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Status Review and Extinction Assessment of Cook Inlet Belugas (*Delphinapterus leucas*)

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**STATUS REVIEW AND EXTINCTION ASSESSMENT
OF COOK INLET BELUGAS (*DELPHINAPTERUS LEUCAS*)**

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Cover photo: Belugas (*Delphinapterus leucas*) in the Susitna River delta, Cook Inlet, Alaska, June 1994.
Photographer: J. Waite (AFSC-NMML).

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EXECUTIVE SUMMARY

Background

After completion (in 2005) of the Draft Conservation Plan for Cook Inlet belugas (*Delphinapterus leucas*) under the Marine Mammal Protection Act (MMPA); the National Marine Fisheries Service (NMFS) recommended that a Status Review be conducted to incorporate new scientific findings available since the publication of a scientific review in 2000 in the journal *Marine Fisheries Review* 62 (3). NMFS formally initiated this Status Review on March 29, 2006 to determine if Cook Inlet belugas should be listed under the Endangered Species Act (ESA). On April 20, 2006, NMFS received a petition from Trustees for Alaska to list Cook Inlet belugas as endangered under the ESA. After reviewing the information contained in the petition, as well as other scientific information readily available, NMFS determined the petitioned action may be warranted. Within 12 months of the date of the petition, NMFS must make one of the following findings:

- 1) the petitioned action is not warranted;
- 2) the petitioned action is warranted and the Secretary of Commerce will publish in the *Federal Register* (FR) a proposed regulation to implement the action pursuant to 50 CFR 424.16; or
- 3) the petitioned action is warranted, but
 - (A) the immediate proposal and timely promulgation of a regulation to implement the petitioned action is precluded because of other pending proposals to list, delist, or reclassify species; and
 - (B) expeditious progress is being made to list, delist, or reclassify qualified species, in which case such findings shall be promptly published in the FR.

This Status Review provides a summary of the best available science to aid NMFS policy makers in this process.

Status of Cook Inlet Belugas

Temporal Changes in Distribution

Since the mid-1990s, 96% to 100% of the observed Cook Inlet belugas have congregated in the upper Inlet in shallow areas near river mouths—they were only occasionally found in the central or southern portions of the Inlet during the summer months. It is unknown if this contracted distribution is a result of changing habitat, prey concentration, predator avoidance, or a more acute reduction of the population into all but a small number of preferred habitat areas. This concentration of belugas in the northernmost portion of Cook Inlet appears to be a fairly consistent pattern from June to October. Data from tagged whales (14 tags between July and March 2000-03) show that belugas use the upper Inlet intensively between summer and late autumn, but during winter months they also disperse to mid-Inlet offshore waters. Tagged whales and extensive surveys both within Cook Inlet and in the Gulf of Alaska indicate that belugas do not have a seasonal migration in and out of the Inlet. Yakutat Bay is the only location outside of Cook Inlet where there is a known, persistent population of several belugas.

Population Size and Trend

NMFS began comprehensive, systematic aerial surveys of the beluga population in Cook Inlet in 1993. Unlike previous efforts, these surveys included the upper, middle, and lower sections of the Inlet. These surveys documented a decline in abundance of nearly 50% between 1994 and 1998, from an estimate of 653 whales to 347 whales. Although this rapid decline stopped after hunting was regulated in 1998, beluga numbers have not increased. In fact, the most recent abundance estimate (in 2005) was 278 whales, the lowest point estimate to date.

Data results indicated that the documented decline in beluga abundance from 1994 to 1998 is adequately explained by the estimated mortalities from the Native subsistence hunt for the same period. With the very limited hunt between 1999 and 2005 (1 to 2 whales per year), NMFS anticipated that the population would begin to recover at a growth rate of 2% to 6% per year. However, a Bayesian analysis including the 2005 estimate of abundance indicates that there is a

likelihood of less than 10% that the growth rate is above 2%, and a likelihood of 65% or more that the population will decline further. The best available data at this time indicate that the Cook Inlet beluga population is not growing as expected despite the limits on subsistence hunting.

Determination of Distinct Population Segment

NMFS established Cook Inlet belugas as a Distinct Population Segment (DPS) and therefore, a species as defined under Section 3(15) of the ESA on June 22, 2000. The population of belugas in Cook Inlet is discrete from other Alaskan and Russian beluga populations in the Arctic. Physically, these whales are isolated from other populations by the Alaska Peninsula. Despite extensive, dedicated marine mammal survey effort, the lack of sightings along the southern side of the Alaska Peninsula and Aleutian Islands chain suggests that the Cook Inlet population does not disperse into the Bering Sea. Behaviorally, belugas show strong maternally-driven site-fidelity to summering areas, suggesting opportunity for intermixing may only occur during winter migrations. However, the available data suggest that belugas remain in Cook Inlet year-round and do not undertake extensive migrations. Furthermore, the genetic characteristics of this population differ markedly from the other four beluga populations that occur off western and northern Alaska. Given the site-fidelity of beluga populations, it is unlikely that immigrants from other Arctic beluga populations would repopulate Cook Inlet in the foreseeable future if the Cook Inlet beluga population goes extinct. As it is the only population found in subarctic waters east of the Alaska Peninsula, the result would be a significant loss in the range of the taxon.

Risk Assessment

Risk Factors

The ESA defines an endangered species as any species in danger of extinction throughout all or a significant portion of its range, and a threatened species as any species likely to become endangered within the foreseeable future. Section 4(b)(1)(a) of the ESA requires that determinations of whether a species is threatened or endangered be based solely on the best

scientific and commercial data available, after taking into account those efforts, if any, being made to protect the species. The Secretary shall determine whether any species is endangered or threatened because of any of the following factors listed under Section 4(a)(1) of the ESA:

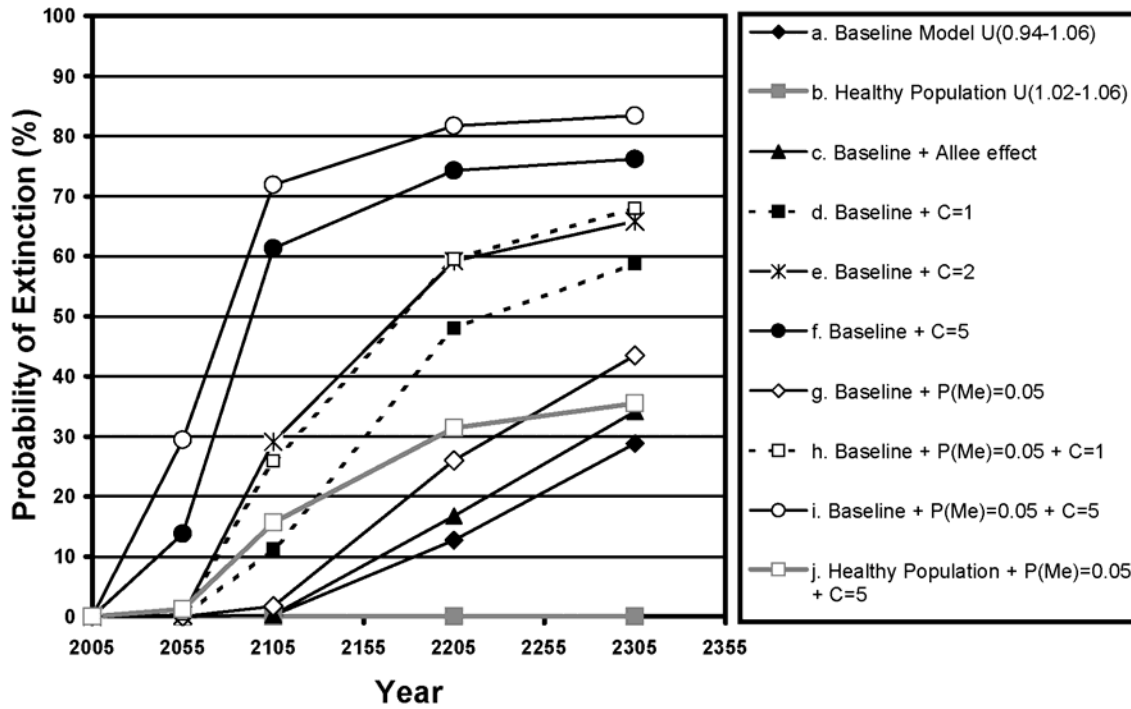
- 1) The present or threatened destruction, modification, or curtailment of habitat or range;
- 2) Overutilization for commercial, recreational, scientific, or educational purposes;
- 3) Disease or predation;
- 4) The inadequacy of existing regulatory mechanisms; or
- 5) Other natural or manmade factors affecting its continued existence.

There are a number of behavioral and ecological characteristics that put Cook Inlet belugas at considerable risk of extinction. These include but are not limited to the following: 1) life history characteristics such as slow population growth rate; 2) distorted age, size or stage structure of the population, and reduced reproductive success; 3) strong compensatory or Allee effects; 4) habitat specificity or site fidelity; and 5) habitat sensitivity. The genetic and spatial isolation of the Cook Inlet beluga population and strong site-fidelity greatly increases the risk of inbreeding and expression of deleterious genes should this population decline further in number. At reduced numbers and with contraction of their range, this population is far more vulnerable to losses due to stranding, predation, or disease. Cook Inlet belugas rely heavily on several fish prey species that are available only seasonally and are also of considerable commercial interest. Disturbances that cause belugas to temporarily or permanently abandon summer feeding areas could reduce their ability to survive through the winter months.

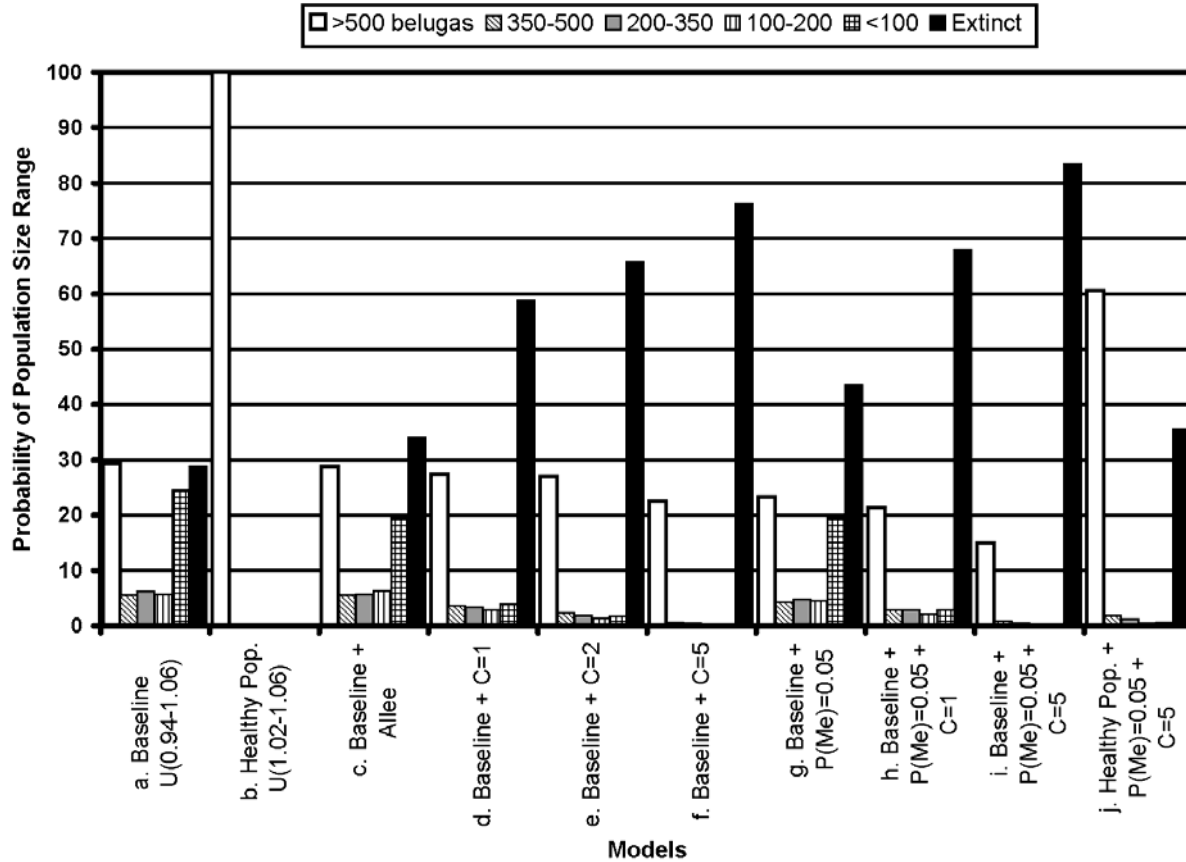
Population Viability Analysis

A detailed population viability analysis model, including immature and mature phases of both sexes, was developed for the Cook Inlet beluga population. This model focused on the behavior of a declining population at sizes < 500 belugas. Small population effects, demographic stochasticity, Allee effects, predation mortality, and unusual mortality events were modeled explicitly. The Allee effect and predation mortality produced thresholds of population size below which the population could not recover; extinction occurred more or less rapidly depending on the height of the population size threshold. This threshold was particularly

pronounced when predation (C) was set at two mortalities or greater per year causing a visible break point below which there was little likelihood of the population avoiding extinction. The probability of extinction within 100 years ranged from 0% to 29%, and within 300 years ranged from 29% to 68% in the models that considered parameters most representative of the Cook Inlet beluga population (ES-Fig.1, models a-e, g-h). What was thought to be the most realistic model (ES-Fig. 1, model h), with an average of one predation mortality per year and a 5% annual probability of an unusual mortality event killing 20% of the population, resulted in a 26% probability of extinction in 100 years and 68% probability of extinction in 300 years. Models with five predation mortalities per year (ES-Fig. 1, models f, i, j) showed that the extinction probability was sensitive to changes or underestimation of this parameter and that the population at its current size of 278 would be near the threshold population size (200 animals) for this model, even if the population was otherwise healthy but suffered occasional unusual mortality events. The model with no threshold effects (i.e., Allee or predation) resulted in a 65% probability of decline and 29% probability of extinction within 300 years (ES-Fig. 1, model a). Even with this most optimistic scenario, with no harvest after 2005, the probability that the population would be larger than 500 animals in 2305 was only 29% (ES-Fig. 2, model a).



ES-Figure 1. Probability of extinction by year for the Cook Inlet beluga population based on each population viability analysis model. Models using the same parameters are the same line style, color, and symbol type with open symbols indicating the inclusion of the unusual mortality event parameter $P(Me)$ set at a 5% annual probability of a 20% mortality. The constant mortality effect parameter (C) was set at 1, 2 or 5 whales per year. U = uniform distribution (of the annual growth multiplier). The Baseline model allowed declining and increasing annual growth while the Healthy Population model allowed only increasing annual growth.



ES-Figure 2. Probability of the Cook Inlet beluga population size based on population viability analysis outcomes after 300 years. Note that in all cases the majority of outcomes are either extinct or > 500 animals. The Baseline Model allowed declining and increasing annual growth while the Healthy Population model allowed only increasing annual growth. U = uniform distribution (of the growth multiplier), C = constant mortality effect parameter (e.g., predation) set at 1, 2 or 5 belugas, P(Me) = unusual mortality event parameter set at 5% annual probability of 20% mortality.

Conclusions of the Status Review

- The contraction of the range of this population northward into the upper Inlet makes it far more vulnerable to catastrophic events with the potential to kill a significant fraction of the population.
- The population is not growing at 2% to 6% per year as had been anticipated since the cessation of unregulated hunting.
- The population is discrete and unique with respect to the species, and if it should fail to survive, it is highly unlikely that Cook Inlet would be repopulated with belugas. This

would result in a permanent loss of a significant portion of the range for the beluga species.

- The importance of anadromous fish runs in Cook Inlet to belugas is evident. The bulk of their annual nutrition is acquired during the summer months.
- The PVA shows a 26% probability of extinction in 100 years and 68% probability of extinction in 300 years (for the model assuming one predation mortality per year and a 5% annual probability of an unusual mortality event killing 20% of the population). It is likely that the Cook Inlet beluga population will continue to decline or go extinct over the next 300 years unless factors determining its growth and survival are altered in its favor.

1. INTRODUCTION

1.1. Scope and Intent of the Status Review Update

Following a 1999 review of the status of the beluga (*Delphinapterus leucas*) population in Cook Inlet, Alaska, the National Marine Fisheries Service (NMFS) determined that listing the Cook Inlet beluga population as a threatened or endangered distinct population segment (DPS) under the Endangered Species Act (ESA) was not warranted. At the time of this determination, NMFS found that: 1) the habitat of the population had not been, nor was it likely to be, destroyed, modified, or curtailed in sufficient extent to cause the population to be in danger of extinction; 2) the population had not been overutilized for commercial, recreational, scientific, or educational purposes; 3) the effects of disease or predation were not well documented but were believed to be minimal; 4) adequate regulatory mechanisms to control the subsistence hunt, which was the only factor that accounted for the observed decline, were in place (the Marine Mammal Protection Act (MMPA) provided an adequate mechanism to ensure that future commercial activity in Cook Inlet would have no more than a negligible impact on the population); and 5) other natural or manmade factors (subsistence hunt) have affected the population's continued existence; however, the current (since 1999) level of hunting would not have a significant adverse impact on the continued existence of Cook Inlet belugas. However, this population continued to remain on the Candidate Species List, and in 2004 it was transferred to the Species of Concern List. After completion of the Draft Conservation Plan for this population under the MMPA in 2005, NMFS recommended that a Status Review be conducted to incorporate new scientific findings collected since the 1999 review (published in *Marine Fisheries Review* 62 (3)). NMFS may conduct Status Reviews on species that are not the subject of a petition. As with a petitioned species, initiation of a Status Review does not mean that an ESA listing is imminent. This AFSC *Processed Report* includes a review of data that have become available since the 1999 review, and it provides models of extinction scenarios for the Cook Inlet beluga DPS.

1.2. History of the Status of Cook Inlet Belugas

1.2.1. Candidate Species Listing—1988

Status Reviews are prepared by NMFS for marine species that are being considered for listing as a “Species of Concern” (69 FR 19975, April 15, 2004), Candidate Species (50 CFR 424.02), or that are already listed as endangered or threatened under the ESA (5 USC 1533). On August 31, 1988, NMFS announced the creation of a list of Candidate Species being considered by the Secretary of Commerce (NMFS is an agency within the Department of Commerce) for listing as threatened or endangered species under the ESA. A Candidate Species is a species that the U.S. Fish and Wildlife Service (USFWS) or NMFS is considering listing as endangered or threatened but which has not yet been the subject of a proposed rule. Candidate Species are afforded no protection under the ESA, but § 4(b)(3)(C)(iii) of the Act requires the agencies to monitor the status of certain candidate taxa “to prevent their extinction while awaiting listing” (58 FR 51146, September 30, 1993).

Belugas found in Cook Inlet, Alaska, and infrequently in waters east of the Alaska Peninsula (Laidre et al. 2000), were included on the 1988 List of Candidate Vertebrate and Invertebrate Marine Species (53 FR 33516, August 31, 1988). The decision to list Cook Inlet belugas as a Candidate Species was based on information summarized in a species account (Hazard 1988) that was part of a larger compendium on selected marine mammal species in Alaska published in early 1988 (Lentfer 1988). This compendium was distributed to the NMFS and USFWS where it was used to develop or update research and management plans for species under their jurisdiction (MMC 1989:173). At the time, the limited available research suggested belugas in Cook Inlet made up a small population numbering less than 500 animals that was isolated from all other beluga populations in Alaska waters. On September 15 1988, the NMFS office in Anchorage, Alaska (NMFS Alaska Region Office) prepared a review of all available information on Cook Inlet belugas including priorities and recommendations for research that would be needed to sustain the population at a stable level (Morris 1988).

Cook Inlet belugas remained on the Candidate List when it was revised on June 11, 1991 (56 FR 26797). Aerial surveys were conducted on 8 and 10 June (Shelden 1994) and 18-21 June (NMFS 1992) in 1991 to determine the size of the population. The highest uncorrected count for these surveys was less than 250 animals. The status report prepared by the NMFS Alaska Region Office again included recommendations for research to determine trends, genetic status, winter distribution and life history parameters (NMFS 1992). Abundance surveys and tissue sampling began in 1992, while other studies such as ship-based oceanographic sampling, tagging studies, and acoustic monitoring have occurred when funding allowed since 1994. When the candidate list was revised on July 14, 1997 (62 FR 37560, December 18, 1997), it was noted that Cook Inlet belugas continued to be listed and that research had been initiated as a result of the 1991 listing.

1.2.2. Status Review—1998-2002

Prompted by a sharp decline in the estimated abundance of Cook Inlet belugas between 1994 (653 animals) and 1998 (347 animals), a reduction of nearly 50% (Hobbs et al. 2000a), NMFS initiated a Status Review of the population on November 19, 1998 (63 FR 64228). The comment period on the Status Review, which began at the same time that workshops were convened to review beluga populations throughout Alaska, extended from November 19, 1998 through January 19, 1999. The workshops were held by the Alaska Beluga Whale Committee (November 16-17, 1998) and the Alaska Scientific Review Group (November 18-20, 1998), a body established under the MMPA to provide scientific advice regarding marine mammals to NMFS and USFWS.

NMFS received two petitions in March 1999 to list Cook Inlet belugas as endangered under the ESA. One petition (brought by Joel Blatchford, a Native Alaskan beluga hunter; the Alaska Center for the Environment, the Alaska Community Action on Toxics, the Alaska Wildlife Alliance, the Center of Biological Diversity, the Center for Marine Conservation, the National Audubon Society, and the Trustees for Alaska) requested an emergency listing under Section 4(b)(7) of the ESA and the designation of critical habitat. Both petitions (the second brought by the Animal Welfare Institute) requested immediate promulgation of regulations to govern the

subsistence hunt. NMFS determined that the petitions contained substantial scientific or commercial information indicating that the petitioned actions may be warranted (64 FR 17347, April 9, 1999). To ensure that the Status Review was comprehensive and based on the best available scientific information, NMFS sponsored a workshop on March 8-9, 1999 in Anchorage that reviewed relevant scientific information on this population. At this workshop, NMFS received additional public comments and recommendations. The abstracts of presentations from this workshop (Moore et al. 1999) were subsequently published in a special volume of *Marine Fisheries Review* 62(3).

1.2.3. MMPA Subsistence Hunt Management—1999-2006

In 1999, a temporary legislative moratorium on hunting Cook Inlet belugas by Native Americans was enacted (Pub. L. No. 106-31, Section 3022, 113 Stat. 57, 100, May 21, 1999). This legislation resulted in no hunt in 1999 and 2000, though hunters voluntarily suspended the hunt in spring 1999. Following the Depleted determination under the MMPA, NMFS proposed regulations limiting the hunt of belugas in Cook Inlet, Alaska, on October 4, 2000 (65 FR 59164). While these regulations were undergoing public comment, the moratorium was made permanent in December 2000 (Pub. L. No. 106-553). The only exclusion to the moratorium is through a co-management agreement between NMFS and Alaska Native organizations (ANO). NMFS has since promulgated regulations for the taking of Cook Inlet belugas by Alaska Natives for the years 2001-2004 (69 FR 17973, April 6, 2004). A Final Environmental Impact Statement (EIS) was released with the final proposed regulations in July 2003 (68 FR 55604, September 26, 2003). Proposed long-term harvest regulations through a period which should see population recovery are currently under review (71 FR 8268, February 16, 2006) and discussed in this document (see Section 3.5). Preparation of a Supplemental EIS reviewing these long-term harvest regulations is underway (71 FR 15697, March 29, 2006).

1.2.4. NMFS MMPA Depleted Decision and ESA Not Warranted Decision—1999-2000

Following these reviews and taking into account the best information available at that time, NMFS proposed designating the Cook Inlet population of belugas as Depleted under the MMPA

on October 19, 1999 (64 FR 56298) and conducted a public hearing on November 22, 1999. NMFS issued a final rule on May 31, 2000 (65 FR 34590) designating these belugas as Depleted based on its determination that the abundance estimate was below the Optimum Sustainable Population (OSP) level. On June 22, 2000, NMFS also determined that Cook Inlet belugas were not in danger of extinction nor likely to become so in the foreseeable future. Therefore, NMFS determined that listing this population under the ESA was not warranted at the time (65 FR 38778). However, NMFS remained concerned about the status of the Cook Inlet beluga population and continued to include the population on the list of Candidate Species under the ESA. During this petition review, NMFS established Cook Inlet belugas as a DPS and therefore, a species as defined under Section 3(15) of the ESA (65 FR 121, June 22, 2000).

1.2.5. Court Challenge to ESA Not Warranted Decision—2001

The decision not to list can be challenged in court under the citizen suit provision of the ESA (16 U.S.C. § 1540(g)). In their suit (*Cook Inlet Beluga, et al. v. Daley*, No. 00-1017 D.C.), the petitioners argued that NMFS had acted in an “arbitrary and capricious” manner by not listing Cook Inlet belugas under the ESA. On August 20, 2001, U.S. District Court Judge James Robertson ruled that the Agency had acted within the scope of its legal authority, adequately explained its decision, based its decision on facts in the record, and considered the relevant factors and, therefore, upheld the decision not to list.

1.2.6. Species of Concern—2004

On April 15, 2004, NMFS moved Cook Inlet belugas from the Candidate Species list to the newly created Species of Concern list (64 FR 19975). This list is limited to species under NMFS jurisdiction and does not apply to the regulatory practices of the USFWS. NMFS uses the term “Species of Concern” to identify species about which NMFS has some concerns regarding status and threats but for which insufficient information is available to indicate a need to list the species under the ESA. This may include species for which NMFS has determined, following a biological Status Review, that listing under the ESA is “not warranted,” pursuant to ESA Section 4(b)(3)(B)(i) but for which significant concerns or uncertainties remain regarding their status

and/or threats, as is the case for Cook Inlet belugas. NMFS may conduct ESA Status Reviews on each Species of Concern as agency resources permit.

1.2.7. Conservation Plan—2005

On March 16, 2005, NMFS completed a draft Conservation Plan for Cook Inlet belugas as required under the MMPA. The comment period for the plan closed June 27, 2005 (70 FR 30697). A final version of the plan is currently under review at the NMFS Alaska Region Office (NMFS 2006).

1.2.8. Status Review—2006

NMFS formally initiated a Status Review on March 29, 2006 (71 FR 14836) to determine if Cook Inlet belugas should be listed under the ESA. On April 20, 2006, NMFS received a petition from Trustees for Alaska to list Cook Inlet beluga as endangered under the ESA. After reviewing the information contained in the petition as well as other scientific information readily available, NMFS determined that the petition presented substantial scientific information indicating that the petitioned action may be warranted (71 FR 44614, August 7, 2006). Within 12 months of the date of the petition, NMFS must make one of the following findings: 1) The petitioned action is not warranted; 2) the petitioned action is warranted, in which case the Secretary shall promptly publish in the *Federal Register* a proposed regulation to implement the action pursuant to 50 CFR 424.16; or 3) the petitioned action is warranted, but A) the immediate proposal and timely promulgation of a regulation to implement the petitioned action is precluded because of other pending proposals to list, delist, or reclassify species, and B) expeditious progress is being made to list, delist, or reclassify qualified species, in which case such findings shall be promptly published in the *Federal Register* (71 FR 44614). This Status Review provides a summary of the best available science to aid NMFS policy makers with this determination.

1.3. Key Questions in ESA Evaluations

1.3.1. The ‘Species’ Question

For the purpose of the ESA, Congress has defined a species as “any subspecies of fish or wildlife or plants, and any distinct population segment of any species of vertebrate fish or wildlife which interbreeds when mature.” As amended in 1978, the ESA allows listing of “distinct population segments” of vertebrates, as well as named species and subspecies. Guidance on what constitutes a DPS is provided by the joint NMFS-USFWS interagency policy on vertebrate populations (61 FR 4722, February 7, 1996). To be considered “distinct,” a population, or group of populations, must be “discrete” from other populations and “significant” to the taxon (species or subspecies) to which it belongs. During the 1999 Status Review, it was concluded that Cook Inlet belugas are discrete from other Alaska beluga populations. In particular, all available data, including morphology, core and summer ranges, as well as genetics, indicated that the Cook Inlet belugas are an independent population that is distinct from other populations (65 FR 121, June 22, 2000). In addition, the loss of the population would result in a significant gap in the range of the taxon. Therefore, Cook Inlet belugas were considered significant with respect to the Alaska taxon and were designated a DPS on June 22, 2000 (65 FR 121). Additional information is presented within Section 4.

1.3.2. The ‘Extinction Risk’ Question

The ESA defines the term endangered species as “any species which is in danger of extinction throughout all or a significant portion of its range.” The term threatened species is defined as “any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.” The ESA states that a variety of information should be used in evaluating the level of risk faced by a species or a DPS. Important considerations include:

- the present or threatened destruction, modification, or curtailment of its habitat or range;
- overutilization for commercial, recreational, scientific, or educational purposes;

- disease or predation;
- the inadequacy of existing regulatory mechanisms; or
- other natural or man-made factors affecting its continued existence.

According to the ESA, the determination of whether a species is threatened or endangered should be made on the basis of the best scientific information available on its current status, after taking into consideration conservation measures that are proposed or are in place. This document is a compilation of biological data and a description of past, present, and likely future threats to the Cook Inlet belugas. It does not represent a decision by NMFS on whether this taxon should be proposed for listing as threatened or endangered under the ESA. That decision will be made by NMFS after reviewing this document, other relevant biological and threat data not included herein, and all relevant laws, regulation and policies. The results of the decision will be announced in the *Federal Register*.

2. UPDATES ON THE BIOLOGY, BEHAVIOR, ECOLOGY, AND POPULATION DYNAMICS OF COOK INLET BELUGAS

This section includes new information that has become available since publication of the dedicated issue of *Marine Fisheries Review* 62(3) on Cook Inlet belugas that covers data collected through 2000.

2.1. Beluga Biology and Behavior

2.1.1. Identifying Characteristics

Belugas and narwhals (*Monodon monoceros*) are the only living species in the family Monodontidae (Rice 1998). The common name beluga is derived from the Russian word for white (belukha) and the species name (*leucas*) also means white which refers to the skin color of adult whales. Beluga calves are dark brown or blue-gray. As they age, their skin turns progressively whiter becoming pure white by about age 9, though Burns and Seaman (1986) report females may retain some gray coloration up to 21 years. The physical and behavioral

characteristics described here vary among beluga populations but in general provide a good overall description of the species (see review in O’Corry-Crowe (2002)). Among whales, belugas are medium-sized (3.5-5.5 m in length) and weigh up to 1,500 kg. Belugas are sexually dimorphic with males being significantly larger than females of the same age (Burns and Seaman 1986). Unlike most whales, belugas do not have fused cervical vertebrae, allowing neck flexibility. Adaptations to the cold environment include: a thick insulating layer of blubber; a relatively small head, fluke, and flippers; a lack of a dorsal fin; and a tough dorsal ridge with little or no innervation – an advantage when breaking through sea ice.

Reports on the age of sexual maturity for belugas vary from region to region (see Section 2.3.3). Females in northern Alaska populations appear to reach sexual maturity 4-5 years earlier than males (Burns and Seaman 1986, Suydam et al. 1999). Gestation is 14-14.5 months with a single calf born in late spring or early summer. Following birth, adult females lactate for approximately 2 years, completing the 3-year reproductive cycle. Dependent nursing may only last a portion of this time, as young whales may begin to consume some prey as early as 12 months of age (Burns and Seaman 1986). If belugas live for about 30 years (Burns and Seaman 1986), their maximum lifetime reproductive capacity would be in the range of 7-10 calves. In Cook Inlet, no evidence is available of a distinct mating or calving period, or calving areas, however, calves are present during the summer months (Huntington 2000, Hobbs et al. 2005). Assuming a gestation period of 14 months and the known presence of pregnant females in late March, April, and June (Mahoney and Shelden 2000, Vos and Shelden 2005) suggests breeding may be occurring in late spring into early summer. .

Belugas have a well-developed sense of hearing and echolocation. These whales hear over a large range of frequencies, from about 40-75 Hertz (Hz) to 30-100 kiloHertz (kHz) (Richardson 1995) although it is most acute at middle frequencies of 10-75 kHz (Fay 1988). Most sound reception takes place through the lower jaw which is hollow at its base and filled with fatty oil. Sounds are conducted through the lower jaw to the middle and inner ears, then to the brain. Belugas modify their vocalizations in response to noise levels (Scheifele et al. 2005). They have acute vision both in and out of water, and because their retinas contain both rods and cones, it is believed they are capable of seeing color (Herman 1980).

Belugas are extremely social animals that typically travel, hunt, and interact together, often in close, dense groups. For example, groups of 10 to over 100 belugas are often seen during early summers in Cook Inlet (Rugh et al. 2000). It is not known whether these represent distinct social divisions. Native hunters have stated that belugas form family groups, and the hunters suggest that there are four types of belugas in Cook Inlet, distinguished by their size and habits (Huntington 2000).

2.1.2. Distribution of Alaska Beluga Populations

Belugas are distributed widely in Arctic and subarctic waters and are generally associated with areas seasonally covered by sea ice (Hazard 1988). Five populations of belugas occur in Alaska waters (Fig. 1): Cook Inlet, Bristol Bay, eastern Bering Sea, eastern Chukchi Sea, and the Beaufort Sea (Angliss and Lodge 2004; O’Corry-Crowe et al. 1997, 2002). Summer populations are found as far southeast as Yakutat Bay (northern portion of Southeast Alaska, 60°N 140°W) and northeast into the Canadian Beaufort Sea (east of 70°N 140°W). The most isolated of these is the Cook Inlet population, separated from the others by the Alaska Peninsula (Laidre et al. 2000).

Genetic analysis suggests there was a rapid radiation of belugas in the western nearctic after the retreat of Pleistocene ice sheets (over 11,000 years ago) and an early divergence of subpopulations into the Beaufort, Chukchi, and Bering Seas (O’Corry-Crowe et al. 1997, 2002). Geographic barriers to dispersal are few yet genetic results showed little exchange among these populations. Mitochondrial DNA analyses revealed strong site fidelity of mothers and their offspring to the same summering areas which they return to generation after generation (O’Corry-Crowe et al. 1997, 2002; Brown Gladden et al. 1997). Some interbreeding may occur between summer populations that overwinter in a common area. However, for belugas in Cook Inlet genetic isolation is compounded not only by the geographic barrier of the Alaska Peninsula but also by their year-round residency in the Inlet (Laidre et al. 2000, Rugh et al. 2000).



Figure 1. Summer locations of belugas found in Alaska waters.

The range of Cook Inlet belugas has been defined as the waters of the Gulf of Alaska (GOA) north of 58°N and freshwater tributaries to these waters based on available scientific data (65 FR 34590, May 31, 2000, MMPA Sec. 216.15(g)). There are only a few accounts of belugas in the GOA outside the environs of Cook Inlet. Laidre et al. (2000) summarized available information on beluga distribution (prehistoric to current) in the GOA and, with the exception of Yakutat Bay, sightings have been rare and sporadic given the extent of survey effort. Calkins (1989) reported sightings in Cook Inlet, Prince William Sound, and Yakutat Bay, and a range that covers the coastal waters of the GOA from the northern portions of Kodiak Island to Yakutat Bay. In the 1970s and 1980s, beluga sightings occurred across much of the northern and central parts of Cook Inlet (Calkins 1984), but in the 1990s the summer distribution diminished to only the northernmost portions of Cook Inlet (Rugh et al. 2000). More of the Inlet was used during

the spring, summer, and fall during these decades than is used now; for instance, sightings in the Kenai River area (Fig. 2) were common, and concentrations of whales were seen in Trading Bay (near Big River) and Kachemak Bay (Calkins 1984). Such areas are rarely, if ever, used by belugas at the present time except perhaps in winter.

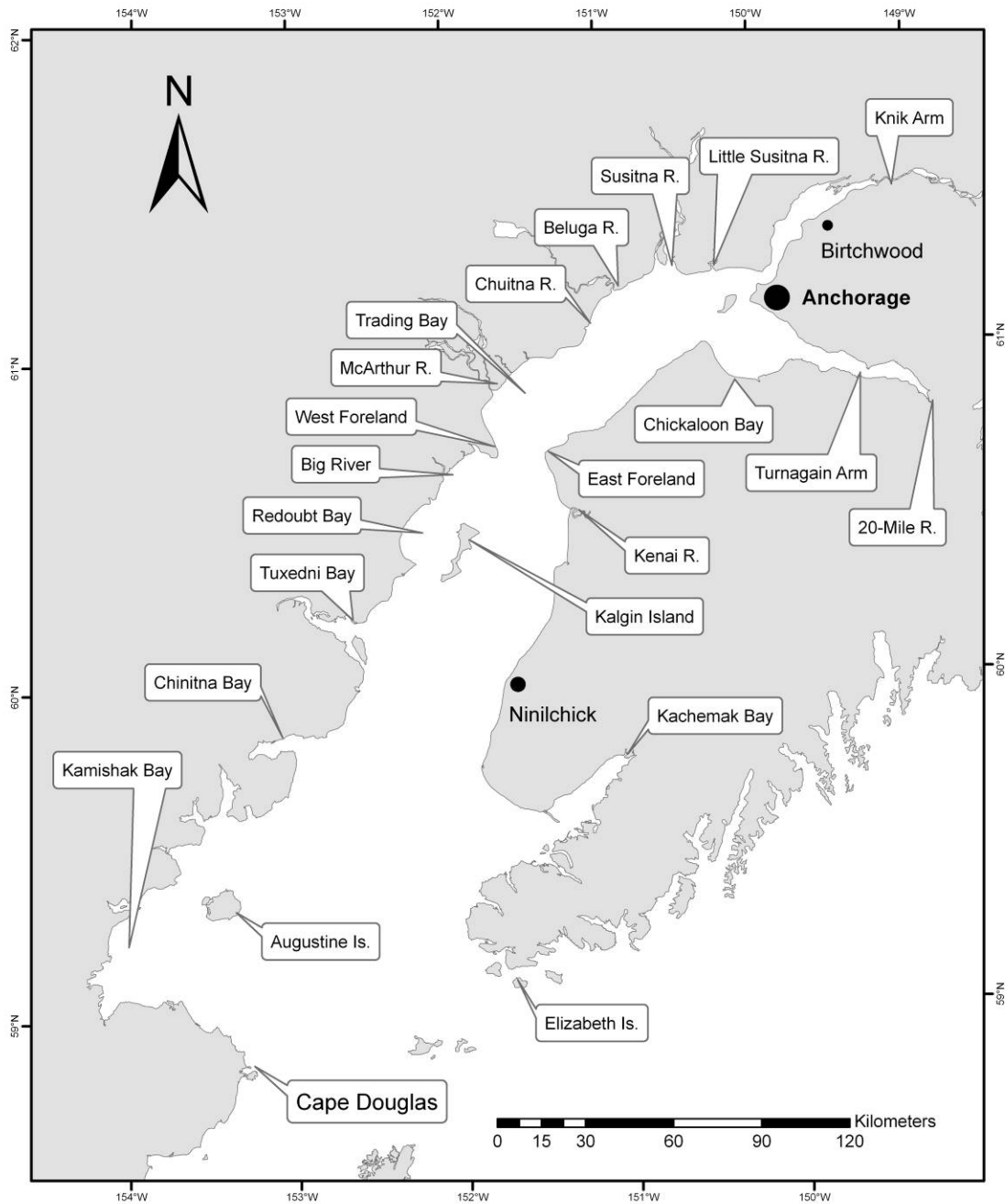


Figure 2. Cook Inlet and place names mentioned in the text.

Although there are a few sightings of belugas in the GOA (Laidre et al. 2000), tagged whales (Hobbs et al. 2005) and extensive sighting efforts both within Cook Inlet (summarized in Rugh et al. 2005a) and the GOA (summarized in Laidre et al. 2000) indicate that belugas do not have a seasonal migration in and out of Cook Inlet. Yakutat Bay is the only location outside of Cook Inlet where there is a known, persistent population of several belugas genetically similar to each other (O’Corry-Crowe et al. 2006). Preliminary genetic analysis showed limited variation among Yakutat whales suggesting either high inbreeding or a closely related family unit (O’Corry-Crowe et al. 2006; G. O’Corry-Crowe, pers. comm.). The mitochondrial DNA haplotype shared by these whales is also found in other Alaska beluga populations, including Cook Inlet, though this haplotype is not as common in these populations (O’Corry-Crowe et al. 2006).

2.1.3. Prey Preferences and Feeding Behavior

Belugas feed on a wide variety of prey species, focusing on specific species when they are seasonally abundant. Stomachs collected from belugas that stranded in Cook Inlet during the spring, summer, and fall provide evidence of prey availability and preferences (Table 1). In the spring, eulachon (*Thaleichthys pacificus*) and two cod species were preferred prey (Table 1). Saffron cod (*Eleginus gracilis*) are indigenous to shallow coastal waters and are found near and in rivers within the zone of tidal influence (Morrow 1980, Cohen et al. 1990). Adult cod exhibit seasonal movements: inshore during winter for purposes of spawning and offshore during summer for feeding (Cohen et al. 1990). Pacific cod (*Gadus macrocephalus*) instead move to progressively deeper water as they age, spawning in deeper, offshore waters in winter and migrating to shallower water in the spring to feed (Cohen et al. 1990). Both species of cod are opportunistic epibenthic feeders (Cohen et al. 1990). Cod consume polychaetes, shrimp, amphipods, mysids, as well as other fish (e.g., walleye pollock (*Theragra chalcogramma*) and flatfish) (see Seaman et al. 1982, Clausen 1981, Cohen et al. 1990) suggesting that many of the invertebrates and possibly some of the fish species found in the stomachs of belugas may be the result of secondary ingestion (Table 1).

Table 1. Prey identified in the stomachs of belugas from Cook Inlet, Alaska, 1995-2003 (NMFS Alaska Region Office, unpublished data). Number of X-symbols indicates the number of belugas that ingested the prey item. * indicates that these prey items may have been consumed by one or more of the fish found in the stomach of this whale (i.e., secondary ingestion).

Prey	Month					
	April (n = 2)	May (n = 2)	July (n = 2)	August (n = 3)	September (n = 2)	October (n = 1)
*Polychaete (jaws & eggs)	X					
*Crab spp.	X					
*Shrimp spp.	X					
Cod spp.					X	
Saffron	X				X	X
Pacific	X					
Walleye pollock	X					
Eulachon	XX	X				
Salmon spp.		X	X	XX	XX	
Coho			X	XX	X	
Chum				XX		
Flatfish spp.						
Yellowfin sole				X		X
Starry flounder						X
Pacific staghorn sculpin						X

Although not evident in the stomach contents reported in Table 1, Natives describe Cook Inlet belugas feeding on anadromous steelhead trout (*Oncorhynchus mykiss*), freshwater fish such as whitefish (*Coregonus oidschian*), northern pike (*Esox lucius linnaeus*), and grayling (*Thymallus arcticus*) (Huntington 2000), and other marine fish such as tomcod (*Microgadus proximus*) during the spring (Fay et al. 1984). These species are abundant in the Susitna River system (www.adfg.state.ak.us/pubs/notebook/notehome.php). By late spring, belugas begin to shift from lipid-poor prey to lipid-rich species (Abookire and Piatt 2005, Litzow et al. 2006) as anadromous fish runs of eulachon enter the Inlet (Table 1).

From late spring and throughout the summer months, the majority of beluga stomachs contained eulachon and Pacific salmon (*Oncorhynchus* spp.), coincident with the timing of fish runs in the area (Table 1). Anadromous smolt and adult fish concentrate at river mouths and adjacent intertidal mudflats to osmoregulate during emigration and immigration, respectively (ADF&G 2004). In May 1998, the stomach of a beluga hunted near the Susitna River was filled exclusively with eulachon (Table 1). Five Pacific salmon species: Chinook (*O. tshawytscha*), pink (*O. gorbuscha*), coho (*O. kisutch*), sockeye (*O. nerka*), and chum (*O. keta*) spawn in rivers

throughout Cook Inlet (Moulton 1997, Moore et al. 2000). Calkins (1989) recovered 13 salmon tags from the stomach of an adult beluga found dead in Turnagain Arm. Beluga hunters in Cook Inlet reported one whale having 19 adult Chinook salmon in its stomach (Huntington 2000), and NMFS (Alaska Region Office unpublished data) found an adult male beluga with 12 adult coho salmon in its stomach. Prey selection likely depends on the size of the whale. Belugas are sexually dimorphic with males being significantly larger than females of the same age (Burns and Seaman 1986); in accordance, males have been found to consume larger fish than females (Seaman et al. 1982). Similarly, young whales consume significantly smaller prey items than adults (Seaman et al. 1982).

In the fall, as anadromous fish runs begin to decline, belugas again return to consume the fish species found in nearshore bays and estuaries. This included cod species observed in the spring diet as well as other bottom-dwellers: Pacific staghorn sculpin (*Leptocottus armatus*) and flatfishes such as starry flounder (*Platichthys stellatus*) and yellowfin sole (*Limanda aspera*). Pacific staghorn sculpin are commonly found near shore in bays and estuaries on sandy substrate (Eschmeyer et al. 1983). Flatfish are typically found in very shallow water and estuaries during the warm summer months and move into deeper water in the winter as coastal water temperatures cool (though some may occur in deep water year-round) (Morrow 1980). As late as October, belugas tagged with satellite transmitters continued to use Knik and Turnagain Arm and Chickaloon Bay but some belugas also ranged into the lower Inlet south to Chinitna Bay, Tuxedni Bay, and Trading Bay (MacArthur River) in the fall (Hobbs et al. 2005).

Stomach samples from Cook Inlet belugas are not available for winter months, November through March (Table 1). Dive data from belugas tagged with satellite transmitters suggest that during the winter whales are feeding in deeper waters (Hobbs et al. 2005), possibly on such prey species as flatfish, cod, sculpin, and pollock. In November, belugas moved between Knik, Turnagain Arm, and Chickaloon Bay, similar to patterns observed in September (Hobbs et al. 2005). By December, belugas were distributed throughout the upper to mid-Inlet. From January into March, belugas moved as far south as Kalgin Island and slightly beyond in central offshore waters. Belugas also made occasional excursions into Knik and Turnagain Arm in February and March in spite of ice cover greater than 90% (Hobbs et al. 2005).

According to local Native knowledge, the importance of the anadromous fish runs during the summer feeding period is evident in the blubber layer of these whales. In spring, the whales were described as thin with blubber only 2-3 inches (5-8 cm) thick compared to the fall when the blubber may be up to 1 ft (30 cm) thick (Huntington 2000). Mature females have additional energy requirements. Distinct mating periods, calving dates, and calving areas for the Cook Inlet beluga population are not well documented; however, calves are present during the summer months (Huntington 2000, Hobbs et al. 2005). Assuming a gestation period of 14 months and the known presence of pregnant females in late March, April, and June (Mahoney and Shelden 2000, Vos and Shelden 2005) suggests breeding may be occurring in late spring into early summer. Calves depend on their mother's milk as their sole source of nutrition and lactation lasts up to 23 months (Braham 1984) though young whales begin to consume prey as early as 12 months of age (Burns and Seaman 1986). Therefore, the summer feeding period is critical to pregnant and lactating belugas.

2.2. Ecology of Cook Inlet Belugas

2.2.1. Temporal Changes in Distribution

Annual aerial surveys for belugas in Cook Inlet have provided systematic coverage of 13-33% of the entire Inlet each June or July since 1993 (Rugh et al. 2000; 2005a,b). Belugas have been consistently found near or in river mouths along the northern shores of upper Cook Inlet (i.e., north of East and West Foreland). In particular, beluga groups are seen in the Susitna River delta, Knik Arm, and along the shores of Chickaloon Bay. Small groups have also been seen farther south in Kachemak Bay, Redoubt Bay (Big River), and Trading Bay (McArthur River) prior to 1996 but very rarely thereafter. Since the mid-1990s, most (96-100%) belugas in upper Cook Inlet have been concentrated in shallow areas near river mouths, no longer occurring in the central or southern portions of the Inlet. It is unknown if this contracted distribution is a result of changing habitat (Moore et al. 2000), predator avoidance (Shelden et al. 2003), or a shift of a reduced population into preferred habitat areas (Rugh et al. 2001, Goetz et al. in press).

This concentration of belugas in the northernmost portion of Cook Inlet appears to be fairly consistent from June to October based on aerial surveys (Rugh et al. 2004; 2005a, b). Studies done for the Knik Arm Bridge and Toll Authority (KABATA) in 2004 and 2005 have confirmed the use of Knik Arm from July to October (Funk et al. 2005). Data from tagged whales (14 tags between July and March 2000-03) show that belugas use the upper Inlet intensively between summer and late autumn (Hobbs et al. 2005). As late as October, belugas tagged with satellite transmitters continued to use Knik and Turnagain Arm and Chickaloon Bay but some belugas also ranged into the lower Inlet south to Chinitna Bay, Tuxedni Bay, and Trading Bay (MacArthur River) in the fall (Hobbs et al. 2005). In November, belugas moved between Knik, Turnagain Arm, and Chickaloon Bay, similar to patterns observed in September (Hobbs et al. 2005). By December, belugas were distributed throughout the upper to mid-Inlet. From January into March, belugas moved as far south as Kalgin Island and slightly beyond in central offshore waters. Belugas also made occasional excursions into Knik and Turnagain Arm in February and March in spite of ice cover greater than 90% (Hobbs et al. 2005). This dispersion was also noted during aerial surveys (Hansen and Hubbard 1999; Rugh et al. 2004).

Tagged whales (Hobbs et al. 2005) and extensive sighting efforts both within Cook Inlet (Rugh et al. 2005a) and in the GOA (Laidre et al. 2000) indicate that belugas do not have a seasonal migration in and out of the Inlet. Yakutat Bay is the only location outside of Cook Inlet where there is a known, persistent population of several belugas (O’Corry-Crowe et al. 2006).

2.2.2. Habitat Use and Requirements

During surveys conducted by NMFS from 1993 to 2005, belugas were frequently seen aggregating near the mouths of rivers and streams in June and July when anadromous fish species were present and often at their peak availability (Moore et al. 2000). The repeated concentrations of Cook Inlet belugas within discrete areas of the upper Inlet and offshore of several important salmon streams is assumed to be a feeding strategy that takes advantage of the bathymetry of the area: the fish are funneled into the channels formed by the river mouths and the shallow waters act as a gauntlet for salmon as they move past waiting belugas. Hazard (1988) hypothesized that belugas were more successful feeding in rivers where prey were

concentrated than in bays where prey were dispersed. If true, this would imply that Cook Inlet belugas cannot simply go where prey escapement (return) numbers are high, but may be at least partially dependent on the physical features of the feeding habitat as well.

Habitat associations of beluga prey species in Cook Inlet include preferences for sand and mud substrates (Cohen et al. 1990, Eschmeyer et al. 1983, ADF&G 2004), and a number of these species move seasonally from shallow to deep water. Movements of belugas within the Inlet are similar to the seasonal movements of their prey. In a study by Goetz et al. (in press), geographic information systems (GIS) and statistical methods were used to apply quantitative terms to the summer habitat preferences of the Cook Inlet beluga population. Two habitat models were used to demonstrate ecological relationships between belugas and several environmental variables. Parameters used in the models were based on June/July beluga sightings (1993-2004) relative to available environmental data: 1) bathymetry, 2) mudflats, and 3) flow rates among freshwater tributaries entering Cook Inlet. The two quantitative models predicted similar size and location of beluga habitat and identified that mudflats and flow rates are important environmental features: belugas are found near mudflats and prefer medium and high flow accumulation areas (i.e., medium to large river basins). Although sighting data in this study were collected primarily in June, other aerial surveys (Rugh et al. 2000, 2004), shore-based systematic and opportunistic observations (Funk et al. 2005; NMFS, NMML unpublished data), and whales tagged with satellite transmitters (Hobbs et al. 2005) show that the distribution documented in early June is fairly representative of the distribution throughout the summer. In fact, belugas continue to access these preferred habitats in winter despite thick ice cover (Hobbs et al. 2005). Tidal movement corridors are also important to Cook Inlet belugas, as beluga movements with the tides may occur up to twice daily and allow or limit access to feeding areas (Hobbs et al. 2005). Knik Arm, Turnagain Arm, Chickaloon River, and the Susitna River delta are used extensively. Access to these areas and to corridors between these areas is important for obtaining prey.

Habitat models predict that beluga distribution would include coastal areas extending nearly the entire length of Cook Inlet (Goetz et al. in press), and, in fact, historically belugas inhabited large parts of the Inlet, including its central and southern reaches (Rugh et al. 2000). However, since 1993, when NMFS began systematic documentation of the distribution, beluga sightings have

been rare (0-4% per year) in areas south of the Forelands (Fig. 2), and almost all sightings have been in the northern Inlet, from the Susitna delta to Knik Arm and Chickaloon Bay (Rugh et al. 2000; 2005a, b). A significantly reduced population (Hobbs et al. 2000a) in combination with beluga preference for estuarine waters with the largest concentration of prey species may explain the current distribution of whales, but data on relative densities of fish by species and season are not yet available.

2.3. Population Dynamics

2.3.1. Population Size

The Cook Inlet population of belugas has probably always numbered fewer than several thousand animals, but has declined significantly from its historical abundance. The full magnitude of the decline is difficult to accurately determine because no reliable abundance surveys were conducted prior to the 1990s; scientists must estimate this historical limit. Based on aerial surveys in 1963 and 1964, Klinkhart (1966) estimated the population at 300-400 animals, but the methodology for the survey was not described. Sergeant and Brodie (1975) presented an estimate for the Cook Inlet population as 150-300 animals, but they offer no source for this figure. Murray and Fay (1979) counted 150 belugas in the central Inlet on three consecutive days in August 1978 and estimated the total abundance would be at least three times that figure to account for poor visibility. Calkins (1984), based on surveys of the upper Inlet between May and August of 1982, estimated that 200-300 belugas were seen in one area. Hazard (1988) stated that an estimate of 450 whales may be conservative because much of Cook Inlet was not surveyed in these efforts.

The most complete survey of Cook Inlet prior to 1994 was conducted by the Alaska Department of Fish and Game (ADF&G) in August 1979. The aerial survey, conducted on August 21, consisted of transects from Anchorage to Homer, covering much of the upper, middle, and lower Inlet. The sum of the counts was 376 belugas (N. Murray, ADF&G, unpublished field notes). On August 22, a sighting of 97 belugas in Bruin Bay (an area not surveyed the previous day due to low clouds) was added to the count for a total of 479 belugas (N. Murray, unpublished field

notes). This survey is considered incomplete because Knik Arm, Turnagain Arm, and Chickaloon Bay were not surveyed. Calkins (1989) calculated an overall abundance estimate of 1,293 whales using a correction factor of 2.7 from these survey data. This correction factor was developed for estimating submerged whales under similar conditions in Bristol Bay (Frost et al. 1985). This is the best available estimate of historical beluga abundance in Cook Inlet. The National Marine Fisheries Service (NMFS) has adopted 1,300 as the value for the carrying capacity (K) to be used for management purposes (65 FR 34590, May 31, 2000).

NMFS began comprehensive, systematic aerial surveys of the beluga population in Cook Inlet in 1993. Unlike previous efforts, these surveys included the upper, middle, and lower Inlet. These surveys documented a decline in abundance of nearly 50% between 1994 and 1998 (Fig. 3), from an estimate of 653 (CV = 0.43) whales to 347 (CV = 0.29) whales (Hobbs et al. 2000a). Estimates since 1998 have ranged from 435 (CV=0.23) to 278 (CV=0.18) whales (Fig. 3).

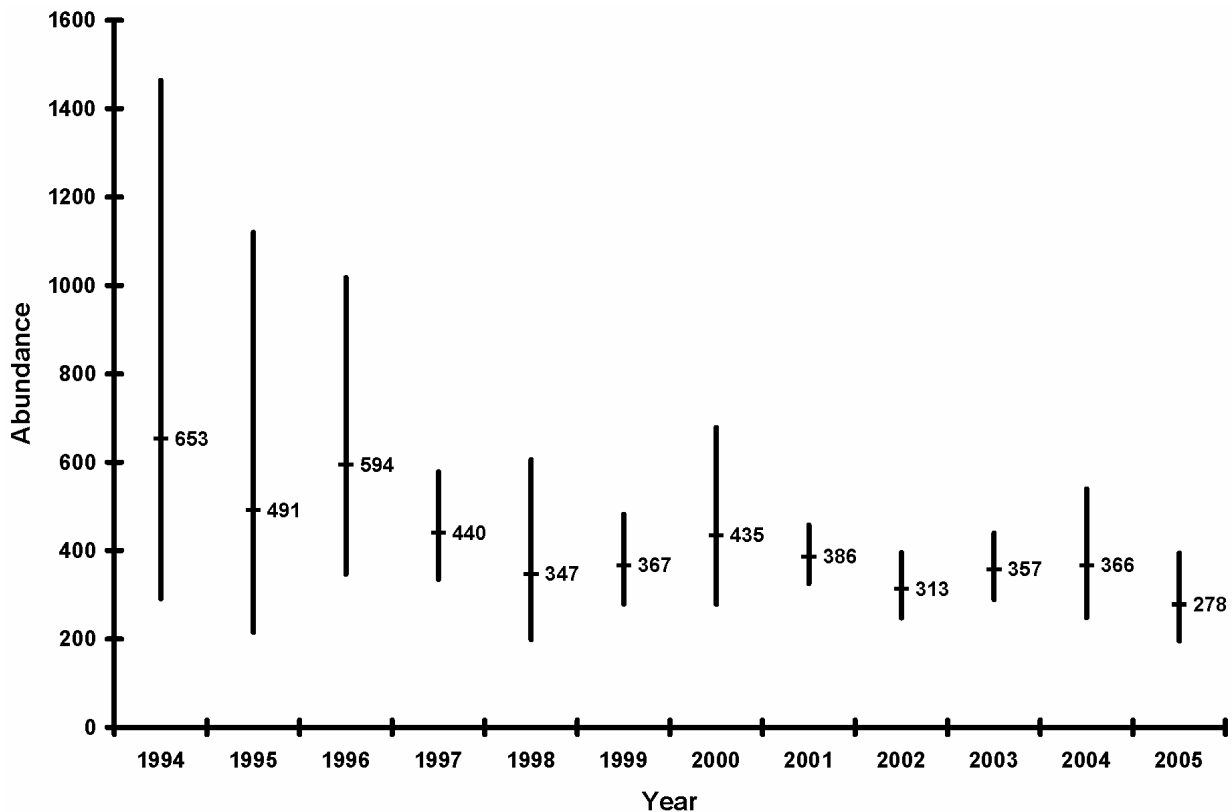


Figure 3. Estimated abundance of Cook Inlet belugas from NMFS annual aerial surveys, 1994-2005.

2.3.2. Population Trends

There are too few records to document the apparent decline from 1,300 to 653 belugas in Cook Inlet for the period between 1979 and 1994. However, there is good documentation of the decline from 1994 to 1998 (Hobbs et al. 2000a, b). Since then, the population has been fairly stable. Native subsistence harvest (enumerated through hunter interviews) was significant prior to 1999 perhaps as far back as the 1970s (NMFS Alaska Region Office unpublished data; Mahoney and Shelden 2000). Also, notable commercial and sport hunts occurred prior to the 1979 ADF&G survey (Mahoney and Shelden 2000). Therefore, an abundance estimate of 1,300 in 1979 may represent a population that was already partially depleted. From 1994 to 1998, NMFS estimated that subsistence hunt-related mortalities averaged over 70 per year (Mahoney and Shelden 2000). Beginning in 1999, the hunt was limited to two or fewer belugas per year (Mahoney and Shelden 2000; 65 FR 59164, October 4, 2000). NMFS has stated that the decline in beluga abundance from 1994 to 1998 is adequately explained by the documented hunt mortality (65 FR 34590, May 31, 2000).

With the very limited hunt between 1999 and 2005, NMFS anticipated that the population would begin to recover at a rate of 2% to 6% per year. However, a Bayesian analysis including the 2005 estimate of abundance indicates that there is only an 8% chance (i.e., it is unlikely) that the growth rate is above 2% (see Section 5). NMFS is concerned that the trend in abundance since 1999 appears to be declining. However, even with this latest data point of 278 belugas, the trend is significantly less than zero (weighted log linear regression slope not less than zero; $T = -1.94$, $P = 0.110$). Also, the data point is not different from the weighted average of the abundance estimates obtained since the hunting moratorium (360 belugas, $T = 2.16$, $P = 0.082$). In this respect, the best available data at this time indicate the Cook Inlet beluga population may not be declining but it also is not growing as expected despite limiting subsistence hunting (Angliss and Outlaw 2005).

2.3.3. Life History Parameters

Although some life history data are available for Cook Inlet belugas, sample sizes are not sufficient to estimate model parameters with the exception of survival rates. There are data from several other beluga populations available in the literature (Table 2). Of particular interest for modeling purposes are survival rates, birth interval, age at first birth, gestation period and lactation period.

Survival data for Cook Inlet belugas consists of annual summaries of carcasses reported to the NMFS Alaska Region Office and consequently represents a minimum estimate of mortality. From 1999 to 2005, years in which a limited hunt occurred, an average of 12 mortalities were reported each year (Vos and Shelden 2005) during a time when the population averaged around 350. This puts an upper bound of 97% for the annual survival rate.

Survival rates have been estimated as low as 0.84/year, but most were above 0.90/year (Table 2). Birth interval is thought to be typically 3 to 4 years depending on the age of the mother but in some cases it may be as short as 2 years (Table 2). The age at sexual maturity is thought to be between 4 and 10 years; gestation lasts more than a year so that the age at first birth is between 5 and 11 years (Table 2). The lactation period is known to last longer than one year, so calf survival is closely dependent on the survival of the mother during the first year after birth. Survival rates and age at maturity have been estimated for males. However, these estimates were not sufficiently different from those for females (Table 2).

Table 2. Review of beluga life history parameters found in the published literature.

Parameters	Data	Source(s)
Age at sexual maturity	4-10 years (females), 8-15 (males)	1, 2, 3, 4, 5, 6, 7
	0% at 4 years and younger	6 ^a
	33% at 5 years 94% at 6 years	
Age of 1 st conception	54% at 4 years	6 ^b
	41% at 5 years	
	5% at 6 years	
Age at senescence	21 years	1
Pregnancy and birth rates	with small fetuses:	with full-term fetuses or neonates:
	0.055 at 0-5 years	0.000 at 0-5 years
	0.414 at 6-10 years	0.326 at 6-10 years
	0.363 at 11-22 years	0.333 at 11-22 years
	0.267 at 23-28 years	0.278 at 23-25 years
	0.190 at 29-38 years	0.182 at 26-28 years
		0.125 at 29-38 years
Lifespan	>30 years (oldest female estimated at 35+ years)	6
	32 years	8
	30 years	1
	25 years	2
Adult annual survival	0.96-0.97	9
	0.955 (based on pilot whale data)	10
	0.935	11
	0.91-0.92	12
	0.906 (includes both natural & human-caused mortality)	6
Immature annual survival	0.84-0.905 (based on body length & lifespan)	13
	0.905 (for neonates in the first half year of life)	2
Reproductive rate	0.10-0.12	14 ^c
	0.11 (based on annual calf production rates)	6
	0.13 (based on annual calf production rates)	2
	0.09 (based on annual calf production rates)	1
	0.09-0.12 (based on annual calf production rates)	5
	0.09-0.14 (based on calf counts)	5
	0.12 (based on calf counts)	15, 2
	0.08-0.14 (based on calf counts)	16
	0.06-0.10 (based on calf counts)	17
	0.08-0.10 (based on calf counts)	11
0.08 (unknown method)	18	
Calving interval	< 3 years	6 ^d
	2 years and 3 years	2 ^e

1. Brodie 1971, 2. Sergeant 1973, 3. Ognetrov 1981, 4. Seaman and Burns 1981, 5. Braham 1984, 6. Burns and Seaman 1986, 7. Suydam et al. 1999, 8. Khuzin 1961 (cited in Ohsumi 1979), 9. Béland et al. 1992, 10. Brodie et al. 1981, 11. Lesage and Kingsley 1998, 12. Allen and Smith 1978, 13. Ohsumi 1979, 14. Perrin 1982, 15. Ray et al. 1984, 16. Davis and Evans 1982, 17. Davis and Finley 1979, 18. Breton-Provencher 1981 (in Perrin 1982).

^a Alaskan sample (n = 52). Sampling occurred in June, a time when most Alaskan belugas are born, it is possible that non-pregnant 4-year olds would have conceived prior to their fifth birth date. ^b Alaskan sample (n = 22). ^c Based on a review of the literature. Adopted by the International Whaling Commission. ^d For some females this was a tentative conclusion based on high conception rates noted in some females between the ages of 6 and 22. ^e The age of 2 years for 25% of mature females in eastern Canada (7 of 29 sampled); presumed after noting pregnancies occurring during lactation and 3 years for 75% of mature females in eastern Canada. Sergeant (1973) concludes that "overlap of pregnancy and previous lactation is infrequent so that calving occurs about once in 3 years."

3. POTENTIAL RISK FACTORS FOR COOK INLET BELUGAS

The following section provides a discussion on those known or likely factors which are believed to have some impact on the Cook Inlet beluga population and mitigation measures that are currently in place. At reduced numbers and with contraction of their range, this population is far more vulnerable to losses due to stranding, predation, or disease. This population relies heavily on several fish species that are available only seasonally and are also of considerable commercial interest. Disturbances that cause belugas to temporarily or permanently abandon summer feeding areas could reduce their ability to survive through the winter months. These risk factors are also described within the MMPA Conservation Plan (NMFS 2006).

3.1. Stranding Events

Beluga stranding events in upper Cook Inlet are not uncommon. NMFS has reports of 804 stranded whales (some of which were involved in mass stranding events) in upper Cook Inlet since 1988 (Vos and Shelden 2005). Mass stranding events occurred most frequently along Turnagain Arm, and often coincided with extreme tidal fluctuations (“spring tides”) and/or killer whale sighting reports (Shelden et al. 2003). Other mass strandings have been reported in the Susitna Delta (Vos and Shelden 2005) and most recently on September 12, 2006 in Knik Arm (B. Mahoney, NMFS Alaska Region Office, unpublished data). These mass stranding events involve both adult and juvenile belugas that are apparently healthy, robust animals. Sex ratios for stranded whales were approximately 1:1. In 2003, an unusually high number of beluga live strandings (5 events) and mortalities (n = 20) occurred in Cook Inlet (Vos and Shelden 2005).

Belugas are usually able to survive through a stranding event and escape to deeper water on the rising tide. However, some deaths during these events do occur. For example, in August 2003, 46 belugas live-stranded in Turnagain Arm for over 10 hours, of these at least 5 whales are known to have died. Another 58 live belugas stranded in two events in Turnagain Arm the following month with no identified mortalities. Once a whale strands, death may result from stress and/or hyperthermia from prolonged exposure. Whales which strand high on a sand bar during an outgoing tide may be exposed for 10 hours or more. Unless caught in an overflow

channel or ponded area and partially covered with water, the whale may have difficulty regulating body heat. An extensive network of capillaries within the flukes and flippers allows belugas to lose excess body heat to the environment but these structures must be submerged for this mechanism to function properly and regulate body temperature, preventing overheating. Additional stress is placed on internal organs and breathing may be difficult without the support provided by water.

It is uncertain why belugas strand in Cook Inlet. Belugas are known to intentionally strand themselves during molting while rubbing their skin against rocky bottoms (e.g., Smith et al. 1992). Belugas may also strand purposely or accidentally to avoid predation by killer whales or when injured or sick. The following sections describe recent information on predation and disease in the Cook Inlet population.

3.2. Predation

The Cook Inlet beluga population is preyed upon by killer whales (*Orcinus orca*), their only known natural predator. NMFS has received reports of killer whales in Turnagain and Knik Arms, between Fire Island and Tyonek, and near the mouth of the Susitna River (Shelden et al. 2003). Native hunters report that killer whales are usually found along the tide rip that extends from Fire Island to Tyonek (Huntington 2000). Killer whales have stranded along Turnagain Arm on at least two occasions. Six killer whales were found alive and stranded in Turnagain Arm in May 1991 and five were stranded alive in August 1993. During the stranding event in August 1993, a large male vomited a large piece of beluga flesh, as well as tissue from a harbor seal(s) (*Phoca vitulina*). In September 23, 2000, a NMFS Enforcement agent observed about four killer whales chasing a group of belugas in Turnagain Arm (Shelden et al. 2003, NMFS Alaska Region Office, unpublished data). Within the next few days, two lactating females stranded with teeth marks, internal hemorrhaging, and other injuries consistent with killer whale attacks.

The number of killer whales visiting the upper Inlet appears to be small, only five and six whales involved in each observed stranding of belugas (Shelden et al. 2003). This may be a single pod

of killer whales which includes upper Cook Inlet as its territory. Killer whales are more commonly found in lower Cook Inlet and the GOA (Shelden et al. 2003) where they may feed on a variety of prey. Killer whales are described by three categories or groupings: resident, transient, and offshore. Transients feed exclusively on marine mammals and have dorsal fins distinct in shape from resident and offshore types. Photographs of the dorsal fins of killer whales that stranded in Turnagain Arm revealed they were transients (Shelden et al. 2003); however, resident types (fish eaters) also occur in Cook Inlet. Therefore, a sighting of killer whales in proximity to belugas in the upper Inlet does not necessarily mean they are feeding on belugas.

Only opportunistic data exist on the level of removals of belugas in Cook Inlet due to killer whale predation, which appears to be at least one beluga per year (Shelden et al. 2003). The impact is unknown but the potential for significant impacts on the Cook Inlet beluga population certainly exists given the low abundance of the beluga population and recent changes in prey availability to killer whales throughout the GOA (referring to declines in pinniped populations in the Central and Western GOA since the mid-1970s). The annual removal of even a few belugas could impede recovery. A significant effect would occur if the level of predation approximates the level of recruitment in the population or may result when predation mortality is added to other sources of mortality.

3.3. Parasitism and Disease

Little is presently known about the effects of disease on Cook Inlet belugas. Some basic information exists on the occurrence of diseases in Cook Inlet belugas, and a considerable amount of information exists for other belugas, toothed whales, or marine mammals in general. Bacterial infection of the respiratory tract is one of the most common diseases encountered in marine mammals. Bacterial pneumonia, either alone or in conjunction with parasitic infection, is a common cause of beach stranding and death (Howard et al. 1983). At least one Cook Inlet beluga death was attributed to infectious disease. This young (130 cm) female stranded on September 17, 2000 with severe parasitic pneumonia and secondary bacterial involvement: hepatic trematodiasis (liver flukes), ulcerative dermatitis (skin infections), linguatuliasis (tongue worms), and probable sepsis (blood poisoning).

Beluga populations in Alaska appear relatively free of ectoparasites, although both the whale louse, *Cyamus* sp., and acorn barnacles, *Coronula reginae*, were observed on belugas outside of Alaska (Klinkhart 1966). Endoparasitic infestations are more common: About 90% of Cook Inlet whales examined had kidneys parasitized by the nematode *Crassicauda giliakiana*. Although extensive damage and replacement to tissues have been associated with this infection, it is unclear whether this results in functional damage to the kidneys (Burek 1999a). Parasites of the stomach (*Contracaecum* or *Anisakis*) also were often present in Cook Inlet belugas. These infestations were not considered extensive enough to cause clinical signs, although *Anisakis* worms associated with stomach ulcers in Canadian belugas were attributed as cause of death in two animals (DFO 1995). Also recorded within muscle tissues of Cook Inlet belugas were *Sarcocystis* sp. The encysted (muscle) phase of this organism is fairly benign though acute infections can result in tissue degeneration leading to lameness or death (Burek 1999b).

While parasites and the potential for infectious disease occur in Cook Inlet belugas, no indication exists that their occurrence has had any measurable (detrimental or adverse) impact on the survival and health of the Cook Inlet beluga population despite the considerable pathology that has been done. However, more work is necessary in this field.

3.4. Ice Entrapment

The environment in which belugas reside makes them vulnerable to entrapment in ice at times. In Greenland waters, this phenomenon has been documented since the 1700s (see Siegstad and Heide-Jørgensen 1994, Heide-Jørgensen et al. 2002). Belugas are more susceptible to entrapment during sudden freeze-ups, fast ice formation (Heide-Jørgensen et al. 2002), and when wind conditions change, driving ice into once open areas (Armstrong 1985). A wind-driven ice entrapment of over 1,000 belugas occurred in Seniavin Strait, Chukotka, Russia in 1984 (Armstrong 1985, Ivashin and Shevlagin 1987), though according to hunters this is the only time such an event has occurred in Chukotka (Mymrin et al. 1999). Entrapments that result in mass mortalities appear to be rare, though under-reporting is possible given these incidents occur during the dark, winter months. Belugas are well-adapted to this icy environment, Chukchi Sea whales tagged with satellite transmitters successfully traversed 700 km with more than 90% ice

cover (Suydam et al. 2001). Cook Inlet belugas on occasion entered Knik and Turnagain Arms despite the presence of sea-ice (> 90% cover) (Hobbs et al. 2005). Ice entrapment, or any other natural event that results in annual removal of even a few belugas, could impede recovery. To date, however, there are no data to suggest ice entrapments are affecting belugas in Cook Inlet at the population level.

3.5. Small Population Effects

In determining population size limits for the long-term harvest plan for Cook Inlet belugas (71 FR 8268, February 16, 2006), NMFS considered the following factors: 1) an Allee effect, 2) inbreeding depression, 3) loss of genetic variability, 4) vulnerability to environmental perturbations due to reduced range, and 5) vulnerability to environmental perturbations and demographic stochasticity due to reduced population size. The Allee effect has been defined as the impact of reduced social interactions and loss of mating opportunities in a small population (Allee et al. 1949). NMFS has considered this factor and concluded that this is not a relevant concern unless the population was smaller than 50 animals (because the Cook Inlet beluga population typically is distributed among a few groups). Tagging data indicate that belugas move between these groups frequently (Hobbs et al. 2005) so that if the population was reduced, mating opportunities were not reduced more than just by the fewer available individuals in the population. An Allee effect would not act on this population until it was reduced to a point where the apparent group structure, currently observed, breaks down or only one small group remained.

A beluga population of 200 represents a point where the approximate effective population size may be as few as 60 reproductively active females. NMFS based its 200/60 determination on published scientific information, which indicates that populations with an effective size of a few dozen individuals are usually sufficiently large to avoid most of the deleterious consequences of inbreeding (Lande 1991). NMFS concluded that inbreeding depression would not be a relevant factor until the population dropped below 200 individuals.

NMFS also relied on theoretical work that indicates that during a rapid decline in population size nearly all (i.e., > 95%) of the diversity in a population is maintained in an effective population of 10 individuals, and more than 99% of the diversity in a population is maintained in an effective population of 50 individuals (Ralls et al. 1983). Losses in genetic diversity will occur if a population remains small for many generations. The rate of loss depends on the effective population size and is estimated to be approximately 0.8% per generation in an effective population of 60 (or an actual population of 200) (Meffe et al. 1997). Based upon a projection model for a healthy cetacean population growing at 2% to 6% per year (see Section 5), the Cook Inlet beluga population would likely recover to a population of more than 780 individuals within 30 to 50 years, or approximately three to five generations. Thus, loss of genetic diversity during this projected recovery is likely to be less than 4%. However, this scenario assumes the population is growing. Loss of genetic diversity does not pose a significant risk to this population over the next few decades unless it is reduced to fewer than 200 animals. Estimates of genetic variation do not, at present, suggest that Cook Inlet belugas are highly inbred or that a critical amount of genetic variation has been lost through drift (O’Corry-Crowe et al. 1997, 2002; G. O’Corry-Crowe, unpublished data).

3.6. Fishery Interactions

State and Federally-permitted commercial fisheries that take fish species also consumed by Cook Inlet belugas have varying likelihoods of interacting with belugas due to differences in gear type, fish species, timing, and location of the fisheries. Interactions refer to entanglements, injuries, or mortalities occurring incidental to fishing operations. Such interactions, when reported, are documented within NMFS’ Alaska Marine Mammal Stock Assessments (e.g., Angliss and Outlaw 2005).

The largest fisheries, in terms of participant number and landed biomass in Cook Inlet, are the State-managed commercial salmon drift and set gillnet fisheries concentrated in the Central and Northern Districts of upper Cook Inlet. In 1999 and 2000, observers were placed aboard some vessels in this fishery to record marine mammal interactions (Angliss and Outlaw 2005). No belugas were observed to be injured or killed in either fishery in either year. Although a few

marine mammals were entangled and released, belugas were never observed within 10 m of a net (i.e., within a distance categorized as an ‘interaction’) in either fishery (NMFS, Alaska Region Office data). NMFS is also unaware of any belugas injured or killed in the Cook Inlet personal use/subsistence gillnet fisheries.

The only reports of beluga mortality incidental to commercial salmon gillnet fishing in Cook Inlet are from the literature. Murray and Fay (1979) stated that salmon gillnet fisheries in Cook Inlet caught five belugas in 1979. Incidental take rates by commercial salmon gillnet fisheries in the Inlet were estimated at three to six belugas per year during 1981-83 (Burns and Seaman 1986). These reports, however, did not differentiate between the set and drift gillnet fisheries.

Aside from direct mortality and injury from fishing activity, fisheries may compete with belugas for salmon and other prey species. There is strong indication these whales are dependent on access to relatively dense concentrations of high value prey throughout the summer months. For example, NMFS made recommendations to the Alaska Board of Fisheries (BOF) to discontinue the commercial fishery for eulachon that now occurs from May 1 to June 30 between the Chuitna and Little Susitna Rivers (State of Alaska, Board of Fisheries 2005). This fishery has occurred sporadically over the years: in 1978, 1980, 1998, 1999, and 2006 (Shields 2005; P. Shields, ADF&G, pers. comm.). No quantitative assessment of the Susitna River smelt stocks has been conducted (Shields 2005). The NMFS recommendations were made, in part, because little data existed on the eulachon runs into the Susitna River, nor had any evaluation occurred as to the effect of this fishery on belugas in terms of disturbance/harassment or competition for these fish. Additionally, it was noted that belugas may be heavily dependent on this oil-rich food source early in the spring (preceding salmon migrations) and that large eulachon runs may occur in only a few upper Inlet streams.

Personal use fishing for eulachon also occurs and there are no bag or possession limits. The two most significant areas where smelt are fished in personal use fisheries occur in the 20-Mile River (and shore areas of Turnagain Arm near 20-Mile River) and Kenai River. Other areas where smelt are fished include the Susitna and Little Susitna River, Deshka River, Placer River, Yentna River, and shoreline areas of Turnagain Arm and Cook Inlet north of the Ninilchik River.

Annual removals have ranged from 2.2 to 5 tons over the past decade. The personal use fishery for smelt is possibly under-reported as some participants may confuse their removals as being subsistence and not personal use. Currently, no subsistence records are kept for smelt or herring fisheries (Shields 2005). Impedance of access to feeding habitat, or significant reductions in the amount of prey available, may impact the energetics of Cook Inlet belugas and delay recovery or cause decline.

3.7. Anthropogenic Sound

Belugas are known to be among the most adept users of sound of all marine mammals. This is, perhaps, not startling when considering that the beluga is often found in waters with very poor visibility and lives in northern latitudes where darkness extends over many months. Belugas use sound rather than sight for many important functions, and have evolved this use to very sophisticated levels. Belugas use sound to communicate, locate prey, and navigate and may make different sounds in response to specific stimuli (see review in O’Corry-Crowe 2002). Belugas produce high frequency sounds which they use as a type of sonar, producing a series of signals which are concentrated and directed through a structure located on the whales head (the melon), and whose returning echoes are received through the lower jawbone and transmitted to the brain. This echolocation is used for finding and pursuing prey and is likely useful in navigating through ice-laden waters.

In Cook Inlet, belugas must compete acoustically with anthropogenic sounds. Sources of such noise in Cook Inlet include large and small vessels, aircraft, oil and gas drilling, marine seismic surveys, pile driving, and dredging (Moore et al. 2000). High frequency sounds diminish more rapidly than lower frequencies. Sound also attenuates more rapidly in shallow waters and over soft bottoms (sand and mud). Much of upper Cook Inlet is generally a poor acoustic environment because of its shallow depth, sand/mud bottoms, and high background noise from currents and glacial silt (Blackwell and Greene 2002). Research on captive animals has found belugas hear best at relatively high frequencies between 10 and 100 kHz (Blackwell and Greene 2002). This is generally above the level of industrial activities. However, belugas may hear

sounds down to 40-75 Hz, although the sound would have to be very loud. The beluga's hearing falls off rapidly above 100 kHz.

Whenever anthropogenic sound exceeds background or ambient levels, it may be detectable by belugas. Anthropogenic sounds above ambient levels and within the same frequencies used by belugas may mask communication between these animals. At louder levels, this may result in disturbance and harassment or cause temporary or permanent damage to the whales' hearing. It is unlikely that anthropogenic sound levels in Cook Inlet would kill belugas, but loud activities may compromise their ability to find prey.

A 2001 acoustic research program within upper Knik Arm identified underwater sound levels (broadband) as high as 149 dB re: 1 μ Pa. (Blackwell and Greene 2002). This was associated with a tug boat which was docking a barge. This level of continuous sound would be below the threshold of 160 dB re: 1 μ Pa. that NMFS has adopted for behavioral impacts for belugas. Observations of beluga off the Port of Anchorage suggest these whales are not normally harassed by such sounds, although it is also possible that in order to feed, the whales are tolerating what would otherwise disturb them. Interestingly, the 2001 acoustic study found the lowest ambient underwater sound levels in upper Cook Inlet at two locations which are highly used by belugas, the mouth of the Susitna River and east Knik Arm (near Birchwood). The 2001 acoustics study also investigated sounds associated with offshore oil platforms. The Phillips A oil platform produced underwater sounds which were generally below 10 kHz. While much of the sound energy fell below the hearing thresholds of belugas, some between 2 and 10 kHz were measured as high as 85 dB re: 1 μ Pa. out to 19 km. This could be audible to belugas. The conclusions of this acoustics study were, overall, that the sounds measured in Cook Inlet would not be expected to have more than a minor effect on the belugas living in the vicinity.

The acoustics study did not address marine geophysical seismic activity in Cook Inlet, although it is known to occur. Seismic exploration is associated with both State and Federal offshore tracts. Geophysical seismic has been described as one of the loudest man-made underwater sound sources and has the potential to harass or harm marine mammals, including belugas. NMFS has and will continue to request that the State of Alaska's Lessee Advisory and Minerals

Management Services' Notice to Lessees regarding offshore seismic operations recognize that these activities may result in the taking (defined under the MMPA as harass, hunt, capture, collect, or kill or attempting to do so) of marine mammals, including belugas. Such taking is prohibited by the MMPA unless otherwise authorized (50 CFR 216.101-108).

Alaska Native beluga hunters have said that Cook Inlet belugas are at times very sensitive to anthropogenic sound and will leave high-use areas (Huntington 2000). Native hunters near Kotzebue Sound reported that belugas in that region abandoned areas due to the increased volume of noise from airplanes, motorboats, and on-shore activities (Morseth 1997). Belugas have been observed to react to ships and icebreakers in the Canadian Arctic at ranges of 35 to 50 km (LGL Ltd. and Greeneridge Sciences 1986). Conversely, belugas appear to be relatively tolerant of intensive fishing vessel traffic in Bristol Bay, Alaska (Frost et al. 1984), and belugas are commonly seen during summer at the Port of Anchorage, Alaska's busiest port (NMFS Alaska Region Office, unpublished data). NMFS researchers have often witnessed avoidance and overt behavioral reactions by Cook Inlet belugas when approached by small vessels (e.g., Lerczak et al. 2000). Vessels which do not alter course or motor speed and remain at some distance from these whales seem to cause little if any reaction. This suggests that proximity may also play a role in disturbance as slower boats, even idling near beluga groups, often alter beluga behavior (NMFS, Alaska Region Office, unpublished data). Small vessels, especially jet skis, are also capable of operating in waters not normally available to mariners, the shallow waters where belugas are often found. On June 16, 1996, jet skiers were observed near belugas by the Lewis River in the Susitna Delta during the NMFS abundance estimate aerial survey (NMFS, NMML, unpublished data). Beluga behavior changed dramatically: the animals disappeared beneath the surface for an extended period. Jet skiers have also been seen along Turnagain Arm, an area of Cook Inlet rarely used by conventional watercraft (NMFS, Alaska Region Office, unpublished data). While noninjurious consequences, such as beluga avoiding an area of boat traffic, may seem unimportant, displacement from feeding or calving habitats could be very harmful to the recovery of this population.

3.8. Pollution

Contaminants are a concern for beluga health, and through subsistence use, human health (Becker et al. 2000). The principal sources of pollution in the marine environment are as follows: 1) discharges from industrial activities that do not enter municipal treatment systems (petroleum, seafood processing, ship ballast, dredging); 2) discharges from municipal wastewater treatment systems (including emerging pollutants of concern (EPOCs) such as endocrine disruptors, pharmaceuticals, personal care products, and prions); 3) runoff from urban areas, mining operations, military sites, airports and agricultural areas; and 4) accidental spills or discharges of petroleum and other products (see review in Moore et al. 2000, NMFS 2006). Tissue samples collected from belugas that died during the subsistence hunt or after stranding were analyzed for polychlorinated biphenyls (PCBs), chlorinated pesticides, and heavy metals (contaminants found in discharges from a number of the activities mentioned above). Thus far, contaminant loads, in general, for belugas in Cook Inlet have been lower than observed in other beluga populations with the exception of hepatic copper levels (Becker et al. 2000). Contaminated food sources and displacement of belugas from feeding areas may occur as a result of any accidental spills or discharges from the sources listed above. Any diminishment of feeding habitat during the summer months could adversely affect belugas.

3.9. Ship Strikes

In Cook Inlet, the presence of belugas, especially while in and near river mouths, predisposes them to strikes by high-speed watercraft associated with sport and commercial fishing and general recreation. The mouths of the Susitna and Little Susitna River in particular are areas where small vessel traffic and whales commonly occur. Belugas with propeller scars have been observed in the upper Inlet (NMFS, Alaska Region Office, unpublished data). A stranded beluga examined in 1999 had scars consistent with an old propeller injury (Burek 1999c). NOAA Enforcement agents investigated a report of a jet skier approaching and striking belugas in Knik Arm in 1994 (NMFS, Alaska Region Office, unpublished data). Presently there are no restrictions on speed limits, areas in which vessels may operate, or on the type or horsepower of

vessels in the upper Inlet. This lack of regulation makes belugas vulnerable to ship strikes that may result in serious injury or death.

3.10. Subsistence Hunting

Alaska Natives have legally hunted Cook Inlet belugas prior to and after passage of the MMPA in 1972 (Mahoney and Sheldon 2000). The hunt removal, which was as high as 20% of the population in 1996, was sufficiently high to account for the 14% annual rate of decline in the population during the period from 1994 through 1998 (Hobbs et al. 2000a). NMFS has since promulgated regulations for the taking of Cook Inlet belugas by Alaska Natives for the years 2001-2004 (69 FR 17973, April 6, 2004), and proposed long-term hunting regulations through recovery (71 FR 8268, February 16, 2006). The approach preferred by NMFS would not allow a harvest from the population if it fell below 350 animals. Currently hunting is allowed only through co-management agreements between NMFS and ANOs.

3.11. Research

Much of the research conducted on Cook Inlet belugas is assumed to be unobtrusive (aerial surveys, shore based observations, acoustic studies (non-tagging), prey studies, habitat studies, pathology and disease studies conducted on dead animals, and contaminant studies, etc.); some activities have the potential to injure, harass, or change the behavior of these whales (e.g., applying tags, taking blood and skin biopsies). Any research that may “take” a whale by harassment or disturbance requires authorization under the MMPA.

4. Determination of DPS

4.1. ESA Discreteness and Significance

Joint NOAA/USFWS policy defines a population to be a DPS if it is both discrete and significant relative to the taxon to which it belongs (61 FR 4722, February 7, 1996). Under the policy, a population may be considered discrete if it satisfies one of the following conditions:

- It is markedly separated from other populations of the same taxon as a consequence of physical, physiological, ecological, or behavioral factors. Quantitative measures of genetic or morphological discontinuity may provide evidence of this separation.
- It is delimited by international governmental boundaries within which differences in control of exploitation, management of habitat, conservation status, or regulatory mechanisms exist that are significant in light of Section 4(a)(1)(D) of the ESA.

Data relevant to the distinctiveness question include the physical, ecological, behavioral, and genetic data that are presented in Section 2 and summarized below. If a population segment is considered discrete, NMFS must then consider whether the discrete segment is “significant” to the taxon to which it belongs. A discrete population segment needs to satisfy only one of the following criteria to be considered significant:

- persistence of the discrete segment in an ecological setting unusual or unique for the taxon,
- evidence that loss of the discrete segment would result in a significant gap in the range of the taxon,
- evidence that the discrete segment represents the only surviving natural occurrence of a taxon that may be more abundant elsewhere as an introduced population outside its historical range, or,
- evidence that the discrete segment differs markedly from other populations of the species in its genetic characteristics.

The policy also allows for consideration of other factors if they are appropriate to the biology or ecology of the species. Data relevant to the significance question include the morphological, ecological, behavioral, and genetic data presented in Section 2 and summarized below.

4.2. Evaluation of ESA Discreteness

The population of belugas in Cook Inlet is discrete from other Alaskan and Russian beluga populations in Arctic and subarctic waters. Despite extensive, dedicated marine mammal survey effort, the lack of sightings along the the Alaska Peninsula and Aleutian Islands chain (Laidre et al. 2000) suggest that the Cook Inlet population does not disperse into the Bering Sea. Behaviorally, belugas show strong maternally-driven site-fidelity to summering areas (O’Corry-Crowe et al. 1997, 2002; O’Corry-Crowe 2002) suggesting opportunity for intermixing may only occur during winter migrations. However, the available data indicate that belugas in Cook Inlet stay year-round (Rugh et al. 2004, Hobbs et al. 2005) and do not undertake extensive migrations. Furthermore, the genetic characteristics of this population differ markedly from the other four beluga populations that occur in western and northern Alaska waters (O’Corry-Crowe et al. 1997, 2002; O’Corry-Crowe 2002).

4.3. Evaluation of ESA Significance

Cook Inlet belugas occupy an ecological setting distinct from other arctic beluga populations. It is the only population found in subarctic waters east of the Alaska Peninsula. Given the site-fidelity of beluga populations (O’Corry-Crowe 2002), it is not likely that these waters would be repopulated by other western Arctic beluga populations in the foreseeable future should the Cook Inlet beluga population go extinct. The result would be a significant loss in the range of the taxon.

5. ASSESSMENT OF EXTINCTION RISK

5.1. Population Viability Analysis

A detailed population viability analysis (PVA) model was developed for the Cook Inlet beluga population to assess the extinction risks faced by this small population. The model included immature and mature phases of both sexes (i.e., age- and sex-structured) and focused on behavior of a declining population at sizes less than 500 belugas. Small population effects were taken into account by examining survival and fecundity under a range of scenarios that considered demographic stochasticity, harvest, density dependence, Allee effects, constant mortality effects (e.g., predations), and unusual mortality events (e.g., catastrophes).

5.1.1. Methods

To foresee the growth or decline of this beluga population in the future, a PVA model was developed using life history and population parameters estimated for this and other beluga populations (see Table 2 in Section 2.3.3). In addition to the selection of parameters, mechanisms affecting small populations (as described above) and time lags inherent in long-lived populations (which can result in a delayed response to changes in mortality probabilities) were also considered. One example of a time lag is the period from birth to reaching sexual maturity. Another is the effect the unregulated harvest had on the number of adult belugas in the Cook Inlet population. Litzky (2001) modeled the fraction of mature animals in the population and found that after cessation of the harvest it took 5-7 years for the adult to juvenile ratio to recover. To account for the time lag from birth to sexual maturity and the preference of hunters for adult animals, an age-structured model was used with adult age classes lumped together. Females and males were also modeled separately to incorporate sex-structure into the model and allow for unequal harvest of males and females.

To account for demographic stochasticity in the model, we considered random variations in the number of individuals that happen to die or reproduce in a given year (Begon et al. 1996:927). To this extent, survival from year to year and births each year were modeled using a binomial

draw. To model the harvest and the stochastic effects of injuring or killing a whale but not retrieving it (struck and lost), we used a negative binomial draw with the reported landings as successes and the probability of success as the probability of landing a struck whale. The resulting stochastic age- and sex-structured model was used to model the current population and project the possible outcomes.

The model was fit to the available abundance estimates for the years 1994 to 2005 (Table 3) using Bayesian statistical methods. The abundance of the Cook Inlet beluga population and subsistence harvest removals from this population were estimated each year between 1994 and 2005 (Table 3, Fig. 3). Limited information is available during periods prior to 1994 to indicate the behavior of this population outside this range of abundance estimates including the original or pristine size of this population and its sustainable harvest level. As mentioned in Section 2.3.1., NMFS has adopted 1,300 as the value for carrying capacity (K) to be used for management purposes (65 FR 34590, May 31, 2000). Finally, although K is included as a parameter, the purpose of this exercise was to model the behavior of the population at sizes below 500 animals. By relaxing the constraint of no population growth or decline at K , a greater variety of possible trajectories were available to the model within the range of interest.

Table 3: Time series used in the Bayesian analysis. Median aerial counts are the median of all observer counts from complete surveys of upper Cook Inlet. Estimated abundance was calculated from observer and video data. Harvest landings and struck and lost data were from Mahoney and Shelden 2000 and NMFS Alaska Region Office, unpublished data. Where conflicting sources occur, all are listed with the numbers used in the model in bold. Note that killed but lost are included with the struck and lost.

Year	Median Aerial Count	Estimated Abundance	Abundance CV	Harvest Landings (struck and lost)
1994	281	653	0.430	19(2)
1995	324	491	0.440	60(14), 52(22) , 42(26)
1996	307	594	0.280	49(49-98)
1997	264	440	0.140	35(30-40), 35(35)
1998	193	347	0.290	21(21)
1999	217	367	0.140	0(0)
2000	184	435	0.230	0(0)
2001	211	386	0.087	1(0)
2002	192	313	0.120	1(0)
2003	174	357	0.110	0(0)
2004	187	366	0.200	0(0)
2005	187	278	0.180	2(0)

Life history parameters of particular interest for modeling purposes were: survival probability, birth interval, age at first birth, gestation period, and lactation period. With the exception of survival probability, life history sample sizes from Cook Inlet were not sufficient to estimate the other model parameters. These data were instead obtained from the available literature on several other beluga populations (see Table 2 in Section 2.3.3.). Upper and lower bounds for the model parameters are described below.

Survival data for Cook Inlet belugas consist of annual summaries of beach-cast and floating carcasses reported to the NMFS Alaska Region Office and consequently represents a minimum estimate of mortality for this population. From 1999 to 2005, years in which a limited harvest occurred (Table 3), an average of 12 mortalities were reported each year (Vos and Shelden 2005) during a time when the population size averaged around 350 animals. This provided an estimated annual survival probability of 0.97/year which was used as the upper bound for the model. From the literature, survival probabilities have been estimated as low as 0.84/year but most were above 0.90/year (Table 2). For modeling purposes, values as low as 0.80/year were

considered; however, values below 0.85/year were not consistent with other parameters in the model so 0.85/year was the effective lower bound for the annual survival probability.

The birth interval for the average mature female in most beluga populations was thought to be 3 to 4 years although it may be as short as 2 years for younger adults (Table 2). The inverse of the birth interval is the annual probability of giving birth (between 0.25 and 0.33) for each adult female. To keep the model simple, an average value was used for all adult females including senescent females. A reduced birth probability in the Cook Inlet population resulting from external effects such as pollution or poor fish runs suggests a lower value than 0.25 is possible so the interval 0.05 to 0.33 was used in the model.

Female belugas reach sexual maturity between the ages of 4 and 10 years (Table 2). The gestation period lasts about 13 months, so age at first birth was set to start at 5 years in the model. The age of first birth is of importance for the model and is referred to hereafter as the age of maturity or age at first birth. The lactation period typically lasts longer than one year so calf survival was modeled as dependent on the survival of the mother during the first year after birth. Survival probabilities and age at maturity also have been estimated for males. However, these estimates were not sufficiently different from those for females to require additional parameters in the model.

At about the time a beluga reaches maturity, its skin changes from gray to white (Burns and Seaman 1986). Hunters have stated that they focus their hunting effort on white adult animals so vulnerability to harvest was set in the model to coincide with the age at first birth.

The population was projected as:

$$\begin{aligned}
f_{0,t} &= B\left(f_{mat,t}, \frac{b_t}{2}\right) & m_{0,t} &= B\left(f_{mat,t}, \frac{b_t}{2}\right) \\
f_{1,t+1} &= B\left(f_{0,t}, s_t^2 \frac{f_{mat,t} - H_{f,t}}{f_{mat,t}}\right) & m_{1,t+1} &= B\left(m_{0,t}, s_t^2 \frac{f_{mat,t} - H_{f,t}}{f_{mat,t}}\right) \\
f_{a+1,t+1} &= B(f_{a,t}, s_t) & m_{a+1,t+1} &= B(m_{a,t}, s_t) \\
&\text{for } a = 1 \text{ to } (a_{mat}-2) & &\text{for } a = 1 \text{ to } (a_{mat}-2) \\
f_{mat,t+1} &= B(f_{mat,t} - H_{f,t} + f_{a_{mat}-1,t}, s_t) & m_{mat,t+1} &= B(m_{mat,t} - H_{m,t} + m_{a_{mat}-1,t}, s_t),
\end{aligned} \tag{1}$$

where,

$f_{a,t}, m_{a,t}$ is the number of females and males, respectively, of age a at the beginning of year t ;

$f_{mat,t}, m_{mat,t}$ is the number of mature females and mature males, respectively, at the beginning of year t ;

$B(x, p)$ is a binomial random variable with x trials and p probability of success;

s_t is the probability of an individual in year t surviving to year $t+1$;

b_t is the probability of a mature female giving birth to a live offspring in year t ;

a_{mat} is the age of maturity or the age at which a female could first give birth; and

$H_{f,t}, H_{m,t}$ is harvest mortality (both landings and struck and lost) of females and males, respectively, in year t .

Harvest mortality was modeled as the sum of the landed whales plus estimates for those struck and lost. During the years 1995-1998 (Table 3), landings were fairly well documented and struck and lost was estimated as between one-half and two whales lost for each whale landed. Or, in other words, for each beluga killed during harvest activities there was a probability between one-third and two-thirds that it would be landed. For the model, this uncertainty in the level of struck and lost for the years 1989 to 1998 was accounted for by drawing from a negative binomial distribution with the landings as the number of successes and the probability of success

for each realization of the model drawn from a uniform distribution between one-third and two-thirds ($U[1/3, 2/3]$). For the years 1999 and later, where harvests have been regulated, the number of struck and lost was set to zero. It was assumed that constant landings occurred from 1989 through 1993 and were similar to the number of landings reported in 1994, so landings for these years were drawn from a uniform distribution between 10 and 30 belugas ($U[10, 30]$). For the years 1994 to 2005, actual landings (Table 3) were used in the model. For the purposes of the model, no harvest occurred after 2005. Data on the sex of whales killed in the hunt are sparse. From 1992 to 1998, 19 male and 15 female belugas were documented during the harvests (Mahoney and Sheldon 2000) corresponding with approximately 55% probability that an animal landed in the harvest was male. Variability in this probability was accounted for by drawing a value for each model realization from a triangular distribution between 0.40 and 0.70 with the peak at 0.55 ($TR[0.40,0.55,0.70]$). This approximated the beta distribution of relative likelihoods for this parameter, without the tails.

The harvest mortality model is

$$\begin{aligned}
 H_t &= CIBL_t + NB(CIBL_t, \mathbf{Pr}(Landing\ Success)) \\
 H_{m,t} &= B(H_t, \mathbf{Pr}(Harvest\ Male)) \\
 H_{f,t} &= H_t - H_{m,t} ,
 \end{aligned}
 \tag{2}$$

where,

H_t is total harvest mortality (both landings and struck and lost) in year t ;

$CIBL_t$ is the recorded harvest landings for 1994 to 2005 and a constant harvest landing per year for 1989 through 1993 in year t ;

$NB(x, p)$ is a negative binomial random variable of failures (struck and lost) for x successes (landings) and p probability of success for the years 1989 through 1998, after 1998 this is always zero;

$\mathbf{Pr}(Landing\ Success)$ is the probability of landing an animal killed in the hunt, drawn from $U[1/3,2/3]$ for years 1989 to 1998, for 1999 and after this is always 1, so all animals struck are landed and, therefore, struck and lost is zero; and

$\text{Pr}(\text{Harvest Male})$ is the probability that an animal taken in the harvest is a male, drawn from $\text{TR}[0.40,0.55,0.70]$.

To allow for density dependence in the annual growth multiplier (ϕ) (discussed in greater detail below), both survival (s) and fecundity (b) in Equation 1 were made density dependent with the following equation:

$$s_t = \left[s_0 - (s_0 - s_k) \left(\frac{N_t}{K} \right)^z \right] (s_e) \quad (3)$$

$$b_t = \left[b_0 - (b_0 - b_k) \left(\frac{N_t}{K} \right)^z \right] (b_e) ,$$

where,

s_0, s_k, b_0, b_k are the values for s and b when the size of the population is close to 0 and at K , respectively;

s_e, b_e are multipliers for s and b that reduce survival or fecundity independent of density;

$N_t = \sum_{\text{all ages}} f_{a,t} + m_{a,t}$ is the size of the population at time t ;

K = the carrying capacity (1,300); and

z = a shape parameter (2.39)

The annual survival probability and annual fecundity probability consisted of three components: a compensatory density-dependent survival or fecundity (Equation 3: within the square brackets); a density-independent component (s_e, b_e); and a modifier such as Allee effects, unusual mortality events, and constant mortality effects which will be discussed later. The density-dependent component used the discrete logistic formulation to decrease the probability of survival and probability of giving birth as the population increases. Parameters were chosen so that the annual growth multiplier (ϕ) of 1.02 to 1.06 (i.e., annual per capita increase between 2% and 6%; cf. Wade and Angliss 1997) fell between these values when the population was

small and declined to 1.00 (zero growth) when the population reached carrying capacity. The density-independent components (s_e , b_e) can be set to 1 to model a healthy population with annual growth between 2% and 6% or they can be set to values less than 1 to model processes that decrease survival or fecundity for each individual such as contaminants or ship strikes.

Choosing efficient and still uninformative prior distributions for the parameters of the annual fecundity probability and annual survival probability requires a bit of tuning to the model in question and the parameter constraints. If we treat fecundity (b) and survival (s) as constant parameters and consider the deterministic projection of the expected values of the abundance with harvest at zero, we have a recursion model in expected births by year. The characteristic equation for this recursion model can be written as:

$$1 = \frac{bs^{a_{mat}+1}\phi^{-a_{mat}}}{2(1-s\phi^{-1})}, \quad (4)$$

which then yields an equation for b if s and ϕ are known:

$$b = \frac{2(1-s\phi^{-1})}{s^{a_{mat}+1}\phi^{-a_{mat}}}, \quad (5)$$

where ϕ is the annual growth multiplier for an expected stable age distribution.

The density-dependent components (Equation 3: square brackets) represent the basic model for a healthy cetacean population with an annual growth multiplier of 1.02 to 1.06. To create a uniform prior distribution for the annual growth multiplier, ϕ_0 was drawn at random from U[1.02, 1.06]. At K , ϕ_K is, of course, 1.00, indicating the population is no longer growing upon reaching carrying capacity. The upper bounds for s_0 and b_0 were 0.97 and 0.33, respectively, and both s_K and b_K were nonnegative. Values for s_0 were then drawn from U[ϕ_0 -0.10, 0.97]

and s_K from $U[s_0 - 0.9(\phi_0 - 1), s_0]$ which allow anywhere from none to all of the density dependence to effect survival while avoiding a significant range of useless parameter space. Equation 5 was then solved for b_0 and b_K . If b_0 and b_K fell in the intervals $[0.05, 0.33]$ and $[0.0, b_0]$, respectively, then the parameter set was retained; otherwise it was discarded and new values for s_0 and s_K were drawn. This approach allowed the density dependence to entirely affect survival or fecundity or any ratio of the two while maintaining a uniform prior for ϕ_0 .

The annual growth multiplier for a healthy cetacean population described in the previous paragraph requires that s_e and b_e are set to 1. To allow a full range of annual growth multipliers, to model populations that may be in decline, we included cases where s_e and b_e were less than 1. To create a uniform prior distribution for the annual growth multiplier, ϕ_0 was drawn at random from $U[0.94, 1.06]$, where the annual per capita change ranged from -6% to +6%. In these cases, ϕ_K is not necessarily 1.00 and instead was chosen from $U[\phi_0 - 0.06, \text{minimum}(\phi_0 - 0.02, 1.00)]$ so that the annual per capita change would be 0% or $< 0\%$ when the population was at K . Density-independent components, s_e and b_e , were multiplied through the density-dependent portion of Equation 3 (square brackets) to form composite parameters: s_0s_e , s_Ks_e , b_0b_e and b_Kb_e . As in the Healthy Population model (where s_0 and b_0 were 0.97 and 0.33, respectively, and both s_K and b_K were non-negative), the upper bounds for the composite parameters s_0s_e and b_0b_e were also set to 0.97 and 0.33, respectively, and both s_Ks_e and b_Kb_e were non-negative. Values for s_0s_e were then drawn from $U[0.85, 0.97]$ and s_Ks_e from $U[s_0s_e - 0.90(\phi_0 - \phi_K), s_0s_e]$ which allowed all of the density dependence to affect survival. Equation 5 was then solved for b_0b_e and b_Kb_e . If b_0b_e and b_Kb_e fell in the intervals $[0.05, 0.33]$ and $[0.0, b_0b_e]$, respectively, then s_0s_e and s_Ks_e were retained, otherwise they were discarded and a new set was drawn. Note that parameters must be drawn as composites in this model, which we will refer to as the Baseline model, to maintain a uniform and uninformative prior distribution. If the parameters are drawn individually and then multiplied together the resulting prior distribution would be peaked and highly informative.

Modifiers to survival and fecundity were intended to model specific processes. These processes included a constant mortality effect and a stochastic or unusual mortality event to modify survival, and an Allee effect to modify fecundity. These were included in the model by rewriting Equation 3 as:

$$s_t = \left[s_0 - (s_0 - s_k) \left(\frac{N_t}{K} \right)^z \right] s_e \left(\frac{N_t}{N_t + C} \right) \{ 1 - M_e B(1, P_{Me}) \}, \quad (6)$$

$$b_t = \left[b_0 - (b_0 - b_k) \left(\frac{N_t}{K} \right)^z \right] b_e \left(\frac{f_{mat,t}}{f_{mat,t} + A} \right) \left(\frac{m_{mat,t}}{m_{mat,t} + A} \right),$$

where,

C is the parameter of the constant mortality effect and represents expected annual mortalities; M_e is the individual probability of mortality during an unusual mortality event; P_{Me} is the probability of an unusual mortality event occurring in a given year; and A is the Allee effect parameter.

Note that these processes were formulated so that if any of these parameters were zero then the corresponding effect does not modify survival or fecundity. The constant mortality effect was intended to model mortality resulting from annual killer whale predation in which the killer whales were thought to take a number of belugas proportional to their own needs regardless of the size of the beluga population. It could also model illegal harvest if that harvest remained constant from year to year regardless of the population size. The values for C represent the average mortalities per year due to killer whale predation or some other constant mortality. Sheldon et al. (2003) estimate an average of one observed predation mortality per year. This was considered a minimum since unobserved predation events may also be occurring. Values considered for the parameter (C) were 0, 1, 2, and 5, with zero events occurring when the constant mortality effect was absent and five events included as an extreme example.

The unusual mortality event (P_{Me} within the curly brackets of Equation 6) models random events such as mass stranding mortality. In this formulation, it included a mortality fraction and a binomial draw which determined whether or not an event occurred that year. The expected mortality from this source was the product of the mortality fraction and the probability of occurrence so that for the values used here ($M_e = 0.20$ and $P_{Me} = 0.05$), the expected or average annual unusual mortality event when it was included was 0.01 (i.e., an increase of average annual mortality of 1% of the population).

The Allee effect (Allee et al. 1949) is thought to occur in small populations where small numbers of adult females and adult males results in reduced mating opportunities or reduced variety of mate selection with consequent declining fecundity. Although other mechanisms affecting both fecundity and survival have been included under the definition of the Allee effect (Courchamp et al. 1999, Stephens and Sutherland 1999), for the purposes of this modeling exercise, its effect was applied to fecundity only (A in Equation 6). Note that in the formulation above the birth probability is zero when either sex is not present. The Allee parameter was set to 0.5 or 0.0 depending on presence or absence of the effect, respectively. There is little information on which to base a choice of this parameter instead it was tuned to affect the population when there were fewer than 50 whales in total as a proxy for a variety of small population effects.

The remaining parameter in the age-structured model was the age at first birth (a_{mat}) which was set to start at 5 years. Note that because birth is a discrete event, either a female gives birth to a calf or not, the value of b determined the distribution of ages of first giving birth for the model population. For instance, if b was 0.25 then 25% of females first gave birth at age 5, 25% at age 6, etc., resulting in an age at first birth distributed from ages 5 to 8. By the same reasoning if b was 0.14 then age at first birth was distributed from ages 5 to 11, or if b was 0.10 then age at first birth was distributed from ages 5 to 14.

To set up the initial age structure and a nearly uniform prior for the population abundance in 1994 (N_{1994}), an abundance estimate for the year 1989 (N_{1989}) was chosen from a uniform distribution ranging from 400 to 1,200 belugas (U[400, 1200]) and a constant harvest level H_{89-93} for the period 1989 to 1993 was chosen from U[10, 30]. In initial trials, the population

prior to 1994 was projected from 1979 to 1994 instead of 1989 to 1994. However, these initial trials indicated that the model results were sensitive to the limits of the uniform distribution from which N_{1979} was drawn and that the resulting N_{1994} and ϕ_0 were correlated in the prior distribution if the projections were begun in 1979. Projecting the model from 1979 without good harvest information also resulted in a somewhat informative prior dependent on the presumed harvest and the abundance in 1979. To minimize this effect while still setting up the five juvenile age classes it was necessary to begin in 1989. Projecting the model through 5 years prior to 1994 allowed the juvenile ages to be filled with values derived from the population model while maintaining nearly uniform and independent prior distributions for N_{1994} and ϕ_0 . A stable age distribution was set up using $s_{N_{1989}}$ (the survival rate calculated based on the population size in 1989) and setting ϕ to 1.00. Age and sex classes were filled as a multinomial distribution of N_{1989} by density at age for each sex. The population was then projected from 1989 to 1994. For computational convenience, if N_{1994} had a likelihood greater than $10^{-6} \times$ likelihood of $N_{1994} = \bar{N}_{1994}$ (the abundance point estimate for 1994), the parameters and age structure were retained as inputs to the Bayesian analysis (parameter values with lower likelihood would have no influence on the results). Each population was then projected from 1994 to 2005 and likelihood was calculated as:

$$L_j = \prod_{t=1994}^{2005} T\left(\frac{N_{t,j} - \bar{N}_t}{\bar{N}_t CV(\bar{N}_t)}, DF = 10\right), \quad (7)$$

where,

L_j is the relative likelihood of the j th population projection;

$T(X, DF = 10)$ is the density of Student's- t distribution at X with 10 degrees of freedom;

$N_{t,j}$ is the population size of the j th projection in year t ; and

$\bar{N}_t, CV(\bar{N}_t)$ are the estimated abundance (point estimate) and associated coefficient of variation in year t .

The Student's-t distribution was chosen for the likelihood model as the best fit compared to the gamma distribution, log-normal distribution and normal distribution to bootstrap results from annual abundance estimates for this population (R. Hobbs, NMFS, NMML unpublished data). Projections to 2005 with likelihoods less than $10^{-10} \times$ the maximum possible likelihood (i.e., the likelihood if the model N_t was equal to the abundance point estimate in all years) were discarded as having no contribution to the posterior distribution. A Sampling-Importance-Resampling (SIR) algorithm was followed (Rubin 1988) in which the acceptable parameter sets were weighted by their relative likelihoods from projections to 2005, and a resample drawn with replacement to give a posterior distribution of outcomes. Projections to 2305 (300 years into the future) for this posterior parameter set were done to estimate the probability of decline and extinction during that period. Model comparisons between the various models were done using the Bayes factor (Kass and Raftery 1994), calculated as twice the natural logarithm of the ratio of the average likelihoods of the two resamples:

$$BayesFactor(x, y) = 2 \ln \left[\frac{\sum_{j=1}^{SIRtot} L_{j,x} / SIRtot}{\sum_{j=1}^{SIRtot} L_{j,y} / SIRtot} \right], \quad (8)$$

where,

$BayesFactor(x,y)$ is the Bayes factor comparing model x and model y ;

$\ln[\]$ is the natural logarithm of the value in $[\]$;

$L_{j,x}$ and $L_{j,y}$ are the likelihoods of the j th projection of model x and model y , respectively; and

$SIRtot$ is the number of projections in the SIR subsample.

Where the Bayes factor had absolute value greater than 2 the model with the higher average likelihood was considered to be the more likely of the two, otherwise the models were of equivalent likelihood.

All models were compared to the Baseline model (U[0.94, 1.06]). The probability of the Healthy Population model (U[1.02, 1.06]) was compared using the Bayes factor. The three options for modifying the Baseline model, the constant mortality effect (C), the unusual mortality event (P_{Me}) and the Allee effect (A) were each considered. The time series of abundance and harvest data covered a sufficient range of population sizes (270-660 belugas) to compare between the Baseline and the Healthy Population models but not among the remaining options. Six models with the modifiers for survival and fecundity were considered, three of the Baseline with the C parameter at 1, 2 or 5 mortalities per year, one of the Baseline with the Allee parameter at 0.50, one of the Baseline with an unusual mortality event ($P_{Me} = 0.05$), and one of the Baseline with the C parameter at 1 and an unusual mortality event ($P_{Me} = 0.05$). Two additional models were included to test the sensitivity of the parameters: a Baseline and Healthy Population model that included an unusual mortality event and a C of five mortalities. For each model, 100,000 trials were projected to 2005 and the likelihood was calculated. Each population projection was fully defined by the 11 parameters: s_0 , s_K , b_0 , b_K , (or s_0s_e , s_Ks_e , b_0b_e , b_Kb_e), N_{1989} , H_{89-93} , C , M_e , P_{Me} , A , and a_{mat} , though, the stochastic nature of the projection meant two projections with identical parameters would have different outcomes. A sample of 10,000 of these trials, weighted by the likelihoods, was drawn with replacement for the SIR algorithm resample for further analysis. For all populations the population size in 1994, 2005, 2105, 2205 and 2305 was retained and for declining populations the year that the population dropped below 200, 100, 10, and 2 animals was retained. A population with 1 or 0 individuals was considered extinct.

5.1.2. PVA Results

The 10 models allowed a range of possible behaviors for the theoretical populations as they became small while behaving similarly within the range of actual abundance estimates (278-653). Examples of the deterministic annual growth multipliers associated with each model are given in Figure 4. For these examples, Equation 4 was solved iteratively for ϕ using values for s and b calculated at population sizes varying from 1 to 500 (Equation 6). In all of the solid line examples, density-dependent survival parameters were chosen so that at a population size of 350, the annual growth multiplier was 1.01. These “tuned” survival parameters were then used throughout the range. For the dashed line example the survival parameters were tuned such that

$\phi = 1.00$ at a population size of 350. The strong density-dependence example set $\phi_0 - \phi_K = 0.06$ while the weak density-dependence example set $\phi_0 - \phi_K = 0.02$, all other examples used strong density-dependence. Where growth increased as population declined crossing the value 1.00 (the dashed example), a stable equilibrium point was formed and, without stochastic variation, the population settled at this size (350 belugas). Where growth decreased as population declined crossing the value 1.00, an unstable equilibrium point resulted forming a population size threshold below which, without stochastic variation, the population continued to decline, and above which, without stochastic variation, the population increased. Consequently, if stochastic variation in the form of demographic stochasticity or unusual mortality events pushed the population below the population size threshold, the population would likely continue to decline to extinction. Note that in these examples, the annual growth multiplier fell below 1.00 for the Allee effect at a population size of about 15 belugas. For varying levels of C , the population size thresholds occurred around 60 belugas for 1 mortality per year, 120 for 2 mortalities, and 200 for 5 mortalities. This demonstrates the possibility of thresholds at different population sizes depending on the parameters used in each model.

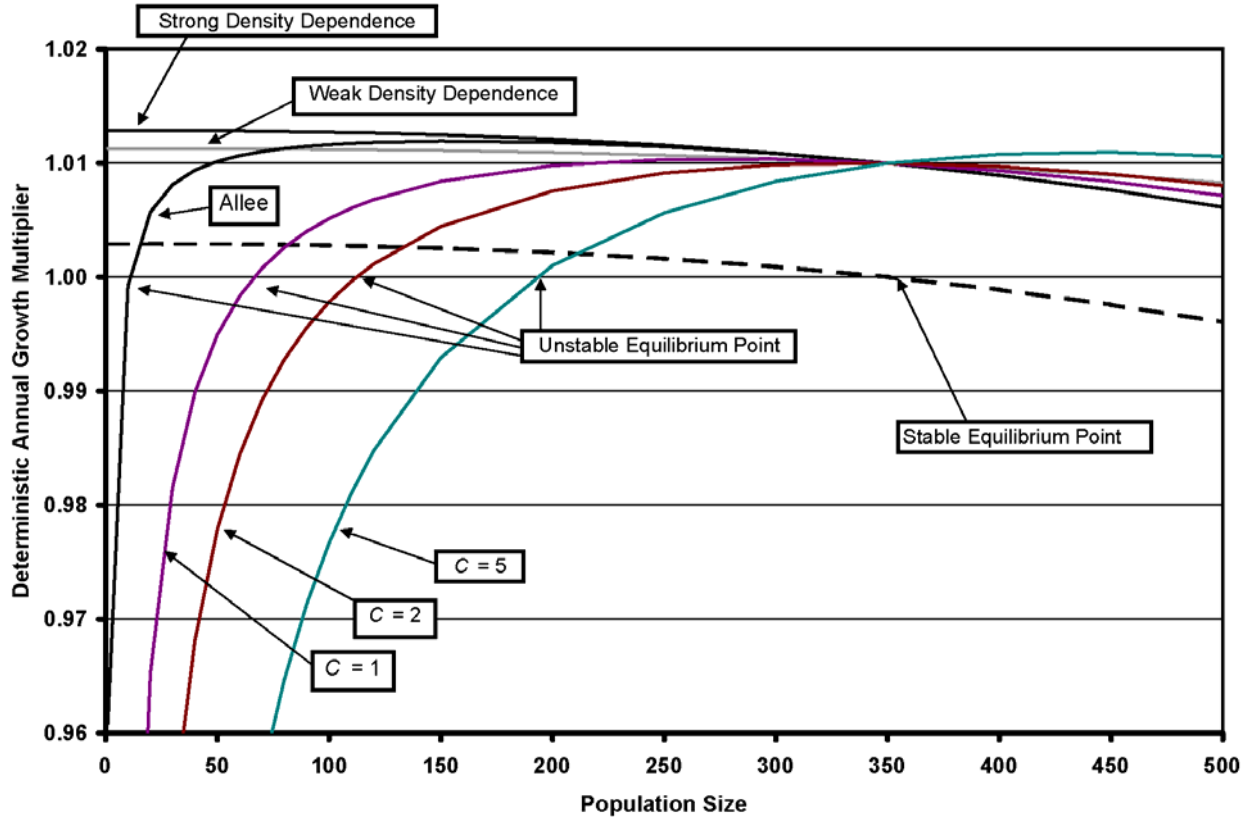
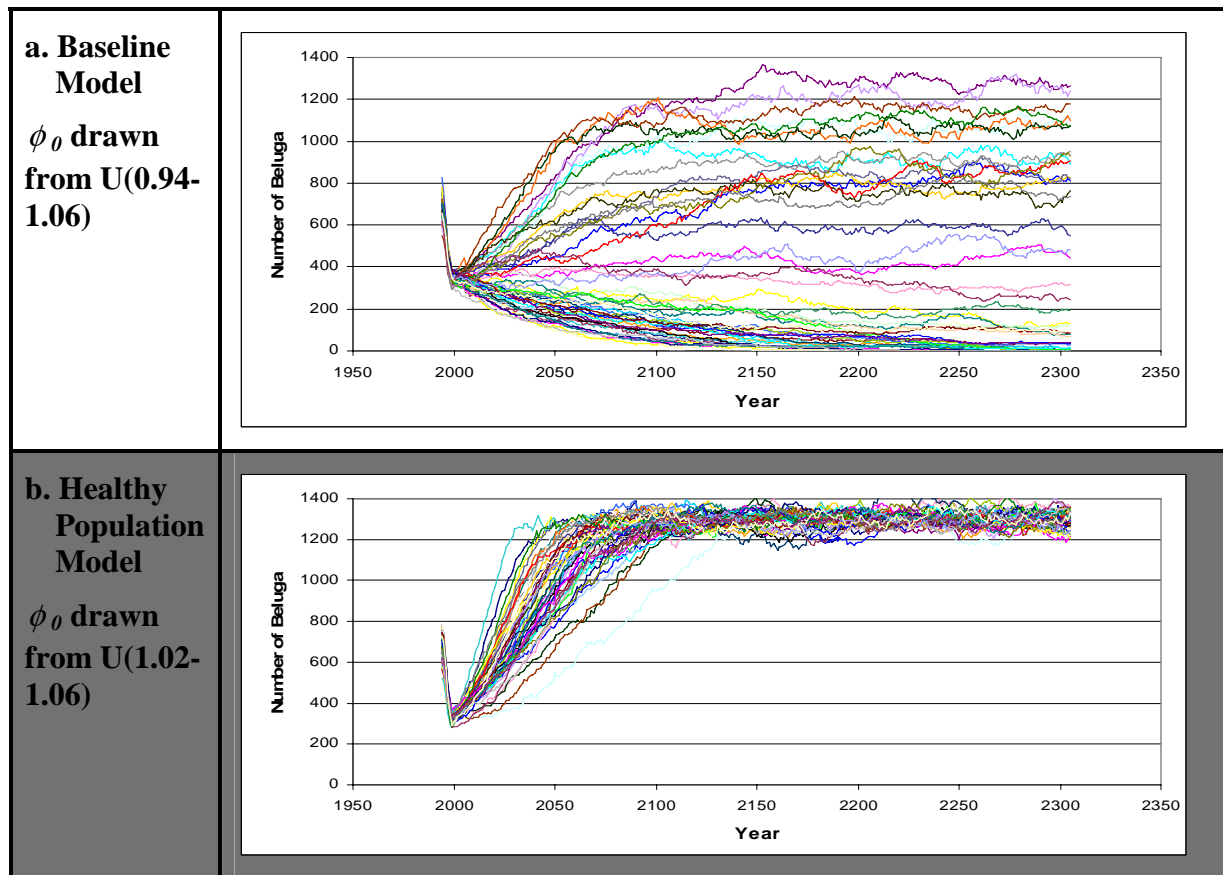


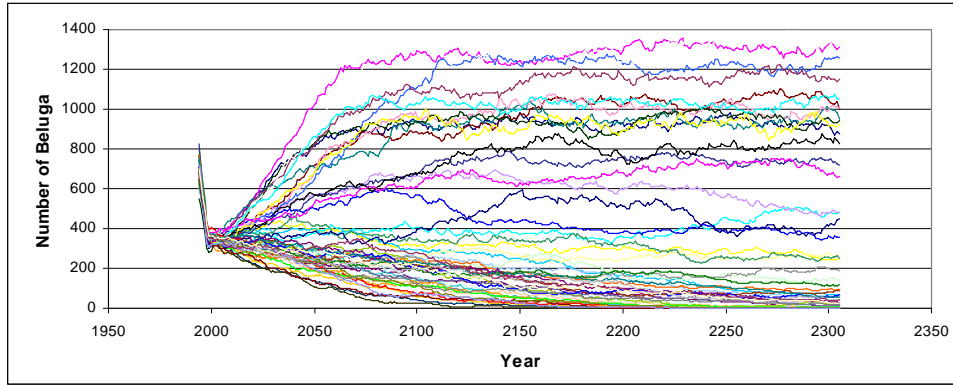
Figure 4: Solutions for the annual growth multiplier (ϕ) to the characteristic equation (Equation 4 in text) by population size for examples of the models. Solid line examples include density-dependent survival parameters for a population of 350 belugas chosen to set $\phi(350) = 1.01$. The dashed line example was tuned to $\phi(350) = 1.00$. Strong density-dependence was set at $\phi_0 - \phi_K = 0.06$; weak density-dependence at $\phi_0 - \phi_K = 0.02$; all other examples used strong density-dependence. C is the annual constant mortality effect parameter.

These growth multipliers and resulting behavior of the populations are reflected in the abundance time series for these example populations (Fig. 5a-j). Note that although the projections match the abundance time series closely during the period from 1994 to 2005, after 2005 there was considerable variation in behavior. Although there was no harvest in these models after 2005, the examples with $C > 0$ could be considered examples of the effect of a constant harvest level. Considering the Baseline model (Fig. 5a), which allowed a growth multiplier between 0.94 and 1.06, we had three typical behaviors: a slow decline to extinction, an increase to K , and an approach to stable equilibria between extinction and K . When only a limited range of values for the growth multiplier (between 1.02 and 1.06) was considered, as in the Healthy Population (Fig. 5b) only one behavior resulted, an increase until the population leveled off near K .

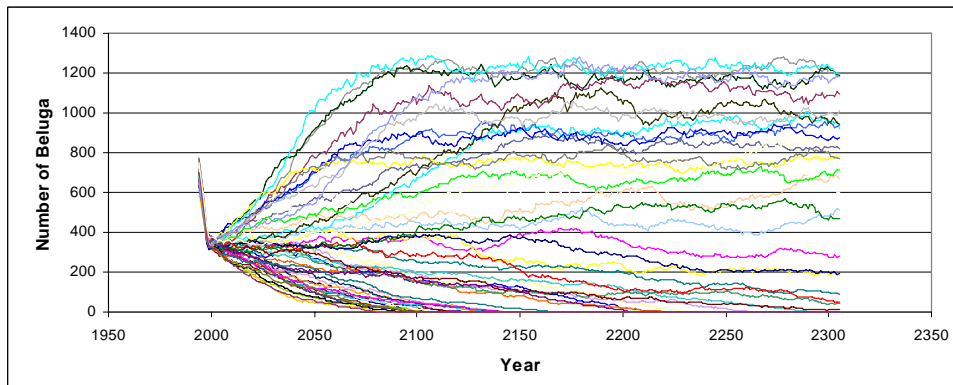
Inclusion of an effect that created a threshold, such as predation (C) or Allee (Fig. 5c-f), added an additional behavior of a rapid decline to extinction with the steepness determined by the height of the threshold effect. This threshold was particularly pronounced when the predation parameter was two or greater (Fig. 5e-f) causing a visible break point below which there was little likelihood of avoiding extinction. Including an unusual mortality event (Fig. 5g-j) had the effect of raising the population size threshold because populations above but near the threshold were still at risk of falling below after an unusual mortality event, and once below the threshold the population most likely would continue to decline. Because unusual mortality events periodically reduced the population, this prevented these populations from settling near an equilibrium. Extreme values of the C parameter alone and mixed with unusual mortality events (Fig. 5f, i, j) provided for sensitivity analysis. In these examples a population size threshold occurred within the range of recent abundance estimates (278-653), and in the Healthy Population model an unusual mortality event combined with $C = 5$ resulted in a significant number of extinctions, populations that would have recovered without these effects (Fig. 5j).



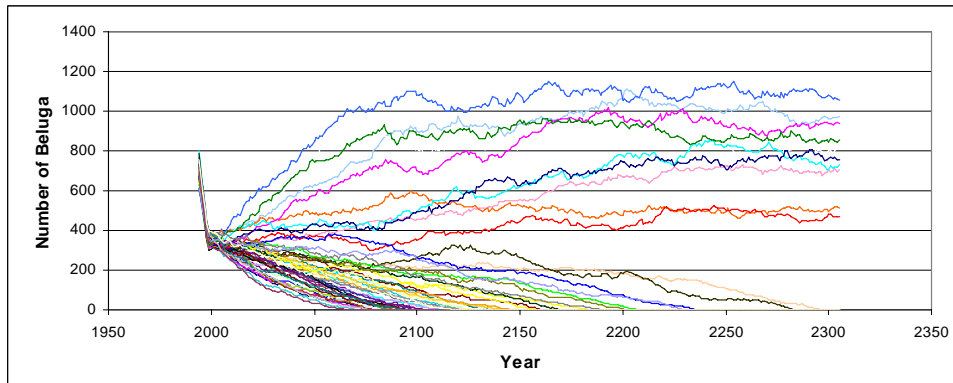
c. Baseline Model
+ Allee effect



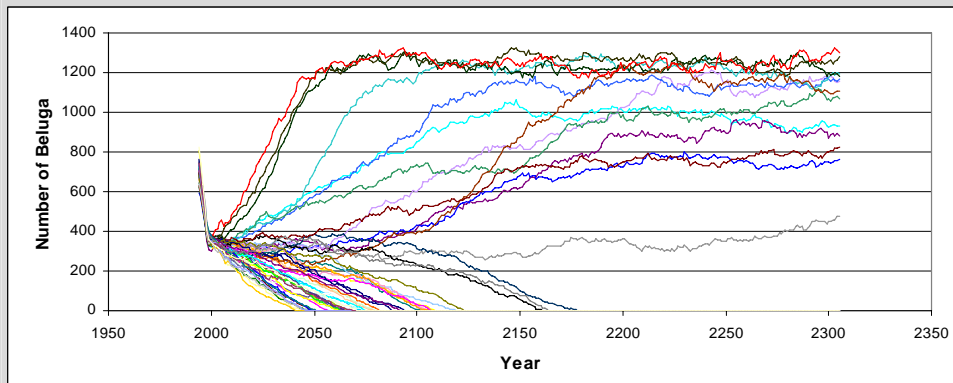
d. Baseline Model
+ C = 1



e. Baseline Model
+ C = 2

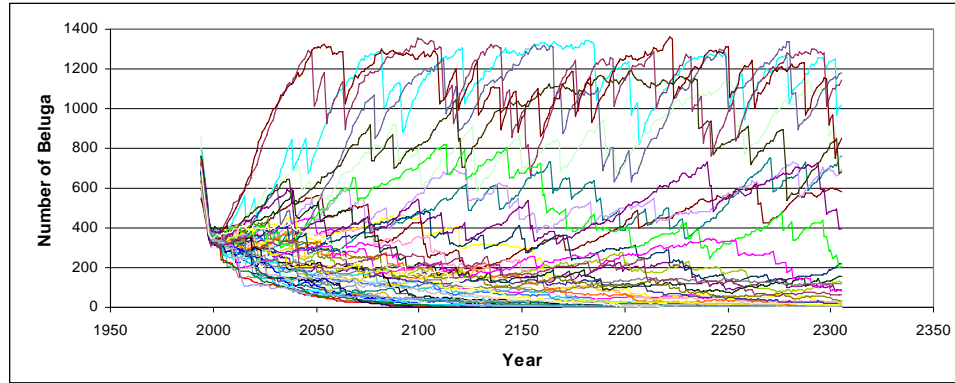


f. Baseline Model
+ C = 5



g. Baseline Model

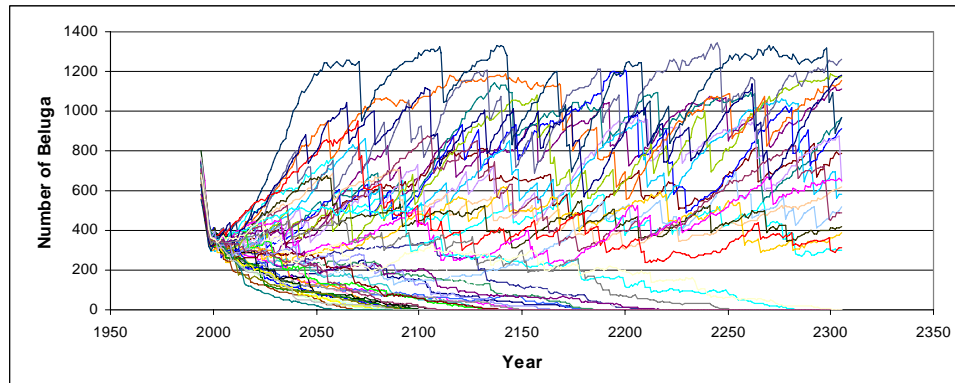
+ $P_{Me} = 0.05$



h. Baseline Model

+ $P_{Me} = 0.05$

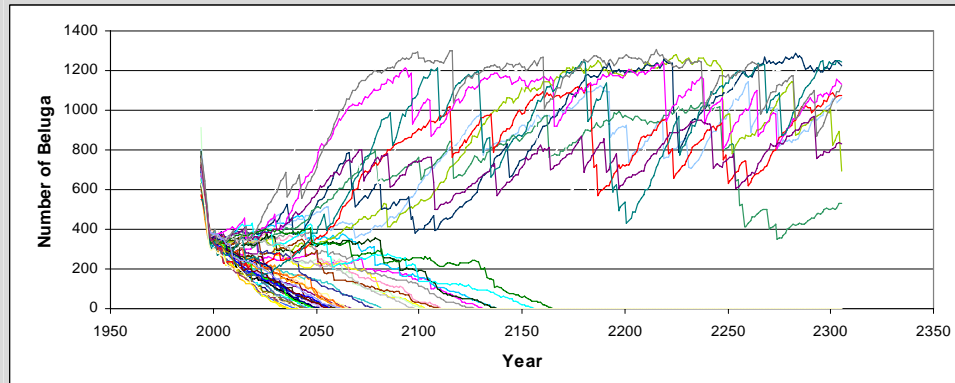
+ $C = 1$



i. Baseline Model

+ $P_{Me} = 0.05$

+ $C = 5$



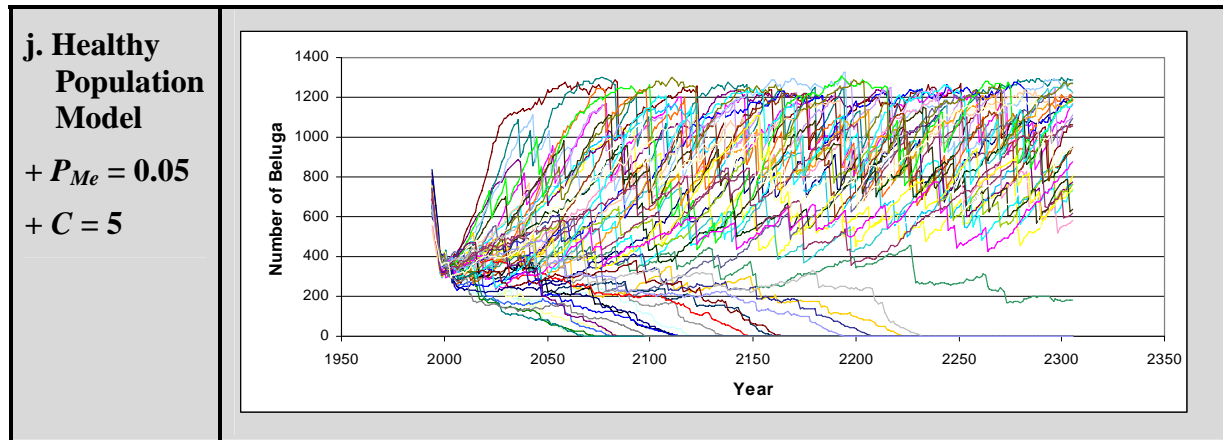


Figure 5. Projections of 50 example cases from the posterior sample of 10,000 trials for each of the 10 models (a-j). The dark shading (b) is the Healthy Population and the light shading (f, i, j) used parameters outside the range supported by the available Cook Inlet beluga predation mortality data and are meant for sensitivity analysis only.

The SIR algorithm provided a posterior distribution for ϕ_0 (Fig. 6) shown here for the Baseline model in the cumulative (black line and left axis) and the density (bars and right axis) forms. The value of ϕ_0 is the annual growth multiplier for a small population (approaching zero) and can be interpreted as similar to $R_{max}+1$ in the PBR population model (Wade and Angliss 1997). However, it should be noted that unlike the PBR model these are idealized growth multipliers and the average per capita growth will be less than these values due to demographic stochasticity. The median value for ϕ_0 is 0.994 and 90% of the probability falls between 0.974 and 1.026. Also note that 92% of the probability falls below $\phi_0 = 1.02$ (i.e., the minimum 2% growth that was anticipated for a healthy population).

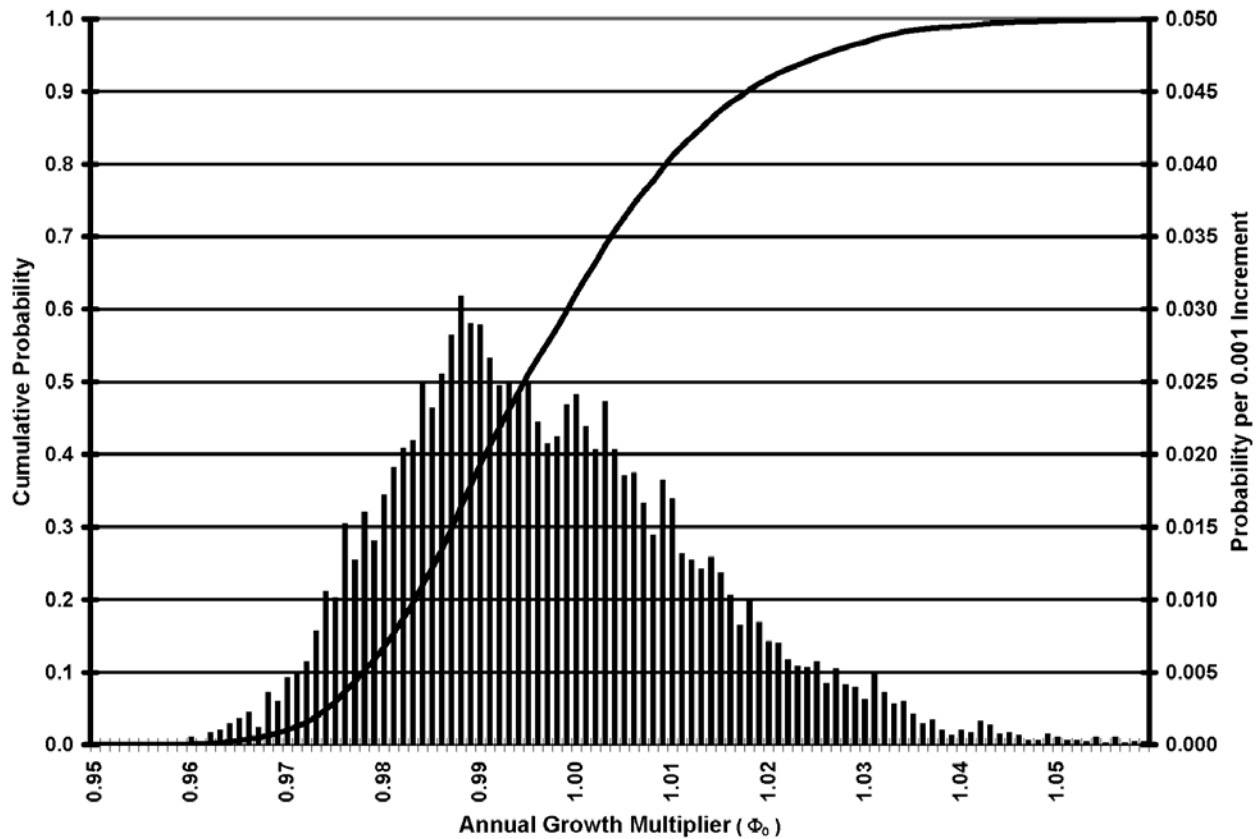


Figure 6: The posterior distribution of ϕ_0 from the Baseline Model which had a prior distribution for ϕ_0 of $U(0.94, 1.06)$ and no Allee effect or constant mortality effect; the solid line is the cumulative distribution (left axis). Note that there is about 8% probability that $\phi_0 > 1.02$; the vertical bars are the probabilities of values of ϕ_0 in 0.001 increments of the distribution (right axis).

As suggested by Figure 5, there was little variation in the fit of the different models to the time series data (1994 to 2005). Posterior distributions for abundance in 2005 were nearly identical with medians ranging between 332 and 342 for the variations of the Baseline model (Table 4). The Healthy Population model indicated a somewhat higher median of 375 (Table 4, row b) but when combined with $P_{Me} = 0.05$ and $C = 5$ (Table 4, row j) the median value nearly fell in the range of the Baseline variations. All of the seven variations of the Baseline considered had probabilities similar to the Baseline model itself although none being significantly better as indicated by the Bayes factor. The Healthy Population model had a much lower probability than any of the variations of the Baseline considered and should not be considered a viable model.

However, the Healthy Population model with $P_{Me} = 0.05$ and $C = 5$ was significantly more likely than the Healthy Population model itself and had a probability equivalent to that of the variations of the Baseline model.

Table 4: Statistics for the posterior distributions of the population size in 2005 (N2005) and the Bayes factors for each model compared to the Baseline model. The dark shading (b) is the Healthy Population and the light shading (i, j) used parameters outside the range supported by the available Cook Inlet beluga predation mortality data and are meant for sensitivity analysis only. Note that the absolute value of the Bayes factor should be greater than 2.0 before a significant difference in probability is indicated. U = uniform distribution, C = constant mortality effect parameter, P_{Me} = unusual mortality event (with a 5% annual probability of 20% mortality).

Model ID	Variation from Baseline Model	N2005 Median	N2005 5 th percentile	N2005 95 th percentile	Probability Relative to the Baseline	2 × Ln Bayes Comparison to the Baseline
a	ϕ_o U(0.94, 1.06)	340	299	388	1.00	0.00
b	ϕ_o U(1.02, 1.06)	375	335	420	0.29	-2.46
c	Allee	340	299	387	0.99	-0.02
d	C = 1	339	297	386	1.02	0.04
e	C = 2	337	296	386	1.03	0.05
f	C = 5	334	291	382	1.06	0.11
g	$P_{Me} = 0.05$	333	272	387	1.26	0.46
h	$P_{Me} = 0.05$ C = 1	332	270	384	1.26	0.46
i	$P_{Me} = 0.05$ C = 5	328	266	379	1.24	0.43
j	Healthy Population $P_{Me} = 0.05$, C = 5	343	277	397	1.18	0.33

During the projection from 2005 to 2305, considerable variation occurred within each model run and between models (Fig. 5; Tables 5 and 6). However, by the year 2305 in the projections, the majority of cases in each model had either gone extinct or recovered to a population size greater than 500. The Healthy Population model was the only one which resulted in a majority of the cases recovering to a population size above 500 (Table 5). For the six unshaded models, the probability of extinction by 2305 was between 29% and 68% (Table 6). While no extinctions occurred before 2055 (within 50 years), the probability of extinction in 100 years ranged from 0% to 29% for the unshaded models (Table 6). The Allee effect had a limited impact on the probability of extinction in 300 years, increasing the probability by 5% over the Baseline.

Where C was 1 or 2 animals per year (models d, e, h) there was an 11% to 29% probability of extinction in 100 years and 59% to 68% in 300 years. The effect of including C = 1 with $P_{Me} =$

0.05 (model h) is roughly equivalent to $C = 2$ (model e) (Table 6). As indicated in Figure 4, the $C = 1$ threshold was around 60 animals and the $C = 2$ threshold was around 120 animals. Three unusual mortality events in a short time span would nearly reduce the population by half making up the difference between the two thresholds. Increasing C to 5 mortalities per year (models f, i, j), raised the population size threshold to 200 belugas, increased the overall risk of decline and extinction in each model to the extent that a significant probability existed for extinction in 50 years (Table 6). Again this population size threshold was increased by including unusual mortality events (c.f. models i and j). In general, unusual mortality events added 10% to 15% to the probabilities of extinction in 300 years in each variation of the Baseline model. In the Healthy Population model, unusual mortality events with $C = 5$ resulted in a probability of extinction in 300 years of 36% while $C = 5$ effect alone resulted in no extinctions, as the projected populations never fell below this parameter's threshold of 200 belugas.

Table 5. Outcomes of projections to year 2305 for each of the models. The dark shading is the Healthy Population (b) and the light shading (i, j) used parameters outside the range supported by the available Cook Inlet beluga predation mortality data and are meant for sensitivity analysis only.

Model ID	Percent probability that the population will be:					Probability of extinction by 2305 (%)
	> 500	< 500 & > 350	< 350 & > 200	< 200 & > 100	< 100	
a	29	6	6	6	25	29
b	100	0	0	0	0	0
c	29	6	6	6	20	34
d	27	4	3	3	4	59
e	27	2	2	1	2	66
f	23	1	0	0	0	76
g	23	4	5	5	20	44
h	21	3	3	2	3	68
i	15	1	0	0	0	83
j	61	2	1	0	1	36

Table 6. Extinction risk for each of the models by 2055, 2105, 2205, and 2305. The dark shading is the Healthy Population (b) and the light shading (i, j) used parameters outside the range supported by the available Cook Inlet beluga predation mortality data and are meant for sensitivity analysis only. Probability of declining is the probability that $N_{2305} < N_{2005}$

Model ID	Percent probability of extinction by:				Probability of declining (%)
	2055 (50 years)	2105 (100 years)	2205 (200 years)	2305 (300 years)	
a	0	0	13	29	65
b	0	0	0	0	0
c	0	0	17	34	66
d	0	11	48	59	69
e	0	29	59	66	71
f	14	61	74	76	77
g	0	2	26	44	72
h	0	26	60	68	76
i	29	72	82	83	84
j	1	16	31	36	38

5.1.3. Discussion and Conclusions

Although the model structure and parameters had obvious effects on the distributions of predicted outcomes, even the best case scenario (model a) with no threshold effects resulted in population declines in 65% of the cases and extinction in 29% within 300 years. With this most optimistic scenario, with no harvest after 2005, only 29% of the cases resulted in a population above 500 animals in 2305. The distributions of possible outcomes were sensitive to a variety of poorly known small population effects; however, the data that we do have supports the choice of the Baseline (model h) as the best approximation of the current population with the estimated mortality due to killer whale predation averaging 1 per year ($C = 1$) and allowing for uncertainty with unusual mortality events occurring on average every 20 years. This model had a 26% probability of extinction in 100 years and a 68% probability of extinction in 300 years. Although there were no data to support higher predation rates or more frequent unusual mortality events, the examples given (models f, i, j) indicate the fragile nature of this population. Should the constant mortality level increase either by increased killer whale predation or other means, or if this mortality level has been underestimated, the population would have a very high probability of decline and a significant probability of extinction in 50 years (e.g., Table 6, row f, i). A synergistic effect occurred when the Allee effect or constant mortality effect acted as traps for

populations hit by a series of unusual mortality events, which hastened the extinction of declining populations and placed even populations with an otherwise healthy annual increase at risk. These modeling results indicate clearly that it is likely that the Cook Inlet beluga population will continue to decline or go extinct over the next 300 years unless factors determining its growth and survival are altered in its favor.

5.2. Application of IUCN Criteria

As an alternative to population models, other categorical measures such as small population size have been used to determine extinction risk. In their comments on the Depleted listing of Cook Inlet belugas (65 FR 38778, June 22, 2000), the Marine Mammal Commission (MMC) noted that, under criteria developed by the International Union for the Conservation of Nature and Natural Resources (IUCN), Cook Inlet belugas would be classified as “endangered” or “critically endangered”. NMFS, in its response, concluded that although the IUCN criteria are appropriate for identifying species at risk, they are limited because they are based only upon characteristics of the population. At the time of the Depleted designation, NMFS determined that under the IUCN criteria, Cook Inlet belugas would qualify as “endangered” only if the population decline was continuing. However, the ESA also requires consideration of the adequacy of existing regulatory mechanisms. The major factor related to the decline of Cook Inlet belugas, the Native subsistence hunt, had been stopped under Federal law and was not likely to revert to unsustainable levels in the near future. Also, under IUCN criteria, the population would be classified as “vulnerable” if there were fewer than 1,000 whales. At 1,000 animals, the Cook Inlet beluga population would likely be within its Optimum Sustainable Population (OSP) level under the MMPA, perhaps at or near its carrying capacity. At that point, NMFS would consider the population as small, isolated, and healthy, but the IUCN would characterize it as “facing a high risk of extinction in the wild in the medium-term future.” When the decision not to use the IUCN criteria was challenged in court (*Cook Inlet Beluga Whale v. Daley*, 156 F. Supp. 2d 16 (DC Cir. 2001)), the Judge ruled that “the agency’s obligations arise under the five statutory criteria of the ESA, and not the IUCN criteria.”

6. CONCLUSIONS OF THE STATUS REVIEW

The small, isolated population of belugas in Cook Inlet has not shown appreciable signs of recovery since 1999 when hunting restrictions began. Prior to this, a significant declining in abundance was documented from 1994 to 1998, but there are little empirical data for the period between 1979 and 1994 to identify a mechanism for the apparent decline of this population from 1,300 to 650. Anecdotal reports suggest Native subsistence hunt (enumerated through hunter interviews) was significant during the 1970s and 1980s and may have been at levels similar to the hunts reported in the mid-1990s. Also, commercial and sport hunts occurred during the 1960s and 1970s, so the highest available abundance estimate of 1,300, based on the 1979 ADF&G survey, may already represent a partially depleted population. With the very limited hunt between 1999 and 2005, NMFS anticipated that the population would begin to recover at a rate of 2% to 6% per year. However, a Bayesian analysis including the 2005 estimate of abundance indicates that there is a likelihood of less than 8% that the annual increases of 2% or greater will occur and a likelihood of 65% or more that the population will decline further.

A population viability analysis was conducted to assess the extinction risks faced by this small population under a range of scenarios that considered density dependence, constant mortality, Allee effects, and catastrophes. The best case scenario, with no threshold effects, resulted in population declines in 65% of the cases and extinction within 300 years in 29%. Even with this most optimistic scenario, and with no harvest after 2005, only 29% of the cases resulted in a population above 500 animals in 2305. There is a significant likelihood that the Cook Inlet beluga population will continue to decline or go extinct over the next 300 years unless factors determining its growth and survival are altered in its favor. The contraction of the range of this population northward into the upper Inlet makes it far more vulnerable to catastrophic events with the potential to kill a significant fraction of the population. The probability of potential catastrophic events--such as oil or toxic substance spills, failure of key fish runs, ice entrapments, or disease or parasitic introductions-- added 10% to 15% to the probabilities of extinction in 300 years in the models. As the models demonstrate, killer whale predation which is documented on a near annual basis, could also significantly impact recovery. Since belugas spend much of their time in shallow waters, stranding is a constant risk. Prolonged stranding

events more than a few hours, although not common, may under unusual circumstances such as unusual tidal cycles, storm surge, flooding, tsunami or earthquake uplift result in significant mortalities.

The importance of anadromous fish runs in Cook Inlet to belugas is evident from stomach contents data as well as Native accounts of blubber thickness. This suggests that belugas are in a caloric deficit through winter and early spring and depend on the fish runs in late spring and summer for the bulk of their annual nutrition. Beluga distribution may not only be driven by the strength of fish runs but how those runs are concentrated within river mouths during the summer months. The summer period is also when calves are born and lactating females will have much greater energetic needs in order to maintain themselves and their calves through the winter.

Belugas in Cook Inlet make up a small, genetically distinct population that appears to have strong site fidelity to the Inlet year-round. Should this population go extinct, it is highly unlikely that Cook Inlet would be repopulated with belugas in the foreseeable future. The closest large population is in Bristol Bay, 1,500 km away by sea and separated by the Alaska Peninsula that extends 3 degrees of latitude south of the southern limit of the Bristol Bay beluga population. It is highly probable that the loss of the Cook Inlet beluga population would result in a permanent loss of range for the beluga species.

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