Southwest Alaska DPS of the Northern Sea Otter
(Enhydra lutris kenyoni)

5-Year Review:
Summary and Evaluation

Photo by Randall Davis

U.S. Fish and Wildlife Service
Marine Mammals Management
Anchorage, Alaska
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5-YEAR REVIEW
Southwest Alaska DPS of the Northern Sea Otter
(Enhydra lutris kenyoni)

1.0 GENERAL INFORMATION

1.1 Reviewers

Lead Regional Office: Alaska Region
Contact: Sonja Jahrsdoerfer, Regional Endangered Species Coordinator, 907 786-3323

Lead Field Office: Marine Mammals Management
Contact: Frances Mann, Sea Otter Program lead, 907 786-3668.

1.2 Methodology used to complete the review

The U.S. Fish and Wildlife Service (Service) conducts status reviews of species on the List of Endangered and Threatened Wildlife and Plants (50 CFR 17.11 and 17.12) as required by section 4(c)(2)(A) of the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.), as amended (ESA). The Service announced this status review via a *Federal Register* notice on April 26, 2013 (78 FR 24767), and requested new scientific or commercial data and information that may have a bearing on the classification of the southwest Alaska Distinct Population Segment (DPS) of the northern sea otter (*Enhydra lutris kenyoni*) as a threatened species.

Biologists from the Service's Region 7 Marine Mammals Management office, located in Anchorage, Alaska, conducted this review. On May 3, 2013, the Service invited 37 Alaska Native tribes within the range of the Southwest DPS of northern sea otters to participate via teleconference in government-to-government consultation on the status of this population. The Service also invited 47 Alaska Native Claims Settlement Act (ANCSA) regional and village corporations within the range of this sea otter population to provide information for the 5-year status review. Alaska Native Organizations, non-governmental organizations, State and Federal agencies, university researchers, and other known interested parties were also invited to provide information.

1.3 Background

1.3.1 FR Notice citation announcing initiation of this review: 78 FR 24767

1.3.2 Listing history

FR notice: 70 FR 46366
Date listed: August 9, 2005
Entity listed: **S**outhwest Alaska DPS of the northern sea otter (*Enhydra lutris kenyoni*)
Classification: Threatened

1.3.3 Associated rulemakings

Final Rule, Designation of Critical Habitat
FR notice: 74 FR 51988
Date: October 8, 2009

Special Rule
FR notice: 71 FR 46864
Date: August 15, 2006
This special rule allows for the limited, noncommercial import and export of items that qualify as authentic Native articles of handicrafts and clothing that were derived from sea otters legally taken for subsistence purposes by Alaska Natives from the listed population. This special rule also allows for cultural exchange by Alaska Natives and activities conducted by persons registered as an agent or tannery under existing law. The Service also amended our definition of "Authentic Native articles of handicrafts and clothing" by striking the stipulation that such items were commonly produced on or before December 28, 1973. This definition change is appropriate in light of a court ruling on the Service's definition of "Authentic Native articles of handicrafts and clothing" and consistent with our current definition of "Authentic Native articles of handicrafts and clothing" under the Marine Mammal Protection Act (MMPA) of 1972.

1.3.4 Review History

Draft Recovery Plan
FR notice: 75 FR 62562
Date: October 12, 2010

Final Recovery Plan
FR notice: 78 FR 54905
Date: September 6, 2013

1.3.5 Species' Recovery Priority Number at start of 5-year review

Priority Number 6

1.3.6 Recovery Plan or Outline

Name of plan or outline: Southwest Alaska Distinct Population Segment of the Northern Sea Otter (*Enhydra lutris kenyoni*) Recovery Plan
Date issued: August 2013
The Recovery Plan for the Southwest Alaska DPS was finalized in August 2013, and the Federal Register notice announcing its completion is expected to be published in August 2013. The Service is beginning the process of implementing several of the Recovery Plan's key aspects. See section 4.0, "Recommendations for Future Actions." Ongoing long-term recovery efforts are identified in the Recovery Plan itself, and include harvest monitoring, oil spill prevention, monitoring of trends in abundance, estimation of population size, disease screening and monitoring, and estimation of survival rates.

2.0 REVIEW ANALYSIS

2.1 Application of the 1996 Distinct Population Segment (DPS) policy

2.1.1 Is the species under review a vertebrate?
Yes

2.1.2 Is the species under review listed as a DPS?
Yes

2.1.3 Was the DPS listed prior to 1996?
No

2.1.4 Is there relevant new information for this species regarding the application of the DPS policy?
No

2.2 Recovery Criteria

2.2.1 Does the species have a final, approved recovery plan[1] containing objective, measurable criteria?
Yes

[1] Although the guidance generally directs the reviewer to consider criteria from final approved recovery plans, criteria in published draft recovery plans may be considered at the reviewer's discretion.

2.2.2 Adequacy of recovery criteria

2.2.2.1 Do the recovery criteria reflect the best available and most up-to date information on the biology of the species and its habitat?

Yes, the Recovery Plan for this DPS was finalized in August 2013, and the biology and habitat of this DPS are well documented.

2.2.2.2 Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and is there no new information to consider regarding existing or new threats)?

Yes, the 5 listing factors are addressed in the recovery plan, and there is no new information to consider regarding threats.

2.2.3 List the recovery criteria as they appear in the recovery plan, and discuss how each criterion has or has not been met, citing information

Criterion 1. Demographic. The probability of becoming endangered within 25 years is <5%. This recovery criterion applies to all 5 Management Units (MUs).

This recovery criterion has not been met for 4 of the 5 MUs. A Population Viability Analysis (PVA) indicates that current population estimates for 4 of the 5 MUs are below the levels estimated to reduce the probability of becoming endangered within 25 years to <5% (Table 1). Status is expressed as a fraction of carrying capacity (K), where a threshold of approximately 35% of K or greater is required to meet this demographic criterion. See section 2.3.1 for more details. Only MU 5 (the Kodiak, Kamishak Bay, and Alaska Peninsula MU) currently meets this criterion for delisting.

Criterion 2. Ecosystem-based. Greater than 50% of islands are in the kelp-dominated state. This recovery criterion applies to the Western Aleutians and Eastern Aleutians MUs only.

This recovery criterion has not been re-evaluated for either MU. The last new data on kelp coverage in the Aleutians were collected in 2000 and used in development of the Recovery Plan (USFWS 2013b). No new data have been collected since then. To our knowledge, this criterion has not been met for either MU. See section 4.0, "Recommendations for Future Actions."

Criterion 3. Threats-based. In the Recovery Plan, the threats-based criteria and their importance to recovery are assessed in Table 10 (USFWS 2013b). The best available information indicates that these assessments have not changed, and that these threats have not been adequately mitigated. While there is spatial variability, predation (Factor C) appears to have the highest potential impact to recovery, with high importance in 3 MUs (Western and Eastern Aleutians and South Alaska Peninsula MUs) and moderate importance in 2 MUs (Bristol Bay and Kodiak, Kamishak, Alaska Peninsula MUs). Oil spills (Factor A) are of

moderate importance to recovery in the Eastern Aleutians and Kodiak, Kamishak, Alaska Peninsula MUs. Subsistence harvest (Factor B), infectious disease (Factor C) and illegal take (Factor E) are of moderate importance in the Kodiak, Kamishak, Alaska Peninsula MU. Available evidence indicates that other potential threats are considered to have low importance to recovery of the listed DPS.

2.3 Updated Information and Current Species Status

2.3.1 Biology and Habitat

2.3.1.1 New information on the species' biology and life history

None

2.3.1.2 Abundance, population trends (e.g. increasing, decreasing, stable), demographic features (e.g., age structure, sex ratio, family size, birth rate, age at mortality, mortality rate, etc.), or demographic trends

Population Sizes and Trends, and Population Viability Analysis (PVA)

An aerial survey of sea otters along the coastline of Katmai National Park and Preserve was completed during July 2012 by the National Park Service (NPS) and US Geological Survey (USGS). The survey area ranged from Cape Douglas to the southwest end of Cape Kubugakli at the park boundary. Although not yet finalized and peer-reviewed, preliminary results indicate a total estimated population size in 2012 of approximately 8,644 sea otters (se = 1,243), with an overall density of 5.96 sea otters/km^2 (NPS and USGS unpublished data). This represents a 22% increase in sea otter population size in this area in the 4 year period 2008 – 2012. The estimated population size in 2008 was 7,095 sea otters (se = 922). With a population size at about 66% of K (carrying capacity), the Kodiak, Kamishak Bay, and Alaska Peninsula MU continues to meet the demographic criterion for delisting.

Conducting aerial surveys for sea otters in the Aleutian Islands is not ideal for various reasons. First, the steep topography and narrow shallow shelf preclude a study design based on random stratified transects, because sea otters inhabit only a narrow strip along the shore. Counts in the Aleutians are made by flying the shoreline of each island, and the counts lack estimates of variability. Additionally, otter behavior in the past two decades has changed. Sea otters are now observed closer to shore than they were 20 years ago, often within a few meters of the shoreline or rocky outcrops, decreasing the detection probability of sighting them from the air and confounding comparisons with earlier datasets (USGS & USFWS unpublished data). Finally, conducting aerial surveys in this vast, isolated area is cost prohibitive, in the range of several hundred thousand dollars to survey the entire Aleutian chain.

For these and other reasons, the Service has worked with USGS to conduct repeated skiff surveys to detect trends in abundance at selected islands (index sites) in the Aleutian Islands, and these efforts are on-going. The islands that have been surveyed have a wide range in physical size, available habitat, and historical sea otter population sizes. These surveys and preliminary results are discussed in detail in the Recovery Plan (USFWS 2013b; see pages 2-13 to 2-15).

Trends in abundance based on skiff survey data from the Western and Eastern Aleutians MUs through 2007 were used in development of a Population Viability Analysis (PVA) model as part of the recovery planning process. The model and its results are discussed in detail in the Recovery Plan (pages 6-1 to 6-6 and Appendix B of the Recovery Plan). In summary, PVAs are useful for understanding how demographic rates (e.g., birth and mortality rates) interact to cause a population to increase, decrease, or remain stable. They have been used widely in the past decade to assess how discrete threats are affecting the continued survival of species of conservation concern.

Objectives of the PVA for this DPS were to develop delisting and uplisting criteria that are flexible and can be modified as new information becomes available, and to provide support for future management decisions. As part of this review, trends in abundance for the Western Aleutians MU were re-examined using new data from 2008 through 2011, which were added to the existing time series. Additionally, the PVA was updated with the new trend information and the delisting and uplisting thresholds were re-estimated. Although not yet finalized and peer-reviewed, these preliminary results are the most up-to-date information available on population trends for the Western Aleutians, and were included in the section "Current Population Trend" in the revised Stock Assessment Report (SAR) for the southwest Alaska DPS (USFWS 2013a). For details of the updated trend analysis and PVA results, see Appendix A of this review.

Population Trend

A Bayesian state-space trend analysis (Clark and Bjornstad 2004) was conducted using all available data compiled from skiff surveys conducted by USGS and USFWS through 2011. Five islands had at least 5 or more surveys, resulting in a total of 42 surveys spanning the period 1993 – 2011: Attu Island (n = 7 surveys), Kiska Island (n = 5), Amchitka Island (n = 9), Adak Island (n = 16), and Kagalaska Island (n = 5).

Updated results indicate that population trends for the Western Aleutians MU over the 1993-2003 period were strongly negative, with an average rate of decline of approximately 20% per year. Population trends changed during the period 2004 – 2011, with an average growth rate of approximately 0. In general, these trends were consistent among islands. Although there was some variation in trends among islands, in all cases the 95% credible intervals (analogous to a confidence interval for frequentist statistics) for the island-specific rates were

negative for time period 1 (1993-2003) but spanned 0 for time period 2 (2004-2011). These results suggest that population trends have stabilized in the western Aleutian Islands over the last 5-8 years, although there is still no evidence of recovery (USGS and USFWS unpublished data; Appendix A).

PVA Summary

The updated PVA results support an adjustment of the delisting threshold, which is the value above which the DPS would be removed from ESA protection, and the uplisting threshold, which is the value below which the DPS would be reclassified as endangered, for each MU (Table 1). In summary, the updated model results support lower delisting and uplisting abundances. For the Eastern and Western Aleutians MUs, we have used a new uplisting threshold of 1.1% of K, or an uplisting density of 0.165 sea otters per km^2 of habitat; and a new delisting threshold of 35% of K, or delisting density of 5.25 sea otters per km^2 of habitat. In the absence of PVA results for the other MUs, we have set the uplisting and delisting threshold values for these MUs to the equivalent proportions of their respective estimates of carrying capacity until more information becomes available (USFWS 2013b; Appendix A). These updated estimates of delisting and uplisting abundance are presented in Table 1. As more information becomes available, the estimates will continue to be refined.

Application of the PVA for the Western and Eastern Aleutians MUs to the other MUs is highly precautionary, in that the Aleutians experienced the steepest population declines and greatest reductions in numbers. PVAs for the remaining MUs will be developed as data become available (see section 4 “Recommendations for Future Actions”).

Table 1. Examples of estimates that were developed by PVA models using available data through 2007, as described in the Recovery Plan (USFWS 2013b), and through 2011 (Appendix A). Estimates shown include carrying capacity, delisting abundance, uplisting abundance, and current status relative to carrying capacity for each of the five Management Units (MUs) in the southwest Alaska DPS of the northern sea otter. These estimates are not fixed, but are dynamic, and will be updated periodically as more data become available.

Management Unit	Date of Estimate	Carrying Capacity (K)	Delisting Abundance	Uplisting Abundance	Abundance Estimate	Status (%K)
Western Aleutians	2007	63,897	31,309	2,556	6,451	0.10
	2011	-	22,364	703	-	-
Eastern Aleutians	2007	30,697	15,042	1,228	2,291	0.07
	2011	-	10,744	338	-	-
Bristol Bay	2007	36,898	18,080	1,476	11,253	0.30
	2011	-	12,914	406	-	-
South Alaska Peninsula	2007	33,476	16,403	1,339	4,724	0.14
	2011	-	11,717	368	-	-
Kodiak, Kamishak, Alaska Peninsula	2007	46,086	22,582	1,843	28,955	0.63
	2011	-	16,130	507	30,504	0.66
Summary	2007	211,054	103,417	8,442	53,674	0.25
Summary	2011	211,054	73,869	2,322	55,223	0.26

Stock Assessment Reports and Guidelines

The National Marine Fisheries Service (NMFS) and USFWS held a workshop in February 2011 to make changes and clarifications to the Guidelines for Assessing Marine Mammal Stocks (GAMMS). GAMMS underlie NMFS policy for implementing provisions of MMPA section 117, and ensure consistent methods for development of marine mammal stock assessments nationwide. One objective of the 2011 workshop was to consider methods for assessing stock status (i.e., how to apply the Potential Biological Removal framework, or PBR) when abundance data are outdated, nonexistent, or only partially available. Workshop recommendations on this and other topics were summarized in a report entitled, "Guidelines for Assessing Marine Mammal Stocks: Report of the GAMMS III Workshop, February 15 – 18, 2011, La Jolla, California" (Moore and Merrick 2011). Additional peer review on the guidelines was solicited in January 2012 (77 FR 3450).

NMFS is in the process of finalizing the changes and clarifications to the GAMMS III guidelines, and the new guidelines will be implemented by NMFS once this process has been completed. While FWS was involved in the workshop, at this time the GAMMS guidelines are not considered FWS policy. The FWS recognizes the value of these efforts and once finalized, FWS will follow the

guidelines to the extent applicable when revising SARs for sea otters and other marine mammals under FWS management authority.

The most current SAR for the Southwest Alaska DPS of the northern sea otter will be finalized in summer 2013. This stock continues to be classified as "depleted" under the MMPA due to its listing as threatened under the ESA. The MMPA requires that depleted stocks are reviewed annually. If the determination is made that the status of the stock has not changed and cannot be more accurately determined, then a revision of the SAR is not warranted for that year. In 2009 and 2010, FWS determined that the status of the southwest Alaska DPS had not changed and could not be more accurately determined, and the SAR for this stock was not revised. Upon the next review, FWS will evaluate whether implementation of the new GAMMS III guidelines will be appropriate for the southwest Alaska DPS.

2.3.1.3 Genetics, genetic variation, or trends in genetic variation (e.g., loss of genetic variation, genetic drift, inbreeding, etc.)

No new information is available to indicate this factor has changed.

2.3.1.4 Taxonomic classification or changes in nomenclature

None

2.3.1.5 Spatial distribution, trends in spatial distribution (e.g., increasingly fragmented, increased numbers of corridors, etc.), or historical range (e.g., corrections to the historical range, change in distribution of the species within its historical range, etc.)

Some anecdotal information was received during our solicitation of public comments. A local observer who has lived in southwest Alaska for many years reported seeing unusually large groups of sea otters around Unalaska Island, in Nantikan Bay, in Broad Bay, on the outside of Amaknak Spit, and near Eider Point. Groups were as large as 60-80 individuals, including mostly females with young. Kelp beds are also growing in new places. He stated that such high numbers of otters have not been seen since the 1940s. The same observer also reported that there has been a slight increase in sea otter numbers in Clam Lagoon, Shagiak Bay, and Bay of Islands in Adak. This information correlates well with survey data from the Aleutians, which indicates that the decline in numbers has leveled off and that numbers may have stabilized or even increased locally (see section 2.3.1.2).

2.3.1.6 Habitat or ecosystem conditions (e.g., amount, distribution, and suitability of the habitat or ecosystem)

No new information is available to indicate this factor has changed.

2.3.1.7 Other

None

2.3.2 Five-Factor Analysis (threats, conservation measures, and regulatory mechanisms)

2.3.2.1 Present or threatened destruction, modification or curtailment of its habitat or range

Present or future destruction of habitat is not considered to be a factor that will limit recovery, however, the Service continues to engage in Section 7 consultations on projects to minimize potential adverse impacts to sea otter habitat. The U.S. Army Corps of Engineers (Corps) has been the primary federal agency engaging in activities that trigger Section 7 consultation within the range of the listed entity. The Service worked with the Corps to identify their permit actions authorized under Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act that may adversely affect sea otter habitat. Corps permits that could potentially impact sea otter critical habitat involve docks, harbors, shoreline fill for upland use, in-stream work, wetland fill, erosion control, drilling, dredging, and cable/pipe laying. Projects that involve filling shorelines are considered to have the most direct impact on sea otter habitat. Of 79 projects authorized by the Corps between 2007 and 2012, approximately 26 involved intertidal or marine fill within sea otter critical habitat. For those projects, the average loss of sea otter critical habitat per project was 1.3 acres, ranging from 0.1 to 6.7 acres of shallow marine or intertidal habitat, and totaling approximately 33 acres overall. If extrapolated over the next 100 years (assuming permit patterns remain the same), approximately 590 acres could be lost. This is a small fraction of the total designated critical habitat for sea otters. The importance of critical habitat, however, not only includes the amount available but also the features of the habitat. The Service currently lacks sufficient information in many areas to determine where these important habitat features are located, but is engaged in on-going efforts to identify high-use areas ("hot spots") to improve recommendations on future federal activities.

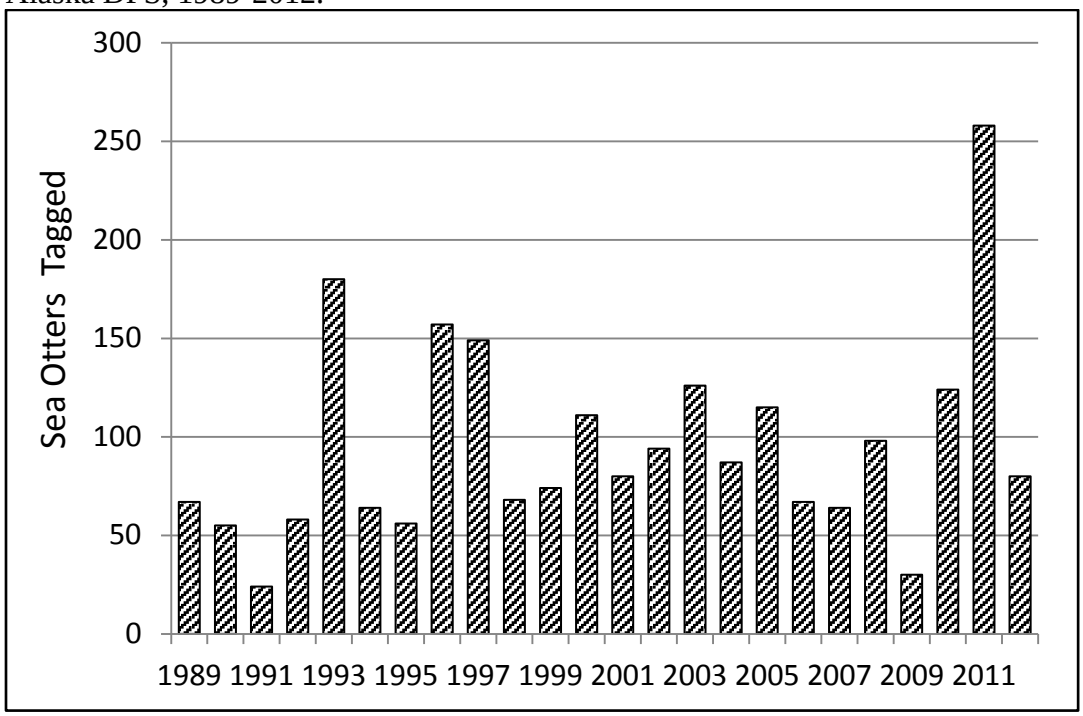
2.3.2.2 Overutilization for commercial, recreational, scientific, or educational purposes

Subsistence harvest. Harvest of marine mammals by Alaska Natives is authorized under Section 101(b) of the MMPA and section 10(e) of the ESA, provided the taking is for subsistence purposes or for the purpose of creating and selling authentic native articles of handicrafts and clothing, and is not wasteful (MMPA) or does not materially and negatively affect the species (ESA). The subsistence harvest of sea otters is monitored by the Service through a marine mammal Marking, Tagging, and Reporting Program (MTRP). The MTRP was established in 1989 in accordance with Section 109(i) of the MMPA. Implementing regulations for the MTRP require hunters to present hides and skulls of sea otters to an authorized Service representative, known as a "tagger," within 30 days of harvest. In addition to attaching tags to the hide and skull, taggers collect biological information about the otter (age class and sex) as well as about the harvest itself (date and location) and attach uniquely numbered plastic tags to the hide and skull. The information is entered into a computer database.

Although there is recognition that some legal sea otter harvest may not be reported, this program is considered sufficient by the Service to indicate whether subsistence harvest levels are a threat to the recovery of the southwest Alaska DPS of sea otters. The Recovery Team concluded that subsistence harvest is a low threat to four of the MUs, and is a moderate threat to the Kodiak, Kamishak, Alaska Peninsula MU, based on the fact that Kodiak Island has the largest human population and the largest reported subsistence harvest (USFWS 2013b).

New harvest data for the southwest Alaska DPS of sea otters indicate that subsistence harvest continues to be variable and generally low (Figure 1). For the past 5 years for which harvest data are complete, 2008-2012, the average reported subsistence harvest for the southwest Alaska DPS was 118 sea otters. For the same 5 year period, the average reported subsistence harvest for the Kodiak archipelago was 101 sea otters, representing an annual average of about 74.8% of the reported harvest for the southwest Alaska DPS. The harvest has been comprised predominantly of adults, and about 81% are males. An average of about 1.07% of the estimated population size of the Kodiak archipelago is reported as harvested for subsistence purposes each year. The current level of harvest is not excessive in relation to the population size, and is not thought to be a population-regulating factor (USFWS 2013b).

Figure 1. Reported subsistence harvest of northern sea otters from the southwest Alaska DPS, 1989-2012.



Illegal harvest. The illegal take of sea otters within the range of the southwest Alaska DPS is thought to be low, and all known occurrences have been in the Kodiak, Kamishak, Alaska Peninsula MU where the largest human population resides (see USFWS 2013b for review). The Aleutian Islands are remote, difficult to access, experience weather and wind extremes, and support few communities. Most of the Aleutian Islands are uninhabited. The Western and Eastern Aleutians MUs have experienced the steepest population declines, but declines appear to be consistent across inhabited and uninhabited islands. The Bristol Bay and South Alaska Peninsula MUs are similarly remote and sparsely populated. The Recovery Team concluded that illegal harvest is a low threat to four of the MUs, and is a moderate threat to the Kodiak, Kamishak, Alaska Peninsula MU (USFWS 2013b) where the largest human population resides. Although illegal take may have occurred and may occur in the future, it is likely that the numbers are small and any impact on the recovery of the DPS would be minimal.

2.3.2.3 Disease or predation

Since 2002 the Service has been collecting and analyzing sea otter carcasses that have been obtained from the three Alaska stocks. The southwest Alaska DPS has yielded the fewest carcasses because sea otter concentrations in the southwest part of the state are not close to large centers of human population compared to the southeast and southcentral stocks. For example, the large number of sea otter carcasses recovered from the southcentral stock, which spurred the declaration of an Unusual Mortality Event (UME) in 2006, was later determined to be partly a result of increased public interest in reporting and collecting stranded marine mammals in Kachemak Bay rather than a spike in mortality.

In general, causes of death and disease prevalence do not differ among the three Alaska stocks. In our investigations using recovered sea otter carcasses, causes of death range from directly human-caused (gunshot, bycatch, boat strike) to disease (*Streptococcus bovis* complex, carcinoma) to idiopathic causes (starvation, impaction, torsion). There have been no apparent changes in these causes over time. The Service is conducting a full epidemiological survey of data collected from stranded animals over the past decade and it is hoped that this summary will illustrate some patterns of mortality that can be used to further assess disease risks and threats.

In addition, the health and disease parameters of all live sea otters captured across the three stocks has been monitored. An assessment of clinical pathology and pathogen exposure in sea otters in and on the borders of the southwest stock was conducted in 2011 (see Goldstein et. al 2011). The study determined that the general health of sea otters was not different on either end of the listed population. However, it was determined that exposure to *Phocine distemper* virus (PDV) has increased in sea otters in Kodiak since the 1990s. Because PDV can be highly pathogenic in naïve and susceptible marine mammal populations, the Service has an on-going study to examine tissues to explore the contribution of this virus to sea otter mortality.

In 2007, the Service began a joint project with the Alaska Department of Fish and Game (ADF&G) to examine the role of chlorinated fatty acids (CFAs) in sea otter disease in Alaska. While preliminary results indicated that concentrations of CFAs in sea otter heart muscle were high and that regional differences in exposure existed across the range of tested sea otters (Smith et al. 2008), sample sizes were too small to be conclusive.

In 2009, the Service initiated a joint project with the Alaska Department of Fish and Game (ADF&G) to examine causes of mortality of sea otters in Kamishak Bay, Alaska. This area encompasses part of the listed DPS and is across Cook Inlet from Kachemak Bay, where the 2006 UME was declared. The study was intended to evaluate the role disease may have played in the decline of sea otters as well as how disease may, or may not, limit their recovery. Although a total of 17 sea otter remains were collected over the three years of the study, only 2 were carcasses suitable for necropsies (Gill 2009, Gill 2010, Gill 2011). Cause of death was determined to be hypoglycemia or hypothermia in a 2 – 3 month old abandoned or orphaned pup. A second carcass was found and sent in for necropsy but the cause of death could not be determined due to decomposition

In August of 2012, USGS led an effort to capture sea otters in Clam Lagoon, Adak. Sea otter densities within the lagoon remain relatively high compared to surrounding areas, presumably because the shallow, narrow entrance to the lagoon restricts killer whale access, providing a refugium from predation for sea otters. Captured sea otters were sedated, measured and weighed, and blood was drawn to evaluate health and body condition. Each otter received unique color-coded flipper tags for identification, and tooth wear was evaluated to assist in age estimation. Collected samples will allow characterization of diet, which will inform understanding of behavior and habitat use, such as whether sea otters venture outside the lagoon or remain there. Similar information was earlier collected from sea otters outside the lagoon before and after the population decline, and from sea otters inside the lagoon before the decline. When finalized, results from this study will be included in future sea otter assessments and management decisions as appropriate.

Section 4.0 of this review describes future actions that will help the Service to further examine the roles of disease and predation in the decline and recovery of the southwest Alaska DPS of sea otters.

2.3.2.4 Inadequacy of existing regulatory mechanisms

The Recovery Team concluded that the inadequacy of existing regulatory mechanisms, including the MMPA and the ESA, did not contribute to the sea otter decline. There is no information to indicate that this conclusion should be changed.

2.3.2.5 Other natural or manmade factors affecting its continued existence

There is no new information to indicate that this factor has changed.

2.4 Synthesis

The southwest Alaska DPS of the northern sea otter was listed as threatened under the ESA in August 2005 (70 FR 46366). At that time, the population was also recognized as depleted pursuant to the MMPA. This population experienced a rapid decline in abundance of more than 50% since the late 1980s. At the time of the 2005 final listing rule, we estimated that the DPS consisted of approximately 42,000 sea otters.

The PVA model developed to assist in recovery planning was updated and re-run to inform the 5-year-review process. The model, initially developed using trend and demographic data through 2007, was updated to incorporate new data obtained from skiff surveys conducted in the Western Aleutians MU from 2007 - 2011. The new PVA results indicate that population trends have stabilized in the Western and Eastern Aleutians MUs, although there is no evidence of recovery, and numbers remain well below historical levels (USFWS 2013a). The updated model also supports lower delisting and uplisting abundances for the Western and Eastern Aleutians MUs.

We concluded that it is also reasonable and precautionary to adjust the uplisting and delisting thresholds in the remaining 3 MUs, using the same model outputs used for the Western and Eastern Aleutians MUs, which had previously experienced the steepest population declines and greatest reductions in numbers. Unique outputs for the remaining MUs will be developed as data become available (see section 4 “Recommendations for Future Actions”).

The only threat factor identified in the Recovery Plan as having high importance to recovery is predation, most likely by killer whales (*Orcinus orca*). Other threats, including infectious disease, biotoxins, contaminants, oil spills, food limitation, disturbance, fisheries bycatch, subsistence harvest, loss of habitat, and illegal take, were identified as potential threats but considerable uncertainty remains about their contribution to population trends. This review supports these conclusions, and finds no new information to alter these conclusions.

Based upon the best information currently available, the listing status of this DPS as threatened should remain and we should move forward with implementing actions identified in the recovery plan to the extent possible. The objective of the recovery plan is to delist this DPS through implementation of a variety of recovery measures which are outlined in section 4.0.

3.0 RESULTS

3.1 Recommended Classification: *Given your responses to previous sections, particularly section 2.4. Synthesis, make a recommendation with regard to the listing classification of the species*

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist (*Indicate reasons for delisting per 50 CFR 424.11):*
- ____ *Extinction*
- ____ *Recovery*
- ____ *Original data for classification in error*

__X__ No change is needed

4.0 RECOMMENDATIONS FOR FUTURE ACTIONS

1) Monitor for trends in sea otter abundance at existing index sites in the Western Aleutians MU, and establish index sites in the Central Aleutians. Monitoring surveys should be conducted every 2 to 3 years. Estimate sea otter population size in Lower Cook Inlet, the Kodiak Archipelago, and along the Alaska Peninsula.

Recovery action number: 1.1. Continue to estimate sea otter population size and trends in southwest Alaska (1.1.2. Conduct surveys in each Management Unit and estimate abundance and population trends); 1.5.1. Investigate PVA models for the Bristol Bay, South Alaska Peninsula, and Kamishak, Kodiak, Alaska Peninsula MUs

2) Continue ecosystem studies in the central and western Aleutians to assess the ecosystem-based recovery criterion of whether greater than 50 percent of islands are in the kelp-dominated state. Metrics include sea otter density and distribution; kelp diversity, density, and coverage; and prey diversity, density, and size, especially for sea urchins.

Recovery action number: 1.6. Monitor the functional role of sea otters in the ecosystem (1.6.1. Monitor status of the kelp forest ecosystem); 2.1. Identify important habitats or areas of special biological significance

3) Develop a specialized telemetry transmitter suitable for implantation in sea otters that can help determine survival and causes of mortality.

Recovery action number: 1.2. Estimate vital rates (1.2.1. birth rates and 1.2.2. survival rates); 1.5.1. Investigate PVA models for the Bristol Bay, South Alaska Peninsula, and Kamishak, Kodiak, Alaska Peninsula MUs; 4.1.5. Evaluate population-level effects of disease; 5.1. Continue to evaluate the role of predation as a threat to recovery;

4) Examine genetic structure of the southwest Alaska DPS of sea otters to determine whether MUs as described in the recovery plan could be uplisted or delisted separately from other MUs.

5.0 REFERENCES

Clark, J.S. and O.N. Bjornstad. 2004. Population time series: Process variability, observation errors, missing values, lags, and hidden states. Ecology 85:3140-3150.

Coletti, H., J. Bodkin, T. Dean, and K. Kloecker. 2009. Nearshore marine vital signs monitoring in the Southwest Alaska Network of National Parks. Natural Resource Technical Report NPS/SWAN/NRTR-2009/252. National Park Service, Fort Collins, Colorado.

Doroff, A.M., J.A. Estes, M.T. Tinker, D.M. Burn, and T.J. Evans. 2003. Sea otter population declines in the Aleutian Archipelago. Journal of Mammalogy 84:55-64.

Gill, V.A. 2009. 2009 Trip Report for Cooperative Endangered Species Conservation Fund (Section 6 ESA) Project: Causes of mortality for threatened northern sea otters in Kamishak Bay, Alaska. Unpublished Trip Report, USFWS, Anchorage, Alaska.

Gill, V.A. 2010. 2010 Trip Report for Cooperative Endangered Species Conservation Fund (Section 6 ESA) Project: Causes of mortality for threatened northern sea otters in Kamishak Bay, Alaska. Unpublished Trip Report, USFWS, Anchorage, Alaska.

Gill, V.A. 2011. 2011 Trip Report for Cooperative Endangered Species Conservation Fund (Section 6 ESA) Project: Causes of mortality for threatened northern sea otters in Kamishak Bay, Alaska. Unpublished Trip Report, USFWS, Anchorage, Alaska.

Goldstein, T., V.A. Gill, P. Tuomi, D. Monson, A. Burdin, P.A. Conrad, J.L Dunn, C. Field, C. Johnson, D.A. Jessup, J. Bodkin and A.M. Doroff. 2011. Assessment of clinical pathology and pathogen exposure in sea otters (*Enhydra lutris*) bordering the threatened population in Alaska. Journal of Wildlife Diseases 47(3): 579–592.

Moore, J.E., and R. Merrick, editors. 2011. Guidelines for Assessing Marine Mammal Stocks: Report of the GAMMS III Workshop, February 15 – 18, 2011, La Jolla, California. Dept. of Commerce, NOAA Technical Memorandum NMFS-OPR-47.

NOAA. 2008. Conservation Units of Managed Fish, Threatened or Endangered Species, and Marine Mammals. Report of a Workshop: February 14-16, 2006. Silver Spring, Maryland. Technical Memorandum NMFS-OPR-37. 108 pp.

Smith, R.T., A.M. Doroff, V.A. Gill, L.D. Rea, and J.M. Kennish. 2008. Chlorinated fatty acids (CFAs) in Alaskan sea otters. Poster presentation at the Alaska Marine Science Symposium, Anchorage, Alaska, January 2-23, 2008.

USFWS. 2013a. Sea Otter (*Enhydra lutris*): southwest Alaska stock. Marine Mammal Protection Act Stock Assessment Report. 8 pp.

USFWS. 2013b. Southwest Alaska Distinct Population Segment of the Northern Sea Otter (*Enhydra lutris kenyoni*) Recovery Plan. U.S. Fish and Wildlife Service, Region 7, Alaska. 171 pp.

U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of the
Southwest Alaska DPS of the Northern Sea Otter

Current Classification: Threatened

Recommendation resulting from the 5-Year Review:

____ Downlist to Threatened
____ Uplist to Endangered
____ Delist
__X__ No change needed

Appropriate Listing/Reclassification Priority Number, if applicable:

Review Conducted By: Suzann Speckman, Marine Mammals Management, 907 786-3479

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve _____ Date 8/13/13

The lead Field Office must ensure that other offices within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. The lead field office should document this coordination in the agency record.

REGIONAL OFFICE APPROVAL:

The Regional Director or the Assistant Regional Director, if authority has been delegated to the Assistant Regional Director, must sign all 5-year reviews.

Lead Regional Director, Fish and Wildlife Service

Approve Kaemp Clark Date 8/21/13

The Lead Region must ensure that other regions within the range of the species have been provided adequate opportunity to review and comment prior to the review's completion. Written concurrence from other regions is required.

Cooperating Regional Director, Fish and Wildlife Service

_____Concur _____ Do Not Concur

Signature_____ Date_____

Southwest Alaska Distinct Population Segment of the Northern sea otter (*Enhydra lutris kenyoni*) Population Viability Analysis (PVA) Update, June 2013.

Dr. M. Tim Tinker, US Geological Survey Western Ecological Research Center, Santa Cruz Field Station

As part of the 5-year review of the southwest Alaska DPS of the northern sea otter, the US Fish and Wildlife Service requested a re-analysis of the status and trends of sea otter populations, including a re-running of the Population Viability Analysis (PVA) model using the most up-to-date available data. Accordingly, data were compiled from all skiff surveys that had been conducted at index sites in the Western Aleutian Management Unit since 2007 (see Table 1). These more recent surveys were not included in the original version of the PVA model included in the draft Recovery Plan (USFWS 2010). However, a key advantage of the PVA model structure developed for the Recovery Plan was that it is both possible and in fact recommended that the model be re-run as new data or information become available, thereby avoiding the inevitable obsolescence of fixed listing threshold recommendations. In particular, it was recognized that if survey trends remained stable or positive, that the incorporation of more years of survey data into the PVA model parameterization would potentially lead to a higher proportion of simulations with positive population growth. It was recommended that this process be conducted at 5-year intervals, and the up-listing and de-listing thresholds be updated accordingly. In the re-running of the PVA model, the probabilistic definitions of the thresholds would not change, but the specific numerical estimates could change to reflect the most recent data.

Methods

A re-analysis of population trends was conducted for the western Aleutian Islands, the western-most management unit of the SW Alaska stock. This region, consisting of 4 Island groups (from west to east, the Near Islands, Rat Islands, Delarof Islands, and Adreanof Islands), exhibited a pronounced population decline in the 1990s (Doroff et al 2003, Estes et al 2005). A Bayesian state-space trend analysis (Clark and Bjornstad 2004) was conducted for the Islands with the most complete survey records (5 or more skiff surveys spanning the period 1993 – 2010). Data were compiled from skiff surveys conducted by USGS and USFWS for 5 Islands: Attu Island (n = 7 surveys), Kiska Island (n = 5), Amchitka Island (n = 9), Adak Island (n = 16) and Kagalaska Island (n = 5), for a total of 42 surveys (Table 1). Counts were standardized by converting to linear densities (numbers of sea otters counted per km of coastline), and a hierarchical exponential model was fit that allowed for random differences between Islands, and also allowed for a time-varying rate of change (r). Specifically, the discreet population growth rate (defined as $r = \log(\lambda)$, where $\lambda = N_t / N_{t-1}$) was estimated for two periods: $t(1)$ = 1993-2003 and $t(2)$ = 2003-2011. At each Island and for each time period, the Island- and time-specific rate of growth ($r_{i,t}$) was assumed to be drawn from a normal distribution with mean $r(t)$ and standard deviation σ_r. The parameters of interest were the regional growth rates for each period, $r(t)$, and additional estimated parameters included the observer error (σ_{obs}), spatial variation in r (σ_r), and the initial population densities at each Island ($N_{i,0}$). Note that we assumed that observation error (σ_{obs}) was the predominant source of year-to-year variability in the counts at each Island after accounting for the difference in r between time periods and the random variation in $r(t)$ among Islands. To fit the model we used a Markov Chain Monte Carlo (MCMC) Gibbs sampling algorithm implemented using the OpenBUGS software package, with

uninformed (vague) prior distributions for all parameters. We ran MCMC simulations initially for 100,000 iterations to ensure convergence, and then for another 100,000 iterations to obtain posterior distributions for each parameter. We report the means and 95% credible intervals (CI_{95}) for each parameter.

The new skiff count data described above were added to existing time-series, and used to re-run the PVA model for the southwest Alaska DPS of the northern sea otter. A detailed description of the development and parameterization of this PVA model can be found in Appendix B of the Recovery Plan (USFWS 2013). The approach to the PVA model can be summarized as five main steps:

1) We develop a matrix-based population model to simulate dynamics in a population that is spatially structured into demographically-distinct sub-populations, linked by dispersal.

2) Using the updated time-series of population surveys available for various islands throughout the Aleutian archipelago, we use maximum-likelihood estimation (MLE) techniques to estimate the annual per-capita death rate (δ) associated with an age-independent source of mortality (e.g., predation) responsible for the recent decline, as well as variation in this parameter. Nine different MLE model forms were evaluated for variation in δ, ranging from a constant value to more complex models including linear and non-linear effects of time and population density (Table 2). Information theory criteria (specifically, AIC values) were used to select the best model (Burnham and Anderson 2002). Recognizing that the particular combination of Islands selected for analysis would potentially affect which model provided the best fit, we took 1000 boot-strap re-samples of the Island time series and re-fit the MLE model to each. These iterated MLE model fits were used for subsequent steps of the PVA analysis, thereby accounting for sampling error and model selection uncertainty

3) For each Management Unit, we simulate 25 years of population dynamics using model projections that incorporate a) density-dependent variation in vital rates and inter-island dispersal, b) variation in age-independent mortality (δ) and c) environmental and demographic stochasticity. To account for various sources of uncertainty (including sampling error and model selection uncertainty: see step #2), we run 1000 simulations and allow all parameters to vary according to the appropriate variance distributions.

4) The suite of simulations described in step #3 are re-run with 10 different starting densities, and for each initial density we record the proportion of simulations that go to extinction within a 25 year period (Ω). We then solve for the density at which $\Omega = 0.05$, the point at which there is ≥ 5% probability of extinction within a 25 year period. This critical density, Ω^{05}, is suggested as an appropriate value for the up-listing threshold, D^U.

5) The suite of simulations are again re-run with 10 different starting densities, and for each initial density we record ω, the proportion of simulations in which population abundance drops to D^U, the up-listing threshold. We then solve for the density at which $\omega = 0.05$; above this density there is <5% probability of the population becoming endangered (dropping below D^U) within 25 years. This critical density, ω^{05}, is suggested as an appropriate value for the de-listing threshold, D^D.

Results

The results of the Bayesian hierarchical trend analysis for 5 Islands in the western Aleutian Islands (Figure 1) indicated that the population trends for the western Aleutian Islands over the 1993-2003 period were strongly negative (Figure 2a), with an average rate of decline of approximately 20% per year ($r(1)$ = -0.206, CI_{95} = -0.3099 – -0.1023). Population trends changed during the later period (2003 – 2011; Figure 2b), with an average growth rate of approximately 0 ($r(2)$ = -0.008, CI_{95} = -0.1262 – 0.1108). In general these trends were consistent among Islands (Figure 3): although there was some variation in trends among Islands, in all cases the 95% CI for the Island-specific rates were negative for period 1 but spanned 0 for period 2. These results suggest that population trends have stabilized in the western Aleutian Islands over the last 5-8 years, although there is still no evidence of recovery.

The PVA model was re-run for the Western Aleutian and Eastern Aleutian Management Units using the updated survey time-series. Of the nine different functional forms evaluated for variation in age-independent mortality (δ) there was greatest empirical support for model 9 (Figure 4), which included first and second order effects of both time and density (Table 2). In general, best-fit models suggest that δ increased through the 1990s but has since declined, and that the highest rate of mortality occurs at densities of 6-10 sea otters per km^2 but decreases sharply at lower densities (Figure 5). The temporal trends in mortality coupled with the low densities that currently prevail throughout the Aleutians mean that the effect of age-independent mortality on population growth is now relatively small, and thus population trends have stabilized at most index sites (Figure 6).

Incorporating these new parameter estimates (and associated uncertainty) into simulations of future population growth resulted in somewhat more positive projections as compared to the earlier (2007) PVA results. The first critical density, Ω^{05}, below which >5% of simulations went to extinction within a 25-year period, was 608 otters (95%CI = 543-647) in the Western Aleutian Management Unit and 310 otters (95%CI = 293-325) in the Eastern Aleutian Management Unit. These densities correspond to 1.05% of *K* (95%CI = 0.94-1.12) for the Western Aleutians (Figure 7) and 0.77% of K (95%CI = 0.72-0.80) for the Eastern Aleutians. The second critical density, ω^{05}, above which <5% of simulations dropped to Ω^{05} within a 25-year period, was 16,035 otters (95%CI = 12,843-20,380) in the Western Aleutian Management Unit and 13,644 otters (95%CI = 11,291-16,677) in the Eastern Aleutian Management Unit. These densities correspond to 27.80% of *K* (95%CI = 22.27-35.34) for the Western Aleutians (Figure 8) and 33.63% of *K* (95%CI = 27.83-41.11) for the Eastern Aleutians.

Based on these results, it can be reasonably inferred that the updated PVA supports an adjustment of up-listing and de-listing thresholds. For the Aleutian management units we would suggest a new up-listing threshold of 1.1% of *K*, or D^U = 0.165 sea otters per km^2 of habitat, and a new de-listing threshold of 35% of *K*, or D^D = 5.25 sea otters per km^2 of habitat. In the absence of PVA results for the other management units, a reasonable approach would be to set the up-listing and de-listing threshold values for these management units to the equivalent proportions of their respective carrying capacity estimates.

Literature Cited

Burnham, K. P. and D. R. Anderson. 2002. Model selection and inference: a practical information-theoretic approach. 2nd edition. Springer-Verlag, New York, NY.

Clark, J. S. and O. N. Bjornstad. 2004. Population time series: Process variability, observation errors, missing values, lags, and hidden states. Ecology **85**:3140-3150.

USFWS. 2010. Southwest Alaska Distint Population Segment of the Northern sea otter (*Enhydra lutris kenyoni*) - Draft Recovery Plan. . U.S. Fish and Wildlife Service, Region 7, Alaska, Anchorage, AK.

USFWS. 2013b. Southwest Alaska Distinct Population Segment of the Northern Sea Otter (*Enhydra lutris kenyoni*) Recovery Plan. U.S. Fish and Wildlife Service, Region 7, Alaska. 171pp.

Tables

Table 1. Time series of skiff counts of sea otter numbers at 5 index sites in the western Aleutian Islands.

Island	Year	Shoreline Length (km)	Number Independ. Otters	Number Otter Pups	Total Sea Otters	Otter Density (#/km)
Adak	1993	117.3898	718	149	867	7.38565
	1995	359.5835	929	156	1085	3.01738
	1996	354.0461	725	146	871	2.460131
	1997	372.311	688	127	815	2.18903
	1998	372.311	525	86	611	1.641101
	1999	372.311	635	124	759	2.038618
	2000	372.311	713	148	861	2.312583
	2001	372.311	515	117	632	1.697506
	2002	372.311	461	112	573	1.539036
	2003	372.311	306	91	397	1.066313
	2004	372.311	277	75	352	0.945446
	2005	361.261	209	41	250	0.692021
	2006	372.311	272	62	334	0.8971
	2007	372.311	204	57	261	0.701027
	2008	353.448	158	35	193	0.546049
	2010	357.8286	184	69	253	0.707042
Amchitka	1993	49.37514	641	159	800	16.20249
	1999	141.3271	356	75	431	3.049664
	2000	30.26423	117	40	157	5.187642
	2003	39			294	7.538462
	2004	38.54918	65	15	80	2.075271
	2005	39			82	2.102564
	2007	39			155	3.974359
	2009	39			159	4.076923
	2011	39			74	1.897436
Attu	1994	272.3576	4156	1250	5406	19.84891
	2000	272.3576	436	170	606	2.225016
	2003	272.3576			132	0.484657
	2005	272.3576			147	0.539732
	2007	272.3576			319	1.171254
	2009	272.3576			318	1.167583
	2011	272.3576			292	1.07212
Kagalaska	1993	88.78112	191	36	227	2.55685
	1997	88.78112	26	6	32	0.360437
	2000	88.78112	43	11	54	0.608237
	2003	88.78112	11	4	15	0.168955
	2006	88.78112	11	2	13	0.146428
Kiska	1993	93.87849	516	146	662	7.051669
	2003	93.87849			230	2.449976
	2005	93.87849			159	1.693679
	2007	93.87849			186	1.981285
	2009	93.87849			260	2.769538

Table 2. Alternate functional forms evaluated for modeling δ, the per-capita rate of age-independent mortality. In each case δ was calculated as a logit of *f*, the function listed in column 2, using the equation:

$$\delta(D, t) = e^{f(D,t)} / 1 + e^{f(D,t)}$$

The simplest function evaluated (Model 1) corresponds to a constant rate of mortality, while the remaining eight models represent linear or non-linear functions of density (D), time (t), or density and time. The symbols $\psi_1, \psi_2 \ldots \psi_n$ represent parameters fit by maximum-likelihood (see text for further details).

Model ID	Functional Form for f(D,t)
1	$f(D,t) = \psi_1$
2	$f(D,t) = \psi_1 + \psi_2 \cdot t$
3	$f(D,t) = \psi_1 + \psi_2 \cdot t + \psi_3 \cdot t^2$
4	$f(D,t) = \psi_1 + \psi_2 \cdot D$
5	$f(D,t) = \psi_1 + \psi_2 \cdot D + \psi_3 \cdot D^2$
6	$f(D,t) = \psi_1 + \psi_2 \cdot D + \psi_3 \cdot t$
7	$f(D,t) = \psi_1 + \psi_2 \cdot D + \psi_3 \cdot D^2 + \psi_4 \cdot t$
8	$f(D,t) = \psi_1 + \psi_2 \cdot D + \psi_3 \cdot t + \psi_4 \cdot t^2$
9	$f(D,t) = \psi_1 + \psi_2 \cdot D + \psi_3 \cdot D^2 + \psi_4 \cdot t + \psi_5 \cdot t^2$

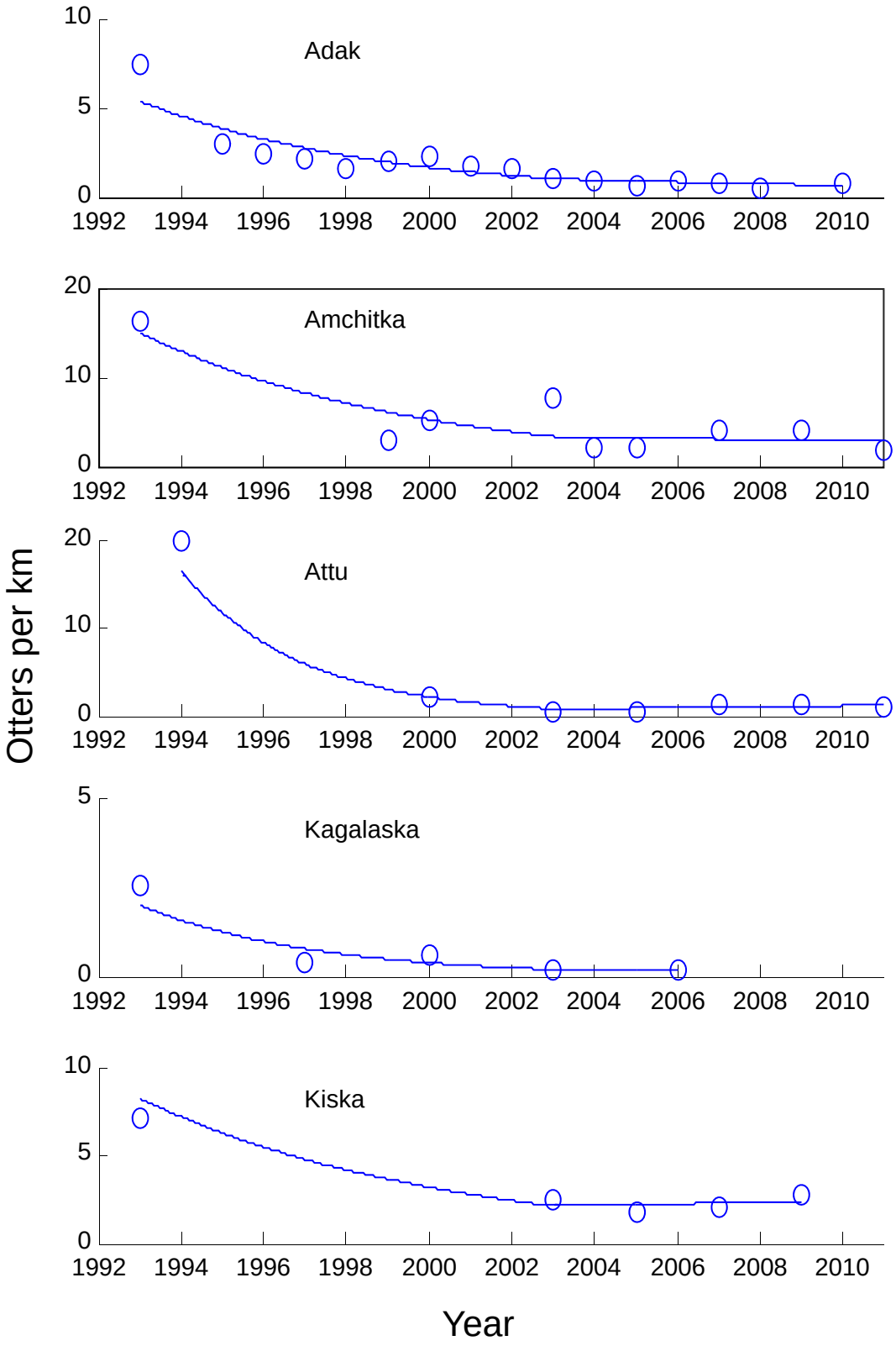


Figure 1. Fitted exponential trends in sea otter populations at 5 Islands in the western Aleutian Islands

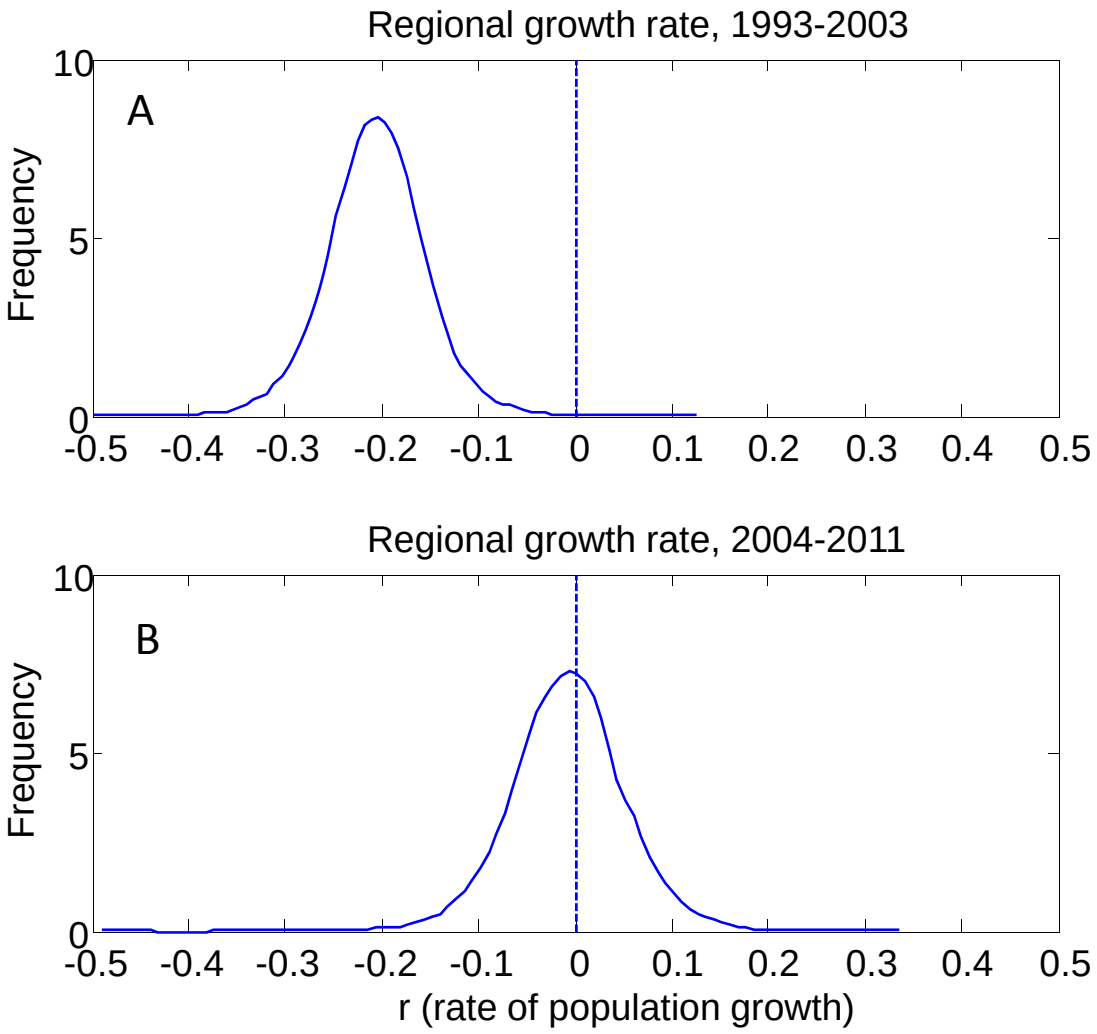


Figure 2. Posterior probability distribution for r, the discreet instantaneous rate of growth in sea otter populations, for two time periods: A) 1993 – 2003, and B) 2004-2011.

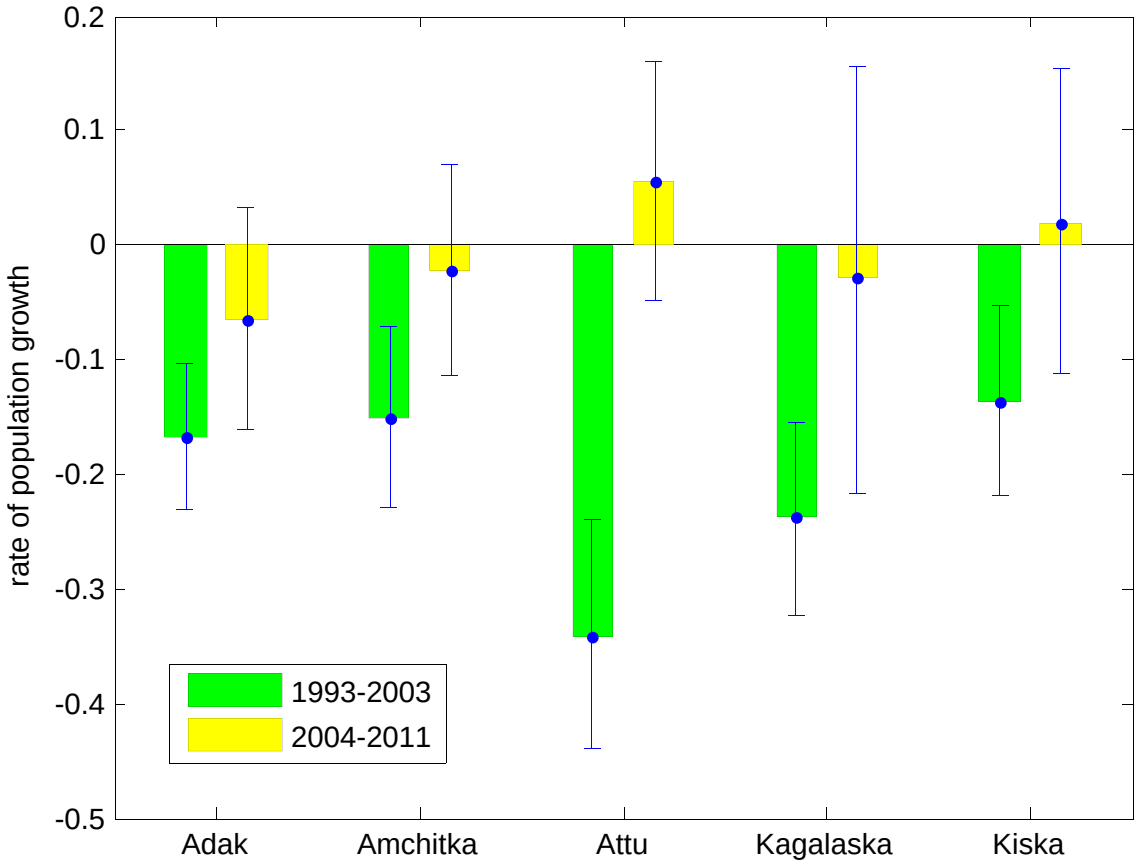


Figure 3. Temporal variation in the island-specific rate of population growth at 5 different Islands in the western Aleutian Island management unit. The rate of growth is shown for two different time periods at each Island, with error bars indicating the 95% credible intervals for each estimate.

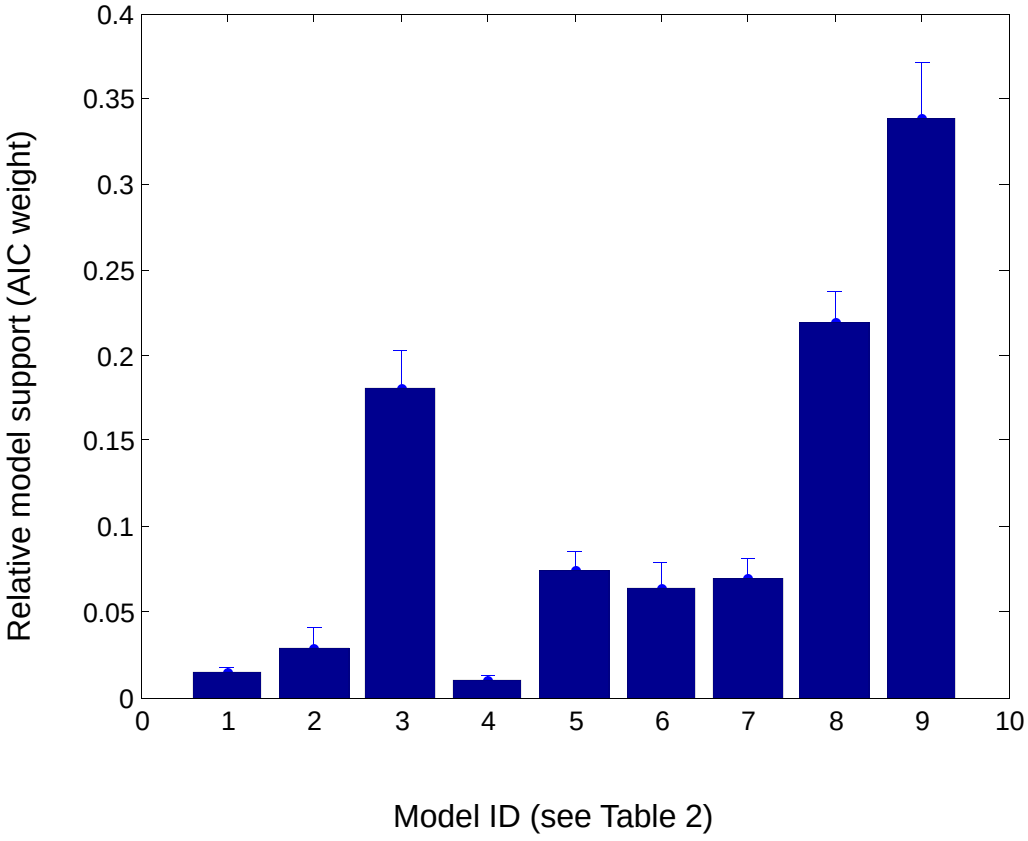


Figure 4. Relative degree of empirical support for each of 9 different functional forms for maximum likelihood estimation (MLE) of "age-independent mortality" (δ) based on time-series of skiff counts of sea otters at index sites in the Aleutians. See Table 2 for definitions of each model. MLE solutions were found and AIC weights were estimated for each of 1000 boot-strap samples of the skiff count time series. Mean AIC weights for each model are shown, with error bars corresponding to standard deviations of AIC weights.

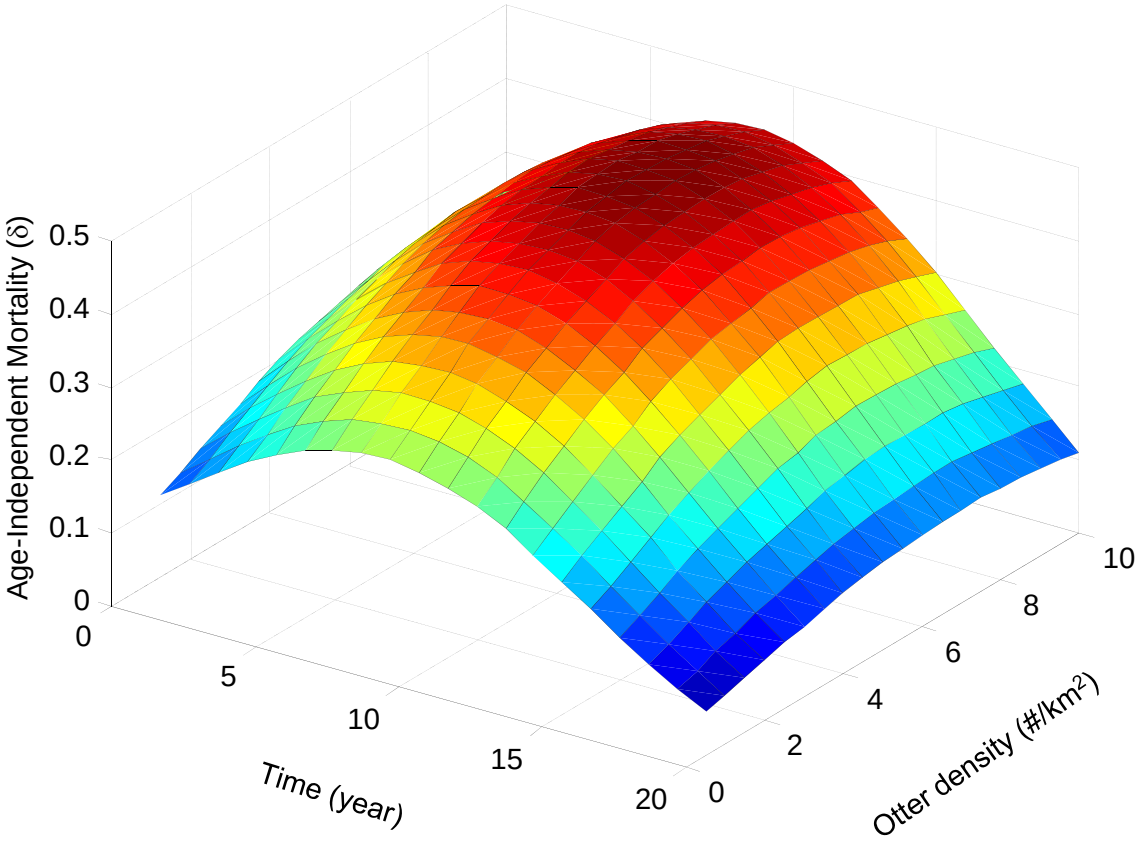


Figure 5. Variation in "age-independent mortality" (δ) as a function of time and sea otter density, as estimated by maximum likelihood analysis of time-series of skiff counts (see text and Table 2, model 9).

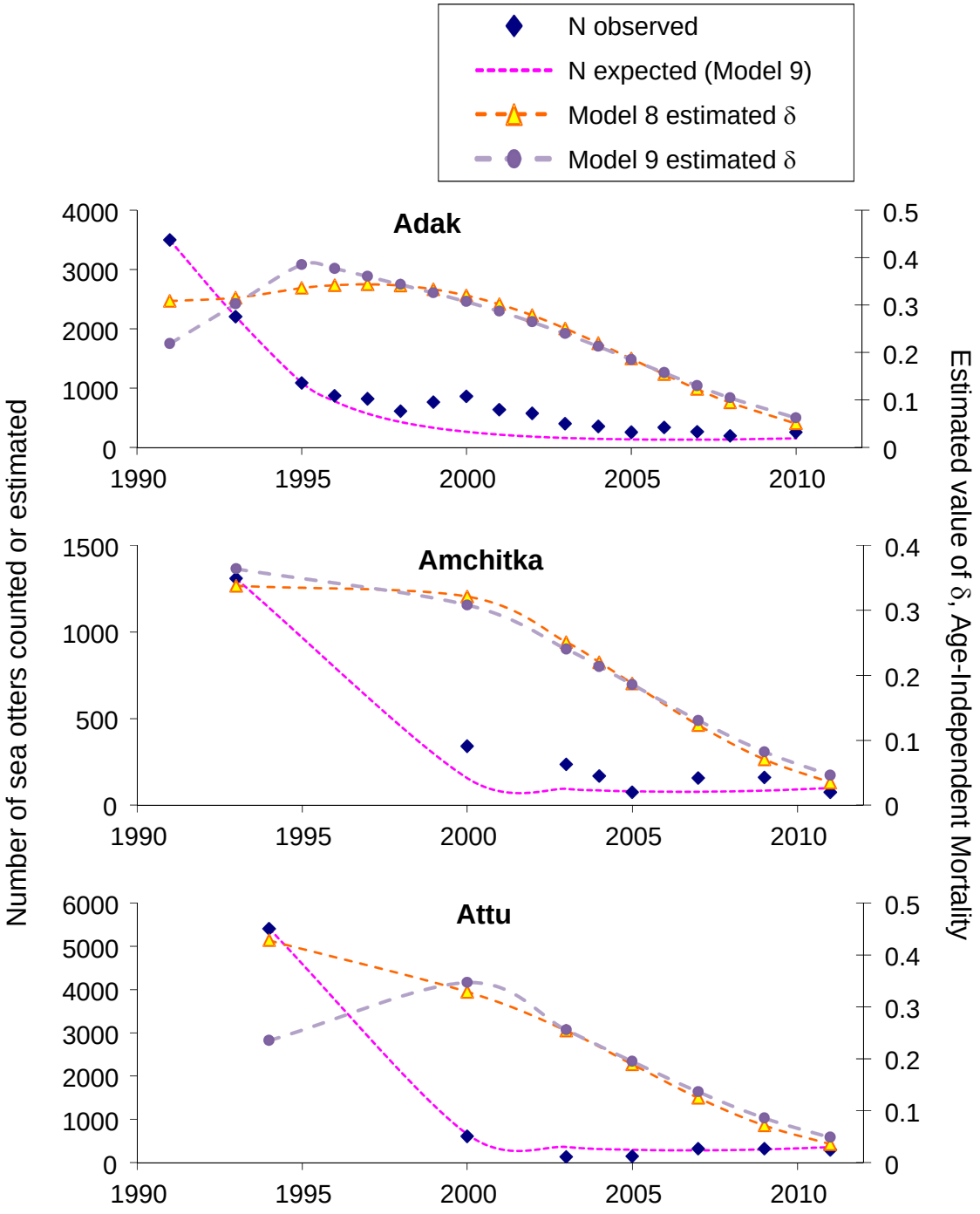


Figure 6. Trends in skiff counts of sea otter abundance at three index sites in the western Aleutians, Adak Island (top panel), north-eastern Amchitka Island (middle panel) and Attu Island (bottom panel). Also shown are the expected trends based on maximum likelihood analysis (see text) and the corresponding point estimates of age-independent mortality (δ) responsible for driving these trends (estimates shown for model 8 and 9; see Table 2).

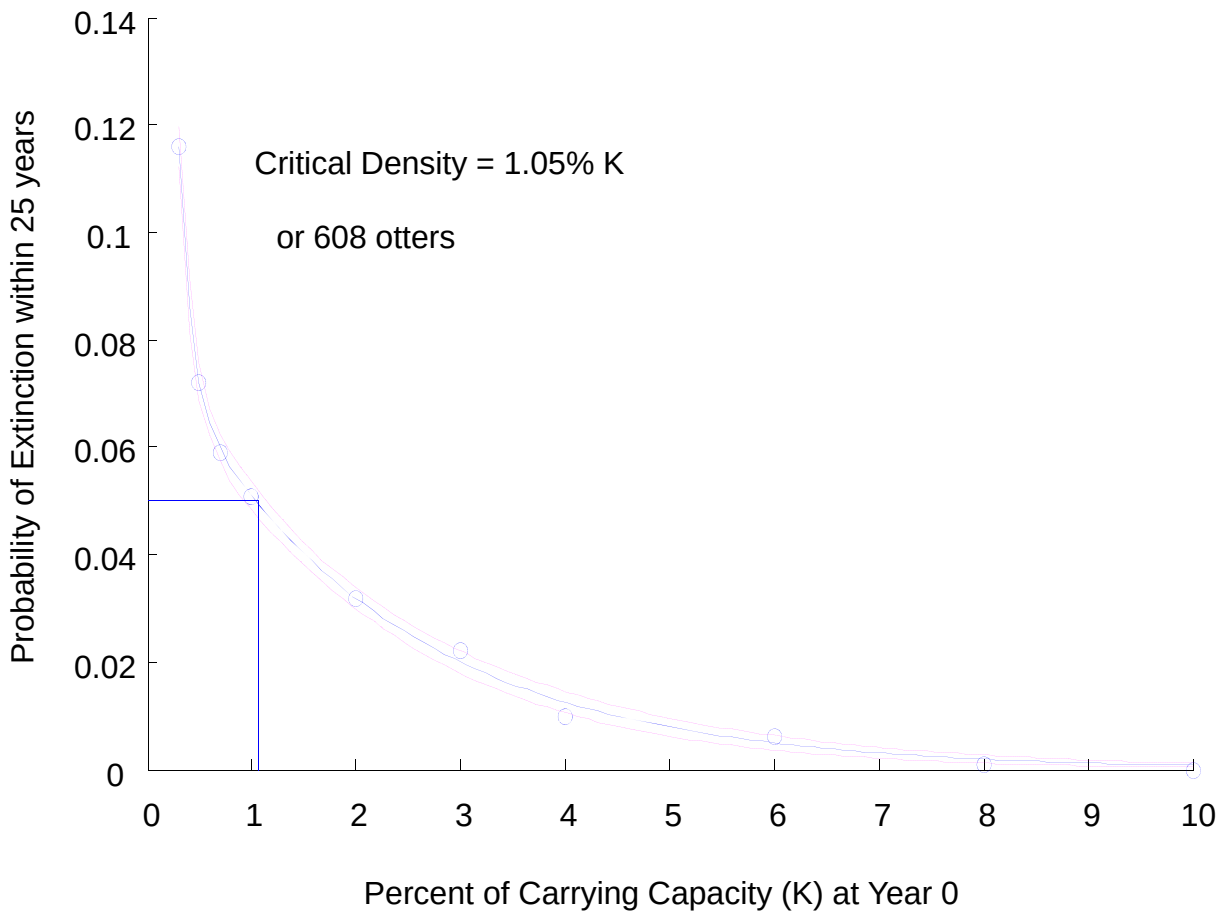


Figure 7. Estimated probability of reaching quasi-extinction within a 25 year period for sea otters in the Western Aleutian Management Unit, plotted as a negative exponential function of sea otter density at year 0 (density is shown as % of carrying capacity, defined as K=15 sea otters per km^2 of habitat). The 95% confidence limits for the function are shown as dashed lines. The critical density shown represents the point at which 5% of simulations go to quasi-extinction.

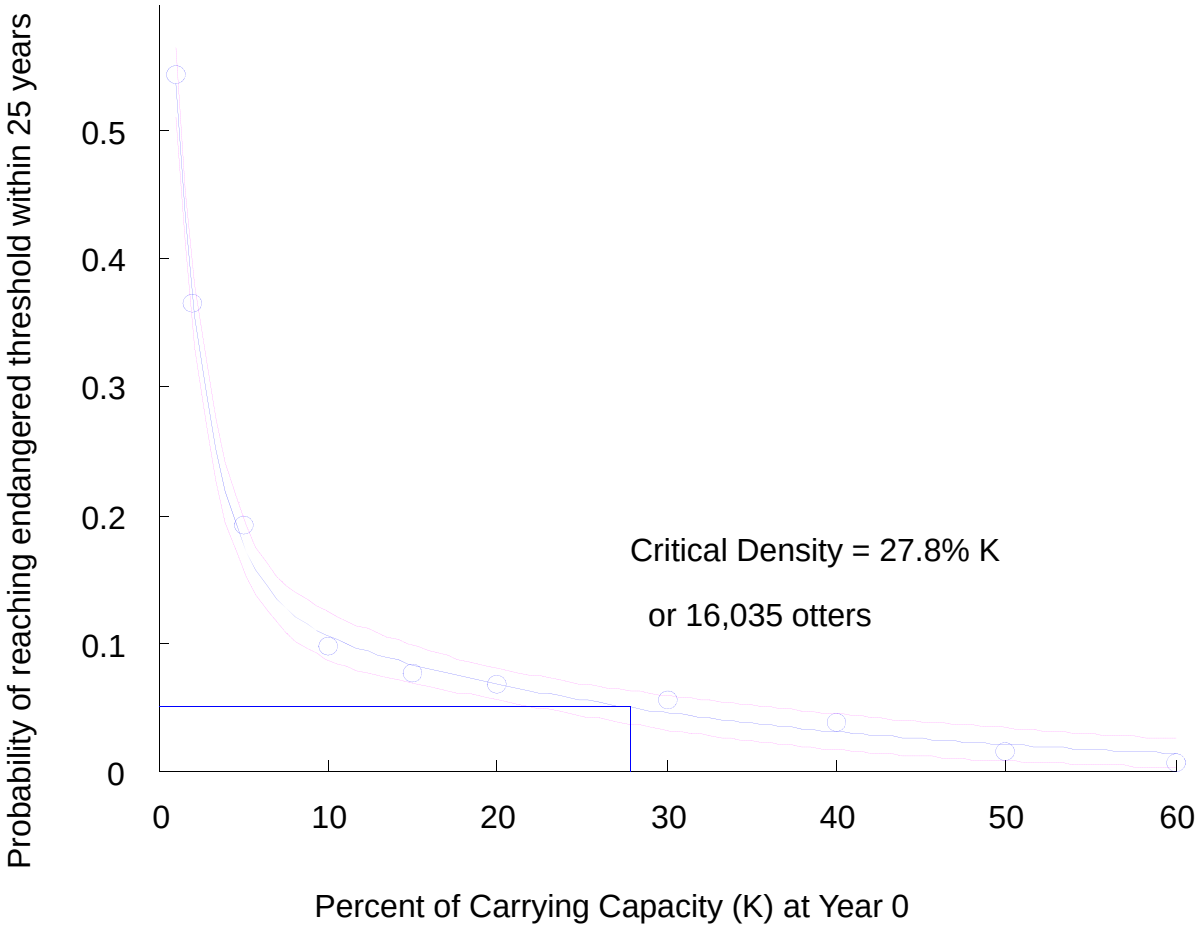


Figure 8. Estimated probability of becoming endangered (see text and Figure 7) within a 25 year period for sea otters in the Western Aleutian Management Unit, plotted as a negative exponential function of sea otter density at year 0 (density is shown as % of carrying capacity, defined as K=15 sea otters per km^2 of habitat). The 95% confidence limits for the function are shown as dashed lines. The critical density shown represents the point at which 5% of simulations drop to the point of becoming endangered within 25 years.