale SH	Bairds beaked whale Japan	Bry-de's whale SH	Ring-ed seal Baltic	Steller sea lion E Alaska
1946	0	573	490	14746	9083	248	14	0	0	304
1947	0	532	810	22006	7122	254	14	55	0	275
1948	0	706	788	19965	7731	461	76	238	0	113
1949	0	959	1504	20636	6240	5869	95	157	0	359
1950	0	639	1157	20068	7035	5355	197	100	0	2110
1951	0	771	1638	24050	5147	4582	242	23	0	231
1952	0	1314	1849	23971	4002	3492	322	0	0	252
1953	0	809	1576	28568	2888	2952	270	7	0	311
1954	2318	1057	825	27505	2270	3898	230	0	0	180
1955	3103	804	908	30932	2023	6338	258	0	0	275
1956	2148	1054	1972	28373	1715	3149	297	0	2950	339
1957	5388	882	3617	27817	1769	4774	186	34	2950	521
1958	2743	1549	3076	27477	1250	8065	229	29	2950	1103
1959	8814	1820	4698	25578	936	15774	186	41	2950	3288
1960	12433	1239	6409	27296	1743	14902	147	9	2950	2050
1961	17278	943	7285	27074	1143	7179	133	10	2950	812
1962	38693	2067	6968	17910	1748	3745	145	70	2950	1386
1963	20950	2581	10906	14197	1508	843	160	136	2950	1015
1964	21376	3661	21963	7958	3347	269	189	681	2950	952
1965	23695	3185	21298	3919	1477	2203	172	428	2950	548
1966	21029	4478	17611	3882	665	1093	171	151	2950	227
1967	23752	6113	16367	3079	462	929	107	89	2950	70
1968	15936	5749	11311	3762	674	5	117	8	2950	15
1969	15707	5158	10802	3120	920	1	138	33	2950	2
1970	17848	3723	9371	8498	834	1700	113	19	2950	2
1971	15954	2698	7376	2337	538	3	118	488	2950	2
1972	15713	2326	4536	1823	7	0	86	3	2950	2
1973	7606	1856	4885	1340	1	9	40	322	2950	2
1974	6951	1280	4311	1010	0	4	40	467	2950	2
1975	8781	508	1997	232	0	8	40	418	2950	2
1976	6628	0	1875	8	0	4	40	639	0	2
1977	5599	0	590	2	0	4	40	501	0	2
1978	5836	0	101	0	0	11	40	302	0	2
1979	2500	0	65	0	0	0	40	420	0	2
1980	2500	0	0	0	0	0	40	211	0	2
1981	2500	0	0	0	0	0	40	162	0	2
1982	2500	0	0	0	0	0	40	320	0	2
1983	2500	0	0	1	0	0	40	333	0	2
1984	2500	0	0	0	0	0	40	0	0	2
1985	3750	0	0	0	0	0	40	0	0	2
1986	4140	0	0	0	0	0	40	0	0	2
1987	4707	0	0	0	0	0	40	0	0	2
1988	5398	0	0	0	0	0	58	0	0	2
1989	3777	0	0	0	0	0	60	0	0	2
1990	3797	0	0	0	0	0	60	0	0	46
1991	723	0	0	0	0	0	60	0	0	46

Catch data table 4 cont ...										
Specie s	Ringed seal NP&A	Sei whale NP	Sei whale SH	Fin whale SH	Blue whale SH	Hump -back whale SH	Bairds beaked whale Japan	Bry-de's whale SH	Ring-ed seal Baltic	Steller sea lion E Alaska
1992	781	0	0	0	0	0	60	0	0	46
1993	530	0	0	0	0	0	60	0	0	46
1994	628	0	0	0	0	0	60	0	0	46
1995	0	0	0	0	0	0	60	0	0	46
1996	0	0	0	0	0	0	60	0	0	46
1997	0	0	0	0	0	0	60	0	0	46
1998	0	0	0	0	0	0	60	0	0	46
1999	0	0	0	0	0	0	60	0	0	46
2000	9567	0	0	0	0	0	62	0	0	46
2001	9567	1	0	0	0	0	62	0	0	46

Catch data table 5 (Minke whale SH – Hooded seal NWA)

Species	Minke whale SH	Bryde whale NA	Minke whale NA	SA sea lion N Patagonia	Killer whale NP	Minke whale NP	Hooded seal Jan Mayen	Bryde whale NP	Harp seal West Ice	Hooded seal NWA
Onset of hunt	1921	1925	1926	1930	1935	1940	1940	1946	1946	1946
1921	1									
1922	0									
1923	0									
1924	0									
1925	0									
1926	0		8							
1927	0		4							
1928	0		0							
1929	0		6							
1930	0		28	6492						
1931	0		0	6492						
1932	0		0	6492						
1933	0		0	6492						
1934	0		0	6492						
1935	0		3	6492	3					
1936	0		3	6492	3					
1937	0		6	6492	3					
1938	0		1353	6492	26					
1939	0		918	6492	26					
1940	0		552	6493	26	95	15000			
1941	0		2124	6493	26	184	15000			
1942	0		2148	6493	26	243	15000			
1943	0		1627	6493	26	183	15000			
1944	0		1363	6493	26	168	15000			
1945	0		1797	6493	26	10	15000			
1946	0		1.92E+03	6493	44	0	56409	71	36070	7500
1947	0		2601	6492	51	0	56409	159	36070	7500

Catch data table 5 cont …										
Species	Minke whale SH	Bryde whale NA	Minke whale NA	SA sea lion N Patagonia	Killer whale NP	Minke whale NP	Hooded seal Jan Mayen	Bryde whale NP	Harp seal West Ice	Hooded seal NWA
1948	0		3628	6492	78	266	56409	107	36070	7500
1949	1		3995	6492	95	193	56409	143	36070	7500
1950	0		2035	6492	65	244	56409	243	36070	10500
1951	4		2861	6492	107	343	69429	280	39590	10500
1952	6		3414	6492	99	489	69429	412	39590	10500
1953	12		2525	6492	108	414	69429	47	39590	10500
1954	0		3591	6492	147	371	69630	2	40097	12694
1955	36		4402	6492	101	446	69773	95	39813	12444
1956	45		3782	6492	111	567	53491	27	27608	11686
1957	11		3741	6492	108	696	53639	43	27596	12094
1958	11		4457	6492	98	812	53592	301	27813	12192
1959	4		3210	6492	72	629	53961	305	27598	12060
1960	3		3409	6492	101	586	54331	407	27788	12430
1961	3		3345	0	59	443	47955	172	23502	11846
1962	21		3473	0	55	409	48118	504	23491	11590
1963	119		3469	0	64	605	47933	210	23505	12284
1964	60		3007	0	103	737	47722	74	23402	14870
1965	81		2759	0	172	608	47114	8	23348	14144
1966	389		2532	0	139	666	32538	63	18567	19142
1967	1115		2586	0	111	621	32215	63	18570	18716
1968	610		3186	0	36	555	32147	541	18690	18284
1969	767		2822	0	25	631	31897	459	18625	19144
1970	915		2706	0	29	1045	32199	509	18703	18324
1971	4161		2648	0	15	1017	30994	1289	11217	18768
1972	6584		3041	0	5	1108	22043	571	15272	20266
1973	8543		2447	0	3	1423	27126	1099	11996	20808
1974	7885		2141	0	2	938	27613	1733	14873	21102
1975	7185		2178	0	5	931	28280	1803	5254	22858
1976	8676		2553	0	1	855	8129	1829	12842	23960
1977	6000		2254	0	2	1281	21091	1316	17191	23002
1978	6156		1970	0	1	1497	21805	966	16919	22770
1979	7897		2430	0	5	1315	25849	1397	15449	22724
1980	7142		2463	0	2	1305	13870	1124	13875	31058
1981	7903		2282	0	6	1135	14526	863	15951	30990
1982	7301		2419	0	5	1226	17888	802	12213	32296
1983	6680		2341	0	0	775	1942	697	7995	19310
1984	5568		1228	0	0	745	1927	709	2564	17728
1985	5567		1152	0	0	449	5814	357	1156	14188
1986	4969		526	0	0	380	7820	317	5331	13796
1987	273		463	0	0	304	14112	317	15819	13333
1988	241		148	0	0	0	9187	0	17163	11000
1989	330		90	0	0	2	181	0	4429	11000
1990	327		100	0	0	0	1236	0	6292	636
1991	288		107	0	0	0	2542	0	6695	6321
1992	330		209	0	0	0	8793	0	9633	119
1993	330		342	0	0	0	384	0	3520	19
1994	330		389	0	0	21	4744	0	8193	149
1995	440		380	0	0	100	933	0	8206	857

Catch data table 5 cont …										
Species	Minke whale SH	Bryde whale NA	Minke whale NA	SA sea lion N Patagonia	Killer whale NP	Minke whale NP	Hooded seal Jan Mayen	Bryde whale NP	Harp seal West Ice	Hooded seal NWA
1996	440		564	0	0	77	811	0	6427	25754
1997	438		665	0	0	100	934	0	2161	7058
1998	389		801	0	0	100	6332	1	1884	10148
1999	439		776	0	0	100	0	0	803	201
2000	440		642	0	0	42	0	43	12343	10
2001	440		708	0	0	101	0	50	2992	140

Catch data table 6 (Long finned pilot whale NWA – Atlantic white-sided dolphin NWA)

Species	Long finned pilot whale NWA	Short finned pilot whale Japan	Ribbon seal Bering	Gray seal Iceland	Gray seal Scotland	Walrus E Green-land	Walrus North-water	Bottle-nose dolphin NWA	Har-bour por-poise North Sea	Atlantic white-sided dolphin NWA (US)
Onset of hunt	1947	1948	1950	1950	1950	1950	1950	1950	1950	1950
1947	0									
1948	215	725								
1949	0	890								
1950	172	715	75	0	0	0	0	0	0	0
1951	3102	618	75	0	0	0	0	0	0	0
1952	3155	335	75	0	0	0	0	0	0	0
1953	3584	460	75	0	0	0	0	0	0	0
1954	2298	75	75	0	0	0	0	0	0	0
1955	6612	61	75	0	0	0	0	0	0	0
1956	9794	297	75	0	0	4	0	0	0	0
1957	7831	174	75	0	0	4	0	0	0	0
1958	789	197	75	0	0	4	0	0	0	0
1959	1725	144	75	0	0	4	0	0	0	0
1960	1957	168	75	0	0	4	180	0	0	0
1961	6262	133	13075	0	0	4	180	0	0	0
1962	150	80	13075	293	0	4	180	0	0	0
1963	221	228	13075	568	0	4	180	0	0	0
1964	2849	217	13075	593	0	4	180	0	0	0
1965	1520	288	13075	767	0	4	180	0	0	0
1966	887	199	13075	404	0	4	180	0	0	0
1967	739	237	13075	449	0	4	180	0	0	0
1968	204	166	75	524	0	4	180	0	0	0
1969	123	130	75	579	0	4	180	0	0	0
1970	155	152	75	404	0	4	180	0	0	0
1971	4	181	75	557	0	4	180	0	0	0
1972	0	91	75	415	0	4	180	0	0	0
1973	0	0	75	483	0	4	180	0	0	0
1974	0	0	75	406	0	4	180	0	0	0
1975	0	0	75	122	0	4	180	0	0	0

Catch data table 6 cont …										
Species	Long finned pilot whale NWA	Short finned pilot whale Japan	Ribbon seal Bering	Gray seal Iceland	Gray seal Scotland	Walrus E Green-land	Walrus North-water	Bottle-nose dolphin NWA	Har-bour por-poise North Sea	Atlantic white-sided dolphin NWA (US)
1976	0	0	75	274	0	4	180	0	0	0
1977	0	0	75	96	3154	4	180	0	0	0
1978	0	0	75	146	2785	4	180	0	0	0
1979	0	0	75	344	2648	4	180	0	0	0
1980	0	0	75	85	3028	4	180	0	0	0
1981	0	0	75	28	2833	4	180	0	0	0
1982	0	0	75	488	0	4	180	0	0	0
1983	0	0	75	1366	0	4	180	0	0	0
1984	0	0	75	782	0	4	180	0	0	0
1985	0	0	75	0	0	4	180	0	0	0
1986	0	0	75	0	0	4	180	0	0	0
1987	0	0	75	982	0	4	180	0	6630	0
1988	0	0	75	1645	0	4	180	0	6727	0
1989	0	0	75	0	0	4	180	72	5230	0
1990	0	0	75	586	0	4	180	115	5257	0
1991	0	0	75	393	0	4	180	130	6573	41
1992	0	0	75	828	0	4	180	101	7099	154
1993	0	0	75	1760	0	8	145	107	7421	205
1994	0	0	75	1615	0	8	145	18	7566	240
1995	0	0	75	1327	0	8	145	22	7308	80
1996	0	0	75	935	0	8	145	73	6762	114
1997	0	0	75	1274	0	8	145	435	5731	140
1998	0	0	75	567	0	8	145	390	4974	34
1999	0	0	75	662	0	8	145	394	3840	69
2000	0	0	75	500	0	8	145	74	3226	26
2001	0	0	75	500	0	8	145	0	2867	26

Catch data table 7 (Killer whale SH – Largha or spotted seal Bering)

Species	Killer whale SH	Ringed seal NA&A	Killer whale NA	Pan-tropical spotted ETP	Spinner ETP	Short beaked common dolphin ETP	Steller sea lion W Alaska	Dall's porpoise Japan	False killer whale Japan	Largha or spotted seal Bering
Onset of hunt	1953	1954	1954	1959	1959	1959	1959	1963	1965	1965
1953	21									
1954	11	30758	13							
1955	33	37986	27							
1956	54	46527	40							
1957	75	44888	48							
1958	110	48010	39							
1959	55	51625	69	16305	6452	728	3271			
1960	64	149822	82	349835	138426	15619	3271			
1961	0	154094	111	387807	153451	17314	3271			

Catch data table 7 cont ...										
Species	Killer whale SH	Ringed seal NA&A	Killer whale NA	Pan-tropical spotted ETP	Spinner ETP	Short beaked common dolphin ETP	Steller sea lion W Alaska	Dall's porpoise Japan	False killer whale Japan	Largha or spotted seal Bering
1962	1	142931	124	157183	62196	7018	3271			
1963	10	163459	90	175380	69396	7830	3271	9040		
1964	1	172164	80	284791	112689	12715	3271	9440		
1965	9	160673	105	334874	132506	14951	3271	9180	2	5000
1966	5	168229	163	272465	107812	12165	3271	7980	0	5000
1967	0	144587	37	182559	72237	8151	3271	5150	0	5000
1968	6	153456	86	165969	65672	7410	3271	6020	5	5000
1969	23	160356	232	317914	125795	14194	3271	7020	0	5000
1970	23	169882	247	300764	119009	13428	3271	8060	1	5000
1971	9	164302	59	173135	68508	7730	3271	5210	5	5000
1972	22	167753	30	254642	100760	11369	3271	5190	2	5000
1973	55	177444	1	141410	18598	5000	417	7230	0	5000
1974	47	173834	9	90783	18561	5000	418	6470	0	5000
1975	24	172851	2	99696	18526	5000	418	7350	0	5000
1976	29	171869	3	68250	16888	5000	418	9899	0	5000
1977	77	181232	15	21631	10440	5000	418	9358	35	5000
1978	49	190757	102	19096	7193	5000	1560	8426	445	5000
1979	916	282493	227	11981	7160	6597	1058	6843	395	5000
1980	0	229671	57	22614	9240	2211	1149	6920	245	5000
1981	0	231809	20	20608	8673	3349	863	12629	0	5000
1982	0	226393	5	19123	7056	1504	1963	18736	6	5000
1983	0	221962	3	7017	5416	1036	1711	17056	0	0
1984	0	139099	0	17854	13165	7409	1590	13119	0	0
1985	0	129086	0	34064	15832	7143	1074	13617	0	0
1986	0	70000	0	72109	30568	24307	655	18234	0	0
1987	0	70000	0	54664	16384	24634	244	26611	0	0
1988	0	70000	0	40541	22338	16176	44	40367	0	0
1989	0	70000	0	57428	23547	14353	31	32113	0	0
1990	0	70000	0	35194	12330	5029	31	24895	0	0
1991	0	70000	0	13826	8853	3458	31	14332	0	0
1992	0	70000	0	6531	4838	3652	580	11403	0	0
1993	0	69945	0	1896	1233	311	518	14318	0	0
1994	0	132216	0	2161	1362	252	447	15947	0	0
1995	0	72560	0	1811	1099	201	370	12396	0	0
1996	0	90309	0	1363	897	158	210	16100	0	0
1997	0	80387	0	1765	889	181	195	18540	0	0
1998	0	82108	0	639	671	466	209	11385	0	0
1999	0	83453	0	611	555	120	209	14807	0	0
2000	0	80425	0	730	537	287	200	16171	0	0
2001	0	78615	0	903	841	343	230	16650	0	0

Catch data table 8 (Largha or spotted seal Okhotsk – Narwhal Hudson)

Species	Larga or spotted seal Okhotsk	Bearded seal Chukchi	Bottle-nose dolphin Japan	Largha or spotted seal NEP	Gray seal Sable Island	Pan-tropical spotted Japan	Narwhal Baffin Canada	Narwhal Hudson
Onset of hunt	1965	1966	1966	1966	1967	1970	1977	1977
1965	8000							
1966	8000	7472	460	2400				
1967	8000	8309	13	2400	1000			
1968	8000	5627	14	2400	1000			
1969	8000	3758	2	2400	1000			
1970	8000	4292	1	2400	1000	1645		
1971	8000	3244	0	2400	1000	0		
1972	8000	2781	0	2400	1000	448		
1973	8000	2793	84	2400	1000	206		
1974	8000	2856	35	2400	1000	0		
1975	8000	2420	38	2400	1000	102		
1976	8000	3769	0	2400	1720	468		
1977	8000	5954	899	1000	1720	344	245	245
1978	8000	6788	1012	1000	1720	756	261	273
1979	8000	6788	565	1000	1720	0	309	371
1980	8000	6788	2756	1000	1720	1058	324	376
1981	8000	6788	18	1000	1720	0	366	434
1982	8000	6788	131	1000	1720	3799	382	426
1983	0	6788	0	1000	1720	2945	333	355
1984	0	6788	0	1000	0	0	258	312
1985	0	6788	0	986	0	0	298	330
1986	0	6788	0	986	0	0	247	261
1987	0	6788	0	1000	0	0	145	215
1988	0	6788	0	1000	0	0	234	286
1989	0	6788	0	1000	0	0	326	358
1990	0	6788	0	5265	0	0	258	292
1991	0	6788	0	5265	0	0	355	393
1992	0	6788	0	5265	0	629	305	345
1993	0	6788	0	5265	0	0	318	346
1994	0	6788	0	5265	40	0	344	356
1995	0	6788	0	5265	364	0	237	277
1996	0	6788	0	5265	132	0	267	321
1997	0	6788	0	5265	72	0	236	326
1998	0	6788	0	5265	275	0	357	407
1999	0	6788	0	5265	98	0	378	700
2000	0	6788	0	5265	342	0	547	665
2001	0	6788	0	5265	76	0	415	631

Catch data table 9 (Narwhal Baffin Greenland – Harbour seal California)

Species	Narwal Baffin Greenland	Northern right whale dolphin NP	California sea lion Califonia	Short beaked common dolphin NWA	Harbour porpoise WNA	Harbour seal California
Onset of catches	1977	1978	1980	1989	1989	1991
1977	387					
1978	612	355				
1979	377	355				
1980	462	1007	1571			
1981	609	982	45			
1982	461	8599	0			
1983	439	10044	4327			
1984	666	13547	2469			
1985	256	18581	2359			
1986	237	18892	4288			
1987	505	19443	2722			
1988	500	22128	3207			
1989	312	31820	0	540	2304	
1990	1057	28746	0	893	7543	
1991	587	12449	0	229	2015	601
1992	587	0	0	259	3488	1204
1993	614	0	0	273	1826	475
1994	995	0	948	163	2207	227
1995	485	0	773	96	1705	228
1996	691	0	1093	212	1861	296
1997	745	0	1468	525	1979	349
1998	775	0	1443	17	1251	392
1999	863	0	1527	195	399	662
2000	600	0	1613	273	21	415
2001	673	0	1291	126	0	329

APPENDIX VII: CATCH DATA SOURCES

Specie	Area	Sources
Antarctic fur seal	Southern Hemisphere	(Richards, 2003, Mori and Butterworth, 2005)
Atlantic white-sided dolphin	Northwest Atlantic	(Waring *et al.*, 2003)
Baird's beaked whale	Japan	(Ohsumi, 1975, Ohsumi, 1983, Klinowska, 1991, Reeves and Mitchell, 1993, IWC, 2004)
Bearded seal	Chukchi sea	(Burns, 1981, Ridgway and Harrison, 1981, Angliss and Lodge, 2002)
Beluga	Arctic	(Mitchell, 1975, Doidge and Finley, 1994, Richard, 1994, Frost and Suydam, 1995, Frost, 1998, Mahoney and Shelden, 2000, Angliss and Lodge, 2002, Heide-Jørgensen and Rosing-Asvid, 2002)
Blue whale	North Atlantic	(Sigurjónsson and Gunnlaugsson, 1990, Sigurjónsson, 1995, Sigurjónsson, 1997, Reeves *et al.*, 1998, IWC/BIWS, 2001)
Blue whale	North Pacific	(Ohsumi and Wada, 1972, IWC/BIWS, 2001, Nichol *et al.*, 2002, Carretta *et al.*, 2004)
Blue whale	Southern Hemisphere	(IWC/BIWS, 2001, Anon., 2005)
Bottlenose dolphin	Northwest Atlantic	(Waring *et al.*, 2003)
Bottlenose dolphin	Japan	(Kasuya, 1985)
Bowhead whale	Arctic	(Ross, 1993, Stoker and Krupnik, 1993, Woodby and Botkin, 1993, Hacquebord, 1999, IWC/BIWS, 2001)
Bryde's whale	Southern Hemisphere	(IWC/BIWS, 2001)
Bryde's whale	North Atlantic	(IWC/BIWS, 2001)
Bryde's whale	North Pacific	(Tillman and Breiwick, 1983, Holt, 1986)
California sea lion	California	(DeMaster *et al.*, 1985, Reijnders *et al.*, 1993, Forney *et al.*, 2000, Anon., 2001, Carretta *et al.*, 2003)
Dall's porpoise	Japan	(Jones, 1990, Northridge, 1991, Yatsu *et al.*, 1994, IWC, 2002, Bass, 2005)
Elephant seal	Southern Hemisphere	(Reeves *et al.*, 1992, Laws, 1994, Le Boeuf and Laws, 1994, Anon., 1999)
False killer whale	Japan	(Kasuya, 1985)
Fin whale	North Atlantic	(Mitchell, 1974, IWC/BIWS, 2001, Waring *et al.*, 2003)
Fin whale	North Pacific	(Doroshenko, 2000, IWC/BIWS, 2001, Nichol *et al.*, 2002, Angliss and Lodge, 2003)
Fin whale	Southern Hemisphere	(IWC/BIWS, 2001)
Gray seal	Iceland	(Anon., 2001)
Gray seal	Scotland	(Bonner, 1990)
Gray seal	Sable Island	(Anon., 2001, Waring *et al.*, 2003)
Gray whale	Northeast Pacific	(IWC, 1993, Urban-Ramirez *et al.*, 2003)
Gray whale	Northwest Pacific	(Kato and Kasuya, 2002)
Harbour Porpoise	Baltic sea	(MacKenzie *et al.*, 2002)
Harbour Porpoise	Greenland	(Anon., 1969, Kapel, 1971, Kapel, 1975, Mitchell, 1975, Teilmann and Dietz, 1998, Stenson, 2003, Anon., 2006)
Harbour Porpoise	North Sea	(Stenson, 2003)
Harbour Porpoise	Northwest Atlantic	(NEFSC, 2001, Read *et al.*, 2003, Stenson, 2003)
Harbour seal	California	(Forney *et al.*, 2000, Carretta *et al.*, 2003)
Harp seal	Northwest Atlantic	(Kapel, 1986, Stenson *et al.*, 1999, Anon., 2001, Walsh *et al.*, 2001, Read *et al.*, 2003, DFO, 2004, Fink and Lavigne, 2005)
Harp seal	White Sea	(Sergeant, 1991, ICES, 2003)
Harp seal	West Ice	(Kapel, 1986, Anon., 2001, Anon., 2001, Fink and Lavigne, 2005)
Hooded seal	Jan Mayen	(ICES, 1990)
Hooded seal	Northwest Atlantic	(Kapel, 1986, Reijnders *et al.*, 1993, Anon., 2001)
Humpback whale	North Atlantic	(IWC/BIWS, 2001, Reeves *et al.*, 2001, Smith *et al.*, 2002, Smith and Reeves, 2003)
Humpback whale	North Pacific	(Clapham *et al.*, 1997, IWC/BIWS, 2001, Nichol *et al.*, 2002, Calambokidis and Barlow, 2004)

Specie	Area	Sources
Catch data sources cont …		
Humpback whale	Southern Hemisphere	(IWC/BIWS, 2001, Clapham and Baker, 2002, Garrigue *et al.*, 2004, Anon., 2005)
Killer whale	North Pacific	(Bigg and Wolman, 1975, Mitchell, 1975, Ohsumi, 1975, Hoyt, 1990)
Killer whale	Southern Hemisphere	(Mitchell, 1975, Hoyt, 1990)
Killer whale	North Atlantic	(Mitchell, 1975, Hoyt, 1990)
Largha or spotted seal	Bering sea	(Popov, 1982)
Largha or spotted seal	Okhotsk sea	(Popov, 1982)
Largha or spotted seal	Northeast Pacific	(Angliss and Lodge, 2002)
Long finned pilot whale	Faroe Islands	(Anon., 2004)
Long finned pilot whale	Northwest Atlantic	(Mercer, 1975)
Minke whale	Southern Hemisphere	(IWC/BIWS, 2001)
Minke whale	North Atlantic	(IWC/BIWS, 2001)
Minke whale	North Pacific	(IWC/BIWS, 2001, Allison (IWC, pers. comm. to Caretta, J.V. *et al*, 2003.), Angliss and Lodge, 2003, Carretta *et al.*, 2003)
Narwhal	Baffin Bay - Canada	(COSEWIC, 2004)
Narwhal	Hudson Bay	(COSEWIC, 2004)
Narwhal	Baffin Bay – Greenland	(COSEWIC, 2004) (Anon., 2006)
Northern bottlenose whale	North Atlantic	(Lubbock, 1937, Mitchell, 1975, Christensen *et al.*, 1977, Reeves *et al.*, 1993, Bloch *et al.*, 1996)
Northern fur seal	North Pacific	(Busch, 1985, Anon., 1993, Angliss and Lodge, 2003)
Northern right whale dolphin	North Pacific	(Mangel, 1993, Yatsu *et al.*, 1994)
Pantropical spotted dolphin	Eastern Tropical Pacific	(Smith, 1979, Allen, 1985, Wade, 1995, IATTC, 2006)
Pantropical spotted dolphin	Japan	(IWC, 1984, Kasuya, 1985)
Ribbon seal	Bering sea	0
Right whale	North Atlantic	(Aguilar, 1986, Reeves and Mitchell, 1986, Reeves *et al.*, 1999, IWC/BIWS, 2001, Commission, 2003)
Right whale	Southern Hemisphere	(Du Pasquier, 1986, IWC/BIWS, 2001)
Right whale	North Pacific	(Reeves *et al.*, 1985, Best, 1987, IWC/BIWS, 2001, Nichol *et al.*, 2002, Angliss and Lodge, 2003)
Ringed seal	North Pacific and Arctic	(Frost, 1985, Kelly, 1988, Reeves *et al.*, 1998, Angliss and Lodge, 2002)
Ringed seal	Baltic sea	(Härkönen *et al.*, 1998)
Ringed seal	North Atlantic and Arctic	(Reijnders *et al.*, 1993, Reeves *et al.*, 1998, Teilmann and Kapel, 1998, NAMMCO, 2003)
Sei whale	North Atlantic	(Horwood, 1987, IWC/BIWS, 2001)
Sei whale	North Pacific	(IWC/BIWS, 2001, Nichol *et al.*, 2002, Carretta *et al.*, 2003)
Sei whale	Southern Hemisphere	(IWC/BIWS, 2001)
Short beaked common dolphin	Eastern Tropical Pacific	(Wade, 1995, IATTC, 2006)
Short beaked common dolphin	Northwest Atlantic	(Waring *et al.*, 1999, Waring *et al.*, 2003)
Short finned pilot whale	Japan	(Ohsumi, 1975)
South African / Australian fur seal	South Africa	(Warneke and Shaughnessy, 1985, Wickens *et al.*, 1991, Reijnders *et al.*, 1993)
South American sea lion	North Patagonia	(Strange, 1979, Anon., 1999, Dans *et al.*, 2004)

Specie	Area	Sources
Catch data sources cont …		
Sperm whale	Global	(IWC, 1969, Best, 1976, Ohsumi, 1980, Gosho *et al.*, 1984, Mitchell and Kozicki, 1984, Christensen *et al.*, 1992, Barnes, 1996, Sigurjónsson, 1997, Brownell *et al.*, 1998 (unpublished), Kasuya, 1998 (unpublished), Perry *et al.*, 1999, Carretta *et al.*, 2001, IWC/BIWS, 2001, Nichol *et al.*, 2002, Reeves, 2002, Waring *et al.*, 2002, Anon., 2005)
Spinner dolphin	Eastern Tropical Pacific	(Wade, 1995, Anon., 2005, IATTC, 2006)
Steller sea lion	East Alaska	(Bigg, 1984, Merrick *et al.*, 1987)
Steller sea lion	West Alaska	(Woodley and Lavigne, 1991, Angliss and Lodge, 2003)
Walrus	Spitsbergen	(Ross, 1993)
Walrus	Chukchi-Bering sea	(Fay *et al.*, 1989, Anon., 2002)
Walrus	West Greenland	(Born, 2005)
Walrus	East Greenland	(Born, 2005)
Walrus	Northwater	(Born, 2005)