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Computations of Historic and Current Biomass Estimates of Marine Mammals in the Bering Sea

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COMPUTATIONS OF HISTORIC AND CURRENT BIOMASS ESTIMATES OF MARINE MAMMALS IN THE BERING SEA

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Abstract

This report documents the overall decline in marine mammal biomass in the U.S. portion of the Bering Sea/Aleutian Island region from before and after the most recent period of commercial harvesting of large whales and pinnipeds. Historic and current biomass estimates of nineteen species of marine mammals were calculated for this region. Results were highly sensitive to the inclusion of sperm whale data. Analysis showed that large whales are the main contributors to historic and current biomass in the Bering Sea on a yearly and seasonal basis. Pinnipeds are the next largest contributors and small cetaceans represent a minute percentage of the overall biomass. More biomass is present in the summer, reflecting the influx of large whales into the Bering Sea during those months. Overall, there was an 80% reduction in marine mammal biomass when the analysis included sperm whales and a 49% reduction when sperm whale biomass was excluded from the analysis. There was an 82% reduction in large whale biomass when sperm whale biomass was included in the analysis, a 54% reduction when it was not included and a 30% reduction in pinniped biomass. Most of this decline occurred 50-100 years ago. Therefore, for species that have experienced some recovery, the current estimates of relative biomass are likely higher than they were at the end of the harvest. The data presented in this report are the best available and provide a general picture of the historic and current levels of marine mammal biomass in the Bering Sea/Aleutian Islands region during the defined time periods.

Contents

Introduction

The Bering Sea ecosystem supports 26 species of marine mammals including large whales, beaked whales, small cetaceans, pinnipeds, the polar bear (*Ursus maritimus*) and the sea otter (*Enhydra lutris*) (National Research Council 1996). Many of these species were severely impacted by large-scale commercial harvesting, of which the most recent phase took place from the early 1800s to the mid-1900s (Clapham and Baker 2002, Webb 1988). During this time period, many individuals of different species were removed from the ecosystem. The effect of this large-scale removal of top predators has yet to be carefully studied and is largely unknown, despite studies that have attempted to quantify changes in trophic interactions from pre- to post-commercial harvest periods (Trites et al. 1999, Sobloevsky and Mathisen 1996).

From an ecological perspective, marine mammals occupy three ecological roles as consumers, prey and detritus. If they are important drivers of ecological process in ocean ecosystems, their removal could have affected top-down and bottom-up food web interactions. As consumers, marine mammals feed on zooplankton, invertebrates, fish and other marine mammals (Heithaus and Dill 2002). As detritus, it is thought that dead whales play an important role in deep seafloor ecosystems by providing a unique habitat that supports highly diverse chemoautotropic communities (Snelgrove and Smith 2002, Smith and Baco 2003).

Throughout the world’s oceans, transient killer whales (*Orcinus orca*) are one of several key predators of marine mammals. They have been documented preying on over 35 different species including cetaceans, pinnipeds, sirenians and mustelids (Jefferson et al. 1991, Ford 2002). How then might the prey field of killer whales have been affected by commercial whaling and commercial pinniped harvests?

Some transient killer whale populations subsist mostly on a diet of pinnipeds (Weller 2002). Therefore, the abundance of either one these populations can directly influence the dynamics of the other. Several potential causes for the lack of recovery of the western Alaska stock of Steller sea lions (*Eumetopius jubatus*) have been identified and include: nutritional limitation, predator- induced mortality, mortality from shooting, incidental mortality in fishing operations, entanglement and disease, and human disturbance of haulouts and rookeries (National Research Council 2003). Killer whale predation, in the context of the predator pit model (Messier 1994, Messier and Crête 1985), has been discussed as a possible contributing factor in the recent decline. This model assumes that killer whales do not solely prey on Steller sea lions, yet the removal rate, combined with the other factors listed above, might be sufficient to keep the sea lion population from recovering.

The decline of Steller sea lions has been linked to killer whale predation on sea otters throughout the Aleutian archipelago. Estes et al. (1998) hypothesized that the recent addition of sea otters to the killer whale diet might have been a nutritional response to previous declines of other pinniped prey species, namely the northern fur seal (*Callorhinus ursinus*), Steller sea lion and harbor seal (*Phoca vitulina richardii*). If the populations of these three pinnipeds declined to the point that they could no longer support the population of transient killer whales, the whales may have expanded their diet to include the sea otter.

In a recent publication, Springer et al. (2003) expanded upon the ideas put forth in the Estes et al. (1998) study, speculating that the removal of large whales in the Bering Sea/Aleutian Islands region led directly to the observed declines in pinniped (i.e., harbor seal, northern fur seal, and Steller sea lion) and sea otter abundance. The proposed mechanism for this relationship was increased predation by killer whales on pinnipeds and sea otters following the severe reduction in availability of the killer whale's primary prey in this region – large whales (i.e., sperm whale (*Physeter macrocephalus*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), gray whale (*Eschrictius robustus*), northern right whale (*Eubalaena japonicus*) and bowhead whale (*Balaena mysticetus*)).

The examples provided above illustrate how predator-prey interactions can influence the structure and dynamics of marine ecosystems. Studies that document the temporal and spatial removal of large whales and quantify the resulting changes in biomass of marine mammal species in the ecosystems from which they were removed provide a foundation for more complex studies regarding the ecological effects of the removal of large whales from the world's oceans. This report documents the overall change in marine mammal biomass from one ecosystem, the Bering Sea, between two time periods: prior to the onset of commercial harvesting of large whales and pinnipeds and the present, taking into account population structure and age- and sex-specific seasonal movement patterns.

Methods

Historic and current biomass estimates of 19 species of marine mammals were calculated for the U.S. portion of the Bering Sea/Aleutian Islands region (Fig. 1). Seven species of large whales, three species of small cetaceans, eight species of pinnipeds and the sea otter were included in the analysis (See Table 1 for a list of these species).

To calculate biomass, the following information was compiled for each species: historic abundance, current abundance, average body weight, percentage of the population present in the region, and seasonal presence. Data were derived from a variety of published and unpublished documents, databases, or through personal communications. When possible, historic abundance estimates were determined for the time period before commercial exploitation of a species and current abundance estimates were reported as the most recent available. In some cases, abundance estimates of populations were not available for the time period prior to the onset of commercial harvest, so I used the historical abundance estimate that was as close to that time period as possible.

All average body weight estimates, except for the sea otter (Kenyon 1969), were taken from Trites and Pauly (1998). In the latter study, mean mass was calculated as the total biomass of all age classes divided by the total population size. When species-specific population growth curves were available, age structure was incorporated into the calculation. Trites and Pauly (1998) reported mean mass (kg) for males and females. To obtain the average body weight estimate for each species, I averaged the two weights and then converted to metric tons (t). Seasonal presence and the percentage of a species' population that spends time in the Bering Sea/Aleutian Islands region were determined from the literature.

Historic and current biomass calculations were made for each species and were calculated as a product of the abundance, average body weight, and number of days spent in the Bering Sea divided by 365. This calculation represents the average biomass by species on an annual basis. For those species that have large distributions, and only a small fraction of the population is found in the Bering Sea, the calculation of average biomass included a term to account for the percentage of the population found in the study area. In addition, percent biomass of each subgroup (i.e., large whales, small cetaceans and pinnipeds) was calculated by dividing the biomass of the subgroup by the total biomass for all species in the Bering Sea. I also calculated the percentage change in biomass from historic to current times by subtracting the historic from the current biomass and then dividing by the historic biomass.

The biomass data was analyzed and broken down into three main categories: annual biomass, summer biomass and winter biomass. Within each of these categories, historic and current biomass estimates were calculated for all marine mammal species and for the three subgroups – large whales, small cetaceans and pinnipeds. In addition, estimates for all marine mammal species and the large whale subgroup were also calculated with and without sperm whales because the results of the biomass calculations are sensitive to the inclusion of sperm whale data. Summer was defined as the time period from May to October and winter was defined as the time period from November to April. Summer and winter biomass were derived using the same calculation, except the product of the variables was divided by 184 and 181, respectively.

Species Accounts

A detailed account of the data that was used to calculate biomass for each of the 19 species is presented in Table 1. The caveats and assumptions included in the biomass calculations for certain species are expanded upon below.

Caveats and Assumptions

General

The biomass calculations involved several assumptions. Regarding the input parameters, I assumed that the information on seasonal presence of the population and average body weight was the same for both historic and current populations of marine mammal species. Abundance estimates, percentage of the population present in the region[1], and the areas for which the estimates were made varied between the two time periods. Historic estimates were not available for eight species: minke whale, harbor porpoise, Dall's porpoise (*Phocoenoides dalli*), beluga whale (*Delphinapterus leucas*) and the four species of ice seals. Therefore, I substituted the current abundance estimates for historic abundance in an effort to provide some information on these species in the model. It is important to point out that these historic estimates are likely negatively biased.

Several marine mammals found in Alaska waters were not included in the analysis. The blue whale (*Balaenoptera musculus*), sei whale (*B. borealis*), Baird's beaked whale (*Berardius bairdii*), Cuvier's beaked whale (*Ziphius cavirostris*), and Stejneger's beaked whale (*Mesoplodon stejnegeri*) are species whose presence has been documented in the Bering Sea, but either in very low numbers (Sobolevsky and Mathisen 1996, Berzin and Rovnin 1966, Moore et al. 2002, Mizroch et al. 1984a, Masaki 1976, as cited in Mizroch et al. 1984b, Nasu 1974) or there were no data available for abundance estimates (Angliss and Lodge 2004, Tomilin 1957) – both scenarios precluded analysis.

I further assumed that all populations were at carrying capacity 150 years ago and that carrying capacity has been constant over time. This assumption implies that humans are the only variable in the system and excludes natural cycles of top-down and bottom-up forcing.

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[1] Percentage of the population present in the region varied between the two time periods depending upon how the abundance estimates were calculated.

Species - Specific

Fin Whale

Two estimates of current abundance are available from Moore et al. (2002): the central eastern Bering Sea (3,368 (CV = 0.29) and the southeastern Bering Sea (683 (CV = 0.32). These are preliminary estimates, as the data were not corrected for animals missed on the trackline, submerged animals, or animals that are attracted to or avoid vessels. In the database, I added the two current abundance estimates together because the estimates were made from the same platform in different years and represent mutually exclusive areas of the Bering Sea. Here, I assumed (as did the authors) that inter-annual variability was low in the distribution and abundance of fin whales in the two survey regions (Moore et al. 2002).

I used the migration path described by Berzin and Rovnin (1966) for fin whales in the North Pacific to estimate the percentage of the historic fin whale population present in the Bering Sea/Aleutian Islands region.

Humpback Whale

The reported historical abundance estimate for the North Pacific stock of humpback whales is 15,000 (Rice 1978a). In 1962, two large whale surveys were conducted in the Bering Sea/ Gulf of Alaska (Berzin and Rovnin 1966) and 22.9% of the humpbacks encountered were present in the Bering Sea/Aleutian Islands region. Seventy-five percent of all whales sighted during the survey were found in the western part of the Gulf of Alaska to the Fox Islands. I assumed that half of these animals (or 37.5%) were found in the Fox Islands area. Based on this information, I estimated the historical population for the Bering Sea/Aleutian Islands at 9,060 animals (60.4% of 15,000).

The current abundance estimate for the central North Pacific stock, which encompasses an area adjacent to the Bering Sea/Aleutian Islands region, is 4,005 (CV = 0.095) (Calambokidis et al. 1997). In 1994, an area south of the Aleutian Islands (between Kodiak and Tanaga Islands) was surveyed for marine mammals and preliminary abundance estimates of humpback whales suggested there were at least 2,000-3,000 individuals in that area (Forney and Brownell 1996, K. Forney, pers. commun.). Only a small portion of the Bering Sea has been surveyed for humpback whales in recent years; Moore et al. (2002) reported a current abundance estimate of 102 (CV = 0.50) for the southeastern Bering Sea. Taking into account the estimates reported for the central North Pacific and the Aleutian Islands region and the fact that it is unclear whether the animals sighted during the surveys belong to the central North Pacific or western North Pacific stock (which includes animals west of the Kodiak Archipelago in the Bering Sea/Aleutian Islands), it is reasonable to assume that the abundance of humpbacks in the Bering Sea/Aleutian Islands region is closer to 3,000-4,000 than to 102. Therefore, I used the estimate from Calambokidis et al. (1997) as the current abundance estimate for the Bering Sea/Aleutian Islands region.

Minke Whale

There are no published estimates for the historical abundance of the Alaskan stock of minke whales. Due to a lack of data and the fact that minke whales in the North Pacific were not heavily targeted during the commercial whaling era (Horwood 1990, Tomilin 1957, Ohsumi 1991), I assumed the historical estimate was the same as the current estimate, for the purpose of the analysis. Current abundance estimates are 810 (CV = 0.36) for the central eastern and 1,003 (CV = 0.26) for the southeastern Bering Sea (Moore et al. 2002). The caveats for these estimates are the same as those reported for fin whales. In addition, the minke whale estimate is likely negatively biased due to missed sightings and vessel avoidance (Moore et al. 2002).

Sperm Whale

The most significant caveat to consider here is that historic and current abundance estimates of sperm whales throughout the world's oceans are considered unreliable and available estimates should be interpreted cautiously (Whitehead 2002). In addition, the stock structure and stock-specific migratory pattern of sperm whales in the North Pacific is unknown (Angliss and Lodge 2004). Given these advisories, I report the following information.

From April to September, male sperm whales congregate in deep waters off the shelf break in the Gulf of Alaska, Bering Sea and around the Aleutian Islands (Tomilin 1957, Berzin and Rovnin 1966, Gosho et al. 1984, and Omura 1955, as cited in Gosho et al. 1984). Females and young whales are not commonly found in this area, as they usually remain in tropical and temperate waters year-round. In the winter, sperm whales are found south of 40˚N (Rice 1978b). The highest concentration of sperm whales has been reported for an area midway between the Pribilof Islands and Cape Navarin (Berzin and Rovnin 1966). In the western Bering Sea, the center of sperm whale distribution is at 59˚N and 175˚E (Berzin and Rovnin 1966). More detailed information about sperm whale distribution in the study area can be found in Tomilin (1957) and Berzin and Rovnin (1966).

The best available estimate for the historic abundance of male sperm whales in the North Pacific is 195,000 (Ohsumi and Fukuda 1974). This estimate was derived using a population model and was revised by Ohsumi and Fukuda (1974) from previous estimates to account for a change in the catch size limit that would presumably influence age at recruitment.

Gosho et al. (1984) estimated that 198,000 adult sperm whales were in the western North Pacific and 274,000 were in the eastern North Pacific. Of these, approximately 15,000 adult male sperm whales were estimated to be in the eastern Bering Sea and Aleutian Islands region from May to October (Perez 1990), the number that I report here for the current estimate. These estimates were not derived from direct line transect data, but based on catch-per-unit-effort data that the International Whaling Commission no longer considers reliable.

Harbor Porpoise

There are no historic abundance estimates available for harbor porpoise. For the purpose of the analysis, historical abundance was assumed to be the same as current abundance, as it is thought that harbor porpoise populations in the eastern North Pacific have not fluctuated much between pre- and post-commercial harvest eras because they were subjected to low direct takes in the commercial fishery (Bjøre et al. 1994, Gaskin 1984, Jones 1984, IWC 1991). There are three abundance estimates for harbor porpoise in the Bering Sea; two from vessel surveys (central eastern Bering Sea, 693 (CV = 0.53); southeastern Bering Sea, 1,958 (CV = 0.21), Moore et al. 2002); and one from an aerial survey (47,356 (CV = 0.23), J. Waite and R.C. Hobbs, unpublished data). These estimates were summed in the database because they represent mutually exclusive areas of the Bering Sea. They were also adjusted for perception bias and area of overlap to give a total estimate of 50,127 harbor porpoise in the Bering Sea region. The abundance estimates from Moore et al. (2002) are likely negatively biased because they were not corrected for missed sightings and vessel avoidance. The estimate from the aerial survey (J. Waite and R. C. Hobbs, unpublished data) was corrected for availability and perception bias;

however, it should be considered conservative because the survey did not include the entire range of harbor porpoise in the Bristol Bay region.

Dall's Porpoise

No historic abundance estimates exist for Dall's porpoise. Therefore, historic and current abundance estimates were considered to be the same for the purpose of this analysis. This is a valid assumption, as it is thought that Dall's porpoise populations in the eastern North Pacific have not fluctuated much between pre- and post-commercial harvest eras because they were subjected to low direct takes in the commercial fishery (IWC 1991, Bjøre et al. 1994). However, the population in the western North Pacific did experience a high rate of incidental mortality in the high seas salmon driftnet fishery that operated from 1952 to 1987 (Jones 1984, Jones et al. 1985, Turnock et al. 1995, Hobbs and Jones 1993, IWC 1991).

There are three current abundance estimates that were derived from vessel surveys conducted in different areas in the Bering Sea/ Aleutian Islands region; the central eastern Bering Sea (14,312 CV = 0.26, Moore et al. 2002), the southeastern Bering Sea (9,807 CV = 0.20, Moore et al. 2002), and the Aleutian Islands (302,000 95% CI = 243,000-377,000; Hobbs and Lerczak 1993). Estimates from the central eastern and southeastern Bering Sea were combined and adjusted for perception bias and area of overlap to give a total estimate of 29,741 Dall's porpoise in the Bering Sea region (R. C. Hobbs and J. Waite, unpublished data). The estimate for the Aleutian Islands region was also corrected for vessel attraction behavior (0.2 correction factor) to yield 60,400 animals, for a total of 90,141 Dall's porpoise in the Bering Sea/Aleutian Islands region. The abundance estimates from Moore et al. (2002) are likely negatively biased because they were not corrected for missed sightings and vessel avoidance behavior. One caveat to the Aleutian Islands estimate is that survey effort was not well distributed throughout the U.S. Exclusive Economic Zone in Alaska or throughout the year.

Beluga Whale

Historic abundance estimates are not available for the four stocks of Alaska beluga whales that were included in this analysis. It has been assumed that these stocks have not substantially increased or decreased in the time periods before and after commercial whaling (As cited in Hazard 1988: IWC 1991, Bjøre et al. 1994, Braham 1984, Lensink 1961, Seaman and Burns 1981, Burns and Seaman 1985, Sherrod 1982, Stickney 1982, Wolfe 1982, and Fraker 1980). Therefore, for the purposes of this analysis, historic and current abundance was assumed to be equal for all four stocks of belugas.

Beaufort Sea Stock

The correction factor for availability bias (Duval 1993) that was used to derive the current abundance estimate (39,258) for belugas in the Beaufort Sea was considered negatively biased by the Alaska Scientific Research Group (Frost and Lowry 1995). No coefficient of variation is available for this corrected estimate (Angliss and Lodge 2004).

Eastern Chukchi Sea Stock

The current abundance estimate for the Eastern Chukchi stock of belugas (3,710) was corrected for the proportion of diving animals and for the proportion of newborns and yearlings that were difficult to spot because of their small size and dark color (Frost et al. 1993, Frost and Lowry 1995, and Brodie 1971). The Alaska Scientific Review Group considered this a minimum estimate of population size because the survey area did not include all areas where the belugas are known to occur (Small and DeMaster 1995).

Eastern Bering Sea Stock

The current abundance estimate for the Eastern Bering Sea stock of belugas (18,142) was corrected for the proportion of newborns and yearlings not observed due to their small size and coloration, and for animals not visible at the surface (R. C. Hobbs, unpublished data).

Bristol Bay Stock

The current abundance for the Bristol Bay stock of belugas is 1,642. This number is an average of the abundance estimates reported for 1999 (1,323) and 2000 (1,960) and represents the minimum population estimate based on the maximum number of whales counted (Frost et al. 2002). These estimates were corrected for animals that were submerged and not counted and for neonates and yearlings that were not counted (Frost and Lowry 1995, Brodie 1971, and Frost et al. 2002).

Steller Sea Lion

Loughlin et al. (1984) reviewed data on the status and population trends of Steller sea lions throughout the North Pacific from 1956 to 1980 and estimated the Alaska population was 196,484. Of those, 89,113 (45%) were found on the Aleutian Islands, 2,221 (1%) on Pribilof and St. Matthew Islands, and 2,000 (1%) in Bristol Bay. The remaining 52% were found in Southeast Alaska and the Gulf of Alaska. During the late 1950s and 1960s, the population of Steller sea lions was considered to be close to its pre-exploitation level, numbering 240,000-300,000 (average 270,000) in Alaska (Hoover 1988a). I applied the percentages derived in the Loughlin et al. (1984) population estimate to the average of the pre-exploitation level reported by Hoover (1988a; 270,000) to derive the historic population estimate of 126,900 sea lions for the Bering Sea/Aleutian Islands region. Angliss and Lodge (2004) reported the best available count for the current abundance of the western stock of Steller sea lions as 34,595. To be conservative, we reported the minimum abundance of 35,194 (Angliss and Lodge 2004).

Harbor Seal

Gulf of Alaska

The current abundance for the Gulf of Alaska stock is reported as 35,981 (SE = 1,833) (Boveng et al. 2003) and includes animals that range from Cape Suckling to Unimak Pass, and throughout the Aleutian Islands (Angliss and Lodge 2004). Boveng et al. (2003) divided their estimate into seven zones, some of which fell outside of my study area, so I took the estimates for the following areas that are a better match with the areas reported for the historic abundance in Sease (1992) and derived a current estimate of 22,376 for the following areas:

Zone	Abundance Estimate
West Alaska Peninsula	3,136, SE = 274
East Alaska Peninsula	4,527, SE = 333
Kodiak Archipelago	9,455, SE = 653
Cook Inlet	5,268, SE = 456
Total	22,376

Pacific Walrus

The current abundance estimate reported by Gilbert et al. (1992) for the Alaska stock (201,039) is considered a minimum population size and should not be used when attempting to assess population trends. The estimate did not account for walrus that were not on the surface at the time of the survey. Also, when the survey was flown during the winter of 1990, ice was not present in the large portion of the Chukchi Sea that is usually inhabited by walrus. Therefore, comparisons with past estimates of walrus abundance should only be made in years with comparable ice cover.

There are two concentrations of walrus in the Bering Sea during the winter: one in the northwestern Bering Sea, south and west of St. Lawrence Island and in Anadyr Gulf; and the other in the southeastern Bering Sea, concentrated in Bristol and Kuskokwim Bays. Male walruses remain in the Bering Sea during summer and occupy Bristol Bay, Anadyr Gulf, and the western Bering Strait (Sease and Chapman 1988).

The adult sex ratio in 1985 was calculated as 1 male: 3 females (Fay et al. 1997). Using this ratio, I assumed that 100% of the walrus population was present in the Bering Sea from December to April (151 days) and 22% (the adult males) were present in the Bering Sea from May to November (214 days) (Sease and Chapman 1988).

Sea Otter

In general, published abundance estimates of pre-exploitation populations of sea otters are not considered to be accurate (Rotterman and Simon-Jackson 1998). That being said, the pre-exploitation abundance estimate for Alaskan sea otters was reported as 200,000 (Johnson 1982) and there is no pre-exploitation abundance estimate for the Southwest Alaska stock. Johnson's estimate cannot be compared to the current abundance estimate for the Southwest Alaska stock because they represent different areas. In an attempt to estimate historic abundance for this particular stock, I calculated the percentage of the current population of the Southwest Alaska stock of the total current population of Alaskan sea otters (59%) and applied that percentage to Johnson's historic estimate for Alaskan sea otters. This resulted in an estimate of 118,000.
I reported the best estimate of current abundance for the southwestern stock of sea otter in Alaska as 41,474 (Angliss and Lodge 2004)[2].

Results

Percent Reduction In Biomass

Marine mammal biomass in the Bering Sea/ Aleutian Islands region has declined from the onset of modern industrial whaling to the present day. This pattern was seen in all taxa on an annual and seasonal basis, regardless of whether sperm whale biomass was included in the analysis (Figs. 2-5). The percent reduction in the biomass of all marine mammals and of the large whale subgroup from the early 1800s to the present is shown in Table 2. Pinniped biomass experienced the following declines: 30% annual, 49% summer, and 18% winter.

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[2] The minimum number of animals was reported as 33,203 (Angliss and Lodge 2004).

Table 2. Percent reduction in the biomass of all marine mammals and of the large whale subgroup from the early 1800s to the present, calculated with and without sperm whale biomass.

Biomass	With sperm whales	Without sperm whales
Annual		
Total	80%	49%
Large whale	82%	54%
Summer		
Total	84%	54%
Large whale	85%	59%
Winter		
Total	63%	31%
Large whale	72%	39%

Analysis of Annual and Seasonal Biomass by Subgroup

On an annual and seasonal basis, the historic and current biomass of large whales dominates the biomass of small cetaceans and pinnipeds, regardless of whether sperm whale biomass was included in the analysis (Figs. 3 and 5). In fact, there is greater than an order of magnitude difference between the historic and current biomass of large whales (with and without the inclusion of sperm whale biomass) versus historic and current small cetacean biomass and between the historic biomass of large whales (when sperm whale biomass is included) and the historic biomass of pinnipeds (Fig. 3). In the summer, there is greater than an order of magnitude difference between large whale biomass and small cetacean and pinniped biomass in every combination of biomass comparisons (historic vs. current, with sperm whales vs. without) except one (current large whale biomass excluding sperm whales and current pinniped biomass; 88%; Fig. 5). In the winter, large whale biomass also dominates small cetacean biomass by an order of magnitude (Fig. 5). The annual and seasonal biomass of small cetaceans ranged from 1% to 4% and represented a minute percentage of the overall biomass. Small cetacean biomass was larger in the winter, mainly due to the presence of the Beaufort stock of belugas. As illustrated in Figures 4 and 5, more total biomass is present in the summer, reflecting the influx of large whale migrants to the Bering Sea. In the winter, pinniped biomass is greater than in the summer, as many individuals enter the Bering Sea to breed on or forage from the extensive pack ice that forms during this season (Fig. 5).

Comparisons of the historic and current biomass of all marine mammal species and of the large whale subgroup shown in Figures 2- 5 illustrate the influence of sperm whale biomass on annual and seasonal biomass totals.

Species Percent Composition of Annual and Seasonal Biomass

Species that are not listed in the following summaries of large whale, small cetacean and pinniped annual and seasonal biomass composed less than 10% of the total biomass reported for each subgroup.

Large whales

On an annual basis, sperm whales dominated historic large whale biomass (74%), yet composed only 32% of current large whale biomass. The other large whale species composed the remainder of the current whale biomass in the following percentages: bowhead (25%), gray

(19%), fin (14%), and humpback whale (10%). When sperm whales were excluded from the analysis, historic biomass was fairly evenly distributed between the bowhead (25%), fin (25%), and gray (21%) whales, and between the humpback (15%) and right (13%) whales and the same species (minus the northern right whale) dominated the current biomass, although the percentage of each species' composition changed slightly: bowhead (36%), gray (29%), fin (20%) and humpback (14%).

In the summer, sperm whales composed 77% of the historic biomass and 38% of the current biomass. Other large whale species that contributed to the current biomass were gray (28%), fin (19%), and humpback (14%) whales. When sperm whales were excluded, historic (H) and current (C) biomass was distributed among the other large whale species in the following way: fin (31% (H); 34% (C)), gray (29% (H); 45% (C)), humpback (21% (H); 23% (C)) and northern right (15% (H)).

In the winter, sperm whales dominated historic biomass (63%), followed by the bowhead whale (34%), but the contribution of each species was reversed for the current biomass composition: bowhead (82%) and sperm whale (18%). It follows that when sperm whales were excluded, bowhead whales dominated historic (92%) and current (99%) biomass.

Small cetaceans

The percentage of small cetacean biomass did not change from historic to current times because historic and current estimates of abundance were assumed to be equal. In general, four species of small cetaceans compose the majority of annual and seasonal biomass in the Bering Sea/Aleutian Islands region, although the percent composition varies as outlined in Table 3.

Table 3. Annual and seasonal percent composition of small cetaceans. The distinction between historic and current biomass percentages is not made because historic and current abundance estimates were assumed to be equal.

Species	Annual	Summer	Winter
Beaufort beluga	**30**		**46**
Norton Sound beluga	19	**43**	22
Dall's porpoise	18	40	14
Harbor porpoise		11	

Pinnipeds

Historically, the walrus (42%), Steller sea lion (15%) northern fur seal (14%), and bearded seal (10%) dominated the annual pinniped biomass whereas currently, the walrus (54%), bearded seal (13%) and ringed seal (10%) compose the majority of pinniped biomass. In historic and present times (respectively), the northern fur seal (36% and 21%), walrus (27% and 47%), Steller sea lion (21% and 11%), and ribbon seal (12%, current only) have dominated summer pinniped biomass. The majority of historic and current winter biomass is also composed of by four species: the walrus (56% and 61%), bearded seal (13% and 15%), Steller sea lion (11%, historic only), and the ringed seal (10% and 12%).

Discussion

Some general patterns emerged from the analysis of the percent composition of biomass. Bowhead whale and gray whale percent composition of biomass relative to total marine mammal biomass from pre-commercial whaling to the present increased, while during the same time period the percent composition of sperm whale and northern right whale biomass relative to total marine mammal biomass decreased.

The increase seen in the percent composition of bowhead and gray whale stocks is consistent with the observed recovery of these populations after they were protected from further commercial harvests. The annual rate of increase for the western Arctic bowhead whale stock from 1978 to 2001 is estimated at 3.4% (George et al. 2003) and between 2.4 and 4.4% for the eastern Pacific gray whale stock, which was removed from the Endangered Species Act in 1994 (Buckland et al. 1993b, Wade and DeMaster 1996, IWC 1995, Breiwick 1999, as cited in Angliss and Lodge 2004). The decrease of percent composition of the sperm whale and northern right whale is consistent with the documented removal of both species by modern commercial whalers and their lack of recovery (Scarff 1991, Doroshenko 2000, Clapham et al. 2001, Brownell et al. 2001, Brownell et al. 2000).

The historic and current abundance estimates used in the biomass calculation are considered reliable for three species: the bowhead whale, gray whale and the northern fur seal. The caveats to the biomass estimates for the other 16 species were presented in detail above and can be classified into the three broad categories listed below.

Old, unavailable or unreliable abundance estimates.

Current abundance estimates for the humpback whale, Aleutian Dall’s porpoise, the Beaufort and Eastern Chukchi stocks of beluga whale, the walrus, both harbor seal stocks and the four ice seals were calculated from surveys that were completed from 1987 to 1996; some of these data are over a decade old. As mentioned above, there are eight species for which historic abundance estimates do not exist. For some species, such as the northern right whale and the sperm whale, some estimates of historic and current abundance exist, however, they are considered unreliable because they are at most a “best guess” or are based on data that is no longer considered reliable by the IWC.

Not all historic and current abundance estimates are representative of the same area, making them difficult to compare.

In some cases, the historic range of certain species (i.e., the northern right whale and the sea otter) was more expansive than the current. In others, the survey area was different for both time periods and may not be representative of the entire Bering Sea/Aleutian Islands region or may not be specific to the region. For example, current abundance estimates for the fin whale, humpback whale, minke whale, harbor porpoise and Dall’s porpoise are only applicable to the central-eastern and southeastern portion of the Bering Sea. Those estimates are likely negatively biased for the entire Bering Sea/Aleutian Islands region, although that determination depends upon information regarding the demographics, distribution and movement patterns of the species that can only be known through more frequent and consistent surveys. On the other hand, historic estimates for the fin whale, humpback whale, sperm whale, Steller sea lion, harbor seal and sea otter were for larger areas such as the entire North Pacific or the Bering Sea, including Russian waters. In this case, an effort was made to adjust the historical estimate to represent the same area as the current, using information on the temporal and spatial distribution of the population. The details of these calculations were presented above in the Caveats and Assumptions section. It is possible to more accurately standardize estimates for particular areas by calculating the exact area and extrapolating abundance estimates to that area, however that type of analysis was beyond the scope of this report.

Information does not exist about the demographics or the distribution of some populations.

Many of the estimates were calculated from surveys done at a particular time of year. Technically, those estimates and patterns of distribution are specific to the time of year the animals were observed. However, I assumed that information was representative of the population year-round and for all years. There are major gaps in information regarding the seasonal distribution and movement patterns of some populations in the North Pacific including, but not limited to, the sperm whale, northern right whale, fin whale, minke whale, and Dall's porpoise.

In conclusion, the data, although incomplete, provide the best available picture of historic and current marine mammal biomass during the defined time period. From these data, it is apparent that there was a reduction in marine mammal biomass from prior to the start of commercial harvesting to the current date. Most of this decline occurred 50-100 years ago. Therefore, for species that have experienced some recovery, the current estimates are likely higher than they were at the end of the harvest. As has been recognized by the IWC's Scientific Committee, it is not possible to estimate pre-whaling abundance solely with information from the commercial harvest; without additional information on the distribution of the catch, stock structure, current abundance, and productivity relative to status, estimates of pre-whaling abundance become unreliable. Figure 6 presents a reliable estimated trajectory of abundance over time for the western Arctic bowhead whale population (Eberhardt and Breiwick 1992). These estimates of abundance over time were generated with information on current abundance, an estimate of the maximum rate of net production, estimates of annual removals, and evidence to indicate that all harvested whales from this time series were from the same stock of whales. In most cases, similar data sets for other stocks of large whales (e.g., all stocks of sperm whale, fin whale, and North Pacific right whale) are currently unavailable. I urge the users of this information to carefully consider the caveats in the data and incorporate them, as possible, into their analyses.

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Citations

Alaska Department of Fish and Game. 1973. Alaska’s wildlife and habitat. Van Cleve Printing, Anchorage, Alaska. 143 p.

Angliss, R. P., and K. L. Lodge. 2004. Alaska marine mammal stock assessments, 2003. U.S. Dep. Commer., NOAA Tech. Memo. NMFS-AFSC-144, 230 p.

Balcomb, K. C. 1989. Baird's beaked whale, Berardius bairdii Stejneger, 1883: Arnoux's beaked whale *Iberardius arnouxii* Douvernoy, 1851, p. 261-288. *In* S. H. Ridgway and R. Harrison (editors), Handbook of marine mammals: River dolphins and the larger toothed whales. Academic Press, New York.

Angliss, R. P., and K. L. Lodge. 2002. Alaska marine mammal stock assessments, 2002. U.S. Dep. Commer. NOAA Tech. Memo. NMFS-AFSC-133. 224 p.

Berzin, A. A., and A. A. Rovnin. 1966. The distribution and migrations of whales in the northeastern part of the Pacific, Chukchi, and Bering Seas. Izvestia TINRO 58:179-207.

Bessonov, B., V. V. Mel’nikov, and V. A. Bobkov. 1990. Distribution and migration of cetaceans in the Soviet Chukchi Sea, p. 25-31. *In* Conference Proceedings, Third Information Transfer Meeting. U.S. Dep. Interior, Minerals Manage. Serv., Alaska OCS Region, Anchorage, AK.

Bigg, M.A. 1986. Arrival of northern fur seals, *Callorhinus ursinus*, on St. Paul Island, Alaska. Fish. Bull., U.S. 84(383-394).

Bigg, M. A. 1981. Harbour seal, *Phoca vitulina*, (Linnaeus, 1758) and *Phoca largha*, (Pallas, 1811), p. 1-27. *In* S. H. Ridgway and R. J. Harrison (editors), Handbook of Marine Mammals, Vol. 2: Seals. Academic Press, New York.

Bigg, M. A. 1969. The harbour seal in British Columbia. Fish. Res. Bd. Can. Bull. 172. 33 p.

Bjøre, A., R. L. Brownell Jr., G. P. Donovan, and W. F. Perrin. 1994. Significant direct and incidental catches of small cetaceans. Rep. Int. Whal. Comm. (Special Issue 15):76-130

Bogoslovskaya, L. S., L. M. Votrogov, and I. I. Krupnik. 1982. The bowhead whale off Chukotka: migrations and aboriginal whaling. Rep. Int. Whal. Comm. 32:391-399.

Boveng, P. L., J. L. Bengtson, D. E. Withrow, J. C. Cesarone, M. A. Simpkins, K. J. Frost, and J. J. Burns. 2003. The abundance of harbor seals in the Gulf of Alaska. Mar. Mammal Sci. 19(1):111-127.

Braham, H. W. 1984. Review of reproduction in the white whale, *Delphinapterus leucas*, narwhal, *Monodon monoceros*, and Irrawaddy dolphin, *Orcaella brevirostris*, with comments on stock assessment. Rep. Int. Whal. Comm. (Special Issue 6):81-89.

Braham, H. W., B. D. Krogman, and G. M. Carroll. 1984a. Bowhead and white whale migration, distribution, and abundance in the Bering, Chukchi, and Beaufort Seas, 1975-78. U.S. Dep. Commer., NOAA Tech. Rep. NMFS SSRF-778, 39 p.

Braham, H. W., J. J. Burns, G. A. Fedoseev, and B. D. Krogman. 1984b. Habitat partitioning by ice-associated pinnipeds: Distribution and density of seals and walruses in the Bering Sea, April 1976, p. 25-47. *In* F. H. Fay and G. A. Fedoseev (editors), Soviet-American cooperative research on marine mammals. Vol 1: Pinnipeds. U.S. Dep. Commer., NOAA Tech. Rep. NMFS-12. 104 p.

Braham, H. W., M. A. Fraker, and B. D. Krogman. 1980. Spring migration of the western Arctic population of bowhead whales. Mar. Fish. Rev. 42(9-10):36-46.

Breiwick, J. W. 1999. Gray whale abundance estimates, 1967/68 – 1997/98: ROI, RY, and K, p. 62. *In* D. J. Rugh, M. M. Muto, S. E. Moore, and D. P. DeMaster (editors), Status review of the Eastern North Pacific stock of gray whales. U.S. Dep. Commer., NOAA Tech Memo. NMFS-AFSC-103, 96 p.

Brodie, P. F. 1971. A reconsideration of aspects of growth, reproduction, and behavior of the white whale with reference to the Cumberland Sound, Baffin Island, population. J. Fish Res. Bd. Can. 28:1309-1318.

Brownell, R. L. Jr, A. V. Yablokov, and V. A. Zemsky. 2000. USSR pelagic catches of North Pacific sperm whales, 1949-1979: conservation implications, p. 123-130. *In* A. V. Yablokov and V. A. Zemsky (editors), Soviet whaling data (1949-1979). Center for Russian Environmental Policy, Moscow.

Brownell, R. L. Jr., P. J. Clapham, T. Miyashita, and T. Kasuya. 2001. Conservation status of North Pacific right whales. J. Cet. Res. Manage. (Special Issue) 2:269-286.

Brueggeman, J. J. 1982. Early spring distribution of bowhead whales in the Bering Sea. J. Wildl. Manage. 46:1036-44.

Brueggeman, J. J., B.Webster, R. Grotefendt, and D. Chapman. 1987. Monitoring the winter presence of bowhead whales in the Navarin Basin through association with sea ice, 179 p. U.S. Dep. Comer., Natl. Tech. Inform. Serv. Rep. No. PB88-101258. Available from NTIS, 5285 Port Royal Road, Springfield, VA 22167.

Buckland, S. T. , K. L. Cattancach, and R. C. Hobbs. 1993a. Abundance estimates of Pacific white-sided dolphin, northern right whale dolphin, Dall's porpoise and northern fur seal in the North Pacific, 1987-1990. INPFC Bull 53(III):387-407.

Buckland, S. T., J. M. Breiwick, K. L. Cattanach, and J. L. Laake. 1993b. Estimated population size of the California gray whale. Mar. Mammal Sci. 9(3):235-249.

Burns, J. J. 1986. Ice seals, p. 216-229. *In* D. Haley (editor), Marine mammals of eastern North Pacific and arctic waters, 2nd Ed., rev. Pacific Search Press, Seattle, WA.

Burns, J. J. 1981. Bearded seal, *Erignathus barbatus*, (Erxleben, 1777), p. 145-170. *In* S. H. Ridgway and R. J. Harrison (editors), Handbook of marine mammals, Vol. 2: Seals. Academic Press, London.

Burns, J. J., and G. A. Seaman. 1985. Investigations of belukha whales in coastal waters of western and northern Alaska: II. Biology and ecology. Final rep. prepared for U. S. Dep. Commer., NOAA, Natl. Ocean Serv., Anchorage, Alaska, contract NA81RAC00049. Alaska Dep. Fish and Game, Fairbanks. 129 p.

Calambokidis, J., and J. Barlow. 1991. Chlorinated hydrocarbon concentrations and their use for describing population discreteness in harbor porpoises from Washington, Oregon, and California, p. 101-100. *In* J. E. Reynolds III and D. K. Odell (editors), Marine Mammal Strandings in the United States: Proceedings of the Second Marine Mammal Stranding Workshop: 3-5 December 1987. Miami, Florida. NMFS, NOAA Tech. Rep. NMFS 98:101-110.

Calambokidis, J., G. H. Steiger, and J. M. Straley, T. Quinn, L. M. Herman, S. Cerchio, D. R. Salden, M. Yamaguchi, F. Sato, J. R. Urban, J. Jacobson, O. VonZeigesar, K. C. Balcomb, C. M. Gabriele, M. E. Dahlheim, N. Higashi, S. Uchida, J. K. B. Ford, Y. Miyamura, P. Ladrón de Guevara, S. A. Mizroch, L. Schlender, and K. Rasmussen. 1997. Abundance and population structure of humpback whales in the North Pacific basin. Final Contract Report 50ABNF500113 to Southwest Fisheries Science Center, P.O. Box 271, La Jolla, CA 92038. 72 p.

Clapham, P. J., and C. S. Baker. 2002. Whaling, modern, p. 1328-1332. *In* W. F. Perrin, B. Wursig, and J. G. M. Thewissen (editors), Encyclopedia of Marine Mammals. Academic Press, San Diego.

Clapham, P. J., C. Good, S. E. Wetmore, and R. L. Brownell Jr. 2001. Distribution of North Pacific right whales (*Eubalaena japonica*) as shown by 19th and 20th century whaling catch and sighting records. Unpubl. Doc. Submitted to Int. Whal. Comm. (SC/53/BRG15). 13 p.

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

Darling, J. D. 1984. Gray whales off Vancouver Island, British Columbia, p. 267-87. *In* M. L. Jones, S. Swartz, and S. Leatherwood (editors), The Gray Whale, *Eschrichtius robustus*. Academic Press Inc., New York, N.Y. 600 p.

DeMaster, D. P. 1996. Minutes from the 11-13 September 1996 meeting of the Alaska Scientific Review Group, Anchorage, Alaska. 20 p.+ appendices. (available upon request-D. P. DeMaster, Alaska Fisheries Science Center, 7600 Sand Point Way, NE, Seattle, WA 98115).

Doroff, A. M., J. A. Estes, M. T. Tinker, D. M. Burn, and T. J. Evans. 2003. Sea otter population declines in the Aleutian Archipelago. J. Mammal. 84(1):55-64.

Doroshenko, N. V. 2000. Soviet whaling for blue, gray, bowhead and right whales in the North Pacific Ocean, 1961-1979, p. 96-103. *In* A. V. Yablokov and V. A. Zemsky (editors), Soviet whaling data (1949-1979). Center for Russian Environmental Policy, Moscow.

Duval, W. S. 1993. Proceedings of a workshop on Beaufort Sea beluga: February 3-6, 1992. Vancouver, B.C. Env. Studies Res. Found. Rep. No. 123. Calgary. 33 p.+ appendices.

Eberhardt, L. L., and J. M. Breiwick. 1992. Impact of recent population data on historical population levels of bowhead whales inferred from simulation studies. Rep. Int. Whal. Comm. 42:485-489.

Estes, J. A., M. T. Tinker, T. M. Williams, and D. F. Doak. 1998. Killer whale predation on sea otters linking oceanic and nearshore ecosystems. Science 282:473-476.

Fay. F. H. 1982. Ecology and biology of the Pacific walrus, *Odobenus rosmarus divergens*. N. Am. Fauna 74:1-279.

Fay, F. H. 1981. Walrus, *Odobenus rosmarus*, (Linnaeus, 1758), p. 1-23. *In* S. H. Ridgway and R. J. Harrison (editors) Handbook of Marine Mammals, Vol. 1: The walrus, sea lions, fur seals and sea otter. Academic Press, London, England.

Fay F. H., L. L. Eberhardt, B. P. Kelly, J. J. Burns, and L. T. Quakenbush. 1997. Status of the Pacific walrus population, 1950-1989. Mar. Mammal Sci. 13(4):537-565

Fay, F. H., G. Carleton Ray, and A. A. Kibal'Chich. 1985. Time and location of mating and associated behavior of the Pacific walrus, *Odobenus rosmarus divergens*, Illiger p. 89-99. *In* F. H. Fay and G. A. Fedoseev (editors), Soviet-American cooperative research on marine mammals. Vol. 1: Pinnipeds. U.S. Dep. Commer., NOAA Tech. Rep. NMFS-12.

Fedoseev, G. A. 1973. The morphological-ecological characteristics of ribbon seal populations and factors affecting the conservation of usable stocks. Izv. TINRO 86:158-177. (Transl. From Russian by Can. Fish. Mar. Serv., 1975, Transl. Ser.676795, 50 p.)

Fiscus, C. H. 1980. Marine mammal-salmonid interactions: a review, p.121-132. *In* W. J. McNeil and D. C. Himsworth (editors), Salmonid ecosystems of the North Pacific. Oregon State University Press, Corvallis.

Fisher, H. D. 1952. The status of the harbour seal in British Columbia, with particular reference to the Skeena River. Fish. Res. Bd. Can. Bull. 93. 58 p.

Ford, J. K. B. 2002. Killer whale, p. 669-676. *In* W. F. Perrin, B. Wursig, and J. G. M. Thewissen (editors), Encyclopedia of Marine Mammals. Academic Press, San Diego.

Forney, K. A. and R. L. Brownell, Jr. 1996. Preliminary report of the 1994 Aleutian Island Marine Mammal Survey. Unpubl. Doc. Submitted to Int. Whal. Comm. (SC/48/O11). 15 p.

Fraker, M. A. 1980. Status and harvest of the Mackenzie stock of white whales (*Delphinapterus leucas*). Rep. Int. Whal. Comm. 30:451-458.

Frost, K. J. 1985. The ringed seal (*Phoca hispida*). Alaska Dep. Fish Game, Game Tech. Bull. 7:79-87.

Frost, K. J., and L. F. Lowry. 1995. Radio tag based correction factors for use in beluga whale population estimates. Working paper for Alaska Beluga Whale Committee Scientific Workshop, Anchorage, AK, 5-7 April 1995. 12 p. (available upon request-Alaska Dep. Fish and Game, 1300 College Rd., Fairbanks, AK 99701).

Frost, K. J., L. F. Lowry, and D. P. DeMaster. 2002. Alaska beluga whale committee surveys of beluga whales in Bristol Bay, Alaska, 1999-2000. Alaska Beluga Whale Committee Report 02-1. 13 p.

Frost, K. J., L. F. Lowry, and G. Carroll. 1993. Beluga whale and spotted seal use of a coastal lagoon system in the northeastern Chukchi Sea. Arctic 46:8-16.

Gaskin, D. E. 1984. The harbour porpoise, *Phocoena phocoena* (L.): regional populations, status, and information on direct and indirect catches. Rep. Int. Whal. Comm. 34:569-586.

Gentry, R. L. 1981. Northern fur seal, *Callorhinus ursinus*, p. 143-160. *In* S. H. Ridgway and R. J. Harrison (editors), Handbook of Marine Mammals, Vol. 1: The walrus, sea lions, fur seals and sea otter. Academic Press, London, England.

George, J. C., J. Zeh, R. Suydam, and C. Clark. 2003. N_4/P_4 abundance estimate for the Bering-Chukchi-Beaufort Seas stock of bowhead whales, *Balaena mysticetus,* based on the 2001 census off Point Barrow, Alaska. Unpubl. Doc. Submitted to Int. Whal. Comm. (SC/55/BRG7).16 p.

Gilbert, J. R., G. A. Fedoseev, D. Seagars, E. Razlivalov, and A. LaChugin. 1992. Aerial census of Pacific walrus, 1990. U.S. Fish. Wildl. Serv. Admin Rep. R7/MMM 92-1, 33 p.

Gosho, M. E., D. W. Rice, and J. M. Breiwick. 1984. The sperm whale, *Physeter macrocephalus*, p. 54-64. *In* J. M. Breiwick and H. W. Braham (editors), The status of endangered whales. Mar. Fish. Rev. 46(4):1-100.

Gosho, M. E., P. J. Gearin, J. Calambokidis, K. M. Hughes, L. Cooke, and V. E. Cooke. 1999. Gray whales in the waters of northwestern Washington in 1996 and 1997. Unpubl. Doc. Submitted to Int. Whal. Comm. (SC/51/AS9).15 p.

Harrison, C. S., and J. D. Hall. 1978. Alaskan distribution of the beluga whale, *Delphinapterus leucas*. Can. Field-Nat. 92(3):235-241.

Harwood, L. A., S. Innes, P. Norton, and M. C. S. Kingsley. 1996. Distribution and abundance of beluga whales in the Mackenzie Estuary, southeast Beaufort Sea and west Amundsen Gulf during late July 1992. Can .J. Fish. Aquat. Sci. 53:2262-2273.

Hazard, K. 1988. Beluga whale (*Delphinapterus leucas*), p. 195-235. *In* J. W. Lentfer (editor), Selected Marine Mammals of Alaska: Species Accounts with Research and Management Recommendations. Marine Mammal Commission, Washington, D.C.

Heithaus, M. R., and L. M. Dill. 2002. Feeding strategies and tactics, p. 412-421. *In* W. F. Perrin, B. Wursig, and J. G. M. Thewissen (editors), Encyclopedia of Marine Mammals. Academic Press, San Diego.

Hobbs, R. C., and L. L. Jones. 1993. Impacts of high seas driftnet fisheries on marine mammal populations in the North Pacific. Bulletin 53(III) – North Pacific Commission:409-434.

Hobbs, R. C., and J. A. Lerczak. 1993. Abundance of Pacific white-sided dolphin and Dall's porpoise in Alaska estimated from sightings in the North Pacific Ocean and the Bering Sea during 1987 through 1991, p. 1-17. *In* H. W. Braham and D. P. DeMaster (editors), Marine Mammal Assessment Program: status of stocks and impacts of incidental take. U.S. Department of Commerce, Seattle. (National Marine Mammal Laboratory - MMPA studies of 1992). Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE, Seattle, Washington 98115-0070.

Hoover, A. A. 1988a. Steller sea lion (*Eumetopias jubatus*), p. 159-193. *In* J. W. Lentfer (editor), Selected marine mammals of Alaska: Species accounts with research and management recommendations. Marine Mammal Commission, Washington, D.C.

Hoover, A. A. 1988b. Harbor seal (*Phoca vitulina*), p. 125-157. *In* J. W. Lentfer (editor), Selected marine mammals of Alaska: Species accounts with research and management recommendations. Marine Mammal Commission, Washington, D.C.

Horwood, J. 1990. Biology and Exploitation of the Minke Whale. CRC Press, Inc. Boca Raton, Florida. 238 p.

International Whaling Commission. 1995. Report of the Scientific Committee. Rep. Int. Whal. Comm. 45:53-95.

International Whaling Commission. 1991. The conservation of small cetaceans: a review. Unpubl. Doc. Submitted to Int. Whal. Comm. (SC/43/SM3).115 p.

Jefferson, T. A., P. F. Stacey, and R. W. Baird. 1991. A review of killer whale interactions with other marine mammals: Predation to co-existence. Mamm. Rev. 21:151-180.

Johnson, A. M. 1982. Status of Alaska sea otter populations and developing conflicts with fisheries. N. Am. Wildl. Conf. 47:293-299.

Jones, L. 1984. Incidental take of the Dall’s porpoise and the harbor porpoise by Japanese salmon driftnet fisheries in the western North Pacific. Rep. Int. Whal. Comm. 34:531-538.

Jones, L., D. W. Rice, and A. A. Wolman. 1985. Biological studies of Dall’s porpoise taken incidentally by the Japanese mothership fishery. Unpubl. Doc. Submitted to Int. Whal. Comm. (SC/35/SM9). 22 p.

Kajimura, H. R. H. Lander, M. A. Perez, A. E. York, and M. A. Bigg. 1980. Further analysis of pelagic fur seal data collected by the United States and Canada during 1958-74, Part 1. Unpubl. Rep. 23rd Annu. Meet. Standing Sci. Comm., N. Pac. Fur Sea. Comm., 7-11 April 1980, Moscow, USSR. 94 p.

Kasuya, T., and S. Ohsumi. 1984. Further analysis of the Baird's beaked whale stock in the western North Pacific. Rep. Int. Whal. Comm. 34:587-595.

Kawamura, A. 1975. Whale distribution in Bering Sea and northern North Pacific in the summer of 1974: results of a visual sighting study aboard the University of Hokkaido training vessel OSHORO MARU. Bull. Japan Soc. Fish. Oceanogr. 26:120-128. *In* Japanese. (Transl. By R. Brownell, U.S. Fish and Wildl. Serv., Washington, D.C., 9 p.)

Kenyon, K. W. 1981. Sea otter *Enhydra lutris*, (Linnaeus, 1758), p. 209-223. *In* S. H. Ridgway and R. J. Harrison (editors) Handbook of marine mammals, Vol. 1: The walrus, sea lions, fur seals and sea otter. Academic Press, London, New York.

Kenyon, K. W. 1969. The sea otter in the eastern Pacific Ocean. N. Am. Fauna 68:1-352.

Lander, R. H., and H. Kajimura. 1982. Status of northern fur seals, p. 319-345. *In* Mammals in the seas, Vol. 4, Small cetaceans, seals, sirenians and otters, Advis. Comm. Mar. Resour. Res., FAO Fish. Ser. 5. Food Agric. Org., United Nations, Rome.

Leatherwood, S., A. E. Bowles, and R. R. Reeves. 1983. Endangered whales of the eastern Bering Sea and Shelikof Strait, Alaska; results of aerial surveys, April 1982 through April 1983 with notes on other marine mammals seen. U.S. Dep. Commer., NOAA, OCSEAP Final Rep. 42(1986):147-490.

LeDuc, R. G., W. L. Perryman, J. W. Gilpatrick Jr., J. Hyde, C. Stinchcomb, J. V. Carretta, and R. L. Brownell, Jr. 2001. A note on recent surveys for right whales in the southeastern Bering Sea. J. Cet. Res. Manage. (Special Issue) 2:287-289.

Lensink, C. J. 1961. Status report: beluga studies. Alaska Dep. Fish and Game, Juneau. 20 p.

Ljungblad, D. K., S. E. Moore, J. T. Clarke, and J. C. Bennett. 1988. Distribution, abundance, behavior and bioacoustics of endangered whales in the western Beaufort and northeastern Chukchi seas, 1979-1987. Technical Report (1111.) Naval Oceans Systems Center. San Diego, CA. 265 p.

Loughlin, T. R., and M. A. Perez. 1985. *Mesoplodon stejnegeri*. Mammalian Species, No. 250.

Loughlin, T. R., D. J. Rugh, and C. H. Fiscus. 1984. Northern sea lion distribution and abundance: 1956-1980. J. Wildl. Manage. 48(3):729-740.

Lowry, L. F. 1985a. The spotted seal (*Phoca largha*). Alaska Dept. Fish Game, Game Tech. Bull. 7:89-96.

Lowry, L. F. 1985b. The ribbon seal (*Phoca fasciata*). Alaska Dep. Fish Game, Game Tech. Bull. 7:71-78.

Lowry, L. F., and K. J. Frost. 1981. Feeding and trophic relationships of phocid seals and walruses in the eastern Bering Sea, p.813-824. *In* D. W. Hood and J. A. Calder (editors), The eastern Bering Sea shelf: Oceanography and resources, Vol. 2. Univ. Washington Press, Seattle.

Lowry, L. F., K. J. Frost, R. Davis, D. P. DeMaster, and R. S. Suydam. 1998. Movements and behavior of satellite-tagged spotted seals (*Phoca largha*) in the Bering and Chukchi seas. Polar Biol. 19:221-230.

Lowry, L. F., K. J. Frost, D. G. Calkins, G. L. Swartzman, and S. Hills. 1982. Feeding habits, food requirements, and status of Bering Sea marine mammals. North Pacific Fishery Management Council Document No. 19. North Pacific Fisheries Management Council, P. O. Box 103136, Anchorage, AK 99510. 292 p.

Lowry, L. F., V. N. Burkanov, K. J. Frost, M. A. Simpkins, R. Davis, D. P. DeMaster, R. Suydam, and A. Springer. 2000. Habitat use and habitat selection by spotted seals (*Phoca largha*) in the Bering Sea. Can J. Zool. 78:1959-1971.

Masaki, Y. 1976. Biological studies on the North Pacific sei whale. Bull. Far Seas Fish. Res. Lab. (Shimizu) 14:1-104.

McAlister, W. B. 1981. Estimates of fish consumption by marine mammals in the eastern Bering Sea and Aleutian Island area. Unpubl. Rep. 89 p.

Messier, F. 1994. Ungulate population models with predation: a case study with the North American moose. Ecology 75(2):478-488.

Messier, F., and M. Crête. 1985. Moose-wolf dynamics and the natural regulation of moose populations. Oecologia 65:503-512.

Mizroch, S. A., D. W. Rice, and J. M. Breiwick. 1984a. The blue whale, *Balaenoptera musculus*, p. 15-19. *In* J. M. Breiwick and H. W. Braham (editors), The status of endangered whales. Mar. Fish. Rev. 46(4).

Mizroch, S. A., D. W. Rice, and J. M. Breiwick. 1984b. The sei whale, *Balaenoptera borealis*, p. 25-29. *In* J. M. Breiwick and H. W. Braham (editors), The status of endangered whales. Mar. Fish. Rev. 46(4).

Moore, S. E., and R. R. Reeves. 1993. Distribution and movement, p. 313-386. *In* J. J. Burns, J. J. Montague, and C. J. Cowles (editors), The bowhead whale. Soc. Mar. Mammal., Spec. Publ. No. 2.

Moore, S. E., J. M., Waite, N. A. Friday, and T. Honkalehto. 2002. Cetacean distribution and relative abundance on the central-eastern and the southeastern Bering Sea shelf with reference to oceanographic domains. Progr. Oceanogr. 55:249-261.

Nasu, K. 1974. Movement of baleen whales in relation to hydrographic conditions in the northern part of the North Pacific Ocean and the Bering Sea, p. 345-361. *In* D. W. Hood and E. J. Kelley (editors), Oceanography of the Bering Sea with emphasis on renewable resources. Institute of Marine Science University of Alaska: Fairbanks.

National Research Council. 2003. The decline of the Steller sea lion in Alaskan waters: untangling food webs and fishing nets. The National Academies Press, Washington, D.C. 204 p.

National Research Council. 1996. The Bering Sea ecosystem. National Academy Press, Washington D.C. 207 p.

Nelson, R. R., J. J. Burns, and K. J. Frost. 1985. The bearded seal (*Erignathus barbatus*). Alaska Dep. Fish Game, Game Tech. Bull. 7:55-63.

Nikulin, P. G. 1946. Distribution of cetaceans in seas surrounding the Chukchi Peninsula. Izv. TINRO 22:255-257. In Russian. (Transl. By U.S. Nav. Oceanogr. Off., Washington, D.C., Trasl. No. 428, 1969, 3 p.)

Ohsumi, S. 1991. A review on population studies of the North Pacific minke whale stocks. Unpubl. Doc. Submitted to Int. Whal. Comm. (SC/43/Mi26). 24 p.

Ohsumi, S. 1966. Sexual segregation of the sperm whale in the North Pacific. Sci. Rep. Whales Res. Inst. Tokyo 20:1-16.

Ohsumi, S., and Y. Fukuda. 1974. Revised sperm whale population model and its application to the North Pacific sperm whale. Unpubl. Doc. Submitted to Int. Whal. Comm. (SC/25/8). 11 p.

Ohsumi, S., and Y. Masaki. 1977. Stocks and trends of abundance of the sperm whale in the North Pacific. Rep. Int. Whaling Comm. 27:167-175.

Ohsumi, S., and S. Wada. 1974. Status of whale stocks in the North Pacific, 1972. Rep. Int. Whal. Comm. 24:114-126.

Ohsumi, S., Y. Masaki., and S. Wada. 1977. Seasonal distribution of sperm whales sighted by scouting boats in the North Pacific and Southern Hemisphere. Rep. Int. Whal. Comm. 27:308-323.

Omura. H. 1955. Whales in the northern part of the North Pacific. Nor. Hvalfangst-Tidende 44(6):323-345.

Osmek, S. P.E. Rosel, A.E. Dizon, and R. L. DeLong. 1994. Harbor porpoise, *Phocoena phocoena*, population assessment studies for Oregon and Washington in 1993. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910. 14 p.

Perez, M. A. 1990. Review of marine mammal and prey population information for Bering Sea ecosystem studies. U.S. Dep. Commer. NOAA Tech. Memo. NMFS/NWC-186. 81 p.

Perez, M. A., and W. B. McAlister. 1993. Estimates of food consumption by marine mammals in the Eastern Bering Sea. U.S. Dep. Commer., NOAA Tech. Memo.NMFS-AFSC-14. 36 p.

Pike, G. C. 1962. Migration and feeding of the gray whale (*Eschrichtius gibbosus*). J. Fish. Res. Bd. Canada 19(5):815-38.

Pitcher, K. W. 1985. The harbor seal (*Phoca vitulina richardsi*), p. 65-70. *In* J. J. Burns, K. J. Frost, and L. F. Lowry (editors), Marine mammal species accounts. Alaska Department of Fish and Game, Juneau, AK. (Wildlife Technical Bulletin No. 7), 96 p.

Rice, D. W. 1986. Beaked whales, p. 102-109. *In* D. Haley (editor), Marine mammals of the eastern North Pacific and Arctic waters. Pacific Search Press, Seattle.

Rice, D. W. 1978a. The humpback whale in the North Pacific: distribution, exploitation, and numbers, p. 29-44. *In* K. S. Norris and R. R. Reeves (editors), Report on a Workshop on Problems Related to Humpback Whales (*Megaptera novaeangliae*) in Hawaii. U.S. Dep. Commer., Natl Tech. Inform. Serv. Rep. No. PB-280-794. Available from NTIS, 5285 Port Royal Road, Springfield, VA 22167.

Rice, D. W. 1978b. Whales and whale research in the eastern North Pacific, p. 170-195. *In* W. E. Schevill (editor), The whale problem: a status report. Harvard Univ. Press, Cambridge, MA.

Rice, D. W., and A. A. Wolman. 1971. The life history and ecology of the gray whale (*Eschrichtius robustus*). Am. Soc. Mammal. Spec. Publ. No. 3. 142 p.

Rosel, P. E., A. E. Dizon, and M. G. Haygood. 1995. Variability of the mitochondrial control region in populations of the harbour porpoise, *Phocoena phocoena*, on inter-oceanic and regional scales. Can. J. Fish. Aquat. Sci. 52:1210-1219.

Rotterman, L. M., and T. Simon-Jackson. 1988. Sea otter (*Enhydra lutris*), p. 237-275. *In* J. W. Lentfer (editor), Selected marine mammals of Alaska: Species accounts with research and management recommendations. Marine Mammal Commission, Washington, D.C.

Rugh, D. J., K. E. W. Shelden, and D. E. Withrow. 1995. Spotted seals in Alaska 1992-93. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

Rugh, D. J., J. M. Breiwick, R. C. Hobbs, and J. A. Lerczak. 2002. A preliminary estimate of abundance of the eastern North Pacific stock of gray whales in 2001 and 2002. Unpubl. Doc. Submitted to Int. Whal. Comm. (SC/54/BRG6). 14 p.

Scarff, J. E. 2001. Preliminary estimates of whaling-induced mortality in the 19th century North Pacific right whale (*Eubalaena japonicus*) fishery, adjusting for struck-but-lost whales and non-American whaling. J. Cet. Res. Manage. (Special Issue) 2:261-268.

Scarff, J. E. 1991. Historic distribution and abundance of the right whale, *Eubalaena glacialis*, in the North Pacific, Bering Sea, Sea of Okhotsk and Sea of Japan from the Maury Whale Charts. Rep. Int. Whal. Comm. 41:467-487.

Scheffer, V. B., and J. W. Slipp. 1944. The harbor seal in Washington state. Amer. Midl. Nat. 32:373-416.

Seaman, G. A. And J. J. Burns. 1981. Preliminary results of recent studies of belukahas in Alaskan waters. Rep. Int. Whal. Comm. 31:567-574.

Seaman, G. A., K. J. Frost, and L. F. Lowry. 1985. Distribution, abundance, and movements of belukha whales in western and northern Alaska. Draft final rep. prepared for U.S. Dep. Commer., NOAA, Natl. Ocean Serv., Anchorage, Alaska. Alaska Dep. Fish and Game, Fairbanks.

Sease, J. L. 1992. Status review: harbor seals (*Phoca vitulina*) in Alaska. AFSC Processed Rep. 92-15, 74 p. Alaska Fish. Sci. Cent., Natl. Mar. Fish. Serv., NOAA, 7600 Sand Point Way NE., Seattle, WA 98115-0070.

Sease, J. L., and C. J. Gudmundson. 2002. Aerial and land-based surveys of Steller sea lions (*Eumetopias jubatus*) from the western stock in Alaska, June and July 2001 and 2002. U. S. Dep. Commer. NOAA Tech. Memo. NMFS-AFSC-131, 45 p.

Sease, J. L., and D. G. Chapman. 1988. Pacific walrus *Odobenus rosmarus divergens,* p. 17-38. *In* J. W. Lentfer (editor) Selected marine mammals of Alaska: Species accounts with research and management recommendations. Marine Mammal Commission, Washington, D.C.

Shelden, K. E. W., and D. J. Rugh. 1996. The bowhead whale, *Balaena mysticetus*: its historic and current status. Mar. Fish. Rev. 57(3-4):1-20.

Sherrod, G. 1982. Eskimo Walrus Commission’s 1981 research report: the harvest and use of marine mammals in fifteen Eskimo communities. Rep. prepared for Eskimo Walrus Comm. Subsistence Section. Kawerak, Inc., Nome, Alaska, and Div. Subsistence, Alaska Dep. Fish and Game, Juneau.

Shustov, A. P. 1969. Relative indices and possible causes of mortality of Bering Sea ribbon seals, p. 83-92 *In* Arsenyev, V.A., V.A. Zenkovich and K.K. Chapskii, editors, Marine mammals (Morskikh mlekopitaiushchie). Publisher Nauka, Moscow, 1969 (Izdatel'stvo "Nauka", Moskva 1969). 341 p. Translation by F. Fay, 18 p.

Sobolevsky, Y. I., And O. A. Mathisen. 1996. Distribution, abundance, and trophic relationships of Bering Sea cetaceans, p. 265-275. *In* O. A. Mathisen and Kenneth O. Coyle (editors), Ecology of the Bering Sea: A review of Russian literature. Alaska Sea Grant College Program Report No. 96-01. University of Alaska Fairbanks.

Small, R. J., and D. P. DeMaster. 1995. Alaska marine mammal stock assessments 1995. U.S. Dep. Commer. NOAA Tech. Memo. NMFS-AFSC-57, 93 p.

Smith, C. R., and A. R. Baco. 2003. Ecology of whale falls at the deep sea floor. Oceanography and Marine Biology: an Annual Review 41:311-354.

Snelgrove, P. V. R., and C. R. Smith. 2002. A riot of species in an environmental calm: the paradox of the species-rich deep sea. Oceanography and Marine Biology: an Annual Review 40: 311-342.

Sobolevsky, Y. I., And O. A. Mathisen. 1996. Distribution, abundance, and trophic relationships of Bering Sea cetaceans, p. 265-275. *In* O. A. Mathisen and K. O. Coyle (editors), Ecology of the Bering Sea: A review of Russian literature. Alaska Sea Grant College Program Report No. 96-01. University of Alaska Fairbanks.

Springer, A. M. J. A. Estes, G. B. van Vliet, T. M. Williams, D. F. Doak, E. M. Danner, K. A. Forney, and B. Pfister 2003. Sequential megafaunal collapse in the North Pacific Ocean: an ongoing legacy of industrial whaling? Proc. Nat. Acad. Sci 100(21):12223-12228.

Stickney, A. 1982. Memorandum from A. Stickney to R. J. Wolfe, Alaska Dep. Fish and Game, Div. Subsistence, Bethel, 24 September 1982.

Tomilin, A. G. 1957. *Zveri SSSR I Prilezhasfchikh Stran. Zveri Vostochnoi Evropy I Severnoi Azii.* Vol. IX. *Kitoobraznye.* Izdatel'stvo Akademi Nauk SSSR, Moscow. 756 p. [Translated in 1967 as *Mammals of the USSR and Adjacent Countries. Mammals of Eastern Europe and Adjacent Countries*. Vol. IX. *Cetacea* by the Israel Program for Scientific Translations, Jerusalem, 717 p.].

Trites, A. W., and D. Pauly. 1998. Estimating mean body masses of marine mammals from maximum body lengths. Can. J. Zool. 76:886-896.

Trites, A. W., P. A. Livingston, S. Mackinson, M. C. Vasconcellos, A. M. Springer, and D. Pauly. 1999. Ecosystem change and the decline of marine mammals in the eastern Bering Sea: testing the ecosystem shift and commercial whaling hypothesis. Fish. Cent. Res. Rep.1999, 7(1), 106 p. Fisheries Centre, Univ. British Columbia, Vancouver, BC, Canada.

Turnock, B. J., S. T. Buckland, and G. C. Boucher. 1995. Population abundance of Dall’s porpoise (*Phocoenoides dalli*) in the western North Pacific Ocean. Rep. Int. Whal. Comm. (Special Issue 16):381-397.

Wada, S. 1981. Japanese whaling and whale sighting in the North Pacific 1979 season. Rep. Int. Whal. Comm. 31:783-792.

Wada, S. 1980. Japanese whaling and whale sighting in the North Pacific 1978 season. Rep. Int. Whal. Comm. 30:415-424.

Wade, P. R. 2002. A Bayesian stock assessment of the eastern Pacific gray whale using abundance and harvest data from 1967 to 1996. J. Cet. Res. Manage. 4(1):85-98.

Wade. P. R., and D. P. DeMaster. 1996. A Bayesian analysis of eastern Pacific gray whale population dynamics. Unpubl. Doc. Submitted to Int. Whal. Comm. (SC/48/AS3). 21 p.

Wahl, T. R. 1979. Observation of Dall’s porpoise in the northwestern Pacific Ocean and Bering Sea in June 1975. Murrelet 60:108-110.

Webb, R. L. 1988. On the Northwest: commercial whaling in the Pacific Northwest 1790-1967. University of British Columbia Press. Vancouver. 425 p.

Weller, D. W. 2002. Predation on marine mammals, p. 985-994. *In* W. F. Perrin, B. Wursig, and J. G. M. Thewissen (editors), Encyclopedia of Marine Mammals. Academic Press, San Diego.

Whitehead, H. 2002. Estimates of the current global population size and historical trajectory for sperm whales. Mar. Ecol. Progr. Ser. 242:295-304.

Withrow, D. E., and T. R. Loughlin. 1996a. Haulout behavior and a correction factor estimate for the proportion of harbor seals missed during molt census surveys near Cordova, Alaska. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

Withrow, D. E., and T. R. Loughlin. 1996b. Abundance and distribution of harbor seals (*Phoca vitulina richardsi*) along the north side of the Alaska Peninsula and Bristol Bay during 1995. Annual report to the MMPA Assessment Program, Office of Protected Resources, NMFS, NOAA, 1335 East-West Highway, Silver Spring, MD 20910.

Wolfe, R. J. 1982. Letter from R. J. Wolfe, Alaska Dep. Fish and Game, Div. Subsistence, Bethel, to J. J. Burns, Alaska Dep. Fish and Game, Dive. Game, Fairbanks, 24 September 1982.

Wolman, A. A. 1985. Gray whale *Eschrichtius robustus* (Lilljeborg, 1861), p. 67-90 *In* S. H. Ridgway and R. Harrison (editors), Handbook of marine mammals. Vol. 3: The Sirenians and baleen whales. Academic Press, London. 362 p.

Zenkovich, B. A. 1955. The migration of whales, whale fishing in the waters of the Soviet Far East, p. 51-68. *In* S. E. Kleinenberg and T. I. Makarova (editors), Kitoiony Promysel Sovetskogo Soyuza, VNIRO, Part I. In Russian. (Transl. By Israel Program Sci. Transl. For U.S. Dep. Int. and Natl. Sci. Found., 1968.

Table 1. Outline of the parameters used in the biomass calculations for each species.

Species[1]	**Stock/Population**	**Historic Abundance**	**Current Abundance**	**Body Weight (metric tons)**[2]	**Percent of population in study area**	**Number of days spent in study area**	**Sources**
Bowhead whale (*Balaena mysticetus*)	Western Arctic	15,000 (range 12,000-18,000)	10,020 (95% CI = 7,800-12,900; SE = 1,290)	31.1*	100%	November to April; 181	Eberhardt and Breiwick 1992, George et al. 2003, Bogoslovskaya et al. 1982, Brueggeman 1982, Ljungblad et al. 1988, Moore and Reeves 1993, Braham et al. 1984a, Braham et al. 1980, Brueggeman et al. 1987, Bessonov et al. 1990, Shelden and Rugh 1996
Northern right whale (*Eubalaena japonicus*)	Eastern North Pacific	31,750	50	23.4*	33%-historic[3] 100%-current	April to September; 183	Scarff 2001, Clapham et al. 1999, LeDuc et al. 2001, Clapham et al. 2001, Scarff 1991, Berzin and Rovnin 1966

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[1] Caveats and assumptions for biomass calculations are elaborated upon in the text for species that are marked with a double asterisk (**).

[2] All body weight estimates were taken from Trites and Pauly (1998). Weights marked with an asterisk (*) were calculated without incorporating age structure of the population.

[3] I assumed that the historic population of North Pacific right whales was evenly split between the Sea of Okhotsk, the Bering Sea and the Gulf of Alaska (Scarff 1991).

Species[1]	**Stock/Population**	**Historic Abundance**	**Current Abundance**	**Body Weight (metric tons)**[2]	**Percent of population in study area**	**Number of days spent in study area**	**Sources**
Fin whale** (*Balaenoptera physalus*)	Northeast Pacific	43,500 (range 42,000-45,000)	4,051	55.6	25% historic 100% current	Late June to October; 138	Ohsumi and Wada 1974, Moore et al. 2002, Nikulin 1946, Berzin and Rovnin 1966, Nasu 1974
Humpback whale** (*Megaptera novaeangliae*)	Central North Pacific	9,060	4,005 (CV=0.095)	30.4	100%	May to October; 184	Rice 1978a, Calambokidis et al. 1997, Tomilin 1957, Zenkovich 1955, Berzin and Rovnin 1966
Minke whale ** (*Balaenoptera acutorostrata*)	Alaska	1,813	1,813	6.6	100%	May to July; 92	Moore et al. 2002, Tomilin 1957, Horwood 1990, Ohsumi 1991
Gray whale (*Eschrictius robustus*)	Eastern North Pacific	28,240 (range 24,640-31,840)	17,414 (95% CI=14,322-21,174)	15.4*	90%	May to October; 184 days	Wade 2002, Rugh et al. 2002, Pike 1962, Rice and Wolman 1971, Darling 1984, Gosho et al. 1999, Wolman 1985

Species[1]	**Stock/Population**	**Historic Abundance**	**Current Abundance**	**Body Weight (metric tons)[2]**	**Percent of population in study area**	**Number of days spent in study area**	**Sources**
Sperm whale** (*Physeter macrocephalus*)	North Pacific	195,000	15,000	26.9[4]	100%	April to September; 183 days	Ohsumi and Fukuda 1974, Perez 1990[5], Tomilin 1957, Berzin and Rovnin 1966, Ohsumi and Masaki 1977, Ohsumi et al. 1977, Ohsumi 1966, Gosho et al. 1984
Harbor porpoise** (*Phocoena phocoena*)	Bering Sea	50,127	50,127	0.03	100%	365 days	Moore et al. 2002, Waite and Hobbs, in prep, Bjøre et al. 1994, Gaskin 1984, Jones 1984, IWC 1991, Osmek et al. 1994, Rosel et al. 1995, Calambokidis and Barlow 1991

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[4] Body weight is for male sperm whales only.

[5] I adopted the estimate that Perez (1990) generated using the following sources: Ohsumi and Masaki 1977, Gosho et al. 1984, Ohsumi 1966, Ohsumi et al. 1977, Wada 1980, Wada 1981.

Species[1]	**Stock/Population**	**Historic Abundance**	**Current Abundance**	**Body Weight (metric tons)[2]**	**Percent of population in study area**	**Number of days spent in study area**	**Sources**
Dall's porpoise** (*Phocoenoides dalli*)	Bering Sea/Aleutian Islands	90,141	90,141	0.06*	100%	365 days	Moore et al. 2002, Hobbs and Lerczak 1993, Kawamura 1975, Wahl 1979, Fiscus 1980, Buckland et al. 1993a
Beluga whale** (*Delphinapterus leucas*)	Beaufort	39,258	39,258	0.31[6]	100%	November to April; 181 days	Duval 1993, Harwood et al. 1996, Hazard 1988, Harrison and Hall 1978, Leatherwood et al. 1983, Fay, pers. commun., as cited in Lensink 1961; Seaman et al. 1985
Beluga whale** (*Delphinapterus leucas*)	Eastern Chukchi	3,710	3,710	0.31	100%	October to April, 212 days	Frost et al. 1993, Frost and Lowry 1995, Brodie 1971, Hazard 1988
Beluga whale** (*Delphinapterus leucas*)	Eastern Bering Sea	18,142 (CV = 0.24)	18,142 (CV = 0.24)	0.31	100%	365 days	R. C. Hobbs, unpublished data, as cited in Angliss and Lodge 2004, Hazard 1988

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[6] Trites and Pauly (1998) reported an average body weight of 0.31 tons for the beluga, which I used for all four stocks.

Species[1]	**Stock/Population**	**Historic Abundance**	**Current Abundance**	**Body Weight (metric tons)**[2]	**Percent of population in study area**	**Number of days spent in study area**	**Sources**
Beluga whale** (*Delphinapterus leucas*)	Bristol Bay	1,642	1,642	0.31	100%	365 days	Frost et al. 2002, Hazard 1988
Northern fur seal (*Callorhinus ursinus*)	Eastern Pacific	3,000,000	888,120	0.03	May-October; 50% Nov.-April; 5%[7]	May-October; 184 days; Nov.-April 181 days	Lander and Kajimura 1982, A. E. York, unpublished data, Bigg, M.A. 1986, Perez and McAlister 1993
Steller sea lion** (*Eumetopius jubatus*)	Western U.S.	126,900	35,194[8]	0.2	100%	365 days	Loughlin et al. 1984, as cited in Hoover 1988a, Sease and Gudmundson 2002, Lowry et al. 1982, Trites et al. 1999

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[7] There is variability in the interannual arrival and departure dates of different age and sex classes of northern fur seals to the Pribilof Islands (Kajimura et al. 1980, McAlister 1981, Gentry 1981, Bigg 1986)

[8] This is a minimum abundance based on pup count data from 2001 and 2002 and non-pup count data from 2002.

Species[1]	**Stock/Population**	**Historic Abundance**	**Current Abundance**	**Body Weight (metric tons)[2]**	**Percent of population in study area**	**Number of days spent in study area**	**Sources**
Harbor seal (*Phoca vitulina richardii*)	Bering Sea	30,000[9]	13,312 (CV = 0.062)[10]	0.06[11]	100%	365 days	Sease 1992, Withrow and Loughlin 1996a and1996b, DeMaster 1996, ADF&G 1973, Scheffer and Slipp 1944, Fisher 1952, Bigg 1969 and 1981, and Perez 1990
Harbor seal** (*Phoca vitulina richardii*)	Gulf of Alaska	140,000	22,376	0.06	100%	365 days	Sease 1992, Boveng et al. 2003, Hoover 1988b, Angliss and Lodge 2004, ADF&G 1973, Scheffer and Slipp 1944, Fisher 1952, Bigg 1969 and 1981, and Perez 1990
Spotted seal[12] (*Phoca largha*)	Alaska	140,000[13]	140,000	0.04*	100%	November to June; 242 days	Perez 1990, Lowry et al. 1998 and Lowry et al. 2000

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[9] The historic abundance estimates for both stocks of harbor seals gives an indication of the overall magnitude of the population, not an exact estimate of population size (Pitcher 1985). They are likely negatively biased.

[10] The Alaska SRG considered the correction factor used to calculate this abundance estimate conservative (DeMaster 1996).

[11] Trites and Pauly (1998) reported an average body weight of 0.06 tons for the harbor seal, which I used for both stocks.

[12] There is no reliable historic or current abundance estimate for the spotted seal (Rugh et al. 1995) in the Bering Sea/ Aleutian Islands region. However, they are present in the Bering Sea ecosystem (Braham et al. 1984b) and should therefore be included in the analysis.

[13] I used Perez's method for calculating abundance (Lowry and Frost 1981, Lowry 1985a, Burns 1986, Braham et al. 1984b, as cited in Perez 1990).

Species[1]	**Stock/Population**	**Historic Abundance**	**Current Abundance**	**Body Weight (metric tons)**[2]	**Percent of population in study area**	**Number of days spent in study area**	**Sources**
Bearded seal[14] (*Erignathus barbatus*)	Alaska	150,000[15]	150,000	0.20	100% winter < 5% summer	November to April; 181 days May to October; 184 days	Burns 1981, Lowry and Frost 1981, Nelson et al. 1985, Braham et al. 1984b, Perez 1990
Ribbon seal (*Phoca fasciata*)	Alaska	85,000	105,000	0.07*	100%	365 days	Shustov 1969, as cited in Fedoseev 1973; Lowry 1985b
Ringed seal (*Phoca hispida*)	Alaska	600,000	600,000	0.04	100%	November to April; 181 days	Perez 1990[16], Braham et al. 1984b
Pacific walrus** (*Odobenus rosmarus divergens*)	Alaska	225,000	201,039	0.59	100% winter 22% summer	December to April; 151 days May to November; 214 days	Fay 1982, Gilbert et al. 1992, Fay 1981, Sease and Chapman 1988, Fay et al. 1985, Fay et al. 1997

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[14] No reliable historic or current abundance estimates exist for the bearded, ribbon or ringed seal (Angliss and Lodge 2004). However, they are present in the Bering Sea ecosystem and should therefore be included in the analysis (Braham et al. 1984b). For the purpose of this analysis, historic and current abundance estimates for the bearded seal and ringed seal were considered equal.

[15] I adopted the estimate that Perez (1990) generated using the following sources: Burns 1981, Lowry and Frost 1981, Nelson et al. 1985, Braham et al. 1984b.

[16] I adopted the estimate that Perez (1990) generated using the following sources: Lowry and Frost 1981, Lowry et al. 1982, Frost 1985, Braham et al. 1984b.

Species[1]	**Stock/Population**	**Historic Abundance**	**Current Abundance**	**Body Weight (metric tons)[2]**	**Percent of population in study area**	**Number of days spent in study area**	**Sources**
Sea otter** (*Enhydra lutris*)	Southwest Alaska	118,000	41,474	0.01*	100%	365 days	Johnson 1982, as cited in Rotterman and Simon-Jackson 1988, Doroff et al. 2003, Angliss and Lodge 2002, Kenyon 1969, Kenyon 1981

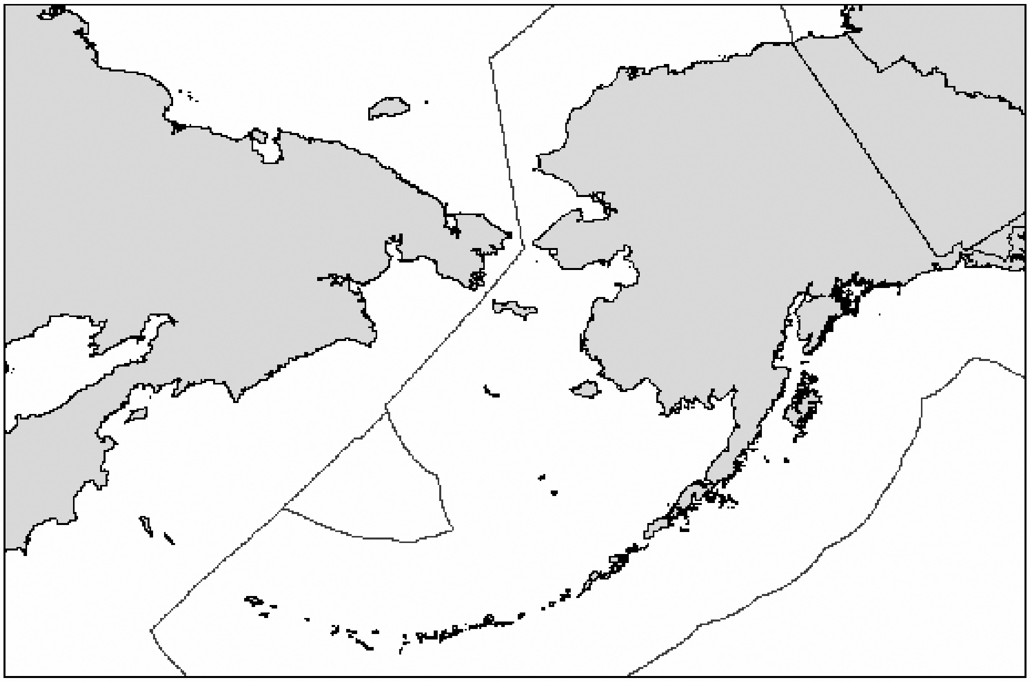


Figure 1.-- Map of the Bering Sea/Aleutian Islands region. The black line delineates the U.S. Exclusive Economic Zone.

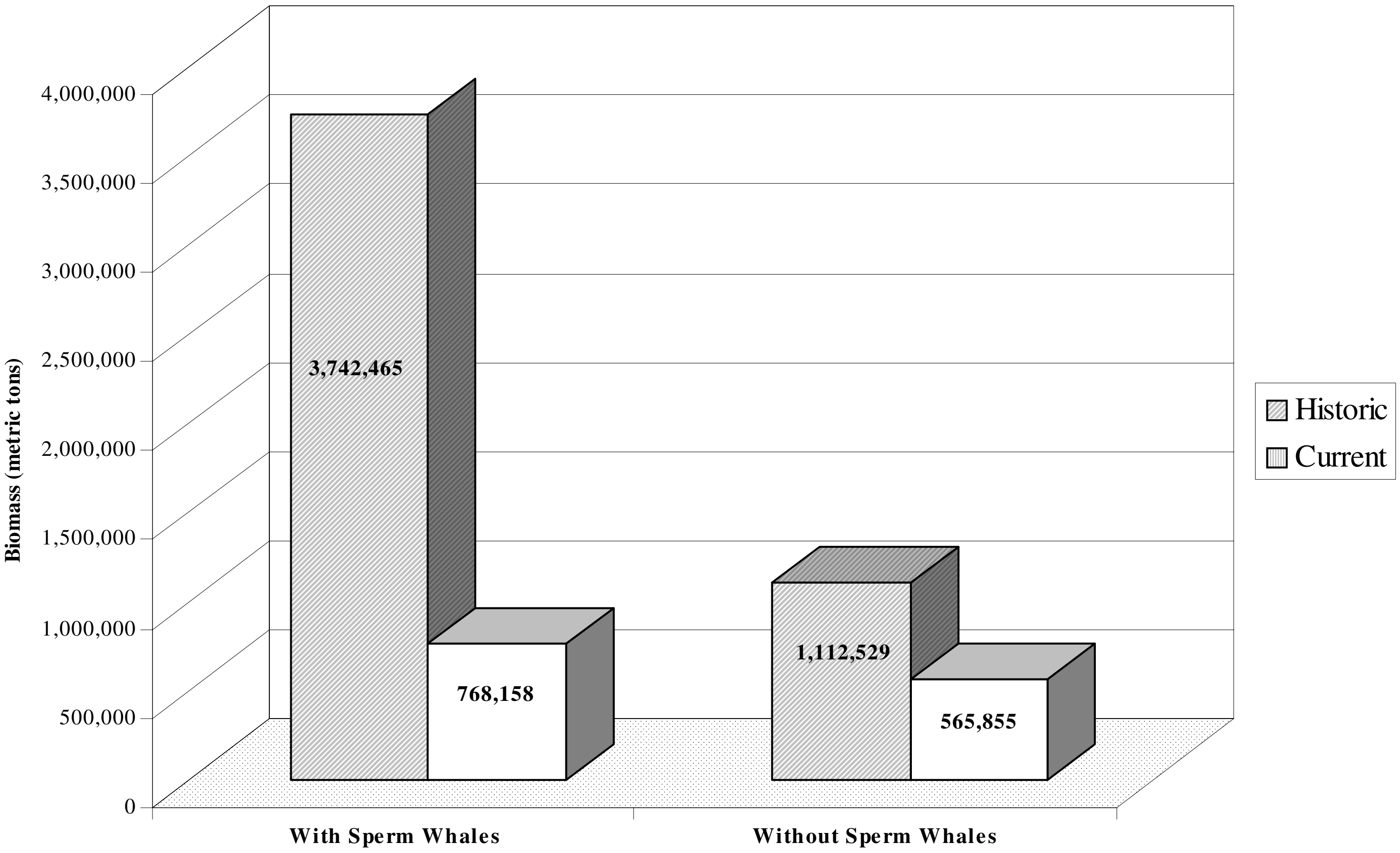


Figure 2 -- Historic and Current Biomass of Marine Mammals in the Bering Sea.

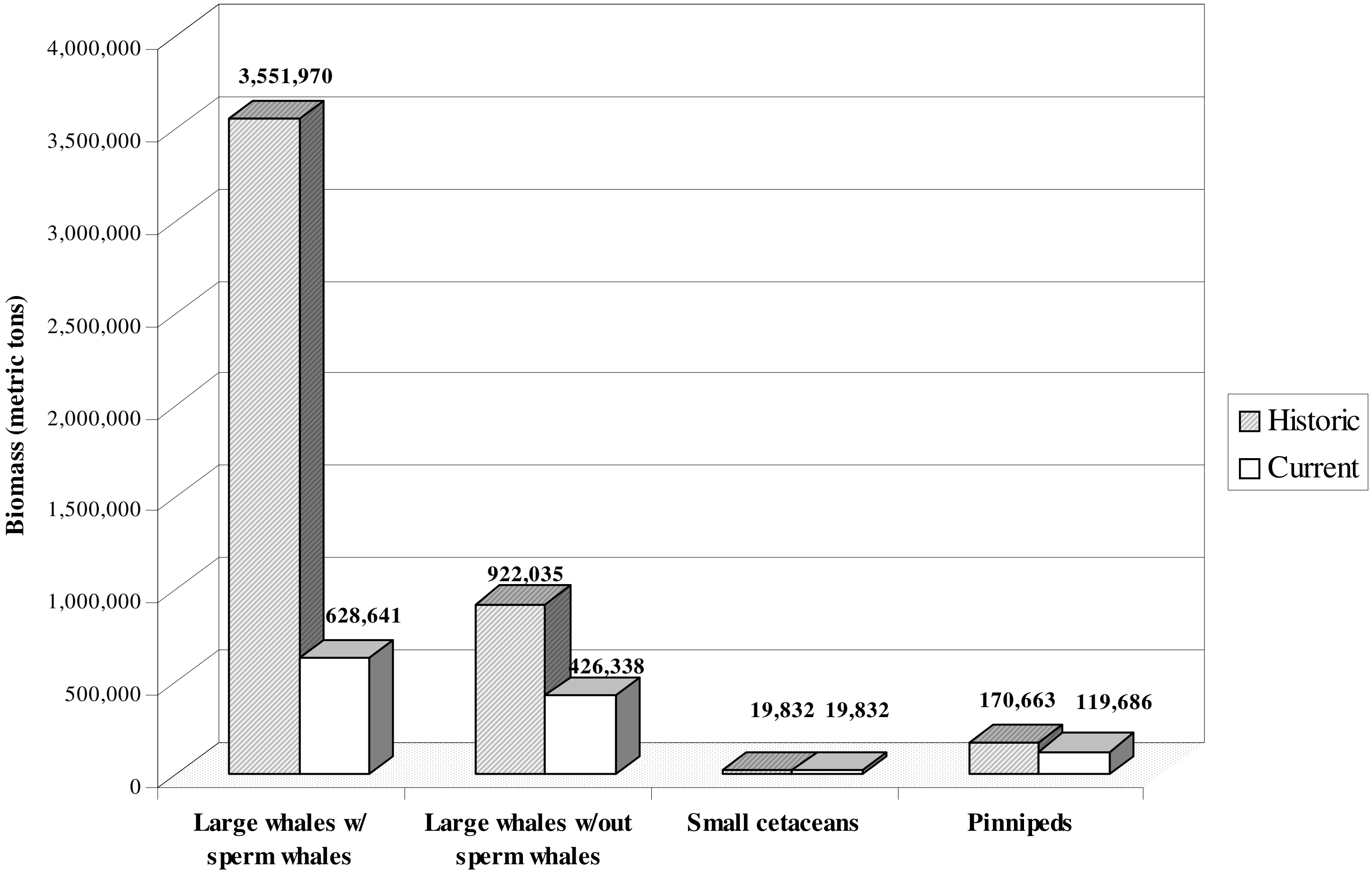


Figure 3. -- Historic and Current Biomass of Marine Mammals Subgroups in the Bering Sea.

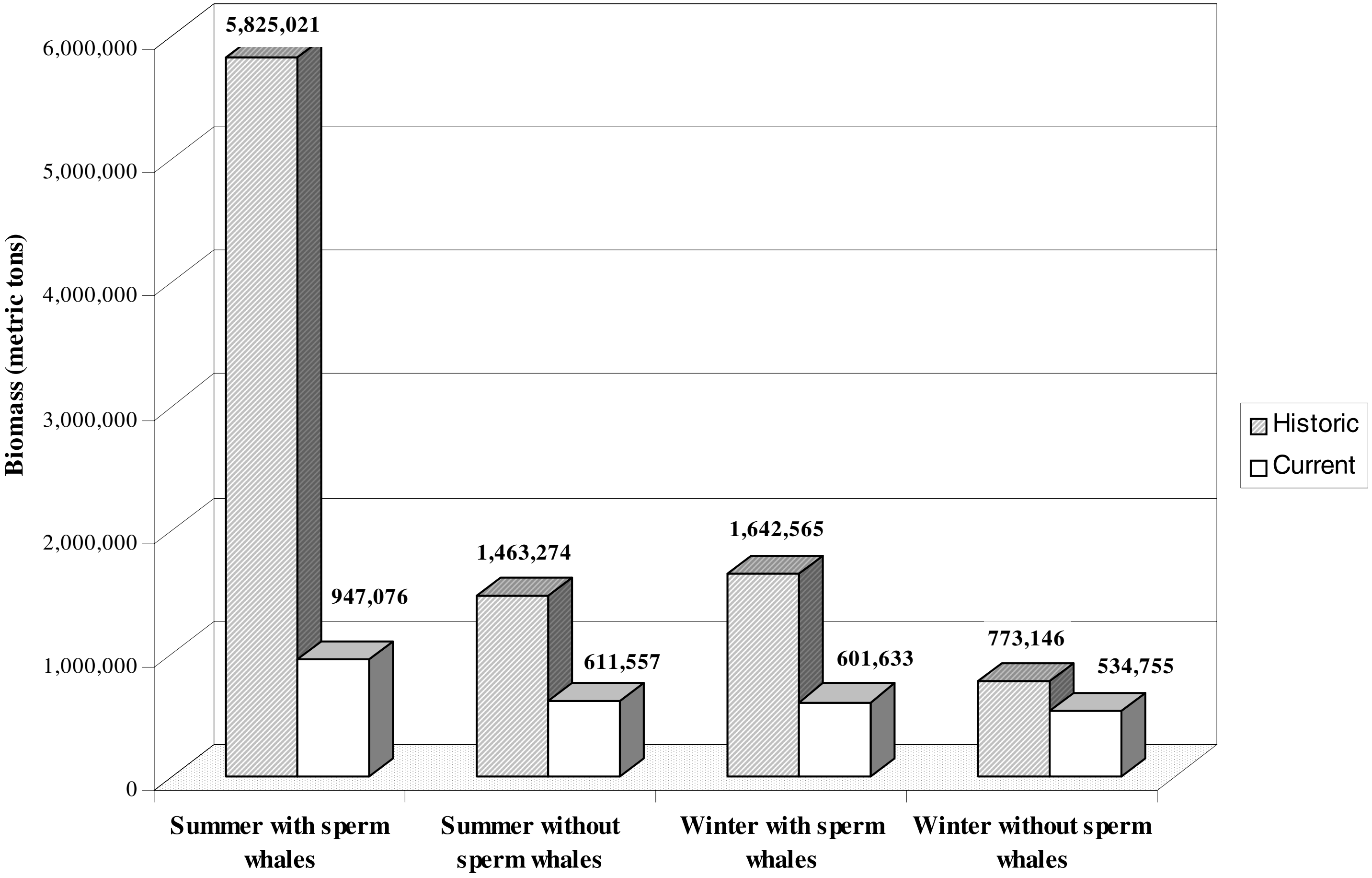


Figure 4.-- Historic and Current Biomass of Marine Mammals in the Summer and Winter.

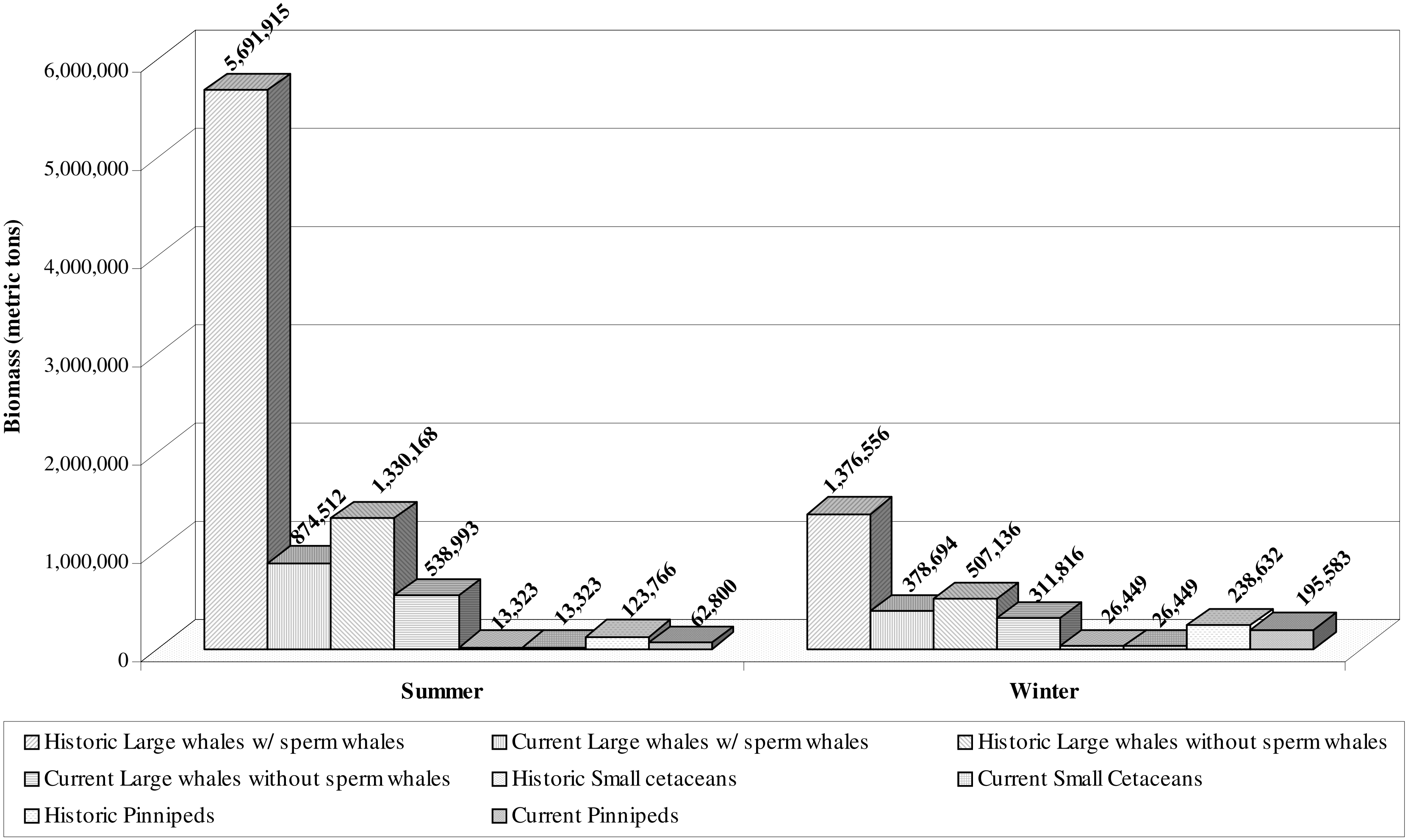
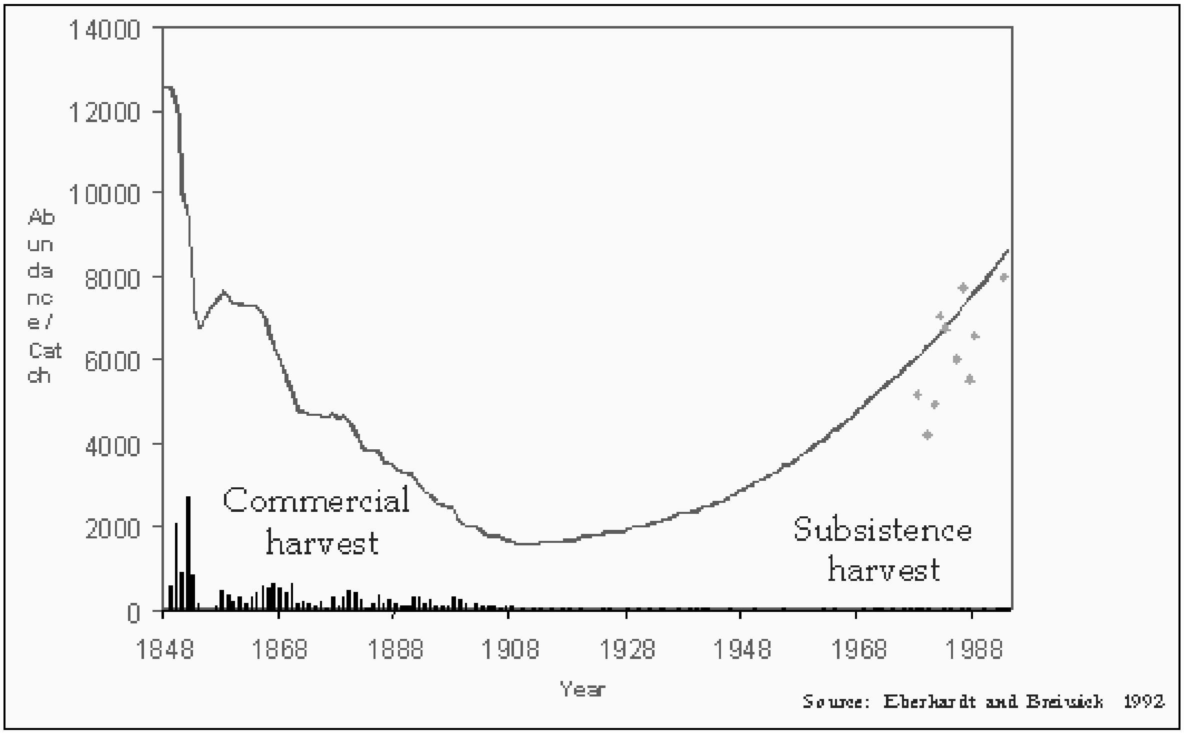


Figure 5.-- Historic and Current Biomass of Marine Mammal Subgroups in Summer and Winter.



Source: Eberhardt and Breiwick 1992

Figure 6.-- Trends in abundance of the Western Arctic bowhead whale. Adopted from Eberhardt and Breiwick (1992).