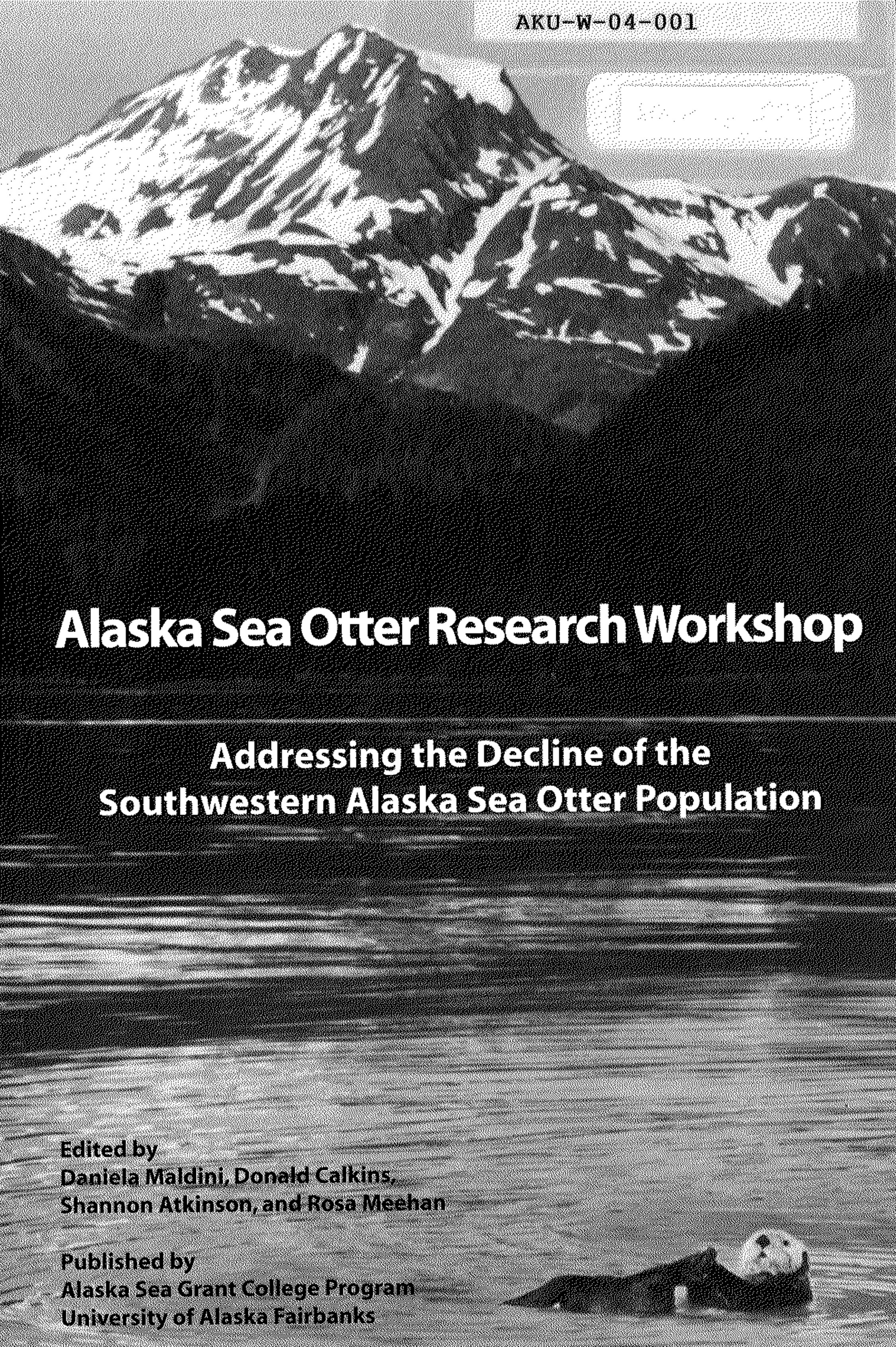

Alaska Sea Otter Research Workshop

Addressing the Decline of the Southwestern Alaska Sea Otter Population

Edited by
Daniela Maldini, Donald Calkins,
Shannon Atkinson, and Rosa Meehan

Published by
Alaska Sea Grant College Program
University of Alaska Fairbanks

Elmer E. Rasmuson Library Cataloging in Publication Data

Alaska sea otter research workshop : addressing the decline of the Southwestern Alaska sea otter population / edited by Daniela Maldini … [et. al]. – Fairbanks : Alaska. Alaska Sea Grant College Program, University of Alaska Fairbanks 2004.
p. : ill. ; cm. – (Alaska Sea Grant College Program, University of Alaska Fairbanks ; AK-SG-04-03)

Includes bibliographical references and index.

Notes: Held "5-7 April 2004, Alaska SeaLife Center, Seward, Alaska, USA."

1. Sea otter—Population viability analysis—Alaska—Congresses. 2. Sea otter—Conservation—Alaska—Congresses. 3. Sea otter—Effect of predation on—Alaska—Congresses. 4. Sea otter—Geographical distribution—Congresses. 5. Sea otter—Alaska—Mortality—Congresses. 6. Sea otter—Alaska—Reproduction. 7. Sea otter—Effect of pollution on—Alaska—Congresses. 8. Sea otter—Diseases—Alaska—Congresses. 9. Sea otter—Predators of—Alaska—Congresses. 10. Sea otter—Research—Congresses. I. Title. II. Maldini, Daniela, 1963–. Series: Alaska Sea Grant College Program report ; AK-SG-04-03.

QL737.C25 A43 2004

ISBN 1-56612-088-8

Credits

The Alaska SeaLife Center helped fund the publishing of this book through a grant received from the U.S. Fish and Wildlife Service. Publisher is the Alaska Sea Grant College Program, supported by the U.S. Department of Commerce, NOAA National Sea Grant Office, grant NA16RG2321, project A/161-01; and by the University of Alaska Fairbanks with state funds. The University of Alaska is an affirmative action/equal opportunity employer and educational institution.

Sea Grant is a unique partnership with public and private sectors combining research, education, and technology transfer for public service. This national network of universities meets changing environmental and economic needs of people in our coastal, ocean, and Great Lakes regions.

Alaska Sea Grant College Program
University of Alaska Fairbanks
P.O. Box 755040
Fairbanks, Alaska 99775-5040
Toll free (888) 789-0090
(907) 474-6707 • fax (907) 474-6285
http://www.uaf.edu/seagrant

Contents

Regional Overviews: The Status of Sea Otter Populations

Current Sea Otter Research Programs

Methodologies in Sea Otter Research

Work Group Discussions

Workshop Agenda

Monday, 5 April 2004

09:00 Welcoming Remarks and Workshop Agenda: Priorities and goals (Shannon Atkinson)

09:15 Plenary Presentation: The Ecology and Population Biology of Sea Otters: An Overview (James Estes)

Regional Overview: Status of Sea Otter Populations

10:00 Research and Conservation of Sea Otters in California (James Estes)

10:20 Status of Sea Otter Populations: Southeast and Southcentral Alaska (James Bodkin)

10:40 Status of Sea Otter Populations: Southwest Alaska (Douglas Burn)

11:00 Age-Sex Structure and Spatial Distribution of Sea Otter Beach-Cast Carcasses on Bering Island, Commander Islands (Sergey Zagrebelny)

11:20 Distribution and Number of Sea Otters in Kamchatka (Victor Nikulin)

11:40 Historical Trends in the Kuril Islands and South Kamchatka Sea Otter Populations (Sergey Kornev)

An Overview of Existing Sea Otter Research Programs

13:00 Introduction to the Alaska SeaLife Center Sea Otter Program (Don Calkins)

13:20 U.S. Fish and Wildlife Service Sea Otter Program (Douglas Burn)

13:40 U.S. Geological Survey Sea Otter Research Program (James Bodkin)

Overview of Methodologies Used in Sea Otter Research

14:00 Recent Findings from Sea Otter Necropsies: California and Alaska (Melissa Miller)

14:20 Methods of Population Assessment: Northern Sea Otters in Alaska (Angela Doroff)

14:40 Sea Otter Mortality: Overview and Methodology (Alexander Burdin)

15:15 Are Killer Whales Responsible for Marine Mammal Declines in Alaska? A Russian Perspective (Vladimir Burkanov)

15:35 Sea Otter Capture Techniques (James Bodkin)

15:55 Feeding Ecology of Sea Otters in Simpson Bay, Alaska (Randy Davis)

16:15 Studying Sea Otter Foraging Ecology: A Review of Some Methodological Approaches (Timothy Tinker)

16:35 Population Demographics, Survival and Reproduction: Alaska Sea Otter Research (Daniel Monson)

Tuesday, 6 April 2004

Priorities in Sea Otter Research to Address the Southwestern Alaska Sea Otter Decline

The Goal: to determine the most important directions and priorities for two years of sea otter studies addressing the Southwestern Alaska sea otter decline

Outcome: to create a list of the identified recommendations for (a), (b), (c), and (d)

09:30-12:00 Workshops a and b

(a) Vital Rates and Environmental Factors (Moderator: Rosa Meehan)

(b) Diseases and Contaminants (Moderator: Melissa Miller)

13:00-17:00 Workshops c and d

(c) Food and Foraging (Moderator: Angela Doroff)

(d) Predation (Moderator: Daniela Maldini)

17:00 General Discussion

Wednesday, 7 April 2004

Given what we know about the decline in Alaska, what studies can we do in the Commander Islands that may help increase our understanding?

This session is an in-house discussion, but workshop attendees are welcome to participate. The goal is to continue previous days' discussions to set up the framework for sea otter studies in the Commander Islands and possibly the Kuril Islands.

Items of discussion follow.

1. Best timing for the sea otter research in the Bering and Medny islands
2. Hypothesis to be tested
3. Methodologies and Procedures
4. Staff Needed
5. Permits Needed
6. Funding
7. Reports Schedule

Introduction to the Alaska Sea Otter Research Workshop

Shannon Atkinson
Alaska SeaLife Center, Seward, Alaska

The decline of the Southwestern Alaska stock of sea otters (*Enhydra lutris kenyoni*) has been perplexing in that it happened over a relatively short period of time, and occurred to a population that had recovered well from earlier extirpation throughout its geographic range. Sea otter populations rebounded so well, after international protection was enacted in the early 1900s, that the Southwestern Alaska stock was thought to have the majority of the world's population of sea otters. However, by the early 1990s the Southwestern Alaska stock was showing signs of demise from unidentified causes.

The Alaska SeaLife Center (ASLC) is dedicated to understanding the integrity of the marine ecosystem of Alaska through research, rehabilitation, and public education. The ASLC has been fortunate to become involved in research relating to northern sea otters, as well as to work with the lead federal agency charged with managing sea otters, the U.S. Fish and Wildlife Service (USFWS). The primary task at hand is to identify and understand the potential causes of the northern sea otter population decline, especially in the area that has suffered the most dramatic decline. Once the potential causes are evaluated, research efforts can further the understanding of the mechanisms behind these causes and explore viable management options to mitigate further demise of the Southwestern Alaska stock of sea otters. As funding for research on northern sea otters has recently increased, it becomes increasingly important to have some form of research plan, or at least research priorities, that can be used to help direct new or future research efforts.

The original purpose of this workshop was to identify research priorities through a combined effort of research scientists and resource managers. To provide common ground to all participants, much of the workshop focused on population status, current research efforts, and study techniques. The subsequent discussions of research recommendations provided general approaches that would benefit our knowledge of northern sea otters. We did not prioritize these recommendations.

The workshop and the following report were divided into two major sections: (1) the first section is a series of papers that serves to present the current status of various populations of sea otters, as well as existing research and management programs; there are also papers on methodologies that may be useful in evaluating potential threats to sea otters; (2) the second section is the outcome of working groups that compiled, through discussion, a series of research recommendations.

In planning this workshop, the attempt was to be inclusive, and to provide a comprehensive outlook of sea otter populations that inhabit the North Pacific regardless of what genetic stock they belong to. The main objective was to develop research recommendations that are broad in focus, yet will quickly advance future research efforts, through insights into population dynamics and life history traits of sea otter populations both in and outside of Alaska. The research recommendations that are presented herein are designed to fulfill our need for knowledge that addresses the decline of sea otters in Southwestern Alaska.

The Ecology and Population Biology of Sea Otters: An Overview

James A. Estes
University of California Santa Cruz/U.S. Geological Survey, Long Marine Laboratory, Santa Cruz, California

Sea otters (*Enhydra lutris*) were hunted to near extinction throughout their range until the end of the Pacific maritime fur trade in 1911. Time series of survey data have been used to describe patterns of population growth in central California, Washington, British Columbia, Southeast Alaska, and Attu Island. Except for the California sea otter population, which has never increased at more than about 5.5% per year, all of these populations increased at about 20% per year (the theoretical maximum rate of intrinsic population growth) from the time of their establishment in the late 1960s or early 1970s through the late 1980s. Rates of population increase have subsequently diminished or ceased, except in British Columbia where growth continues unabated. The most dramatic trend change has been at Attu Island, which has declined by about 95% since the late 1980s. Sea otter numbers have undergone similar declines throughout the Aleutian Islands and eastward across the Alaska Peninsula and Kodiak archipelago. As of summer 2003, the number of sea otters in the Aleutian archipelago had declined to about 5% of its estimated pre-decline abundance, and to about 3% of the area's estimated carrying capacity. The rate of population decline in this region appears to be increasing.

The loss of sea otters has profoundly influenced coastal ecosystems in the central and western Aleutian archipelago, and possibly elsewhere. Sea otters feed on sea urchins, which in turn feed on kelp, together creating a trophic cascade. Lush kelp forests thus characterize otter-dominated systems whereas deforested sea urchin barrens characterize systems lacking sea otters. The sea otter-urchin-kelp trophic cascade influences a broad array of other species through a complex interactive web. Before the otter's demise, dense kelp forests characterized coastal ecosystems throughout much of the Aleutian archipelago. Nearly all of these previously lush kelp forests have become extensively overgrazed following the sea otter's decline, with predictable effects on other groups of species. For instance, kelp forest fish populations have declined by more than tenfold; glaucous winged gulls (*Larus glaucescens*) have shifted their diets from small fishes to intertidal invertebrates; and both sea otter pups and kelp forest fishes, once important prey of bald eagles (*Haliaeetus leucocephalus*) in the Aleutian archipelago, are now largely absent from the diet of this species.

The current "weight of evidence" indicates that the sea otter decline was caused by increased killer whale predation. Every other potential explanation for the decline is inconsistent with the available evidence in one or more important ways. For instance, starvation is contra-indicated by the presence of abundant prey resources and what would appear to be excellent body condition in the remaining living sea otters; disease is contra-indicated by the lack of any direct or indirect evidence, despite a rather thorough assessment in the late 1990s; unusually high levels of natural biotoxins or anthropogenic contaminants have not been detected in living otters or in their environment; and other predators, including humans, seem to be either rare or absent in the system, or otherwise incapable of causing such widespread and precipitous population declines. Conversely, there is a variety of evidence to support the killer whale hypothesis. Killer whale sightings in nearshore waters of the Aleutian archipelago greatly increased at about the onset of the decline but have, again, become rare in the area now that sea otters are uncommon. The rate of observed attacks by killer whales on sea otters increased significantly during the period of the decline. Both the survival rates and population densities of sea otters have remained high in a shallow coastal lagoon at Adak Island, which appears inaccessible to killer whales. Finally, the added mortality required to reduce a sea otter population at the observed rate and magnitude was estimated by population modeling. If killer whale predation is assumed to have been responsible for all of these added losses, an estimate of the expected number of observed kills (5.05) closely corresponds with the actual number of kills seen (6). The sea otter decline in the central and western Aleutian archipelago could have been caused by as few as 3.7 individual killer whales, based on the estimated field metabolic rate of killer whales (51-59 kcal per kg killer whale per day), the caloric value of a sea otter (1.81 kcal per gram wet mass), the assimilation efficiency of killer whales (80-90%), and the number of sea otters that must have been eaten to account for the decline under the killer whale predation hypothesis. While these observations do not prove the killer whale hypothesis, they establish its feasibility and are consistent with its expectations.

The more difficult and important question is how and why a change of this sort suddenly occurred. The most likely explanation is that killer whales have altered their foraging behavior to include sea otters. Such a behavioral change might occur for any number of reasons, the most logical of which is that their preferred prey became less available. Transient killer whales are known to consume a wide range of other marine mammal species, including pinnipeds. Various pinniped species have declined within a region that is roughly similar to the range of the sea otter decline. The most recent of these pinniped declines (Steller sea lions) occurred just before the onset of the sea otter decline, thus providing what is perhaps the most obvious explanation. If this latter hypothesis is correct, it suggests that the sea otter decline is functionally linked to a larger megafaunal collapse in the region, and that an understanding of the cause or causes of this megafaunal collapse will provide the ultimate explanation for the demise of sea otters in Southwestern Alaska.

Research and Conservation of Sea Otters in California

James A. Estes
University of California Santa Cruz/U.S. Geological Survey, Long Marine Laboratory, Santa Cruz, California

Following cessation of the Pacific maritime fur trade in 1911, the abundance and range of the California sea otter (*Enhydra lutris nereis*) slowly began to increase. The rate of population increase was fairly constant through the mid-1970s at about 5.5% per year. However, the number of animals abruptly began to decline in about 1975. By the early 1980s there was evidence that sea otters were being killed by incidental entanglement in a recently developed gill and trammel net fishery. Once this discovery was made, the State of California placed an emergency closure on the fishery, and subsequent analyses indicated that overall losses in the fishery were sufficient to cause the decline. Sea otter population numbers began to increase again following the fishery closure, and this increase continued through the mid-1990s. Population size declined through the late 1990s and has remained roughly stable for the past three or four years.

The California sea otter population, currently thought to number about 2,500, is well below the estimated carrying capacity of about 16,000 for the state of California. Because of its small size, sluggish growth, and numerous perceived threats, the California sea otter population is listed as "threatened" under the U.S. Endangered Species Act (ESA). The population is surveyed annually, and the Southern Sea Otter Recovery Team has recommended the following criteria for listing changes based on three-year running averages of the survey results: a count of 1,850 animals would lead to uplisting to "endangered," and a count of 3,100 animals would lead to delisting.

Time-related patterns in the distribution and abundance of any population must be driven by some combination of three factors—reproduction, mortality, and redistribution. In the case of California sea otters, elevated mortality appears to be largely responsible for its sluggish overall growth and the more recent fluctuating trends in abundance. The causes of mortality are not well understood and are being studied in two general ways—by examining carcasses stranded on California's beaches, and by conducting detailed longitudinal studies of individuals in the living population.

The stranding program has been under way since 1968 and now contains records of more than 3,500 stranded carcasses, with detailed information on age, sex, date, and location of recovery, and cause of death when it can be determined. These data have been sorted into periods of population increase and decline in an effort to better understand reasons for the declines. The per capita recovery rate (number of strandings per estimated size of the living population) is greater during the periods of decline, thus supporting the view that the population dynamics are driven by changes in mortality. Aside from this general pattern, however, there are no clear correlates in the frequency or magnitude of mortality to population change. Stranded carcasses are recovered in large numbers throughout the year, although the rate of recovery is typically greatest during summer months and the summer increase in carcass recovery rate is greatest during periods of population decline. The patterns are perplexing and apparently unique to the California sea otter population.

Detailed analyses of freshly stranded carcasses (approximately 72 hours or less since time of death), through necropsies by veterinary pathologists, was initiated in 1992. These analyses have identified various infectious diseases as the proximate cause of death in about 40-50% of the freshly stranded carcasses, thus implicating this source of mortality as a significant deterrent to recovery. Whether the high incidence of mortality from infectious diseases is a recent phenomenon or is currently on the increase remains unclear. However, the inevitable influence on the land and adjacent coastal ocean of a large human population living in coastal California is a problem of substantial concern.

The living population of California sea otters is being studied through longitudinal records of individuals marked with flipper tags, VHF radios, and archival time-depth recorders. The flipper tags and radios are used to relocate individuals, whereas the time-depth recorders provide continuous records of activity, body temperature, and depth of dive profiles. Diet, movements and spatial use patterns, reproduction, and mortality are also determined for the marked animals. These data, when combined with the salvage records and information from similar studies conducted earlier in California (when the population was growing), and elsewhere within the species' range (Washington and Alaska), will provide a means of assessing the causes of population change. The collective data indicate a gradual long-term reduction in survival probability that is consistent with observed trends in abundance of the living population.

Status of Sea Otter Populations in Southcentral and Southeast Alaska, 2002-2003

James Bodkin
U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska

During the years 2002-2004 estimated sea otter population sizes were calculated for Southeast Alaska, Prince William Sound, and the Kenai Peninsula and Cook Inlet regions of Alaska. Aerial surveys were conducted by a single observer from a float-equipped Bellanca Scout fixed-wing aircraft flying at 91 m altitude and 65 mph. The surveys followed protocols written by Bodkin and Udevitz (1999). The survey design consisted of systematic sampling of 400 m wide transects that were uniformly placed throughout the survey area. Selection and sampling of transects was proportional to expected sea otter abundance, with most effort taking place in transects over waters 0-40 m in depth. Intensive searches were periodically conducted within transects to estimate the proportion of sea otters not detected on strips. To obtain an adjusted population size estimate, strip counts are adjusted for the area not surveyed and by a correction factor.

Comparisons of recent surveys were made with prior surveys of abundance to determine trends in population size over time. Only in Prince William Sound were prior data obtained with the identical survey methodology. In Southeast Alaska, prior surveys were conducted by small skiffs along shorelines. Yakutat Bay was surveyed using the Bodkin and Udevitz method in 1998, and counts of otters along the outer coast from Cape Suckling to Icy Point were made by aircraft in 1998. Counts made by Pitcher (1988) and estimates made by Agler (1994) were adjusted by dividing their total by 0.70, to approximate the detection bias recognized in skiff surveys of sea otter abundance in Prince William Sound by Udevitz et al. (1995). The 1989 Kenai Peninsula survey was conducted by helicopter and included a correction for detection bias. No prior surveys of west Cook Inlet are available.

Trends in population size over time were made by regressing the natural logs of population sizes over time (Table 1). Trends in population

Table 1. Trends in sea otter population abundance in Southeast and Southcentral Alaska. The Southeast survey areas include all waters between Dixon Entrance and Icy Point. The Prince William Sound surveys include only inside waters and exclude Orca Inlet. The Kenai Peninsula surveys include Kachemak Bay and the waters east of central Cook Inlet. All surveys include areas of known sea otter occupation.

Area	Population estimate	Year	Annual rate of change	No. surveys	Period
Southeast		2003	**+0.14**	6	1969-2003
Northern SE	3,187	2002	0.00	2	1988-2002
Southern SE	5,844	2003	+0.04	2	1988-2003
Yakutat Bay	898	1998	NA	1	1998
Prince William Sound	9,284	2003	0.00	4	1994-2003
Kenai Peninsula	2,673	2002	+0.01	2	1989-2002
Cook Inlet	6,918	2002	NA	1	2002
Total	**28,804**				

sizes that are significant at the alpha level of 0.05 are bolded, and the number of surveys and the period of time included are provided. Skiff surveys were adjusted for detection bias by a factor of 1.43.

Surveys since 1969 in Southeast Alaska indicate a significant average annual increase of about 14% per year. Recent survey results suggest that the rate of increase has been reduced since 1988 and that the current population status is stable in the north and increasing at a low rate in the south. A lack of prior survey data of the outer coasts from Icy Point to Cape Cleare precludes assessment of population trend. In Prince William Sound the sea otter population appears to have been stable over the past decade. Significant average annual increases of about 4% in abundance were detected in western Prince William Sound in the decade following the *Exxon Valdez* oil spill (Bodkin et al. 2002), although some areas have not recovered to pre-spill levels of abundance. The Kenai Peninsula sea otter population has remained stable since 1989. In western Cook Inlet, predominantly Kamishak Bay, sea otters are abundant, although lack of prior survey data precludes assessment of population trend.

Status of Sea Otter Populations: Southwestern Alaska

Douglas Burn
U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska

The U.S. Fish and Wildlife Service (USFWS) currently recognizes three population stocks of the northern sea otter (*Enhydra lutris kenyoni*) in Alaska. The Southwestern Alaska stock extends from Attu Island at the westernmost end of the Aleutian chain, to lower western Cook Inlet, and is also found in the Alaska Peninsula, the Pribilof Islands, the Kodiak archipelago, and the Barren Islands. Past commercial exploitation of sea otters by Russian and American fur hunters drove the worldwide population to the brink of extinction. At the time of their protection by the International Fur Seal Treaty in 1911, an estimated 1,000-2,000 sea otters existed in 13 remnant colonies. Six of these remnant colonies were located within the range of the present Southwestern Alaska stock. In the absence of commercial hunting, these populations grew and began to recolonize their former range. By the mid-1980s, scientists believed that over 80% of the world's population of sea otters were in Southwestern Alaska.

Sea otters in Southwestern Alaska had not been systematically surveyed during their recovery period. By 1965 sea otters had recovered in the Aleutian Islands and reached equilibrium density in the Rat, Delarof, and portions of the Andreanof Islands group, but had yet to recolonize the Near Islands to the west, or the Islands of Four Mountains and Fox Islands to the east. A USFWS aerial survey conducted in the Aleutian archipelago in April 1992 indicated that, while otters had recolonized all major island groups, they had unexpectedly declined by roughly 50% since 1965. In the mid-1990s, skiff surveys at several islands in the western and central Aleutian archipelago conducted by the U.S. Geological Survey (USGS) documented continued sea otter declines in this area. In April 2000, the USFWS repeated the 1992 aerial survey pattern, and reported an overall 70% decline in the sea otter population since 1992. In 2003, the USFWS and the USGS conducted skiff-based surveys at six islands in the western and central Aleutian archipelago and reported continuing declines in these areas. However, these surveys did not identify the easternmost extent of the sea otter population decline.

In May 2000 and April 2001, the USFWS conducted additional aerial surveys along the Alaska Peninsula for comparison with baseline surveys conducted in 1986 and 1989, and determined that the sea otter population declined by an estimated 27-49% on the north side of the peninsula, and by as much as 93-94% on the south side between 1986 and 2001. Areas of former sea otter concentrations, such as Sandman Reefs, were almost vacant of sea otters. In May 2001, the USFWS also surveyed the shoreline of the Alaska Peninsula from Cape Douglas to False Pass for comparison with a similar survey conducted in 1989. These data corroborated the occurrence of a sea otter decline along the western end of the peninsula. However, the population east of Castle Cape appeared to have grown from 1,766 animals in 1989 to 2,115 animals in 2001, an increase of nearly 20%.

In 1989, the Kodiak archipelago was surveyed by helicopter as part of an *Exxon Valdez* oil spill damage assessment study. The area was surveyed again in 1994 using a fixed-wing aircraft. Here the sea otter population declined from around 13,500 animals in 1989 to 9,800 animals in 1994, although this difference was not statistically significant. In June 2001, the USFWS repeated the 1994 aerial survey pattern using the same aircraft, pilot, observer, and study design. Results from this survey indicated that the sea otter population in the Kodiak archipelago is approximately 5,800 animals, a 56% decline since 1989.

The final survey area within the range of the Southwestern Alaska stock is lower western Cook Inlet. This area was surveyed by the USGS in 2002, and yielded an estimate of 6,900 sea otters. There is no previous baseline information available to determine if the population is increasing or decreasing in this area.

In August 2002, the USFWS issued revised stock assessment reports for all three stocks of northern sea otters in Alaska. Summarizing the most recent survey data, the best estimate for the Southwestern Alaska stock was 41,474 animals. This estimate was compiled from surveys conducted between 2000 and 2002 and was adjusted for otters not recorded by observers. The estimate, which represents an overall 56-68% decline since the mid-1980s, prompted the USFWS to designate sea otters in Southwestern Alaska as a candidate species under the U.S. Endangered Species Act (ESA). On February 11, 2004, the USFWS published a proposed rule to list the Southwestern Alaska population of northern sea otter as "threatened" under the ESA.

Age-Sex Structure and Spatial Distribution of Sea Otter Beach-Cast Carcasses on Bering Island, Commander Islands

Sergey Zagrebelny
State National Reserve Komandorsky, Nikolskoe, Aleutian District, Kamchatka, Russia

Sea otter (*Enhydra lutris*) recolonization of Bering Island began in the 1970s because of movements of animals from neighboring Medny Island. Sea otter numbers around Medny Island at the time remained relatively stable and probably reached carrying capacity, thus creating the premises for movement of animals to other locations. Today extensive data exist on the dynamics that led to the recovery of this sea otter population, which was exterminated in the eighteenth century. Our longitudinal research on the age-sex structure of beach-cast carcasses has the purpose of tracking the basic trends in population dynamics and the state of this population during a period of abundance and age-sex structure stabilization. The goals of our work are the following: (1) to estimate the relationship between sea otter spatial distribution off Bering Island and the distribution of beach-cast carcasses; (2) to test the usefulness of seasonal mortality rate data to estimate age-related spatial distribution of animals; and (3) to assess population dynamics at the present stage of population growth.

The investigation is based on surveys conducted by inspectors at the Sevvostrybvod Commander Division since the early 1970s. Although major sea otter mortalities on Bering Island occur throughout the winter-spring period, early October has been accepted as the beginning of an annual cycle, being the month when the majority of beach-cast sea otter carcasses have been collected.

From October 1995 to September 2003, 2,186 sea otter carcasses were collected. On Bering Island, the sex of 1,846 carcasses was determined using the width of the upper canine tooth and the hip bone structure; for 1,535 carcasses the age was determined using cement annuli growth in the upper canine tooth. All animals collected for which the sex and age were determined were grouped in three age classes: (1) subadults (0-3 years); (2) adults (4-10 years); (3) old (>10 years). To estimate changes in sea otter spatial distribution off Bering Island the entire coastline was subdivided into three areas: north (156 km^2), east (482 km^2), and west (391 km^2). The offshore limit of each area was the 50 m isobath.

Age distribution of beach-cast carcasses from the 1988/1989 through the 2002/2003 season (excluding the period from 1993 to 1995, where data were not available) was compared using a chi square test. For each age class, the proportion of total mortality was calculated separately for each sex.

Results showed that (1) annual mortality rate could be used as a criterion for estimation of the Commander Islands sea otter population health; (2) since 1999, the distribution and age-sex structure of the sea otter population off Bering Island has been relatively stable; (3) the stabilization period for the Bering Island sea otter population took 2-3 years on average after peaks in mortality in 1990-1991 and 1997-1998; (4) when age-sex ratios and distribution were stable there was a high mortality rate for older individuals (>10 years), while mortality in animals in younger and middle age classes was not significantly different from mortality during periods of depression (1990-1991 and 1997-1998); and (5) beach-cast carcass data were not suitable to determine density, distribution, and population age-sex structure.

Distribution and Number of Sea Otters in Kamchatka

Victor Nikulin and Vladimir Vertyankin
Sevvostrybvod, Marine Mammal Service, Petropavlovsk-Kamchatsky, Russia

Along the Kamchatka Peninsula (Fig. 1) sea otters occur mainly along the east coast, from Korfa Bay in the north to Cape Lopatka in the south, because of the availability of abundant food resources and of good protection from weather conditions (bays, reefs, etc.). Some records are available of sea otter sightings near the west coast of Kamchatka all the way to the Oblukovina River (55º31'N, 150º20'E) (Kornev 2003). It appears that sea otters are reoccupying their historic range although the distribution of sea otters around the Kamchatka Peninsula is patchy, and sea otters concentrate mostly near capes.

North of Cape Kronotsky, we observed only single sea otters. However, since 1984 we have observed a stable sea otter colony of up to 70 animals near Cape Kamchatsky (20.9% females with pups). There are some indications that the maximum number of sea otters near this cape used to be 150 animals. Near the Kronotsky Peninsula, sea otters spread from the Baraniya River to Olga Bay. In 2003 we counted 246 adult sea otters (13.4% females with pups) in this area. The total number of sea otters in the Kronotsky Peninsula Biosphere Preserve is close to 300 animals.

On the rest of the Kamchatka coast, south of the Kronotsky Preserve, only single sea otters were observed, but in July 2003 a group of 37 sea otters was seen in Russkaya Bay (south from Petropavlovsk-Kamchatsky). The counts in the year 2000 have shown the biggest concentrations (ca. 6,969 animals) near the southernmost tip of the Kamchatka Peninsula, Cape Lopatka. Near Utashud Island the number of sea otters can reach more than 1,000 individuals (1,120 animals in 2001, and 1,140 in 2002).

The number of sea otters in Kamchatka (Table 1) is variable because of emigration/immigration between the Northern Kuril Islands and Kamchatka, and fluctuates from 2,000-2,500 animals in the summer up to 5,000-6,000 individuals in winter. Mortality in Kamchatka is rather low, but numbers may be biased by the lack of information and small effort

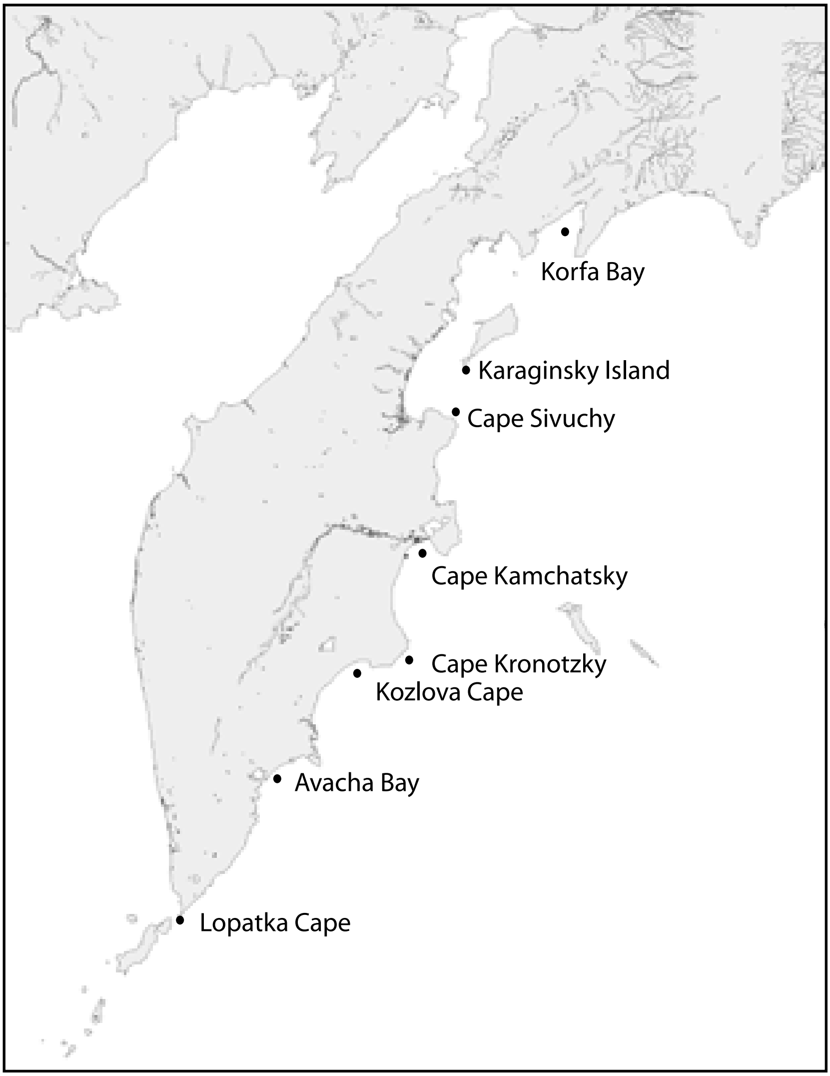

Figure1. Map of the Kamchatka Peninsula.

of carcass collection. The majority of carcasses were found at Cape Lopatka, Utashud Island, and Cape Kamchatsky. Carcasses were mainly adult males (43%).

Table 1. Sea otter numbers in the Kamchatka Peninsula (maximum number on a single count).

Year	Cape Kamchatsky	Kronotsky Preserve	Utashud Island	Cape Lopatka	West Coast
1993	N/A	N/A	350-370 (April)	2,400-2,500 (January)	N/A
1994	N/A	N/A	1,000 (May)	2,587 (June)	1 otter dead, Opala River
1995	N/A	128 (June)	100 (December)	1,772 (August)	N/A
1996	2 (July)	20 (September)	300 (May)	3,000 (July)	1 otter, Fourth River
1997	73 (August)	61 (December)	200 (May)	3,034 (May)	3 otters near Mitoga River
1998	71 (August)	22 (October)	500 (April)	2,160 (May)	N/A
1999	52 (September)	1 (July)	250 (August)	3,694 (September)	N/A
2000	ND	74 (July)	1,000 (April)	6,969 (September)	1 dead near Bolshaya River
2001	20 (September)	100 (July)	1,120 (April)	998 (July)	3 near Oblukovina (Kornev 2003)
2002	71 (July)	196 (June)	1,140 (March)	2,787 (July)	1 dead Bryumka
2003	67 (August)	300 (June-July)	600 (April)	2,250 (April)	N/A

Historical Trends in Sea Otter Populations of the Kuril Islands and South Kamchatka

S.I. Kornev and S.M. Korneva
KamchatNIRO, Marine Mammal Laboratory, Petropavlovsk-Kamchatsky, Kamchatka, Russia

There are no data on sea otter abundance in the Kuril Islands before intensive hunting began in the eighteenth and nineteenth centuries. Pre-exploitation abundance has been estimated at 20,000-25,000 animals based on data from commercial hunting (Yoshiyuki 1925, Sergeev 1947, Uspensky 1955, Nikolayev 1960) and trends in population dynamics that have been simulated using computer-based modeling. In the eighteenth century, hunting pressure was not high enough to result in population declines. At the beginning of the nineteenth century, hunting pressure increased and sea otter populations in the Kuril Islands rapidly declined to less than 759 animals in the twentieth century (Kawauchi 1930). However, some movements of sea otters from areas of high exploitation to other areas during this period cannot be discounted (Nikolayev 1960).

Southern Kuril Islands

In the Chirnye-Brathers Islands, maximum sea otter abundance in 1973 was 120 animals (Kuzin et al. 1984). In 2000 the number of animals was estimated at 22 including five pups. Around Urup Island abundance was estimated at 2,300 animals in 1967 and 2,500 animals in 1991, with a further increase in number not likely (Nikolayev 1968). Animals have been evenly distributed around the island. On Iturup Island, abundance was estimated at 238-365 animals in the 1970s, and increased to approximately 1,052 animals in 1991 (Maminov 2002). Numbers have been stable since that time. On Kunashir Island, surveyors encountered only two sea otters on the northeast sector in 2000. In the Small Kuril Chain, one or two sea otters have been recorded yearly since the 1960s. In 2000-2001 there were 31-44 sea otters including seven pups (Kornev et al. 2001, Hattori 2003).

In the Central Kurils, from Simushir Island to Onekotan Island, abundance varied from 400 to 600 animals between 1960 and 2000. Number of animals has decreased in some islands (Simushir, Shishkotan, and Rashu).

Around Paramushir Island, in the Northern Kurils, surveyors counted 2,980 animals, including 287 pups, on 23-27 May 2003, whereas one month later, on 27-30 June 2003, 1,898 animals, including 211 pups, were counted. For the same period, the abundance of sea otters around Shumshu Island increased significantly suggesting emigration of animals from the neighboring Paramushir. Sea otter distribution has changed within the Northern Kuril Islands as a whole with a reduction in number in south Paramushir Island, and an increase in the northern sector of Paramushir Island and in central Shumshu Island.

Cowfish populations (family Ostraciidae) appear to have increased in the Fourth Kuril Strait and around southern Paramushir Island since the 1990s, in conjunction with a decrease in the number of large rafts of sea otters suggesting that sea otters might have been preying on this fish. However, additional data are needed to support a cause-effect relationship between these two events.

Between the mid-1990s and today, the highest sea otter abundance in the Kuril Chain has been recorded around Shumshu Island. In 2003, surveyors have observed 13,437 animals around the island, including 1,645 pups. In 2000 and 2003, high densities of sea otters have been observed in the southern and western sides of the island. Large sea otter rafts associated with kelp beds have been recorded around Shumshu Island, especially during the summer. The area of kelp bed coverage has been increasing with increasing predation pressure by sea otters on sea urchins (*Strongylocentrotus* spp.). Two small volcanic islands, Antsiferov and Atlasov, located southwest and northwest of Paramushir Island respectively, may have a sea otter population of several dozens (Antsiferov's) to several hundreds of animals (Atlasov).

In the southern part of the Kamchatka Peninsula (i.e., Cape Lopatka) there were up to 800 sea otters in the 1970s (Kromovskikh 1982). More comprehensive surveys, carried out in the early 1980s, estimated the presence of 2,000 to 3,500 animals in southern Kamchatka (Burkanov 1988, Kornev 2000).

Sea otters in southern Kamchatka aggregate primarily around Cape Lopatka, where the largest rafts, mostly composed of males, have been recorded. North of Cape Lopatka, in the Sea of Okhotsk, and along the Pacific coast, sea otter abundance has been decreasing, and rafts contained lower numbers of animals. In the spring, near Utashud Island, up to 1,000 animals may be encountered (Nikulin et al. 2002). In southern Kamchatka abundance has been stable, although animals are spreading farther northward along the coast.

The growth of sea otter populations in the areas discussed probably caused some structural changes in the nearshore ecosystem, mainly because of active predation by sea otters on sea urchins, and the consequent increase of kelp biomass. The annual increase in the Kamchatka-Kuril sea otter population abundance since the last century has been approximately 4% to 10%. Predictions indicate that this increase may continue at the same rate because of the abundance of food resources in shallow-water areas to 50 m in depth, and because of predicted moderate ice coverage in the water during winter.

One of the reasons for the observed increase in sea otter abundance undoubtedly relates to movements of animals into new and unexploited territories as a result of natural dispersal, such as the colonization of coastlines in the Sea of Okhotsk, and around Paramushir and Shumshu islands. The other reasons are the increased protection afforded to the species by new regulations, and the decrease of human settlements in the Kuril Islands. Current sea otter abundance in the Kuril Islands is estimated at approximately 19,000 animals, including more than 15,000 in the northern Kurils, 400-600 in the central Kurils, and more than 3,500 in the southern Kurils (Urup and Iturup islands and Small Kuril Chain).

In the Commander Islands, sea otter abundance is probably similar to that existing before hunting pressure started affecting the population and is estimated to be at about 5,500 animals (Sevvostrybvod and Commander's Preserve, unpubl. data).

Total abundance of sea otters in Russia is currently estimated at approximately 27,000 animals. A revision of the listing of the sea otter under the Russian Federation Endangered Species List and of the status of this species under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) has been proposed. However, changes in the protection status of the Russian sea otter population should only allow exploitation of the subspecies for scientific and educational purposes.

Alaska SeaLife Center Sea Otter Research Program

Donald Calkins
Alaska SeaLife Center, Seward, Alaska

The Alaska SeaLife Center (ASLC) sea otter research program came into being in 2003 with an appropriation from Congress, administered by the U.S. Fish and Wildlife Service (USFWS) Alaska Regional Office. The ASLC was required to submit a proposal to the Marine Mammals Management office detailing the research that would be conducted. We then collaborated with the USFWS to develop a working proposal for the $685,515 made available for this work. The Marine Mammal Management office recommended that we use the Southwest Alaska Sea Otter Decline Workshop Summary Report (USFWS 2002) to help guide the work for the first year.

Because we were uncertain about the possibility of this work continuing to receive funding from Congress, we began our program cautiously. The decision was made to draw our personnel from existing staff at the ASLC; thus I became the interim Program Manager with 25% of my salary paid from the sea otter budget. Other staff members involved in this program are Dr. Alexander Burdin, visiting scientist (50% of salary paid by sea otter budget); Dr. Russel Andrews, scientist (no salary from the sea otter budget); Dr. Tracey Goldstein, post-doctoral fellow working on diseases (25% of salary paid by sea otter budget); Dr. Daniela Maldini, research associate (50% of salary paid by sea otter budget); Howard Ferren, administrative director of research operations; Mike Pendergast, computer scientist; Dr. Tara Riemer Jones, chief administrative assistant (25% of salary paid by sea otter budget); and Angie Steeves, administrative assistant (6% of salary paid by sea otter budget). We are also planning to hire a computer associate.

The initial program was designed to complete four tasks by taking advantage of the strengths that already exist at the ASLC and by using our current staff to build the new research program. A description of the proposed tasks follows.

Task 1: Infrastructure and Workshops

Dr. Tara Riemer Jones and I are responsible for the completion of this task which used $342,341 of the available funds, since it includes all of the salaries, the costs of overhead paid to the ASLC facility, and much of the travel budget. Our objective under Task 1 is to develop a long–term research program focusing on sea otters, and, particularly, on their decline in Southwestern Alaska. For this purpose we organized the current workshop and are planning a second one in fall 2004. These workshops draw from the wealth of expertise available in the sea otter field in the United States and Russia in helping to identify research priorities and common goals in the sea otter field. This approach was agreed upon by both the ASLC and the USFWS as a method to help the ASLC and other agencies to design research that addresses the decline of the Southwest Alaska sea otter stock.

The second workshop will address population monitoring with the objective of developing a comprehensive monitoring plan for sea otters in Southwestern Alaska. The structure of the second workshop will be similar to that of the first: we will invite experts in the fields of sea otter biology and censusing, many of whom will have participated in the first workshop. A report will be prepared from that workshop with specific recommendations for developing population monitoring techniques.

Task 2: Web Repository for Sea Otter Information

Task 2 is the primary responsibility of Michael Pendergast, computer scientist, and of the new computer associate. This task has $11,000 in funding, and the objective is to develop a centralized location for published information on sea otters that can be easily accessed over the Web. This has previously been accomplished at the ASLC for the Steller sea lion research program and the eider research program. We have found it to be extremely useful to the scientific community and have received a great deal of encouragement in our other programs. We feel that this will also make a very useful contribution to all who wish to have access to sea otter literature. We will create a flexible structure that allows expansion of the database. The Internet has emerged as a valuable tool for quickly retrieving information, and relational database enhancements provide more sophisticated methods for indexing and retrieving information. This software engineering project will create an Internet-accessible database of sea otter literature and provide access to electronic versions of available articles and reports. Sea otter literature will be identified and converted to a searchable electronic format. The documents will then be entered into a database containing detailed information on the article. A Web interface will be created to allow searching for literature based on author, title, or keyword, or by full-text search of the document. The full document will be available for viewing or downloading by the user.

Task 3: Biotelemetry Development

Biotelemetry development for sea otter monitoring, led by Dr. Andrews, is the main objective of this project, and its primary focus is developing innovative tools for monitoring the behavior, physiology, and movements of sea otters. Specifically, the ASLC will develop satellite telemetry devices of the appropriate size and weight to be deployed on sea otters. In collaboration with engineers at Wildlife Computers and Davis RF Engineering, ASLC has been making progress toward the development of a miniaturized satellite transmitter that incorporates a flat patch antenna, as opposed to the typical 7 inch long whip antenna, for implantation into Steller sea lions. For this sea otter project, we propose to make the necessary modifications to the sea lion design to suit sea otters. We also propose to investigate the possibility of using new, miniature, position-only satellite transmitters as externally mounted tags for sea otters. In addition, a new downloadable archival tag will be developed that can be downloaded by a land station. These tags have an additional advantage over current time depth recorders (TDRs) in that new sensors could be added.

Task 4: Commander Island Study

The Commander Island study is being carried out by Dr. Burdin and assisted by Dr. Maldini and Dr. Goldstein. The objectives of this task are to (1) conduct annual boat- and land-based sea otter surveys in the Commander Islands; (2) monitor sea otter mortality on Bering Island; (3) estimate annual changes in the sex-age structure of dead sea otters; (4) investigate sea otter pathology and determine, if possible, the cause of death; and (5) investigate sea otter food habits in the Commander Islands.

Sea otters will be censused nearshore from an inflatable outboard vessel in summer 2004. Each island in the Commanders (Bering and Medny) will be divided into counting units. Sea otters will be counted from the boat using high-powered binoculars. If too many otters are in a single group, the observers will select a vantage point from shore and use a telescope to count the otters. All separate rocks and small islands around the Commanders will be surveyed to allow complete coverage of the shoreline. Data collected will include a description of each group, including sex and age composition. Mortality monitoring will be conducted on Bering Island by carrying out surveys and collecting carcasses in late winter and early spring through summer in areas reachable by transport. Some areas may be accessed by snowmachine, others by all-terrain vehicles, and still others by boat. At the same time carcasses are being counted, we will recover and necropsy those that are suitable. Surveys may be conducted on Medny Island but will occur in the summer only. Often carcasses are decomposed beyond being useful at that time of year so this will be primarily a count to use for comparison to previous counts.

Feeding habits and food resources will be investigated by periodic visits to areas known to be used by sea otters as haul-outs to collect scats. Scats will be scraped off the rocks into plastic bags for later identification. After scats are collected, they will be frozen until such time as it is convenient to examine them in the laboratory. Hard parts will be identified to the lowest taxon possible. A reference collection of invertebrate shells and fish bones from the Commander Islands will be prepared to aid in identification of hard parts from scats

U.S. Fish and Wildlife Service Sea Otter Program

Douglas Burn
U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska

The U.S. Fish and Wildlife Service (USFWS) under the authority of the Marine Mammal Protection Act (MMPA), has management responsibility for sea otters (*Enhydra lutris*), polar bears (*Ursus maritimus*), walruses (*Odobenus rosmarus*), manatees (*Trichechus manatus*), and dugongs (*Dugong dugon)* within U.S. waters. The mission statement of the USFWS is "to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people." In Alaska, USFWS recognizes three population stocks of sea otters: Southwestern, Southcentral, and Southeast Alaska.

The USFWS sea otter program has several management goals, including: (1) conservation planning; (2) monitoring of the health and status of sea otter populations; (3) monitoring of the subsistence harvest of sea otters by Alaska Natives; and (4) other activities. Some of the tools used to help accomplish these goals include cooperative agreements, grants, and interagency agreements with partner agencies and organizations. The USFWS also engages in outreach and education efforts to inform the general public about the status of sea otters in Alaska.

The existing sea otter conservation plan has three main goals: (1) maintain sea otter populations within their optimum sustainable population range; (2) maintain healthy habitats for sea otters; and (3) allow for a variety of human uses (USFWS 1993). In accordance with the MMPA, the USFWS periodically reviews and revises stock assessment reports on sea otters in Alaska, such as the most recent revision in August 2002. We monitor the status and health of sea otters in Alaska by conducting statewide population surveys, operating the stranding network, conducting capture studies for animal health assessment, and conducting telemetry studies to assess vital life history parameters.

The stranding network is operated in collaboration with National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS), and the Alaska SeaLife Center (ASLC). In January 2004, the USFWS held a training session in Homer, Alaska, for over 50 stranding network volunteers and is planning a second training session in Southeast Alaska later this year. Necropsies of stranded sea otters can provide a wealth of information about diseases, parasites, contaminants, biotoxins, human-otter interactions, and predation. An ongoing disease profile project, in conjunction with the U.S. Geological Survey (USGS), Alaska Veterinary Pathology Services (AVPS), and ASLC involves detailed necropsies, tissue sampling, and analysis of freshly dead (< 24 hours) sea otters. Tissues from a variety of sources, including subsistence harvested and stranded otters, are archived at the USFWS Regional Office in Anchorage, as well as at the University of Alaska Fairbanks. These tissues are being used for a variety of purposes, including graduate studies at the University of Alaska Anchorage.

Beginning this year, the USFWS is involved in a number of live-capture studies for health assessment of sea otters. In March 2004, a USFWS representative accompanied ASLC staff to Bering Island, Russia, where over 30 otters were captured and sampled. Additional captures are planned in the Kodiak archipelago, eastern Aleutian Islands, and Alaska Peninsula in conjunction with USGS. In 2005, USFWS and USGS will conduct a radio telemetry study of sea otters in Kodiak to collect information on survival, movement, reproduction, and foraging ecology. The USFWS is also working with the ASLC and the Monterey Bay Aquarium (MBA) in Monterey, California, to develop new telemetry instruments for use in sea otter studies. Of particular interest is the possibility of using satellite telemetry to study sea otters.

The USFWS monitors the subsistence harvest of sea otters by Alaska Natives by means of the marine mammal Marking, Tagging, and Reporting Program (MTRP). The purpose of the MTRP is to (1) monitor the harvest of sea otters, polar bears, and walruses in Alaska; (2) collect biological information about the harvest; and (3) help control the illegal take, trade, and transport of specified marine mammal parts. MTRP information can be mapped to show geographic distribution or graphed to look at the age and sex demographics of the harvest.

The USFWS also conducts other activities under the authorization of the MMPA, including review of scientific research and public display permits and issuance of letters of authorization for harassment. The sea otter decline in Southwestern Alaska has also resulted in new activities authorized under the Endangered Species Act (ESA), including candidate species designation, proposed listing, and interagency consultations. If the Southwestern Alaska population is eventually listed under the ESA, the USFWS will play a lead role in the recovery planning process.

All of the studies and programs listed above are conducted in close cooperation with other agencies and organizations. For the past several years, the USFWS has entered into annual cooperative agreements with the Alaska Sea Otter and Steller Sea Lion Commission to implement section 119 of the MMPA. The purpose of these agreements is to conserve marine mammals and co-manage subsistence use by Alaska Natives. More recently, the USFWS has issued a grant to the ASLC for research into the sea otter decline. The USFWS also works closely with the USGS through interagency agreements on a number of studies. Outreach and education are an important component of the USFWS sea otter program; information about ongoing studies is regularly presented at public meetings.

The Alaska Science Center's Sea Otter Research Program

James Bodkin
U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska

The U.S. Geological Survey (USGS) provides expertise and research results and capabilities to Department of Interior agencies, and other federal, state, and local governments and nongovernmental organizations. USGS sea otter research is organized into two programs, one based in Santa Cruz, California, and led by Dr. James Estes, and the other based in Anchorage, Alaska, and led by James Bodkin. Both programs are organized similarly with two basic research directions, one being the assessment of wild sea otter populations and the other being the understanding of the ecological role of sea otters in North Pacific coastal marine communities. The following summary describes the organization and research projects within the Alaska Science Center's Marine and Freshwater Ecology Branch.

The Alaska sea otter project includes research on (1) developing and applying methods to assess sea otter populations; (2) understanding the direct and indirect effects of sea otters on the structure and function and nearshore marine communities; and (3) understanding the consequences of, and recovery from, the *Exxon Valdez* oil spill of 1989.

Population Assessment

In 1991 we began a major research project directed at developing, testing, and implementing a sea otter survey design that would reduce the widely recognized detection bias inherent in most prior methods, provide reasonable levels of precision, and be applicable throughout the species' range. Following successful testing, an aerial survey design was implemented in Prince William Sound, Alaska, in 1994 (Bodkin and Udevitz 1999). The method uses a single engine, float equipped, fixed-wing aircraft and a single observer. Systematic transects 400 m wide are surveyed from 300 feet at a speed of 65 miles per hour and intensive circular searches within strips are used to estimate detection along strips. Since 1994 the survey method has been applied to sea otter populations from

Southeast Alaska to the Kodiak archipelago. Because sea otter populations currently occur at densities below, at, or near carrying capacity, testing of other means of population assessment generally includes contrasts between populations of known or assumed status, usually considered in relation to available food or space resources. Other projects directed at population assessment include estimates of age- and sex-specific survival and reproduction (Bodkin et al. 1993, 2000; Monson et al. 2000b; Ballachey et al. 2003) and the effects of population bottlenecks on genetic diversity (Bodkin et al. 1999). Ongoing assessment programs include evaluating measures of condition (morphometrics and health), diving behavior, and time budgets in relation to population status.

Coastal Marine Ecology

The ecological aspects of sea otters in Alaska are largely being addressed by using Glacier Bay National Park and Preserve as a laboratory in which the effects of sea otters can be investigated in an experimental framework. Sea otters were essentially absent from Glacier Bay prior to 1998, yet currently number more than 1,500. Since 1993 we have been monitoring sea otter abundance and diet in and near Glacier Bay. Since 1997 we have established and sampled more than 100 sites to evaluate the species composition, abundance, and sizes of conspicuous echinoderms, mollusks, and crustaceans prior to sea otter colonization. We will continue to monitor sea otter abundance and diet in Glacier Bay and begin the process of resampling invertebrate sites as the process of sea otter recovery continues (Bodkin et al. 2003).

Exxon Valdez oil spill: In 1989 we began research to understand the acute and chronic effects of the *Exxon Valdez* oil spill, and to understand the process of, and potential constraints to, sea otter recovery from this event. We have conducted studies of sea otter abundance, survival, reproduction, diet, prey populations, and biomarkers of exposure to hydrocarbons. Results of our work have identified the mechanisms of population recovery in addition to the unanticipated impediments to complete recovery (Bodkin et al 2002, Peterson et al. 2003).

Recent Findings from Sea Otter Necropsies: California and Alaska

Melissa Miller[1] and Kathy Burek[2]
[1] *University of California Davis Wildlife Health Center, California Department of Fish and Game, Marine Wildlife Veterinary Care and Research Center, Santa Cruz, California*

[2] *Alaska Veterinary Pathology, Eagle River, Alaska*

This presentation was divided into three parts: (1) a summary of general recommendations for implementing a cross-comparative sea otter (*Enhydra lutris*) necropsy program for Alaska and Russia; (2) examples of common lesions detected at necropsy of California sea otters; and (3) comparisons with reported findings from necropsies of Alaskan sea otters.

The process of postmortem examination begins at the time of carcass discovery. Factors such as carcass location, proximity to other dead and live animals, local environmental features, weather conditions, and other clues at the scene may all provide critical insight. Also important are antemortem behavioral observations and diagnostic tests that were initiated while the animal was alive. It may be necessary to perform a field necropsy and to consider sampling of local prey species, water, or the environment. However, if possible the carcass should be chilled in ice or snow, prevented from freezing, and quickly transported to a specialty laboratory with appropriate equipment and trained veterinary pathologists. Samples can be collected and banked for a number of diagnostic tests, depending on the circumstances of each case. It is important to collect both biological and diagnostic data, as each yields critical information that is important for understanding the living population. It is important to fit the necropsy protocol to what is practical and achievable, but much can be accomplished even under the harshest conditions with some ingenuity and creativity. Under optimal sampling conditions, a systematic postmortem examination can include radiographs, scanning for the presence of a passive integrated transponder (PIT) tag; internal and external morphometrics; digital photographs; sampling of all major tissues for histopathology; bacterial, fungal, viral, or protozoal culture from tissue samples; lesions or feces; serology; tests for the presence and concentration of anthropogenic pollutants or marine biotoxins; and parasite and prey species identification. Not all of these procedures need to be performed all at once or even on every necropsied sea otter. However, many are quite amenable to utilizing cryopreserved samples and completing the testing in batches at a more convenient time and location. In addition, systematic sampling greatly facilitates later, retrospective research. Samples of serum, cerebrospinal fluid, bile, urine, milk, and tissue can easily be stored at –80ºC for later study, especially if a computerized system is used to label and code the samples. Additional samples may be collected for forensics, petroleum fingerprinting, cytology, or other purposes, depending on the case. The overall goal is to make the necropsy process as systematic and therefore cross-comparative as possible. The greatest strengths of wildlife pathology lie in the ability to objectively study specific causes of mortality, to detect spatial, temporal and environmental patterns, and to accurately compare disease processes occurring in geographically distinct populations. However, if differing techniques, protocols, and levels of detection are used during the necropsy process, all subsequent investigators will be forced into the unenviable position of having to compare "apples and oranges" and the likelihood of missing or misidentifying range-wide mortality patterns is increased.

Once a systematic necropsy program is implemented, maximum benefit is derived from the resulting data by incorporating it into a computerized database. Organizing the data in this way will greatly facilitate efforts to locate interesting cases, to compare specific causes of mortality, to locate banked samples or biological data, and to conduct epidemiological investigations. Several databases with complementary functions already exist for California sea otter necropsy and sampling data. These existing database frameworks may be adaptable for use by other sea otter programs and modified to fit their specific needs. Cross-collaboration is the key to success; there are not enough research funds, people, or resources to maintain several independent programs with redundant capabilities. Each group has strengths and weaknesses in terms of personnel, expertise, professional mandates, and equipment. Identifying those key areas and seeking ways to cross-collaborate will greatly increase productivity and also enhance the overall quality of the research program by providing a balanced perspective.

A necropsy and data archiving system has allowed researchers in California and Wisconsin to identify and study common causes of California sea otter mortality, including white shark predation, acanthocephalan peritonitis, protozoal meningoencephalitis, bacterial infections, and cardiomyopathy syndrome (Thomas and Cole 1996, Kreuder et al. 2003; Table 1). In addition, this system has permitted the identification of specific temporal and spatial trends for California sea otter mortality (Ames et al. 1996; Thomas and Cole 1996; Kanaan et al. 1998; Cole et al.

Table 1. Patterns of California sea otter mortality. Adapted from Thomas and Cole 1996 (*n* = 195) and Kreuder et al. 2003 (*n* = 105). NR = not reported.

Findings	1992-1995	1998-2001
Acanthocephalan peritonitis	14%	16.2%
Protozoal encephalitis	8.5%	22.9%
Bacterial infection	12%	6.7%
Coccidiomycosis	4%	<1%
Cardiomyopathy	NR	13.3%
Shark predation	7%	13.3%
Boat strike	NR	4.8%
Gunshot	4%	1.9%
Domoic acid intoxication	NR	>4%

2000; Miller et al. 2002a,b; Kreuder et al. 2003; Mayer et al. 2003; Miller et al. 2004).

For example, a spatial "hotspot" for white shark predation of sea otters, first reported by Ames et al. (1996), was later statistically confirmed by Kreuder et al. (2003). High risk areas have also been detected for other causes of California sea otter mortality, including coccidiomycosis (Thomas and Cole 1996), acanthocephalan peritonitis (Kreuder et al. 2003, Mayer et al. 2003) and *Toxoplasma gondii*–associated infection and disease (Miller et al. 2002a,b; Kreuder et al. 2003). Similarly, temporal trends have been identified for otters dying due to *Sarcocystis neurona* infection (Kreuder et al. 2003) and cardiomyopathy syndrome (C. Kreuder, U.C. Davis, pers. comm.). In the case of confirmed or suspected marine biotoxin-related mortality, it is feasible to examine the temporal association between confirmed "blooms" of the causative diatom and animal mortality in both time and space, and to examine mechanisms of food web transfer (Scholin et al. 2000). In addition, a relationship between sea otter infection with *T. gondii* and exposure to major plumes of freshwater runoff along the California coast was detected (Miller et al. 2002b). Recognition of environmental disease patterns will allow research and potential mitigation efforts to be focused in the areas where the potential impact is greatest.

Comparisons of aspects of biology and necropsy findings from California and Alaska sea otters have yielded some interesting trends (Table 2). This information must be interpreted with some caution as only a small sample of Alaska otters were available for comparison and because much has yet to be learned about some disease processes. However, some

Table 2. Preliminary comparative findings from California and Alaska sea otters. Findings for Alaska sea otters should be interpreted with caution because sample sizes are low.

Postmortem finding	California	Alaska
Fatal mating (nose) wounds	Common or rare	Not reported
Reported predators	Sharks	Killer whales, humans
Cardiomyopathy syndrome	Common	Not reported
Acanthocephalan peritonitis	Common	Not reported
Protozoal meningoencephalitis	Common	Not reported
Malignant tumors	Rare (low sample size)	Common?
Vegetative valvular endocarditis	Relatively uncommon (low sample size)	Common?
Congenital defects	Polycystic disease	Porencephaly
Anthropogenic pollutants	Multiple "hotspots"	Aleutians, especially Adak
Marine biotoxin intoxication	Increasing?	Not reported
Natural petroleum seeps	Present, rare mortality	Not reported
Fish in diet (wild otters)	Very rare	Common
Parasite flora:		
A. Cestodes	None	Common
B. Nematodes	Very rare	Common
C. Acanthocephalans	Common	Common
D. Trematodes, gallbladder	Not present or rare?	Common
E. Trematodes, intestine	Common	Common
F. *Toxoplasma gondii*	Common	Not detected
G. *Sarcocystis neurona*	Relatively common	Not detected

distinct differences have been reported with respect to mating habits, predators, diet, and resulting parasite flora, seroprevalence to infectious agents, and mortality due to infectious agents such as protozoa and acanthocephalans (Riedman and Estes 1990, Estes et al. 1998, Miller et al. 2002a, Hanni et al. 2003). Early comparisons of the data suggest some differences in prevalence of certain malignant tumors, but more work needs to be done to confirm this. There is also much to learn about disease syndromes that are newly recognized, such as cardiomyopathy syndrome and its possible relation to previous exposure to infectious agents or toxicants. This syndrome could also be affecting Alaskan and Russian otters, but has yet to be discovered.

In closing, there is great advantage to pooling resources and knowledge across state and international borders. The goal of this presentation was to assist with the process of brainstorming and growing autonomous sea otter necropsy programs in Alaska and Russia, so that the following objectives could be achieved for the benefit of the entire sea otter population:

1. To develop systematic, cross-comparative necropsy data within and between sea otter populations.
2. To facilitate comparisons of "like with like" (e.g., to maximize the scientific quality of the data).
3. To help distinguish between disease exposure versus mortality.
4. To facilitate detection of temporal, spatial, and environmental mortality patterns to more precisely focus research and mitigation efforts.
5. To help analyze findings in the context of population data and broader management implications.
6. To identify points for potential human intervention.
7. To help facilitate assessment of immune function and competence.
8. To help facilitate assessment of environmental contaminant exposure and relation to specific disease.

Methods of Population Assessment: Northern Sea Otters in Alaska

Angela Doroff
U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska

A variety of methods can be used to assess sea otter (*Enhydra lutris*) populations. These methods include population surveys (population trend/abundance estimates), physiological parameters (weight/length ratio, serology/serum chemistry, immune/stress response), and behavioral parameters (time/activity budgets). In order to interpret the physiological and behavioral data, however, we need to know the population status relative to an equilibrium density. Some of the questions we may ask regarding sea otter populations relate to their distribution, population trends, population abundance, and the rate of population change.

The chosen method of population survey relates to the question being asked, the feasibility of implementing such a method, and the geographic scale of the project. Three main approaches have been used to census sea otters: shore-based, skiff-based, and aerial-based surveys. Each method has strengths and limitations. Shore-based surveys work well in areas where (1) high-density sea otter habitat is concentrated nearshore (≤ 1 km); (2) there is access to the entire shoreline to be surveyed; and (3) there is enough relief along the coast to easily view the habitat. Shore-based surveys can provide a wealth of information on sea otter activity, foraging, adult/pup ratios, and habitat use. However, this method is not often employed in Alaska because few areas provide enough accessible vantage points over a broad geographic scale.

Similarly to shore-based surveys, skiff-based surveys also provide information on sea otter activity, adult/pup ratios, and habitat use, and also work well where high-density sea otter habitat is found nearshore. In Alaska, this method is employed primarily to estimate relative abundance of sea otters at long-term monitoring sites. A common limitation of skiff-based surveys is that they are often not corrected for otters not observed during the course of the survey.

Aerial-based surveys provide the greatest habitat and area coverage per unit time both near and offshore. As a result, aerial-based surveys are often employed in Alaska. However, it is more difficult to obtain detailed information on sea otter activity and accurate adult/pup ratios with this method because of the speed of the aircraft.

Surveys in Alaska have been conducted using all these methods either alone or in combination.

The best way to ensure consistency and comparability of survey data over time, whether the objective is to monitor population trends or to estimate abundance, is to (1) standardize survey protocols across field crews and agencies; (2) train observers well; and (3) replicate surveys.

To document population trends over time and range expansion, which are important parameters for the management of populations, it is necessary to monitor key areas consistently through time. For example, sea otter distribution throughout the Kodiak archipelago has been monitored using aerial surveys since the 1940s, as the sea otter population expanded in range. Surveys of sea otter distribution have also occurred in potential (not known to be recolonized) and in very low density habitats, such as Albatross Banks offshore Kodiak archipelago, to help document range expansion.

Surveys repeated at seasonal intervals are useful to assess changes in distribution and abundance relative to season. An example of this approach is provided by quarterly surveys of the Alaska Peninsula conducted in 1986. This region includes extensive offshore habitats (up to 40 km offshore) and requires a twin-engine aircraft to safely survey the area.

Using different survey methodologies in combination can be beneficial to obtain correction factors and to compare results obtained using different survey platforms. For example, the USFWS used both skiff-based and aerial-based surveys to estimate relative abundance of sea otters in the Aleutian archipelago, and two types of strip-transect methods were used in Southwestern Alaska: one that does not correct for undetected otters and one that does. The second method was developed by Bodkin and Udevitz (1999) for obtaining estimates of absolute abundance and observer-specific correction factors. The method requires the use of a single engine aircraft with tandem seating, and allows for adjustable sampling intensity in high and low density habitats, complete counts of large groups (> 25 otters), and an adjusted population estimate that incorporates variation from the strip count and the correction factor. In Southwestern Alaska, this method has been used only along the Kodiak archipelago.

In 2000-2003, our initial questions for Southwestern Alaska were (1) has the population changed in absolute or relative abundance from historical data; and (2) if there has been a population change, what was the rate of change? To answer these questions, consistent sampling protocols and survey methods were developed for all our study areas. The methodologies are consistent within areas but may vary between areas based on differences in survey history, habitat type, and logistic feasibility. Given the severe population declines in the Southwestern population stock, we need to refine our tools for population monitoring including methods, precision, frequency, and seasonal sampling patterns.

Sea Otter Mortality: Overview of Methodology

Alexander Burdin and Donald Calkins
Alaska SeaLife Center, Seward, Alaska

It is well-known that there are two main components that influence population dynamics: loss of animals (mortality and emigration) and recruitment (birth and immigration). This simple model provides an explanation of what may happen in a population if one of these components becomes dominant. Although emigration may be significant in some situations, in the sea otter (*Enhydra lutris*), mortality appears to be the leading factor of population change. For example, catastrophic events like a tsunami or an epidemic can cause dramatic declines within weeks.

Mortality is generally either related to natural or anthropogenic factors. An example of mass mortality caused by natural factors was an event on Bering Island, Russia, in 1990-1991. This event was estimated to be mostly due to the population responding to increasing density (density dependent) such that the population was beyond the carrying capacity of the environment. An anthropogenic event causing mass sea otter mortality was the *Exxon Valdez* oil spill in 1989.

Other factors also play a role in population dynamics. In some cases age-specific mortality can be important; for example, recently weaned sea otters and very old animals experience much higher mortality rates during cold and stormy winters than during mild and calm weather. Natural and human related pollution can cause some mortality. Most sea otter habitats are located within a volcanic zone, and volcanic eruptions can bring millions of tons of volcanic ash to the ocean causing natural pollution by heavy metals or other toxins.

In trying to understand why sea otter populations decline, we must be able to determine how many sea otters died and the reason for the mortality. Some newly developed methods such as fatty acid analysis of killer whale blubber, or some standard methods such as direct observation of killer whale predation have been proposed to estimate the effects of killer whale on sea otter populations. However, these methods are unlikely to provide a definitive answer to the question of how many sea otters are being taken by transient killer whales.

Well tested methods available to study population loss are live animal tagging programs, carcass salvaging, and monitoring of loss by emigration. A recently developed tagging program in the Commander Islands will provide an opportunity to learn more about individual animal health over time by marking them with temple tags of different colors. Live animals captured for tagging are also anesthetized to collect many of the samples that are generally obtained during a necropsy. However, sampling live and healthy animals provides invaluable data on normal health profiles, which can be contrasted to data collected from carcasses. The future recovery of tagged carcasses will also be instrumental to understanding mortality patterns. Other types of tags (including VHF or satellite tags) are available, and their use may be more appropriate in some studies depending on available funds.

The Russia sea otter research program has been conducting an intensive effort of salvaging beach-cast sea otter carcasses. Currently, researchers that have participated in this program are striving to find ways to improve the protocols used for collecting mortality data. For example, protocols are necessary to keep track of carcass recovery rates in different types of ecosystems (i.e., in areas where arctic foxes, brown bears, and/or scavenging birds are present or absent), since the time that carcasses remain intact on shore can vary dramatically at different locations and in different seasons. Improved protocols would provide information on how many carcasses were not recovered due to scavenging. In addition, carcass recovery efforts need to be expanded to other areas of the Russian Far East coast so that potential future population declines can be identified early.

Carcass necropsy has provided much information about the pathology, disease profile of dead sea otters, and cause of death. The extraction of teeth from carcasses also provides estimates of the age of the animals at death. In addition, female reproductive tracts (uterus and ovaries) can be retrieved to investigate the breeding history of individuals. The improvement in the protocols used to necropsy sea otter carcasses would also be beneficial to the Russian research program.

At the moment, the collection of beached carcasses is still the most informative source of mortality data in Russian waters. A well developed program of carcass collection, necropsy, and tooth and skull collection using uniform protocols should be generated for the entire sea otter range in Alaska and Russia for comparative purposes. In addition, capture and tagging of sea otters should be continued in the Commander Islands, Northern Kuril Islands (Russia), and in the Aleutian Islands (USA). To allow improved opportunity for comparative studies, a Web-based sea otter biosampling and mortality database should be developed.

Are Killer Whales Responsible for Marine Mammal Declines in Alaska? A Russian Perspective

Vladimir N. Burkanov
Kamchatka Branch the Pacific Institute of Geography, Russian Academy of Sciences, Petrovavlovsk-Kamchatsky, Russia

The recent publication by Springer et al. (2003) has resulted in controversial discussions regarding the impact that killer whale (*Orcinus orca*) predation may have on the population declines of Western Alaska pinnipeds and sea otters (*Enhydra lutris*). The theory has many supporters and opponents, and was a major topic at a number of recent scientific meetings (e.g., Marine Mammal Conference in Greensboro, North Carolina; EVOS meeting in Anchorage, Alaska) and has had significant press coverage. However, no convincing and/or unequivocal evidence has been brought forward regarding the role that killer whales may have in the megafaunal collapse of North Pacific marine mammal populations. In theory, however, it is plausible that killer whale predation may be responsible, or contribute in part, to the population declines recently documented for Steller sea lions (*Eumetopias jubatus*), harbor seals (*Phoca vitulina*), and sea otters in the Aleutian Islands. Declines of these species, however, do not occur near the western coast of North America where the proportion of transient killer whales is greater than in the Aleutian Islands. Supporters of the theory reason that there is a significant difference in the structure and function of ecosystems between the two areas, and that the situation occurring in the Aleutian Islands may thus be very different from that occurring off the western coast of North America.

The Commander Islands are part of the Aleutian Island archipelago and are located in the western part of the Aleutian chain. They are separated from the Near Islands ridge by a strait 275 km wide. Climatic conditions and sea current characteristics greatly resemble those of the Near Islands and of other islands of the Aleutian chain. Four species of marine mammals including killer whales, sea lions, seals, and sea otters, which make up the essence of the problem and discussion, inhabit the Commander Islands (Barabash-Nikiforov 1947). For the last 30 years, sea lion numbers in the Commander Islands have been declining. This trend is similar to that reported for the Aleutian Islands and the Gulf of Alaska (Burkanov et al. 2003). Changes in the numbers of the other two species (harbor seals and sea otters), however, differ greatly between the two regions (Zagrebelny and Fomin 2001; Burkanov et al. 2003). Unlike the population declines observed in the Aleutian Islands, populations of harbor seals and sea otters are increasing in the Commander Islands.

Initially, sea otters were discovered to be declining around the central part of the Aleutian ridge, and later this phenomenon was documented west and east along the Aleutian chain (Springer et al. 2003). The sea otter population in the Near Islands declined rapidly in 2003 (A. Doroff, U.S. Fish and Wildlife Service, pers. comm.). If killer whales are directly responsible for this phenomenon, then, logically, one would expect that transient killer whales should move west and begin to appear near the Commander Islands; if this were the case, there would be a unique opportunity to test the hypothesis that killer whale predation is responsible for the sea otter decline.

Based on the results of preliminary studies conducted by North Pacific Wildlife Consulting in 2002, it has been demonstrated that long-term observational studies documenting the interactions among killer whales, seals, and sea otters are possible on the Commander Islands. This type of research may prove to be very successful in assessing the role that killer whale predation may have on marine mammal populations (Burkanov et al. 2003). The following is a proposed outline of the research to be conducted in the Commander Islands.

Purpose of the Research

The objective of this study is to verify the hypothesis that killer whales are responsible for the decline in numbers of sea lions, seals, and sea otters in the Aleutian Islands.

Sites and Stages of Work

Commander Islands

Several nearshore areas off both Bering and Medny islands have relatively high densities of prey for transient killer whales (e.g., fur seal [*Callorhinus ursinus*] and Steller sea lion rookeries, harbor seal haul-outs, and sea otter habitats). Prey density in this area changes seasonally. For fur seals, populations are much higher in June through November when fur seals are present on the rookeries. With the onset of November and December and departure to the wintering grounds, fur seal numbers are reduced in this area. Conversely, there is no seasonal variation in harbor seal, sea otter, and Steller sea lion density; however, some redistribution of these species within the area has been documented.

Shore-Based Observations

Two to four sites will be selected on both Bering and Medny islands as shore-based stations. The sites will be selected based on the differences observed in prey species composition, biomass, and densities, reflecting the overall prey base available for transient killer whales. A long-term study (at least one annual cycle) will be carried out to monitor both the presence and absence and activity of both predator and prey. Acoustic monitoring of killer whale activity in sea otter habitats will be conducted throughout the time data are being collected from shore. During the summer (May-September), shore-based observations will be combined with data collection from a Zodiac launched from shore when killer whales are sighted to obtain good quality photo-identification pictures, biopsy samples, acoustic data, and a detailed description of killer whale behavior in sea otter habitats. If transient killer whales are found regularly in the area where shore-based observations are being conducted, radio or satellite transmitters will be deployed on the whales to track their movement and activities in sea otter habitats for extended periods of time.

Boat-Based Observations

Two, 2- to 3-week long research cruises will be conducted off the Commander Islands to search for transient killer whales. Areas searched will be based on previously collected information gathered by the shore-based observers (i.e., the frequency of occurrence of transient killer whales at survey sites, duration of their stay, and activity). When killer whales are encountered, they will be followed for extensive periods of time. Data collected will include photo-identification, underwater recordings, biopsy sampling, and detailed records of behavioral activities. One cruise will be conducted during the periods of highest prey density (e.g., during pup weaning in August and September). The second cruise will occur during the low prey density season (winter or early spring).

Expected Yield

1. The Commander Island study will produce quantitative data on the annual occurrence of killer whales and their associated behavior in areas that are regularly inhabited by pinnipeds and sea otters. Seasonal changes in the number and occurrence of killer whales will be characterized both by visual and acoustic frequency of occurrence. Information on killer whale group structure, ecotype assessment (i.e., resident, transient, offshore), and individual identifications will also be collected during this study.

2. Seasonal data on potential prey species composition, population levels, and mortality (to include cetaceans, pinnipeds, and sea otters) in the waters viewed from the observational field sites have already

been collected. Changes in the number, species composition, age, and biomass structure are available by season for all species. In addition, records of recent injuries to pinnipeds and sea otters hauled out onshore are known and samples have been collected from stranded dead animals.

3. Identifications (photographic, acoustical, and genetic) will be made of transient killer whales that inhabit waters off the Commander Islands. The ability to recognize individual whales will allow us to determine if the same killer whale pods/groups repeatedly occur off the Commander Islands.

4. Quantitative data will be collected on the activity and feeding behaviors of killer whales in areas where high concentrations of pinnipeds and sea otters occur (e.g., frequency of occurrence of transient killer whales near survey sites, number of attacks/kills, or other interactions visible from shore, or detectable with a hydrophone, etc.). Data will be analyzed and compared to determine if seasonal changes occur in killer whale behavior.

5. This study will provide a quantitative assessment of predation frequency and the type and number of prey currently being targeted by killer whales. From these data, we will be able to predict the potential future impact that killer whale predation may have on prey populations in the Commander Islands.

Sea Otter Research Methods and Tools

James Bodkin
U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska

Sea otters possess physical characteristics and life history attributes that provide both opportunity and constraint to their study. Because of their relatively limited diving ability they occur in nearshore marine habitats that are usually viewable from shore, allowing direct observation of most behaviors. Because sea otters live nearshore and forage on benthic invertebrates, foraging success and diet are easily measured. Because they rely almost exclusively on their pelage for insulation, which requires frequent grooming, successful application of external tags or instruments has been limited to attachments in the interdigital webbing of the hind flippers. Techniques to surgically implant instruments into the intraperitoneal cavity are well developed and routinely applied. Because they have relatively small home ranges and rest in predictable areas, they can be recaptured with some predictability using closed-circuit scuba diving technology. The purpose of this summary is to identify some of the approaches, methods, and tools that are currently engaged for the study of sea otters, and to suggest potential avenues for applying advancing technologies.

Capture

Three common methods are employed to capture sea otters. These include floating tangle nets set in the ocean and dip-nets used to capture individuals either on haul-outs, or on the sea surface. These methods require training and experience for success and the safety of the animals. Much of the capture work conducted today, however, relies on the use of closed-circuit scuba, underwater propulsion vehicles, and an attached trap, known as the Wilson trap. The Wilson trap has contributed substantially to advancing our understanding of the species by allowing for the directed capture and recapture of known individuals. The capacity to recapture provides for the deployment of instruments in, or on individuals that can subsequently be recovered with relatively high probability, and will allow for the long-term study of individuals through the application, and reapplication, of remote sensing instruments. The Wilson trap capture method requires advanced scuba diving training as well as extensive experience to become effective.

Handling

Handling of live sea otters requires experience and care to ensure the well being of the sea otter, as well as the handler. Because of the stress and risks associated with handling alert sea otters, most procedures requiring handling wild animals utilize anesthesia. Standard operating protocols related to the capture, handling, anesthesia, and surgical procedures, approved by the USGS, Alaska Science Center's Institutional Animal Care and Use Committee, are available from the author.

Common Approaches

Common research approaches include study at the level of the population and at the level of the individual. Study of abundance, proportion of pups in the population as an index of reproduction, mortality from collection of carcasses, dietary data to estimate diet and foraging success, and scan sampling to estimate activity-time budgets, does not require marked individuals and provides information at the level of the population. Marking of individuals with visual tags, or radio transmitters, facilitates recognition of known age and sex individuals over time. Observations of known individuals over time allows estimating age-specific survival and reproduction, diet and foraging success, movements, and activity-time budgets. Additional study at the individual level includes measures of morphology and collection of tissues that can be used to evaluate health, physiology, contaminants, disease, and endocrinology.

New Technologies

In recent years, new technologies and instruments have furthered our understanding of the basic biology and ecology of sea otters. Archival time-depth recorders have been applied externally and surgically implanted in sea otters, and have yielded new data on dive attributes and foraging dive depths and also provide a continuous record of behaviors over time periods up to one year. Temperature modulated internal radio transmitters are also providing new information on sea otter physiology. Endoscopic procedures have successfully been applied to sea otters to obtain biopsies of internal organs for histology and the evaluation of biomarkers, specifically the cytochrome P4501-A enzyme, as a measure of exposure to hydrocarbons.

Emerging technologies that may soon be applicable to wild sea otters include satellite transmitters and geographic positioning systems

(GPS). Application of these technologies will reduce the potential biases associated with the limited transmission distances of implanted conventional radio transmitters. Subcutaneous implants of instruments such as radiotransmitters may reduce the invasiveness of current implant surgery and improved battery capacities should extend the functional life of instruments deployed.

Feeding Ecology of Sea Otters in Simpson Bay, Alaska

Randall Davis[1], Andrea Gilkinson[1], Heidi Pearson[1], and Fred Weltz[2]

[1]*Texas A&M University at Galveston, Marine Mammal Research Program, Galveston, Texas*

[2]*Alice Cove Research, Cordova, Alaska*

Sea otters (*Enhydra lutris*) are opportunistic predators of sessile and slow-moving prey, especially benthic invertebrates. Their diet is diverse and varies geographically, temporally, and individually. Over 112 species of prey have been reported for Alaskan sea otters, although individuals probably specialize on fewer prey species (Table 1).

Sea otters are the smallest marine mammal and have the highest mass specific metabolic rate. However, they are the least adapted for diving and typically make short (< 2 min), shallow (< 50 m) dives. These characteristics limit their ability to exploit the marine environment for food, despite having the greatest mass specific food requirement (about 25% of body mass per day) of any marine mammal. The hind flippers of sea otters are used for aquatic locomotion and the forepaws are used to capture and manipulate prey.

The senses of touch and vision are probably used to locate prey. Sea otters use their molariform teeth to crush the exoskeletons of invertebrates, although they also use stones as tools. Maximum recorded dive depth is approximately 100 m for males and 76 m for females. Maximum recorded dive duration is about 4.5 min. Potential effects of sea otter foraging on coastal marine communities include the following.

1. Changes in the size, age classes, abundance, and distribution of prey.
2. Influence on kelp forest communities—the sea otter/sea urchin/kelp scenario.
3. Disturbance and resorting of sediments in soft-sediment communities and disruption of non-prey infauna.

Table 1. Phylogenetic categories of prey eaten by sea otters in Alaska.

Echiura
Sipuncula
Nemertea
Annelida
Polycheata
Mollusca
Gastropoda
Bivalvia
Polyplacophora
Cephalopoda
Arthopoda
Crustacea
Cirripedia
Malacostraca
Isopoda
Amphipoda
Decapoda
Echinodermata
Echinoidea
Asteroidea
Ophiuroidea
Holothurioidea
Chordata
Ascidiacea
Pices
Aves

During the past three years, we studied the intra-annual movements, feeding behavior, territorial male behavior, and habitat-associations of sea otters in Simpson Bay (about 60.7ºN, 145.8ºW), located in northeastern Prince William Sound, Alaska. Following are the objectives of this study.

1. Photo-identify sea otters to create a library of known individuals that can be re-identified over time.
2. Monitor intra-annual movements and behavior of photo-identified sea otters, including adult males and females with pups.
3. Determine seasonal habitat associations and prey preferences.
4. Determine size, location, and quality of male territories.

5. Assess potential predation of sea otters by killer whales and sharks.

We used photo-identification as a noninvasive technique for visually monitoring the movements, diving behavior, and prey preferences of recognizable individuals based primarily on distinctive nose scars. Digital images and behavioral observations were made from a 6 m skiff. In 2002, we digitally imaged 806 otters, of which 44 were re-identified with an average of 3.6 re-sightings per individual during the three month field season (June to August). In 2003, we imaged 835 otters, of which 65 were re-identified with an average of 4.8 re-sightings per individual.

During the past three years, we have also characterized the physiography of the study area. To accomplish this, we measured ocean depth (depth sounder) and sampled or visually inspected the benthos (Ekman grab, gravity corer, drop camera) at 200 sampling locations evenly distributed over the study area on a rectangular grid. We also acoustically imaged the subtidal area of the bay with a side scan sonar, visually surveyed and mapped the intertidal zone (substrate, slope, presence of streams), and examined adjacent terrestrial features such as drainage area for freshwater input. We correlated sea otter behavior (feeding, resting, grooming, patrolling) with habitat characteristics using GIS and various statistical methods. Preliminary analysis showed that feeding occurred more often in water that was less than 30 m deep, while resting, grooming, and traveling occurred more frequently in water that was 30-70 m deep ($p < 0.05$). Feeding also occurred most frequently in benthic areas with mud and sand with some gravel sediments, while resting, grooming and traveling occurred most frequently in areas composed mostly of mud with some sandy sediments ($p < 0.05$). The duration of male feeding dives (2.2 ± 0.9 min) was 22% longer than for females with pups (1.8 ± 0.9 min). In addition, the average depth of male feeding dives (36 ± 24 m) was 64% deeper than for females with pups (22 ± 20 m). Over 18 prey species were identified in the summer diet of sea otters in Simpson Bay (Table 2). However, most prey were clams (69%, probably *Saxidomus gigantea* and *Protothaca staminea*) or mussels (12%, *Mytilus edulis*). The quality of male territories was assessed using principal components analysis for the following variables: size, degree of enclosure by shoreline, access, and resources (feeding, resting, and grooming sites). Accessibility and resources were found to be important territory attributes for attracting females.

Future research will focus on the following.

1. Continuation of photo-identification to enlarge the number of identifiable otters in our database.

2. Assessment of intra-annual movements of identifiable otters with the additional deployment of intraperitoneal VHF radios in selected individuals.

Table 2. Summer prey of sea otters in Simpson Bay, Alaska, 2001-2003.

Butter clam (*Saxidomus gigantea*)
Pacific littleneck (*Protothaca staminea*)
Blue mussel (*Mytilus edulis*)
Nuttall cockle (*Clinocardium nuttallii*)
Reddish scallop (*Chlamys rubida*)
Alaska falsejingle (*Pododesmus macroschisma*)
Weathervane scallop (*Pectin caurinus*)
Pacific giant octopus (*Octopus dofleini*)
Alaska spoonworm (*Echiurus echiurus alaskanus*)
Dungeness crab (*Cancer magister* or other *Cancer* crabs)
Tanner crab (*Chionoecetes bairdi*)
Other brachyuran crabs (possibly box crab *Lopholithodes mandtii*)
Spot shrimp (*Pandalus* sp.)
Sea cucumber (*Parastichopus californicus*)
Sea stars (*Pisaster ochraceus* and others)
Skate egg case (*Raja* sp.)
Spoon (innkeeper) worm (*Echiurus echiurus*)
Sea anemone (*Anthopleura* spp.)

3. Enlargement of the database on feeding dives and prey preference with the additional deployment of intraperitoneal time/depth recorders in selected individuals.

4. Mapping territories of adult males and assessing indices of territory quality.

5. Assessment of the diversity, distribution and abundance of macroinvertebrates in the study area and correlation with habitat characteristics (e.g., sediment composition).

6. Assessment of habitat associations for different behaviors for adult males and females

7. Initiation of a carcass salvage program in collaboration with the U.S. Fish and Wildlife Service (USFWS).

8. Expansion of studies to include autumn (i.e., a period of heightened breeding) and to areas with habitats other than soft sediments.

Studying Sea Otter Foraging Ecology: A Review of Some Methodological Approaches

M.T. Tinker[1], J.A. Estes[1], J.L. Bodkin[2], M.M. Staedler[3], and D.H. Monson[2]

[1]*University of California Santa Cruz/USGS, Long Marine Laboratory, Santa Cruz, California*

[2]*USGS Alaska Science Center, Anchorage, Alaska*

[3]*Monterey Bay Aquarium, Monterey, California*

The study of foraging ecology plays a central role in our understanding of animal populations and natural communities, and can also provide information necessary for the effective conservation of rare or endangered species. Sea otter researchers are interested in foraging ecology for many different reasons, but for heuristic purposes we identify three general types of research questions: (1) questions about the implications of foraging decisions to individual fitness, the evolutionary significance of feeding strategies, and the selective forces and constraints that shape an individual's diet and feeding behavior; (2) questions about the population-level implications of foraging ecology; for example, how is the status of a population (with respect to carrying capacity) reflected by the foraging success or diet composition of individuals within the population (Fig. 1); and (3) questions about the community-level consequences of sea otter foraging. Sea otters provide an excellent study system for all three types of questions because they are a tractable species to study (generally feeding near shore and bringing all prey to the surface to consume), they exhibit a wide range of diets and foraging strategies in different habitats and at different population densities, they tend to have strong trophic interactions with their prey species, and their foraging behavior can have profound effects on community structure in the nearshore marine community.

We focus here on the population-level implications of sea otter foraging behavior, because of their relevance to our current understanding

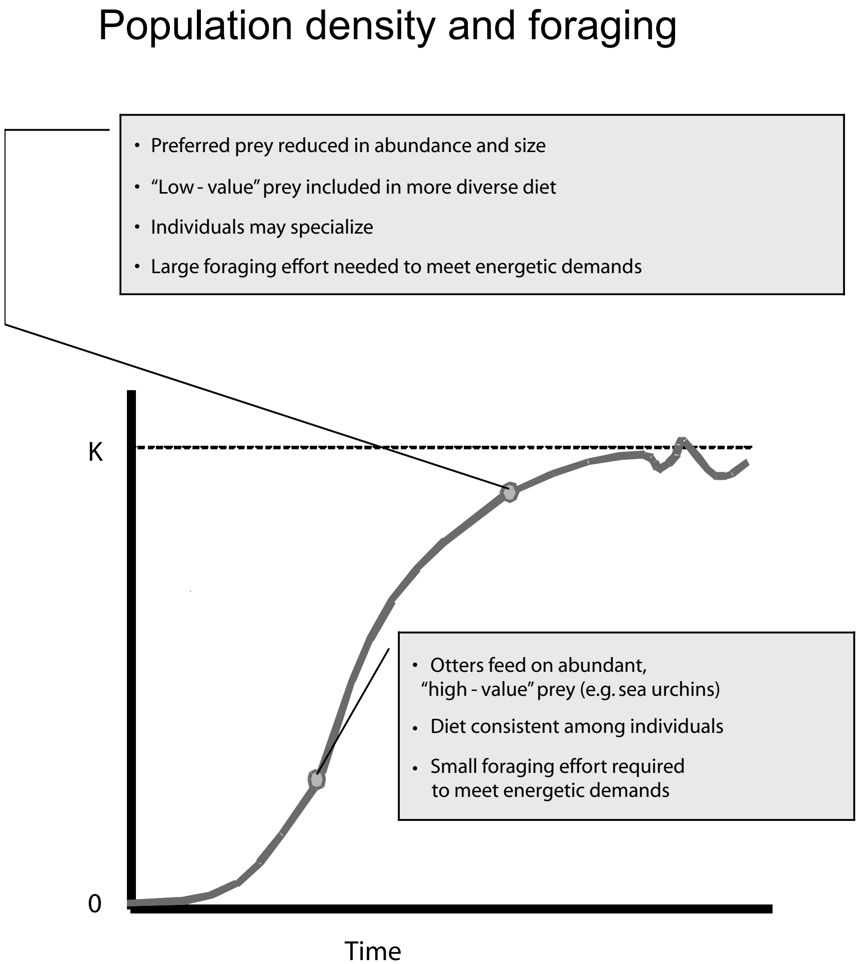

Figure 1. A conceptualization of the growth of a sea otter population toward carrying capacity, illustrating the relationship between sea otter population density and foraging behavior.

of the extensive population decline that has occurred throughout Southwestern Alaska (Doroff et al. 2003). As island populations decreased rapidly throughout the Aleutian archipelago in the mid-1990s (Estes et al. 1998), we wished to evaluate some of the most likely hypotheses about the cause of the decline (or the causes that seemed most likely based on previously documented instances of sea otter population declines). Principal among these was the food limitation hypothesis. Specifically, the hypothesis that population declines occurred as a result of decreased survival of individuals in response to a change in the abundance or nutritional quality of available prey (similar to the density-dependant, resource-driven decline documented in the Commander Islands around 1990; Bodkin et al. 2000). Fortunately, two telemetry-based studies of sea otters were conducted in the Aleutian Islands during the decline: one at Amchitka Island between 1992 and 1994 (when the decline was in its early stages) and one at Adak Island between 1995 and 1996 (when the decline had further progressed), and both of these projects included foraging studies. We used three related methods for studying sea otter foraging—direct foraging observations, analysis of collected scats, and benthic surveys—to characterize the foraging ecology of sea otters at these two study sites, and to thereby assess the status of the populations with respect to their food resources and the level of support for the hypothesis of food limitation as a causal agent of population decline. We use these case studies to illustrate complementary methodological approaches to studying foraging ecology.

The first and most powerful method to study foraging ecology involves direct observations of marked individuals within the population. Field observers locate individual, radio-tagged otters using standard telemetric techniques, and monitor each otter throughout a feeding bout (or for a continuous sequence of dives more than 30 minutes), recording the following: (1) date, time, and precise location of dives (using GPS); (2) duration of dive and surface intervals; (3) success of each dive (was prey captured?); (4) prey species; (5) prey size (maximum diameter, generally classified into 5 cm size classes); (6) number of prey items; (7) prey handling times; and (8) a variety of other information, including whether or not tools were used to process prey, whether food was stolen by/from another otter, whether food was shared with a pup, etc. These data are entered into a relational database, and can be used to compare diet and forage behavior among individuals or between populations, and to directly estimate the net rate of energy gain of each recorded feeding bout. While it is not absolutely necessary that longitudinal data be collected from marked individuals in order to characterize a population, it is greatly preferred because this allows researchers to account for potential bias due to the following known sources of variation in feeding behavior: (1) geographic or habitat-related variation; (2) age/sex-class differences; (3) seasonal variation; and (4) differences between individual prey

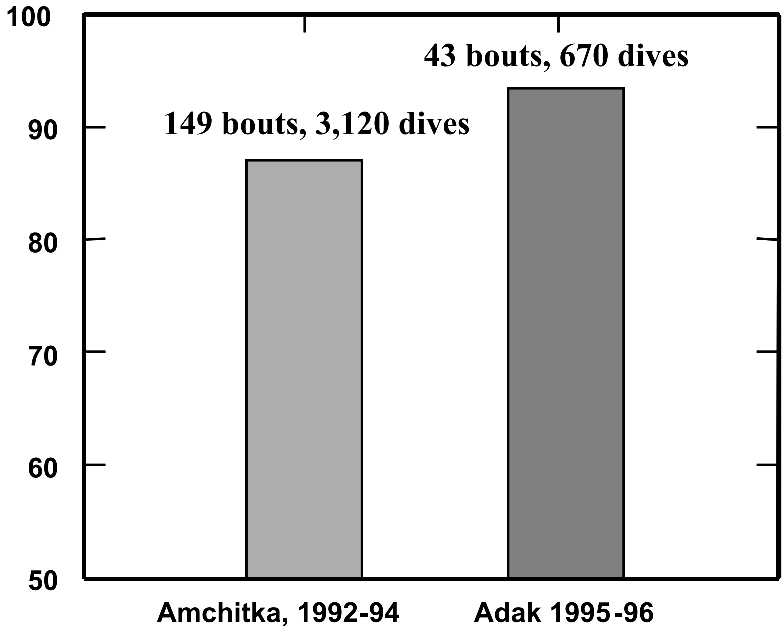

Figure 2. Comparison of dive success rate between adult females at Amchitka Island (early in the decline) and Adak Island (later in the decline). Analysis was limited to feeding bouts of more than 10 recorded dives, and bouts during which more than 80% of captured prey were green sea urchins (*Strongylocentrotus droebachiensis*). Dive success was significantly greater at Adak Island ($P < 0.01$).

specialists. Using marked individuals, sampling effort can be appropriately distributed, and the above sources of variation can be incorporated into the study design, and all analyses conducted accordingly. For example, after controlling for age/sex class and diet type in the Aleutian Islands studies, we saw a significant increase in the dive success rate of adult females foraging on sea urchins as the decline progressed (Fig. 2). We also found a general tendency toward decreased prey diversity in the 1990s, as compared to previous studies (Estes 1990, Watt et al. 2000).

A second method for investigating sea otter foraging and diet is the analysis of collected scats. This method is subject to considerable bias and is of more limited utility than direct feeding observations, but it can be very useful as a complement to observational studies. Sources of potential bias include seasonal (sea otters primarily haul out in the winter, and thus most scats collected are from the winter), individual

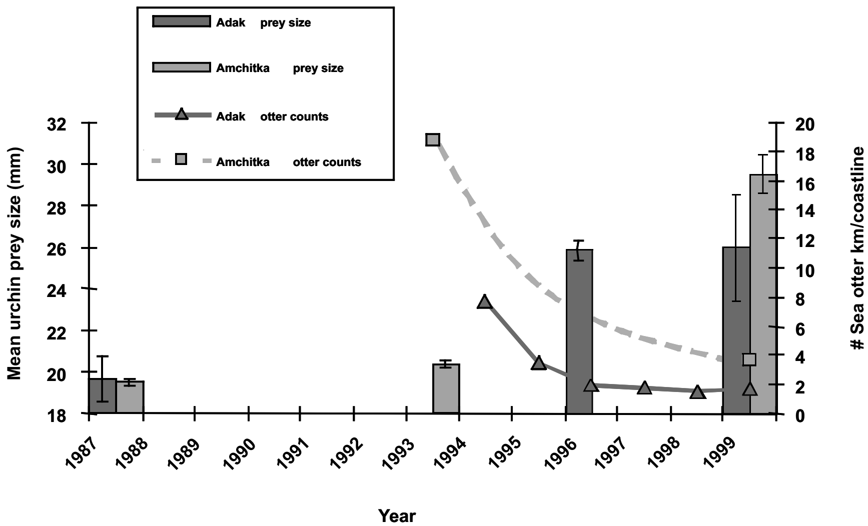

Figure 3. Trends in the size of sea urchins (*Strongylocentrotus droebachiensis*) consumed by sea otters at Adak and Amchitka islands between 1987 and 1999, as estimated from measurement of urchin mouth parts collected from sea otter scats. Bars indicate the estimated mean urchin diameter, and error bars correspond to standard errors. Differences between years are all statistically significant (nested ANOVA, $N = 5{,}732$ mouth parts nested within scats, $F = 31.0$, $P < 0.001$). Population counts for both islands are also shown for reference. In both cases, the size of consumed urchins increased as population counts decreased.

(some individuals or age/sex classes may haul out more than others) and compositional bias (prey types without small hard parts will be underrepresented in scats). While these biases will generally preclude using scats to accurately characterize the dietary composition of a population, scat analysis can nonetheless be used very effectively to address specific questions. For example, the observed increase in the success rate of feeding dives during the Aleutian population decline (Fig. 2) would suggest an increased rate of energy acquisition, but only if the individual urchins consumed were not decreasing in size or nutritional quality (i.e., if urchins were getting smaller, otters would have to capture more just to maintain constant energy input). To determine whether this was the case, we collected scats and measured the length of sea urchin mouth parts sampled from these scats; because there is a highly significant relationship between mouth part length and sea urchin diameter, we could infer from these data the mean size of urchins being consumed. This analysis showed a clear increase in consumed sea urchin size as the decline progressed (Fig. 3).

A third tool that can be used in studies of sea otter foraging is the sampling of sea otter prey species themselves. Benthic sampling can be conducted in both soft-bottom and rocky-bottom substrates in order to sample important prey species, and measure both prey density and size (as a proxy for energy content). As with the previous two methods, it is important to consider potential sources of variation—for instance, differences between locations, habitat types, or bottom depth—when designing benthic sampling studies, as these can introduce bias into the results. In the Aleutian Islands, for example, measurements conducted at long-term sampling sites at Adak and Amchitka islands all showed a dramatic increase in sea urchin size and density between 1987 and 1999, corresponding to a net fivefold increase in available urchin biomass at both locations. This pattern was consistent at both shallow (10 m) and deep (20 m) sampling locations.

As the above examples make clear, foraging studies are most powerful when a suite of techniques are used, rather than just a single method. A high degree of correspondence between independent analyses provides much better support for conclusions drawn. In the Aleutian data, all three approaches pointed toward an increase in food resources for sea otters during the decline, thus failing to support the food limitation hypothesis. Of the three methods, scat analyses are perhaps the cheapest, and for specific questions (e.g., trends in the size of prey consumed) they can provide enormous statistical power; however, they are also the most subject to bias. Longitudinal observational studies of marked individuals provide the most unbiased measurement of foraging success. New telemetric technologies, particularly archival time depth recorders (TDRs, which collect continuous measurements of dive depth), can now be paired with observational studies to gain an even more comprehensive picture. Early results from TDR-equipped sea otters in Southeast Alaska and California indicate that this combination of observational data and dive profiles can be used to assess foraging effort, net rate of energy gain, and the energetic implications of individual feeding strategies. Future foraging studies will thus provide a better tool than ever for assessing the status of populations with respect to their food resources, and therefore give us a clearer understanding of the threats to imperiled sea otter populations.

Population Demographics, Survival, and Reproduction: Alaska Sea Otter Research

D.H. Monson[1], J.L. Bodkin[1], D.F. Doak[2], J.A. Estes[2], M.T. Tinker[2], and D.B. Siniff[3]

[1]*U.S. Geological Survey, Alaska Science Center, Anchorage, Alaska*

[2]*University of California Santa Cruz, Santa Cruz, California*

[3]*University of Minnesota, St. Paul, Minnesota*

The fundamental force behind population change is the balance between age-specific survival and reproductive rates. Thus, understanding population demographics is crucial when trying to interpret trends in population change over time. For many species, demographic rates change as the population's status (i.e., relative to prey resources) varies. Indices of body condition indicative of individual energy reserves can be a useful gauge of population status. Integrated studies designed to measure (1) population trends; (2) current population status; and (3) demographic rates will provide the most complete picture of the factors driving observed population changes. In particular, estimates of age specific survival and reproduction in conjunction with measures of population change can be integrated into population matrix models useful in explaining observed trends. We focus here on the methods used to measure demographic rates in sea otters, and note the importance of comparable methods between studies. Next, we review the current knowledge of the influence of population status on demographic parameters. We end with examples of the power of matrix modeling as a tool to integrate various types of demographic information for detecting otherwise hard to detect changes in demographic parameters.

Longitudinal studies of individually marked otters provide the most detailed information on age-specific survival rates and reproductive rates including birth rate and weaning success rate (Siniff and Ralls 1991, Jameson and Johnson 1993, Riedman et al. 1994, Monson and DeGange 1995, Monson et al. 2000a). Radio telemetry studies in particular allow the consistent resighting of individuals over time and precise estimates of the timing of pup births, and length of gestation and pup dependency. Radio instrumentation requires capture, thus allowing the collection of additional information on individual condition (i.e., mass/length ratio), current reproductive status, and health. In addition, the carcasses of radio-instrumented individuals dying during the study are more likely to be recovered in suitable condition for necropsy (especially in remote areas) so that cause of death might be determined.

In contrast to longitudinal studies, survey methods provide less detailed reproductive information, little information on individual condition or health (but see Bodkin et al. 1993), but generally more detailed information on age-specific survival. Specifically, surveys provide measures of population trends, general measures of reproductive output in the population (i.e., number of pups/number of independents), and carcass surveys can provide the age structure of a part of the dying population (Bodkin et al. 2000, Monson et al. 2000b, Dean et al. 2002). Both study methods require careful attention to potential biases in sampling. For example how representative of the population are the tagged individuals? Or are there sources of mortality not reflected in carcass collections? However, when combined, these two methods provide complementary information, which when used together can fill in missing information and identify potential biases within each data set.

Studies to date indicate that condition as measured by mass/length ratio may be a sensitive indicator of population status especially when controlling for age, sex, and reproductive status of individuals (Monson et al. 2000a, Dean et al. 2002). Mass/length ratio of young females less than 5 years of age (prior to most becoming sexually mature) appears to be the most sensitive indicator (Fig. 1). In general, population status and thus female condition appears to have little effect on age-specific female reproductive rates (Fig. 2; Jameson and Johnson 1993, Monson et al. 2000a). A small proportion of females mature as early as 2 years of age with reproductive rates reaching adult levels approaching 0.90 by 4 years of age. However, at Amchitka, females with extended or unsuccessful pregnancies tended to have the lowest mass/length ratios suggesting that during periods of extreme resource limitation reproduction may be reduced (Monson et al. 2000a).

Reproductive intervals themselves also do not appear to be greatly affected by population status. Gestation (measured as the date of pup separation to date of birth of the subsequent pup) is fairly consistent among populations, and is approximately 200 days. Pup dependency periods are much more variable with successful pup dependency periods averaging 150 to 180 days (Monson and DeGange 1995, Monson et al. 2002a). However, most unsuccessful pup dependencies (i.e., less than 120 days) end within a month of parturition, which may result in missed reproductive events without intensive monitoring efforts.

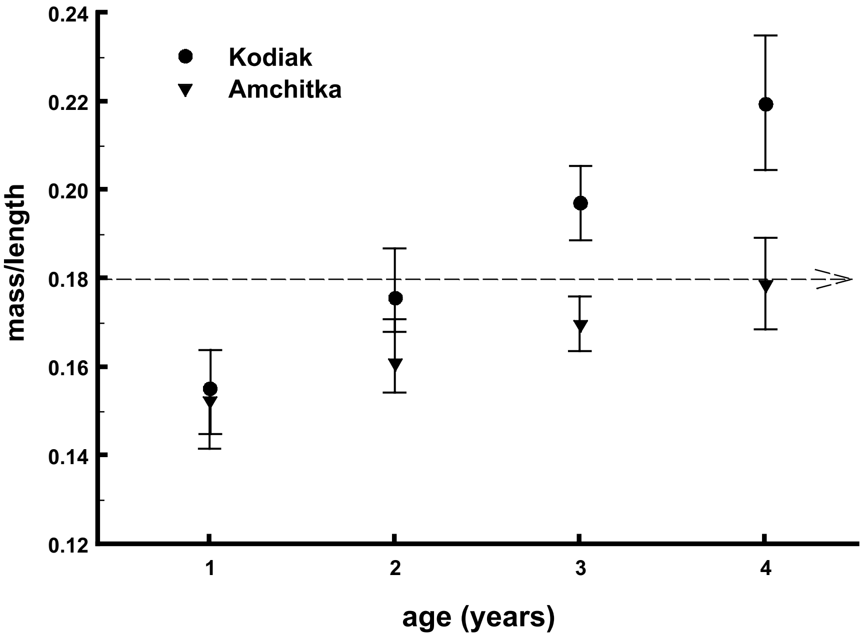

Figure 1. General linear model of mass/length ratios of young, nonpregnant female sea otters at Amchitka (near equilibrium density population) and Kodiak (rapidly expanding population) islands, Alaska. Values are predicted means and associated confidence intervals for each age class. The slopes of the two regressions are statistically different (GLM, $F_{location \times age}$ = 6.89, 1 df, P = 0.01), and age-specific mass/length ratios are statistically different by 3 years of age ($F_{age\,3}$ = 13.5, df = 1,10, P = 0.004). Dashed arrow is the mean mass/length ratio for adult, nonpregnant sea otters at Amchitka. (Note: no females older than 4 years of age were captured at Kodiak.) Graph reproduced from Monson et al. 2000a.

In contrast with the fairly rigid reproductive schedules observed among sea otter populations of varying status, pup survival rates (both pre- and post-weaning survival) appear to be the principal demographic mechanism of population regulation (Fig. 2; Monson et al. 2000a). Preweaning survival rates between 0.80 and 0.90 may be indicative of growing populations with abundant food while populations closer to equilibrium densities may have variable preweaning survival rates near or below 0.50 with evidence of near 0 recruitment during particularly unfavorable years (Monson et al. 2000a). As condition tends to decrease as a population nears equilibrium densities, it is not surprising that weaning success tends

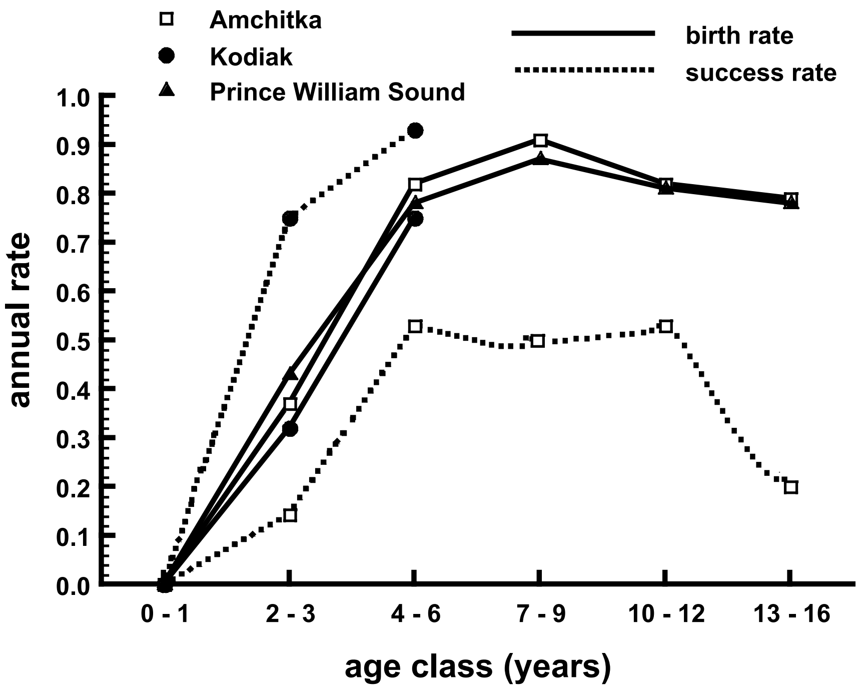

Figure 2. Annual birth rate and weaning success rates of female sea otters at Amchitka (near equilibrium population) and Kodiak (rapidly expanding population) islands, Alaska. (Note: no females older than 4 years of age were captured at Kodiak.) Graph reproduced from Monson et al. (2000a). Reproductive rates from Prince William Sound, Alaska, summarized from Bodkin et al. (1993).

to also decrease with the condition of the mother. In fact, mean mass/length ratio of adult, nonpregnant females in a population may provide a fairly good estimate of mean weaning success of the population (Fig. 3).

Pup ratios from surveys may provide the best measure of the seasonality of reproduction for the population as a whole. Pupping occurs throughout the year with varying levels of seasonality. Carcass surveys provide an independent and often more detailed age-specific survival estimate than can be assessed by tagging studies simply due to generally small sample sizes within specific ages in the longitudinal studies (Bodkin et al. 1993, 2000; Monson et al. 2000a). In general, sea otter survival patterns are similar to other long-lived animals (Caughley 1966). Juvenile survival tends to be low and variable, "prime-age" survival is high (e.g., 0.95 for 2-8 year olds), with survival declining again after age 9 or

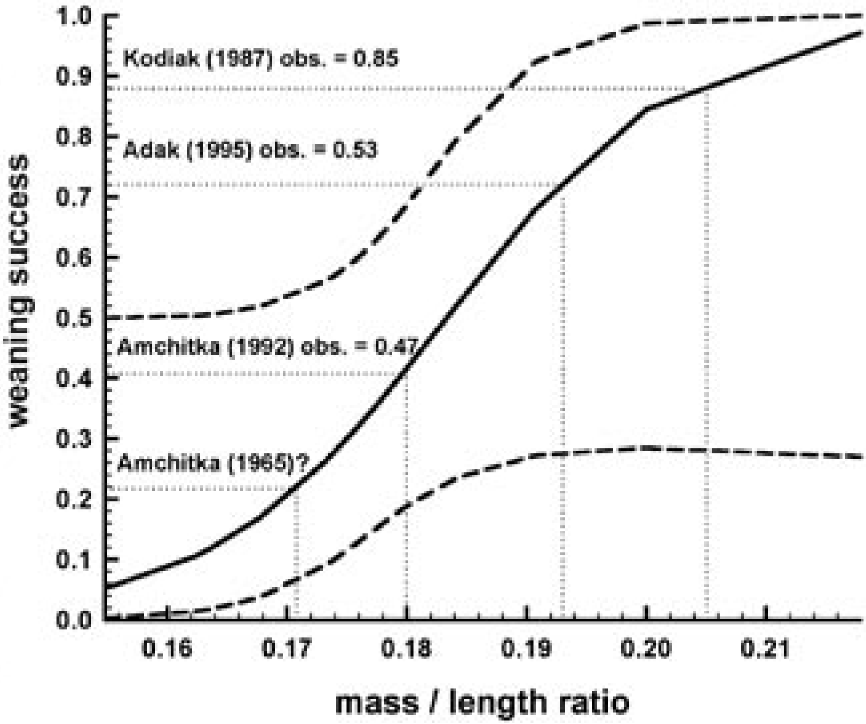

Figure 3. The relation (logistic regression) between weaning success and female mass/length ratio for sea otters at Amchitka Island, Alaska, 1992-1993. Dashed lines are 95% confidence intervals. Dotted drop lines are graphically predicted weaning success rates based on mean mass/length ratio of sea otters captured at Kodiak Island in 1987 (Monson and DeGange 1995), Amchitka Island in 1965 (Kenyon 1969), and at Adak Island in 1995 (Estes and Tinker 1996). Graph reproduced from Monson et al. 2000a.

10 (Kenyon 1969; Monson et al. 2000a,b). However, during "population adjustments" at the very peak of a population growth curve, significant numbers of prime-age males may appear (Bodkin et al. 2000). "Unusual" non-age-specific mortality factors that affect prime-age female survival may be particularly important in explaining historically slow population growth rates or population declines (e.g., shark predation, mating injury, disease, fisheries interactions in California [Estes et al. 2003], or potentially killer whale predation in the central Aleutians [Estes et al. 1998]).

Likelihood statistical methods in conjunction with population matrix models can integrate even incomplete demographic data sets, and provide estimates for unknown demographic parameters and changes in these parameters over time and space (Doak and Morris 1999, Monson et al. 2000b). We used reproductive rates from telemetry studies and survival rates derived from the age structure of carcasses collected at Amchitka (1992-1994) in a population matrix model, and found the population was expected to be stable or increasing slowly over that period. In contrast, concurrent survey data indicated the population was declining (Doroff et al. 2003). Using the model to examine the hypothesis that killer whales may have caused the decline (Estes et al. 1998), we found that a uniform increase of about 10% in mortality rates across all age classes could explain the difference between the predicted and observed population trend. Twenty-five of 80 (31%) radio-instrumented sea otters "disappeared" during the telemetry study, and disappearances were uniformly distributed across all ages. This corresponds well to the model prediction of 27 radio-instrumented otter mortalities due to the age-independent mortality source. These results are consistent with the killer whale hypotheses. More important, they demonstrate that carcass data alone may not provide a complete picture of survival.

Literature Cited

Agler, B.A., S.J. Kendall, P.E. Seiser, and J. Lindall. Estimates of marine bird and sea otter abundance in Southeast Alaska during summer 1994. USFWS unpublished report. Anchorage, Alaska.

Ames, J.A., J.J. Geibel, F.E. Wendell, and C.A. Pattison. 1996. White shark–inflicted wounds of sea otters in California, 1968-1992. In: P.E. Klimley and D.G. Ainley (eds.), Great white sharks: The biology of *Carcharodon carcharias*. Academic Press, San Diego, California, pp. 309-316.

Ballachey, B.E., J.L. Bodkin, S. Howlin, A.M. Doroff, and A.H. Rebar. 2003. Correlates to survival of juvenile sea otters in Prince William Sound, Alaska. Can. J. Zool. 81:1494-1510.

Barabash-Nikiforov, I.I. 1947. Kalan [The sea otter]. Soviet Ministry RSFSR. Translated from Russian by Israel Program for Scientific Translation, Jerusalem, Israel, 1962. 227 pp.

Bodkin, J.L., and M.S. Udevitz. 1999. An aerial survey method to estimate sea otter abundance. In: G.W. Garner, S.C. Armstrup, J.L Laake, B.F.J. Manly, L.L. McDonald, and D.G. Robertson (eds.), Marine mammal survey and assessment methods. A.A. Balkema, Rotterdam, Netherlands, pp. 13-26.

Bodkin, J.L., A.M. Burdin, and D.A. Ryazanov. 2000. Age- and sex-specific mortality and population structure in sea otters. Mar. Mamm. Sci. 16:201-219.

Bodkin, J.L., D. Mulchay, and C.J. Lensink. 1993. Age specific reproduction in the sea otter (*Enhydra lutris*): An analysis of reproductive tracts. Can. J. Zool. 71:1811-1815.

Bodkin, J.L., B.E. Ballachey, M.A. Cronin, and K.T. Scribner. 1999. Population demographics and genetic diversity in remnant and re-established populations of sea otters. Conserv. Biol. 13(6):1278-1385.

Bodkin, J.L., K. A. Kloecker, G.G. Esslinger, D.H. Monson, H.A. Coletti, and J. Doherty. 2003. Sea otter studies in Glacier Bay National Park and Preserve. Annual Report 2002. USGS Alaska Science Center, Anchorage.

Bodkin, J.L., B.E. Ballachey, T.A. Dean, A.K. Fukuyama, S.C. Jewett, L.M. McDonald, D.H. Monson, C.E. O'Clair, and G.R. VanBlaricom. 2002. Sea otter population status and the process of recovery from the *Exxon Valdez* oil spill. Mar. Ecol. Prog. Ser. 241:237-253.

Burkanov, V.N. 1988. Sovremennoe sostoyanie resursov morskikh mlekopitayushchikh na Kamchatke. Ratsional'noe ispol'zovanie bioresursov Kamchatskogo Shel'fa. [Current status of marine mammal resources on Kamchatka. In: Rational use of bioresources of the Kamchatka shelf.] U.S.S.R. Academy of Sciences, Petropavlovsk-Kamchatsky, pp. 138-176.]

Burkanov, V.N., A.M. Burdin, V.V. Phomin, V.V. Vertyankin, S.V. Zagrebelny, S.N. Sergeev, E. Ivashkin, V.Y. Nikolaeva, N. Bocharova, A.O. Molachnov, and R.V. Belobrov. 2003. Distribution and abundance of sea otter, Steller sea lion, and killer whale in the Commander Islands (Russia) during 2002. North Pacific Wildlife Consulting, Limited Liability Company, Research Report 2002. 37 pp.

Caughley, G. 1966. Mortality patterns in mammals. Ecology 47:907-918.

Cole, R.A., D.S. Lindsay, D.K. Howe, C.L. Roderick, J.P. Dubey, N.J. Thomas, and L.A. Baeten. 2000. Biological and molecular characterizations of *Toxoplasma gondii* strains obtained from southern sea otters (*Enhydra lutris nereis*). J. Parasit. 86:526-530.

Dean, J.A., J.L. Bodkin, A.K. Fukuyama, S.C. Jewett, D.H. Monson, C.E. O'Clair, and G.R. VanBlaricom. 2002. Food limitation and the recovery of sea otters following the *Exxon Valdez* oil spill. Mar. Ecol. Prog. Ser. 241:255-270.

Doak, D.F., and W.F. Morris. 1999. Detecting population-level consequences of ongoing environmental change without long-term monitoring. Ecology 80:1537-1551.

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

Estes, J.A. 1990. Growth and equilibrium in sea otter populations. J. Anim. Ecol. 59:385-402.

Estes, J.A., and M.T. Tinker. 1996. The population ecology of sea otters at Adak Island, Alaska. Final report, Department of Defense Legacy Program. 37 pp.

Estes, J.A., B.B. Hatfield, K. Ralls, and J. Ames. 2003. Causes of mortality in California sea otters during periods of population growth and decline. Mar. Mamm. Sci. 19:198-216.

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

Hanni, K., J. Mazet, F. Gulland, J. Estes, M. Staedler, M. Murray, M. Miller, and D. Jessup. 2003. Clinical pathology and assessment of pathogen exposure in southern and Alaskan sea otters. J. Wildl. Dis. 39:837-850.

Hattori, K. 2003. Population status of sea otters in the Southern Kuril Islands (Etorofu, Kunashiri, Shikotan and Habomai) from skiff surveys. In: Morphological and genetic studies on population ecology of the Asian sea otter (*Enhydra lutris lutris*). Sapporo, Japan, pp. 27-40.

Jameson, R.J., and A.M. Johnson. 1993. Reproductive characteristics of female sea otters. Mar. Mamm. Sci. 9:156-167.

Kanaan, K., K.S. Guruge, N.J. Thomas, S. Tanabe, and J.P. Giesy. 1998. Butyltin residues in southern sea otters (*Enhydra lutris nereis*) found dead along California coastal waters. Environ. Sci. Technol. 32:1169-1175.

Kawauchi, K. 1930. Mammals in Hokkaido and Sakhalin. Sapporo, Japan. Manuscript translation, Kamchatsky KNII, DVO RAN-Kamchatka Complex, Scientific Research Institute of the Far-Eastern Department of the Russian Academy of Sciences.

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

Kornev, S.I. 2000. Current numbers and distribution of the Kamchatka-Kuril sea otter population. Marine Mammals of the Holarctic International Conference, September, 2000, Arkhangelsk, Russia. Marine Mammal Council, 36 Nakhimovsky av., 117997 Moscow, Russia, pp. 175-179. (In Russian.)

Kornev S.I., A.M. Trukhin, Y.B. Artykhin, and S.Y. Purtov. 2001. Results of the marine mammal survey in the South Kamchatka and Kuril Islands in June-August, 2000. Results of the investigation of marine mammals of the Far East in 1991-2000. VNIRO, Moscow, pp. 191-204.

Kreuder, C., M.A. Miller, D.A. Jessup, L.J. Lowenstine, M.D. Harris, J.A. Ames, T.E. Carpenter, P.A. Conrad, and J.K. Mazet. 2003. Recent patterns of mortality in southern sea otters (*Enhydra lutris nereis*). J. Wildl. Dis. 39:495-509.

Kromovskikh, B.V. 1982. Current numbers and age-sex structure of local groups of sea otters on the Kamchatka Peninsula. Pacific Ocean Scientific Research Institute of Fishery and Oceanography, Vladivostok, Russia, 23.

Kuzin A.E., M.K. Maminov, and A.S. Perlov. 1984. The number of pinnipeds and sea otters on the Kuril Islands. Marine mammals of the Far East. Pacific Ocean Scientific Research Institute of Fishery and Oceanography, Vladivostok, Russia, pp. 54-72.

Maminov, M.K. 2002. The results of the study of sea otter inhabiting Iturup Island in 1996. Marine mammals: Results of the investigation held in 1995-1998. Advice on marine mammals, Moscow, pp. 259-262.

Mayer, K., M. Dailey, and M. Miller. 2003. Helminth parasites of the southern sea otter (*Enhydra lutris nereis*) in central California: Abundance, distribution and pathology. Dis. Aquat. Org. 53:77-88.

Miller, M.A., I.A. Gardner, A. Packham, J.K. Mazet, K.D. Hanni, D. Jessup, J. Estes, R. Jameson, E. Dodd, B.C. Barr, et al. 2002a. Evaluation of an indirect fluorescent antibody test (IFAT) for demonstration of antibodies to *Toxoplasma gondii* in the sea otter (*Enhydra lutris*). J. Parasitol. 88:594-599.

Miller, M.A., I.A. Gardner, C. Kreuder, D.M. Paradies, K.R. Worcester, D.A. Jessup, E. Dodd, M.D. Harris, J.A. Ames, A.E. Packham, and P.A. Conrad. 2002b. Coastal freshwater runoff is a risk factor for *Toxoplasma gondii* infection of southern sea otters (*Enhydra lutris nereis*). International Journal for Parasitology 32:997-1006.

Miller, M., I. Gardner, A. Packham, J.K. Mazet, K.D. Hanni, D. Jessup, J. Estes, R. Jameson, E. Dodd, M. Miller, et al. 2004. An unusual genotype of *Toxoplasma gondii* is common in California sea otters (*Enhydra lutris nereis*) and is a cause of mortality. International Journal for Parasitology 34:275-284.

Monson, D.H., and A.R. DeGange. 1995. Reproduction, preweaning survival, and survival of adult sea otters at Kodiak Island, Alaska. Can. J. Zool. 73:1161-1169.

Monson, D.H., J.A. Estes, J.L. Bodkin, and D.B. Siniff. 2000a. Life history plasticity and population regulation in sea otters. Oikos 90:457-468.

Monson, D.H., D.F. Doak, B.E. Ballachey, A. Johnson, and J.L. Bodkin. 2000b. Long-term impacts of the *Exxon Valdez* oil spill on sea otters, assessed through age-dependent mortality patterns. Proc. Natl. Acad. Sci. U.S.A. 97:6562-6567.

Nikolayev, A.M. 1960. Dynamics of number of the sea otters in USSR. Transactions of Sakhalinsk Integrated Research Institute 9:108-121.

Nikolayev, A.M. 1968. The sea otters of the Kuril Islands: Biology and problems of economic use. Abstract of Ph.D. Dissertation. Voronezh State University, Voronezh. 20 pp.

Nikulin V.S., V.V. Vertyankin, A.M. Burdin, and A.P. Kononov. 2002. Distribution and number of sea otters on the Kamchatka Peninsula. Conservation of Biodiversity of Kamchatka and Coastal Waters. Materials of Third Scientific Conference, Kamchatka Institute of Ecology and Nature Management, Russian Academy of Sciences, Petropavlovsk-Kamchatsky, pp. 79-81.

Peterson, C.H., S.D. Rice, J.W. Short, D. Esler, J.L. Bodkin, B.E. Ballachey, and D.B. Irons. 2003. Long-term ecosystem response to the *Exxon Valdez* oil spill. Science 302:2082-2086.

Pitcher, K.W. 1989. Studies of Southeastern Alaska sea otter populations: Distribution, abundance, structure, range expansion, and potential conflicts with shellfisheries. U.S. Fish and Wildlife Service and Alaska Department of Fish and Game cooperative agreement no. 14-16-0009-954, final report.

Riedman, M.L., and J.A. Estes. 1990. The sea otter (*Enhydra lutris*): Behavior, ecology, and natural history. U.S. Fish Wildl. Serv. Biol. Rep. 90(14). 126 pp.

Riedman, M.L., J.A. Estes, M.M. Staedler, A.A. Giles, and D.R. Carlson. 1994. Breeding patterns and reproductive success of California sea otters. J. Wildl. Manag. 58:391-399.

Scholin, C.A., F.M. Gulland, and G.J. Doucette. 2000. Mortality of sea lions along the central California coast linked to a toxic diatom bloom. Nature 403:80-84.

Sergeev, M.A. 1947. The Kuril Islands. OGIZ, Moscow, pp. 95-127.

Siniff, D.B., and K. Ralls. 1991. Reproduction, survival, and tag loss in California sea otters. Mar. Mamm. Sci. 7:211-229.

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

Thomas, N.J., and R.A. Cole. 1996. Risk of disease and threats to wild populations. Endangered Species Update 13:23-27.

Udevitz, M.S., J.L. Bodkin, and D.P. Costa. 1995. Sea otter detectability in boat-based surveys of Prince William Sound, Alaska. Mar. Mamm. Sci. 11(1):59-71.

Uspensky, S.M. 1955. Past distribution of the fur seal (*Callorhinus ursinus*) and sea otter (*Enhydra lutris*) in the Islands of Kuril Range. Bulletin of Moscow Society of Nature Use, Biology Dep. T. 60(4):916.

U.S. Fish and Wildlife Service. 1993. Conservation plan for the sea otter in Alaska. USFWS, Marine Mammals Management, 1011 East Tudor Road, Anchorage, AK 99503. 47 pp.

U.S. Fish and Wildlife Service. 2002. Southwest Alaska sea otter decline: Summary report. USFWS Marine Mammals Management, 1011 East Tudor Road, Anchorage, AK 99503. 65 pp.

Watt, J., D.B. Siniff, and J.A. Estes. 2000. Inter-decadal patterns of population and dietary change in sea otters at Amchitka Island, Alaska. Oecologia (Berlin) 124:289-298.

Yosiyuki, I. 1925. The sea otter. Fur trade in the Kuril Islands, part 2. Tokyo. Manuscript translation, Science about the earth, Sakhalin KNII funds.

Zagrebelny, S.V., and V.V. Fomin. 2001. Some parameters of sea otter mortality on Bering Island in 1995-1999 and the main trends in their population dynamics in 1980-1999. Results of the Far East Marine Mammal Research in 1991-2000. Materials to the 16th Working Group Meeting, project 02.05-61 Marine Mammals, U.S.-Russia Agreement on Cooperation in the Field of Environmental Protection (Santa Cruz, April 23-26, 2001), pp. 186-190.

Work Group Discussions

The overall goal of the discussion work groups was to recommend research strategies that will help (1) improve understanding of the reasons for the sea otter decline in the Southwest Alaska stock and the sea otter population dynamics; and (2) develop appropriate conservation management actions to be applied in the geographic area of the decline.

Discussion work groups were organized in two concurrent sessions (morning and afternoon) to allow for maximum participation of panelists. A moderator directed and focused each of the discussions. Recommendations are not prioritized and relevant discussion is summarized below each of the recommendations.

The following general recommendations were made in one or more of the discussion groups.

A. Emphasize comparability between studies to improve the power of data sharing. Strive for systematic, cross-comparable sampling techniques wherever possible, including matching the same sampling techniques, diagnostic facilities, or labs running tests and protocols for samples and data collected in both Russia and Alaska.

B. Develop a Web-based approach to database management so that information and ideas are shared by all interested parties.

C. Emphasize research effort within the areas of decline and the immediately adjacent areas where populations have not yet declined (or are declining). Samples should also be collected from other areas for comparative purposes, but as a secondary priority subject to adequate funding.

Work Group 1: Vital Rates and Environmental Factors

Moderator: Rosa Meehan

U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska

Participants

Russ Andrews, Alexander Burdin, Vladimir Burkanov, Douglas Burn, Donald Calkins, Randall Davis, James Estes, Thomas Gelatt, John Haddix, Charles Hamilton, Carl Kava, Brenda Konar, Sergey Kornev, Lloyd Lowry, Daniela Maldini, Mikhail Maminov, Craig Matkin, Daniel Monson, Victor Nikulin, Ken Pitcher, Don Siniff, LaVerne Smith, Timothy Tinker, Glenn VanBlaricom, Vladimir Vertyankin, Sergey Zagrebelny

Recommendations and Discussion

A. Focus detailed studies on areas adjacent to the decline, with particular focus on mark-recapture programs and modeling of population dynamics.

The Commander Islands (Bering Island in particular) are adjacent to the areas of current sea otter decline, and for this reason have the potential to be affected by future declines, although there are no data to suggest this. Kodiak Island (including Kamishak and Kachemak bays) is an area of decline that has not been targeted for detailed studies and should be focused on more directly. It is currently unknown what environmental factors are contributing to the differences in the status of the Southwestern Alaska and adjacent sea otter populations (i.e., Commander Island populations appear to be at or approaching carrying capacity in stark contrast with the significant decline in the rest of the Aleutians). Researchers in the Aleutian Islands have looked extensively at many possible causes of the decline, including disease and contaminants, but none of the hypotheses explored (with the exception of the killer whale predation hypothesis) appears to play a role in the population crash in the Aleutians. It is important, however, to do additional research in areas outside the area of decline where we have less information.

The panelists recommended that detailed studies include mark/recapture efforts in the Commander Islands and in Kodiak. These efforts should be aimed at collecting information on individual animals such as monitoring health and reproduction rates. Studies in the Commander Islands would be particularly useful, since there is already a longstanding scientific effort in the area and data on various sea otter life history parameters (mainly based on beach-cast carcasses) have been collected for over 20 years. This background information, paired with the development of mark/recapture programs and year-round monitoring of target populations, would set the stage for being able to detect potential declines early and to potentially determine their mechanisms. Developing a detailed population model for the Commander Islands would provide a critical framework for analyzing and tracking population changes. Such a model could be developed using new population modeling techniques.

Data on deaths, births, and fecundity need to be refined by following animal cohorts through time and looking at when individual animals disappear over time. Such studies will not be possible in the core area of the population decline, as there are very few animals left to study. However, such studies would be feasible in the Kodiak archipelago, where a decline is documented but overall numbers and densities of sea otters remain sufficient to support detailed studies.

B. Complete longitudinal studies on rates of reproductive mortality and age-specific mortality.

In order to successfully document a population decline in its early stages, it is critical to document survivorship by age class with sufficient precision (i.e., an estimated 5-10% decrease in the survival of prime-age animals could result in a decline the size of that documented in the Aleutians). In particular, it is critical to monitor female prime-age mortality.

Studies of beach-cast carcasses, which can be easily collected, are a valuable source of information as they can be an independent measure of mortality. However, carcasses reflect mortality of only those animals that wash up on the beach and data may or may not be representative of actual mortality in the population. To avoid biases, pairing studies of beach-cast carcasses with studies of marked animals is the best approach.

Detailed ecological studies that include reproduction and survivorship information are available from various regions of Alaska, and from California and Russia. Panelists suggested that combining the analysis of these data with longitudinal studies of live animals may provide important insights into sea otter population dynamics.

C. Track population status throughout sea otter range.

Populations in the Commander Islands peaked in the 1990s when Aleutian populations were crashing; however, relationships between that population and other Russian populations is unclear. A study throughout the sea otter range should include the Kuril Islands and Southcentral and Southeast Alaska. Panelists also suggested basic large-scale tagging programs to study possible migrations between regions to clarify basic population dynamics in key areas (Cape Lopatka, Kamchatka coast, Kuril Islands, and Commander Islands). Intensive studies in areas where otters have existed for a long time may help identify whether current patterns are within natural population fluctuations. While currently there is no evidence of a crash in Russian waters, we should still monitor these populations because this is an area in a similar ecosystem with a dramatically different population status.

Monitoring of shelter, kelp beds, and other environmental factors should also play a part in the evaluation.

Panelists felt that surveys at Amchitka Island (in the area of decline) should be continued to track long-term population dynamics. Because a lot of data from this area of the decline are available, it may be useful to re-evaluate basic assumptions used at the time of original analyses and re-analyze the data now that we know the information/samples were collected from a declining population.

D. Re-examine stock boundaries or conservation units.

The question was raised of whether the sea otter scientific community is satisfied with the current understandings of population dynamics. Do we understand the unit/structure of populations and stocks, or is greater evaluation/investigation required? There was no agreement on this point but some felt that our understanding of the population stock structure might be worth re-evaluating. Studies should also address inter- and intra-dispersal/movement patterns for adjacent stocks. Although current understanding of these patterns (e.g., dispersal) may be limited, many samples (although not complete across the sea otter range) are available for further analysis with emphasis on genetic evaluation. Additional studies relevant to the question of stock boundaries and conservation units should address gene flow between stocks as well as any potential genetic differences between small and potentially isolated stocks.

E. Study killer whale predation.

Hypotheses related to the role of killer whale predation in the sea otter decline may not be testable. Detailed discussion was tabled, as this was the subject of a later discussion section.

Work Group 2: Mortality, Diseases, and Contaminants

Moderator: Melissa Miller

University of California Davis Wildlife Health Center, California Department of Fish and Game, and Marine Wildlife Veterinary Care and Research Center, Santa Cruz, California

Participants

Shannon Atkinson, Jim Bodkin, Kathy Burek, Angela Doroff, Todd Erickson, Verena Gill, Lianna Jack, Dan Martinez, Leslie Slater, Nancy Thomas

Recommendations and Discussion

A. Increase sampling effort in the areas of decline, adjacent areas and, where possible, throughout Russia and Alaska.

Panelists recommended facilitating this effort through field training, public outreach, public education, and further development and mentoring of stranding programs. If not presently available, designating a centralized call center or person for coordination of collection and proper disbursement of live and dead-stranded otters should be considered.

Researchers should strive to obtain sufficient sample sizes to facilitate later epidemiological (statistical) analyses when possible, and seek ways to increase and standardize sampling effort for carcasses or develop correction coefficients to account for variation in sampling effort.

B. Develop standardized sampling protocols for live and dead otters throughout Russia and Alaska.

Established necropsy protocols should be continually refined and reviewed. Guidelines for proper specimen handling and storage should also be included. For example, for tissue sampling in remote areas, consider formalin fixing, drain off the excess formalin once the tissue is fixed, and ship it in a scant volume of formalin (just enough to keep the tissue moist) to a centralized lab for embedding and histopathology. This would ease shipping constraints, danger, and costs.

The flexibility required for concurrent collaborative and extramurally funded research should be recognized by designating "standard" samples to collect versus "elective" samples. For comparative purposes the process of standardization should extend to sample analysis. Wherever possible the same laboratories and techniques should be used to complete diagnostic assays (e.g., chemistry panels, serology, microbiology, and contaminant analysis) so that the resulting data are directly comparable. Once the protocols are standardized, and written, step-by-step protocols should be developed as a guideline for field sampling of both live and dead otters. Facilitate the completion of examinations on Russian otters through purchase of necessary equipment and supplies and facilitation of shipping.

Other recommendations included maintaining "nonfresh" otter recovery data for demographics and stranding patterns data, and considering carcass recovery studies (e.g., placing carcasses on the beach and looking at the number that are found and collected or sampled).

C. Develop comprehensive necropsy programs for Russia and Alaska.

Funds should be designated specifically for covering the costs for performing complete postmortem examinations, including histopathology, microbiological culture, and serology. Collaborative extramural funding sources for further developing the necropsy program were encouraged. As controls, panelists recommended performing full necropsy examination (e.g., histopathology, tissue banking, and serology) on subsets of subsistence-harvested otters from different areas (ideally at least 20 over time from each discrete area).

D. Develop a comprehensive pathology database.

With approval from appropriate levels of U.S. Geological Survey and California Department of Fish and Game, panelists recommended adapting the framework of the existing southern sea otter pathology database for use for the Alaskan and Russian programs.

E. Create a complete sample inventory that includes both Russia and Alaska.

Such samples should include blood, serum, frozen tissues or fluids, paraffin blocks, and pathology reports. Previously collected data should be summarized for contaminants, hematology, and clinical pathology (e.g., complete blood counts, chemistry panels, serology), and used to identify locations and specific contaminants or pathogens for prioritized effort. Live and dead otter data should be organized to facilitate epidemiological investigation with respect to threats to recovery, including spatial trends, proportional mortality, and temporal trends. These data should be compiled into a centralized database, and a person should be designated and funded to complete this task and to manage and maintain this database.

F. Review existing data on marine biotoxin occurrences in Alaska and Russia for marine mammals, key prey species, and plankton.

Seek to set up collaborative programs for ongoing monitoring and detection of biotoxin exposure.

Work Group 3: Foraging Ecology

Moderator: Angela Doroff
U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska

Participants

James Bodkin, Randall Davis, Rosa Meehan, Melissa Miller, Don Siniff, Leslie Slater, Tim Tinker

Recommendations and Discussion

Studies of sea otter foraging ecology are most productively done in coordination with studies of marked otters. Observations of foraging sea otters using radio tags that incorporate a time depth recorder (TDR) allow for the verification of activity patterns. Subtidal studies of sea otter prey population health and toxicity are available for the Alaska Peninsula and the Kodiak archipelago.

A. Compile all available foraging data from Southwestern Alaska and Russia and examine the data record for changes in foraging patterns that may provide information about the current decline.

Two methods are generally used to quantify sea otter prey: (1) scat analysis; and (2) direct observation. Both methods have limitations; however, using both techniques within a study area strengthens a study. Questions that can be answered using direct observation of foraging otters include

(1) type of forage species; (2) estimates of foraging efficiency (i.e., kcal per dive); and, for individually marked otters, (3) variation in prey species among individuals.

B. Conduct broad-based habitat sampling.

(1) Replicate the subtidal plots sampled by Kvitek and colleagues in the Kodiak archipelago; and (2) compile all available data and samples to document the occurrence of toxic algal blooms that may have affected sea otter prey in Southwestern Alaska.

C. Standardize foraging observation techniques and databases among all sites in Southwestern Alaska and in the Commander Islands using the standards developed in California.

Panelists emphasized the importance of (1) developing standardized protocols between research teams working in different geographical areas; and (2) making available standardized procedures that will facilitate comparative studies.

D. Contribute to current studies on prey caloric value across the sea otter range, and for various life stages of prey items.

Panelists suggested an intensive collection of sea otter prey samples to be subjected to calorimetric evaluation for different prey sizes and life stages to provide baseline data to evaluate optimal foraging strategies by sea otters and caloric intake in different geographic areas.

E. Complete sea otter foraging studies in conjunction with radiotelemetry studies.

Panelists suggested such studies should focus on the Commander and Kodiak islands, and also be expanded to include the Alaska Peninsula, the Aleutian archipelago, Kachemak Bay, and Prince William Sound. The primary objective of the proposed telemetry studies would be to monitor survival, reproduction, and movement patterns. Panelists recommended conducting direct forage observations on study animals to verify time depth recorder (TDR) data on individual sea otter activity budgets. Within the intensive study area, there was also a recommendation to collect forage observations on unmarked otters and to collect and analyze scat. Panelists recommended pairing multiple methods to fully characterize foraging ecology parameters.

Work Group 4: Predation

Moderator: Daniela Maldini
Alaska SeaLife Center, Seward, Alaska

Participants

Russ Andrews, Shannon Atkinson, Alexander Burdin, Kathy Burek, Vladimir Burkanov, Douglas Burn, Donald Calkins, James Estes, Thomas Gelatt, Verena Gill, John Haddix, Lianna Jack, Lloyd Lowry, Mikhail Maminov, Dan Martinez, Craig Matkin, Daniel Monson, Victor Nikulin, Don Siniff, LaVerne Smith, Timothy Tinker, Glenn VanBlaricom, Sergey Zagrebelny

Recommendations and Discussion

The main focus of the session was predation by transient type (marine mammal eating) killer whales, since this is the leading hypothesis for explaining the sea otter decline. This topic has been highly controversial and panelist opinions varied markedly. The panel briefly considered alternate forms of predation (i.e., sharks, eagles, ravens, bears, and humans). However, these factors were considered negligible and no further research recommended.

Panelists disagreed about whether studying killer whales would yield any useful information about the sea otter decline. However, some of the panelists felt it would be important to study the predator even if the issue of the decline was not addressed directly: more information about transient killer whales is needed to be able to focus future studies of predator-prey interactions.

A. Concentrate predator-prey interaction studies in areas at the edge of the decline such as Kodiak Island and the Alaska Peninsula, and areas where the decline has not occurred such as the Commander Islands and the Russian Far East.

Studies of killer whales in these geographic areas should be comparative, and provide insight into the potential differences in behavior and foraging strategies between killer whales in the areas of sea otter decline and killer whales in areas where the sea otter population is stable.

B. Conduct shore- and boat-based observational studies on killer whale activity budgets.

Observational studies of wild-ranging killer whales have been conducted for the past 50 years in many areas of the world. Only recently the focus has shifted, in the North Pacific, to the study of transient killer whales and their predation habits. Panelists discussed two methods used to observe killer whale–sea otter interactions: (1) land-based observations near sea otter areas; and (2) vessel-based observations. One panelist commented that the odds of witnessing a predation event are very small from a fixed location on land, and that this technique used alone may be a waste of time. Conversely, staying with the killer whales for prolonged periods of time using a vessel may yield a lot of information and has been the method of choice to observe interactions between transient killer whales and Steller sea lions. In general, panelists favored the use of a suite of tools such as fatty acid analysis, and radio and acoustic monitoring in conjunction with direct observation.

Panelists suggested placing land-based observers in strategic locations near sea otter areas so that, while keeping an eye out for killer whales, observers could collect a variety of other data on sea otters, such as behavioral budgets and foraging data. One of the panelists commented that since observers have been told to look for killer whales around haul-out sites in Russia, the number of killer whale sightings reported has increased significantly, suggesting that observer attention to this factor made a big difference in reporting frequency.

It is also important to determine which whales to target for an observational study. It is currently unclear whether all transient killer whales are generalists, always feeding on a variety of marine mammal prey, or specialists, feeding on a variety of prey but targeting a preferred prey species with high frequency. This difference may be absolute or seasonal. The few existing observational studies suggest a certain degree of specialization for at least some transient killer whales. If we are assuming that some transients may have become sea otter specialists, then we should also assume these whales, having depleted their prey base in the areas of decline, will move to other areas where otters are more abundant. If this scenario is true then there is a possibility that only a few killer whales may need to be identified and targeted for a study. Conversely, if sea otters constitute a small portion of the diet of a large number of transient killer whales, the sample whale population and the approach to the study may need to be dramatically different.

C. Conduct studies on fatty acid profiles to identify prey composition in killer whale blubber.

Evaluation of fatty acids in marine mammal blubber is an emerging technique in evaluating marine mammal diet, providing a temporal perspective on dietary patterns not available from traditional methods of study. High resolution insight to diet can be obtained when samples of likely prey species are also available for analysis. Where samples of prey are less available for analysis, more general inferences regarding diet can still be obtained from fatty acid analysis of marine mammal blubber samples. Currently, specific analytical and quantitative methods are under development that will improve resolution and reliability of this method. The temporal persistence of fatty acid profiles from particular prey species in killer whale blubber must be better understood. It was suggested that fatty acid work should be undertaken with captive animals under experimental protocols before attempting application to data from samples taken from free-ranging animals.

A very large sample size of killer whale blubber collected in the wild would be needed to look for the signature for sea otters, and obtaining such a large sample size may be costly, time consuming and difficult.

However, some panelists felt it would be important to develop this technique starting with a captive study on killer whales. Panelists suggested that the Alaska SeaLife Center and the U.S. Fish and Wildlife Service consider urging other agencies to facilitate obtaining a permit for a captive study. Cooperation with facilities such as Sea World or other organizations having access to captive killer whales would be instrumental.

D. Evaluate whether a major shift in the prey base for killer whales occurred historically by analyzing isotopic values in their tooth layers using existing museum specimens.

One of the panelists proposed conducting isotopic analysis on killer whale teeth. The isotopic signature found in killer whale teeth from pre-whaling periods should show relatively few “prey switching” events through the killer whale’s lifetime, arguing for the choice of a consistent prey source. Conversely, killer whales that lived post whaling and through the marine mammal declines should exhibit higher “prey switching rates.” Interpretation of changes in isotopic signatures would be aided by studies on prey population isotopic signatures through time which would account for climatic changes that cause shifts in prey signatures (these studies are already under way). The timing of prey switching could be used in modeling exercises to determine the likelihood that killer whales switched prey because their primary prey became scarce (i.e., animals are reacting to, not driving, the marine mammal declines) or that killer whales drove the declines and then were forced to switch to alternate prey. If prey switching rates are constant pre- to post-whaling, and switching events do not follow a pattern consistent with changes in marine mammal population declines, then we can conclude the results do not support the killer whale hypothesis. To conduct this study it would be necessary to compile a list of available killer whale teeth from museums around the country and possibly the world.

E. Collect acoustic data in areas of high sea otter concentration to detect killer whale predation activity and to verify the presence of transient type killer whales in the vicinity of sea otter habitats.

Acoustic monitoring can be used as a method to detect killer whale presence/absence near areas of sea otter concentration and to potentially detect the occurrence of predation events by recording a typical call type used by transient killer whales immediately after a kill. Acoustical detection is also good to separate killer whale populations (residents versus transients) but generally does not give detailed information. Identifying that a kill has occurred in a specific area does not give any information on prey species unless the acoustic data are paired with direct observations. Nonetheless, placing hydrophones, which are relatively inexpensive, near areas of high sea otter abundance, may provide some quantitative data on the frequency of kill calls in the area.

F. Develop satellite tags to follow transient killer whale movement patterns over time and to determine habitat use by these predators.

Many of the panelists supported developing satellite tags to be attached to transient killer whales for long-term monitoring of movement patterns and habitat use. The majority of the panelists agreed that this method would provide the most information about transient killer whales in a shorter period of time. Paired with geographic information system (GIS) analysis, satellite tags would give information on killer whale habitat use patterns. However, this methodology would provide little direct evidence of killer whale feeding rates and feeding events unless paired with observational studies or other types of data.

G. Develop life history transmitters to be implanted in sea otters.

A few of the panelists supported the use of life history transmitters, which recently have been developed for Steller sea lions, to study sea otter life history parameters. These transmitters can be implanted into a live sea otter and record basic life history parameters to the end of the animal's life. Upon death of the otter, the transmitters are retrieved and the data downloaded.

Work Group 5: Russia Sea Otter Program

Moderator: Alexander Burdin
Alaska SeaLife Center, Seward, Alaska

Recommendations and General Discussion

The moderator introduced the purpose of the work group: to determine what kind of information needs to be collected in the Commander Islands and other areas of the Russian Far East to understand the current status of Russian sea otter populations in light of what is happening in the Aleutian Islands. Following the introduction, the panelists discussed potential data collection protocols in the following areas: (1) population surveys; (2) mortality data; (3) tag and release programs; (4) collection of scat samples; (5) predation by killer whales.

A. Continue population surveys on Bering and Medny islands and possibly expand efforts to other areas.

Population counts on Bering and Medny islands are currently being conducted using skiff-based surveys because of the difficulty of finding a suitable aircraft for this work. Panelists recommended continuing current skiff surveys, which are generally done in June because of weather conditions. June is also the best month to estimate pup numbers. Panelists recommended repeating the surveys using the same pattern at least twice within a period of time short enough to allow for the calculation of a standard deviation for the census. It was also recommended that multiple observers be trained using similar protocols to those used by the U.S. Fish and Wildlife Service (USFWS) and that quieter outboard motors be purchased for the skiffs being used (otters appear to dive when the survey boat approaches).

Panelists underscored that it would be important to set up studies during a period of stable population numbers to enhance future ability to detect population changes. Methods would vary depending on how small a population change such studies should be capable of detecting.

B. Continue and expand beach-cast carcass collection efforts and standardize current collection protocols.

A long-term program of collection of beach-cast carcasses has been conducted in Russia since the early 1980s. Carcass collection is currently being done more intensively on Bering Island but this effort should be expanded to other areas of the Russian Far East.

Panelists suggested conducting as complete a necropsy as possible on all carcasses collected. If necropsy is not possible it would be good to take a picture of the carcass and of the main organs so that a trained veterinarian may be able to make a determination at a later time. It was suggested that digital cameras be provided to people who commonly search for carcasses, together with a laminated photographic atlas of healthy sea otter organs. It was also recommended that a very detailed protocol, of what samples to take in the field and how to preserve them, be available to field crews. Panelists suggested adapting the form currently given to Native subsistence hunters in Alaska by translating it into Russian. California carcass databases could also be translated to Russian and provided to field crews.

C. Start intensive tag and release studies in the Commander Islands.

Tagging would be better done in winter/spring. On Medny Island sea otters could be caught in shallow water at low tide when large areas of the reef are exposed. It is especially important to catch females of reproductive age. Once an animal is captured comprehensive sampling should be conducted to monitor health parameters. Panelists recommended the use of passive integrated transponder (PIT) tags in conjunction with cattle tags to mark an animal. In particular, PIT tags will be scanned for when a beach-cast carcass is retrieved. The possibility of placing PIT tags at capture was suggested to increase the number of otters that later will be re-sampled as carcasses. Since many of the otters are scavenged by foxes, it was suggested that placing PIT tags subcutaneously in the tail (which is usually left uneaten) might be optimal. PIT tags should be placed on either side of the tail, but not on the upper or lower surfaces because of the presence of big blood vessels.

If the PIT tagging program is initiated, then skulls, tags, and tails should be collected. Also an incentive program was discussed whereby the Russian public would be paid for retrieving and shipping otter skulls from the most remote areas. Thus the PIT tag scanning could be done in part at the scientists' convenience at their own labs.

Radio-tagging studies were considered a priority by many participants, with emphasis on the importance of tracking and observing known animals as focal animals for forage observations. While flipper tags help in being able to identify carcasses, and in some cases free-ranging animals, animals that can be tracked are the most useful. To initiate radio-tagging studies, paperwork is necessary to obtain a permit from the Russian government. Delays due to this process should be considered when scientists plan for future studies. This kind of permit may be difficult to obtain.

D. Develop a tooth-aging program to analyze teeth samples from Russia.

A large collection of sea otter teeth is currently available, paired with a variety of ancillary data such as population trends, habitat surveys, prey availability, and reproductive parameters over time. In addition, increased efforts of carcass recovery and live-captures in Russia (Alaska SeaLife Center) and the United States (U.S. Fish and Wildlife Service) are being planned in the next three years, and a large collection of teeth will be obtained from these efforts as well. Some of the goals of the program would be to (1) calibrate aging using canines and using pre-molars to develop comparative charts; (2) analyze all available tooth samples collected from beach-cast carcasses in the Russian Far East to determine trends in age-mortality profiles through time; and (3) explore the possibility of determining number of pregnancies for female sea otters using cementum layers.

E. Continue ongoing collection of scat samples.

Russian observers have been collecting and analyzing sea otter scat samples since the 1970s and this program will be continued and expanded. Panelists suggested standardizing scat sample collection and analysis to be able to compare results to samples collected in Alaska and California.

F. Initiate killer whale studies based on the recommendations developed by the killer whale work group.

Most of the discussion was a repetition of the recommendations developed during the killer whale work group discussion and included ideas on how to specifically implement them in Russian waters. Currently, killer whale surveys in the Russian Far East are being funded by the Alaska

SeaLife Center Steller Sea Lion Program. Land-based observations at specific Steller sea lion rookeries and sea otter foraging and haul-out areas will be initiated in summer 2004.

Summary of Recommendations

Work Group 1: Vital Rates and Environmental Factors

A. Focus detailed studies on areas adjacent to the decline, in particular on mark-recapture programs and modeling of population dynamics.

B. Complete longitudinal studies on rates of reproductive mortality and age-specific mortality.

C. Track population status throughout sea otter range.

D. Re-examine stock boundaries or conservation units.

E. Study killer whale predation.

Work Group 2: Mortality, Diseases, and Contaminants

A. Increase sampling effort in the areas of decline, adjacent areas and, where possible, throughout Russia and Alaska.

B. Develop standardized sampling protocols for live and dead otters throughout Russia and Alaska.

C. Develop comprehensive necropsy programs for Russia and Alaska.

D. Develop a comprehensive pathology database.

E. Create a complete sample inventory that includes both Russia and Alaska.

F. Review existing data on marine biotoxin occurrences in Alaska and Russia for marine mammals, key prey species, and plankton.

Work Group 3: Foraging Ecology

A. Compile all available foraging data from Southwestern Alaska and Russia and examine the data record for changes in foraging patterns that may provide information about the current decline.

B. Conduct broad-based habitat sampling.

C. Standardize foraging observation techniques and databases among all sites in Southwestern Alaska and in the Commander Islands using the standards developed in California.

D. Contribute to current studies on prey caloric value across the sea otter range, and for various life stages of prey items.

E. Complete sea otter foraging studies in conjunction with radiotelemetry studies.

Work Group 4: Predation

A. Concentrate predator-prey interaction studies in areas at the edge of the decline such as Kodiak Island and the Alaska Peninsula, and areas where the decline has not occurred such as the Commander Islands and the Russian Far East.

B. Conduct shore- and boat-based observational studies on killer whale activity budgets.

C. Conduct studies on fatty acid profiles to identify prey composition in killer whale blubber.

D. Evaluate whether a major shift in the prey base for killer whales occurred historically by analyzing isotopic values in their tooth layers using existing museum specimens.

E. Collect acoustic data in areas of high sea otter concentration to detect killer whale predation activity and to verify the presence of transient type killer whales in the vicinity of sea otter habitats.

F. Develop satellite tags to follow transient killer whale movement patterns over time and to determine habitat use by these predators.

G. Develop life history transmitters to be implanted in sea otters.

Work Group 5: Alaska SeaLife Center Russia Sea Otter Program

A. Continue population surveys on Bering and Medny islands, and possibly expand efforts to other areas.

B. Continue and expand beach-cast carcass collection efforts and standardize current collection protocols.

C. Start intensive tag and release studies in the Commander Islands.

D. Develop a tooth-aging program to analyze teeth samples from Russia.

E. Continue ongoing collection of scat samples.

F. Initiate killer whale studies based on the recommendations developed by the killer whale work group.

Speaker Biographies

Shannon Atkinson, Ph.D.

Alaska SeaLife Center and University of Alaska Fairbanks, Seward, Alaska

Shannon earned her B.S. and M.S. from the Animal Science Department at the University of Hawaii at Manoa, and a Ph.D. in veterinary sciences from Murdoch University in Western Australia. She is a professor of marine science at the University of Alaska Fairbanks and serves as the science director at the Alaska SeaLife Center (ASLC). Shannon oversees the ASLC research programs and is the principal investigator on grants on the sea otter, Steller sea lion, harbor seal, and spectacled and Steller's eider. Her position at the University of Alaska supports the scientific oversight and integrity of the research, education, and rehabilitation mission of the Alaska SeaLife Center. Shannon conducts research on a variety of species from corals to seabirds, and marine mammals.

Her interests in the study of marine animal populations around the world are broad but her main interest is understanding the physiology and reproductive biology of marine animal populations that are failing to thrive in their natural environment. The failure of marine animals to adapt to changes in their environment has been the focus of Shannon's personal research program for the past 15 years.

James Bodkin

U.S Geological Survey, Alaska Science Center, Anchorage, Alaska

Jim leads Alaska sea otter research and the marine science program for the Alaska Science Center. The mission of the center is to provide biological information and research findings to resource managers, policymakers, and the public to support sound management of biological resources and ecosystems in Alaska and throughout the North Pacific Ocean. The Alaska project is one of two U.S. Geological Survey sea otter research programs; the other, led by Dr. James Estes, is located in Santa Cruz, California.

Jim is responsible for designing, developing, and directing multidisciplinary research programs for studying North Pacific coastal marine ecosystems, focusing on sea otter populations and their role in structuring coastal marine communities in Alaska. Current research programs encompass three broad objectives, including (1) designing, developing, and testing methods to assess the status of sea otter populations; (2) describing processes responsible for structuring coastal marine communities; and (3) determining the status of recovery of sea otter populations affected by the 1989 *Exxon Valdez* oil spill in Prince William Sound, Alaska.

Alexander Burdin, Ph.D.

Alaska SeaLife Center, Seward, Alaska

Alexander (Sasha) graduated as a wildlife biologist from the Kirov Agriculture Institute in 1977. He has since worked in the Chukotka Peninsula, Commander Islands, Kuril Islands, and Kamchatka Peninsula on marine mammals. He received his Ph.D. in zoology at the Severtsov's Institute of Evolutionary Morphology and Ecology of Animals, of the Russian Academy of Sciences, in 1987. Sasha worked at the Commander Field Station of the All-Union Research Institute of Fisheries and Oceanography from 1979 to 1985, at the Kamchatka Branch of the Pacific Institute of Fisheries and Oceanography from 1985 to 1989, and has been with the Kamchatka Branch of the Pacific Institute of Geography, Far East Division, Russian Academy of Sciences, since 1989. He has served since 1988 as a member of the Marine Mammal Council, a scientific advisory council to the Interdepartmental Ichthyological Commission of Russia.

Sasha studies marine mammals, primarily sea otters, killer whales, the western population of gray whales, and the Okhotsk Sea population of bowhead whales. He has conducted research projects on marine mammals in collaboration with American and Japanese colleagues, in the Commander Islands, in the Okhotsk Sea, on Sakhalin Island, and in the western Bering Sea.

He is currently a visiting scientist at the Alaska SeaLife Center conducting gray whale, sea otter, killer whale, and Steller sea lion research of the Russian Far East.

Vladimir Burkanov, Ph.D.

Natural Resources Consultants, Inc., and National Marine Mammal Laboratory, Seattle, Washington

Vladimir was educated as a wildlife biologist and received his M.S. in marine mammal studies in 1980 at the Kirov Agriculture Institute, in Russia. He has been involved in marine mammal research and conservation projects, and in fishery management in the Russian Far East since 1979. In 1990 he received his Ph.D. in environmental studies and ecology of marine mammals from the All-Union Research Institute of Evolution, Ecology and Morphology of Animals of the Academy of Science of USSR in Moscow. His interests include distribution, abundance, and conservation of marine mammals in the North Pacific, and his primary interests are Steller sea lion, ice-associated seals, sea otters, walruses, harbor seals, and marine mammal–fisheries interactions. Vladimir has conducted a number of joint marine mammal research projects with American and Japanese scientists in waters of the Russian Far East and Alaska, including the northern part of the Kuril Islands, eastern part of the Sea of Okhotsk, Commander Islands, and western Bering Sea.

Vladimir worked for the Federal Committee of Fisheries of Russia in the Kamchatka region on a variety of projects, from the conservation of marine mammal and fish resources and fisheries data collection, to fishery regulations and fishery enforcement in the Bering Sea and Russian Far East. From 1995 to 1999, he served as a member of the Russian Far East Fishery Management Council, and since 1984 has been a member of the Marine Mammal Council, a scientific advisory council to the Interdepartmental Ichthyological Commission of Russia.

Douglas Burn

U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska

Doug received his B.S. in wildlife biology from the University of Maine and his M.S. in biological oceanography from the University of Miami. His thesis work focused on the digestive strategy and efficiency of the West Indian manatee (*Trichechus manatus*). Doug worked for the National Marine Fisheries Service in Miami, Florida, on research and management of bottlenose dolphins and North Atlantic right whales. He began working for the U.S. Fish and Wildlife Service (USFWS) in Alaska in May 1989. While with the USFWS, he has participated in a variety of studies of sea otters, polar bears, and Pacific walruses.

Donald Calkins

Alaska SeaLife Center, Seward, Alaska

Don received his B.S. in biological science from Western Washington State University and went on to the University of Alaska at Fairbanks to complete his M.S. in wildlife management in 1972 with a thesis on the ecology of sea otters in Prince William Sound. From 1974 to 1998 Don worked for the Alaska Department of Fish and Game (ADFG), where he conducted research on beluga whales, harbor seals, sea otters, and Steller sea lions. He also led the State of Alaska's efforts to determine damages to all wildlife resulting from the *Exxon Valdez* oil spill in 1989. Don is internationally recognized as an authority on the biology and ecology of Steller sea lions. After he retired from ADFG, Don became the senior marine mammal scientist and Steller Sea Lion and Sea Otter Program manager for the Alaska SeaLife Center where he continues his research.

Don has served on both National Marine Fisheries Service (NMFS) Steller sea lion recovery teams. He helped write the first Steller Sea Lion Recovery Plan. Don has participated in and coordinated joint U.S.-Russian studies on Steller sea lions since 1979 and is a member of the Marine Mammal Working Group Steering Committee under the U.S.-Russia Environmental Agreement, section 02.05-61.

Randall Davis, Ph.D.

Texas A&M University at Galveston, Marine Mammal Research Program, Galveston, Texas

Randy is a professor in the Department of Marine Biology and the Department of Wildlife and Fisheries Sciences at Texas A&M University. He received his Ph.D. in physiology from the University of California, San Diego. Randy's research interests include the physiological ecology of marine mammals and birds, the comparative physiology and behavior of diving vertebrates, animal energetics, and locomotory performance. His current research projects focus on (1) the ecology and behavior of sea otters in eastern Prince William Sound; (2) the diving and hunting behavior of Weddell seals in Antarctica and of Steller sea lions in Alaska; and (3) the physiological adaptations for diving in the tissues and organs of pinnipeds.

Angela Doroff

U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska

Angie works as a wildlife biologist in the Marine Mammals Management office of the U.S. Fish and Wildlife Service (USFWS). Her work involves a variety of sea otter population assessment techniques (surveys, indices of population health, behavior), conservation plan development and implementation, international coordination, public outreach activities, co-management of subsistence harvest of sea otters, and development and implementation of tissue collection programs.

Prior to working in the Marine Mammals Management program, Angie worked four years as a wildlife biologist at the U.S. Geological Survey Alaska Research Center. During that period, she developed and implemented a two-year radio telemetry study to determine post-weaning survival of sea otters affected by the *Exxon Valdez* oil spill and was involved in a wide variety of damage assessment studies which included (1) survival and reproduction; (2) foraging ecology and contaminant loading; and (3) characteristics of carcass drift patterns. Prior to her studies in Alaska, Angie worked with the University of Minnesota on southern sea otter studies of survival, reproduction, movement patterns, and forage ecology in California.

James Estes, Ph.D.

University of California Santa Cruz/U.S. Geological Survey, Long Marine Laboratory, Santa Cruz, California

Jim is an internationally recognized expert on sea otters and a specialist in the critical role of apex (top level) predators in the marine environment. He has been a research biologist at the Western Ecological Research Center of the U.S. Geological Survey for more than 30 years. Jim also holds academic posts as research associate and adjunct professor with the Biology Department, Environmental Studies Department, and Institute of Marine Sciences at the University of California Santa Cruz.

Jim's interest in predation as an ecosystem-level process began in the early 1970s, shortly after he began working with sea otters. Using the otters' fragmented distribution across the Aleutian archipelago, which resulted from a history of near-extinction and recovery, he discovered the species' keystone role in kelp forests by contrasting islands where it was abundant or rare. This work provides one of the better-known examples of how apex predators influence ecosystem function. These early findings led Jim to explore the spatial, temporal, and functional dimensions of sea otter–kelp forest interactions. Jim's most recent research addresses the unanticipated collapse of sea otters and kelp forests in Western Alaska. He is currently involved with studies designed to better understand the vexing problem of decline in the threatened California sea otter.

Sergey Kornev, Ph.D.

KamchatNIRO, Marine Mammal Laboratory, Petropavlovsk-Kamchatsky, Kamchatka, Russia

Sergey was born in Belorussia and attended the Institute in Kirov City (Russia) in 1985. From 1985 to 1993, together with his wife Svetlana, he lived and worked on Cape Lopatka, where he was engaged in observing sea otters and promoting conservation efforts. In 1997, Sergey finished his doctoral dissertation on the sea otters of southern Kamchatka. Currently, he works at the Kamchatka Research Institute of Fishery and Oceanography where he continues to study the biology of sea otters and other marine mammals in Kamchatka and in the Kuril Islands.

Daniela Maldini, Ph.D.

Alaska SeaLife Center, Seward, Alaska

Daniela completed her B.S. degree in biological sciences at the University of Pavia, Italy, in 1988. During this time she managed the Marine Biology laboratory and completed a thesis on the conservation biology of pleuronectiform fishes in the Ligurian Sea. She moved to the United States in 1988 and started working on sea turtles at the University of Texas at Austin Marine Laboratory located in Corpus Christi, Texas, and later on marine mammals and birds at Moss Landing Marine Labs in Monterey Bay, California, where she completed her M.S. in marine sciences in 1996 studying the ecology of bottlenose dolphin in Monterey Bay. During this time she was involved in a variety of ecological studies focusing on whales, dolphins, sea otters, and pinnipeds; co-founded the Pacific Cetacean Group, a nonprofit corporation focusing on research, education, and conservation; and led the Marine Mammal Center Monterey Bay Operations stranding network in 1994-1995. Daniela completed her Ph.D. in zoology at the University of Hawaii at Manoa in 2003 with a study of abundance and distribution patterns of odontocetes around the Island of Oahu. She is also the co-founder and vice president of the Oceanwide Science Institute, a Hawaii nonprofit. She has been contracting as a biologist with the Hawaiian Islands Humpback Whale National Marine Sanctuary since 1998. Since 2001 she has been working as a research associate at the Alaska SeaLife Center focusing on the ecology of killer whales and, more recently, sea otters in Alaska and Russian waters. Daniela is interested in the behavioral ecology of marine mammals and colonial water birds, population biology, and predator-prey relationships. Her work focuses on the ecology of odontocetes in various parts of the world.

Rosa Meehan, Ph.D.

U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska

Rosa received her B.S. degree in biology from the University of California Santa Cruz, in 1976. She completed her M.S. in biology at the University of Alaska, Fairbanks, in1980, and her Ph.D. in environmental, population, and organismic biology at the University of Colorado, Boulder, in 1986 with a dissertation on the impact of oil field development on shorebirds in Prudhoe Bay, Alaska. Rosa is currently the division chief of the Marine Mammals Management Division at U.S. Fish and Wildlife Service (USFWS) in Anchorage, and is involved with policy development and management of polar bear, sea otter, and Pacific walrus and their subsistence use by Alaska Natives under the Marine Mammal Protection Act and the Endangered Species Act. From 1996 to 1999 she served as the chief of the

Resources Division, Subsistence Management and worked on the regulation development and biological and anthropological assessment of subsistence uses relative to implementation of subsistence harvest management on federal lands in Alaska. From 1993 to 1996 she worked as the chief in the Division of Habitat Conservation dealing with policy development and review of the implementation of resource management related statutes (Coastal Zone Management Act, Clean Water Act, Endangered Species Act) in Alaska.

Rosa is a member of the Alaska SeaLife Center Scientific Advisory Committee and the Russia program coordinator for the USFWS. She was a member of the U.S. National Assessment Team of the Potential Consequences of Climate Variability and Change, Alaska Region, from 1997 to 2003, and was a member of the Bering Sea Impact Study Steering Committee from 1996 to 1999. She was the president of AAAS-Arctic Division in 1994.

Melissa Miller, D.V.M., Ph.D.

University of California Davis Wildlife Health Center, California Department of Fish and Game, and Marine Wildlife Veterinary Care and Research Center, Santa Cruz, California

Melissa earned a B.S. and M.S. in wildlife management/animal science at the University of New Hampshire, and completed her veterinary degree at the University of California Davis. She completed an internship in small animal medicine and surgery at North Carolina State Veterinary School, a residency in anatomic pathology at the U.C. Davis Veterinary Medical Teaching Hospital, and a Ph.D. in comparative pathology at the U.C. Davis School of Veterinary Medicine. Melissa currently works as a wildlife pathologist for the U.C. Davis Wildlife Health Center and the California Department of Fish and Game (CDFG), based at the CDFG's Marine Wildlife Veterinary Care and Research Center in Santa Cruz. Melissa's research focuses on infectious and toxic diseases of marine wildlife, particularly sea otters, and the potential environmental implications of biological pollution.

Daniel Monson

U.S Geological Survey, Alaska Science Center, Anchorage, Alaska

Dan received his B.A. in biology from Luther College in Decorah, Iowa, in 1983. As a wildlife technician he worked with terrestrial species in the midwestern United States conducting intensive telemetry studies on wolves, white tail deer, red fox, and black bear. In 1987, he took a position with the Alaska Science Center (ASC) and began working on sea otters in Alaska and California. He also spent four seasons working on seals in Antarctica and has participated in studies on a variety of other marine mammal species including killer whales, elephant seals, and Steller sea lions.

Dan completed his M.S. at the University of California Santa Cruz (UCSC) in 1995, and continues to work with sea otters in Alaska and California while completing a Ph.D. at UCSC. His past work has concentrated on the population biology and reproductive ecology of sea otters in Alaska.

Most recently Dan worked with a multidisciplinary team on the Nearshore Vertebrate Predator Project in Prince William Sound where he concentrated on the foraging efficiency of sea otters at several sites and developed simulation models to estimate caloric intake rates from sea otter forage data. In addition, Dan has been involved with studies using time depth recorders (TDRs) in sea otters in Southeast Alaska and California. Along with assisting in all aspects of the field work, Dan has developed many of the analytical methods used to classify and analyze dive information from TDR records.

Victor Nikulin

Sevvostrybvod Marine Mammal Service,
Petropavlovsk-Kamchatsky, Russia

Victor earned his M.S. degree in biology at Irkutsk (Eastern Siberia) in 1977. In 1980 he worked on the Commander Islands as a state fish inspector dealing with conservation and monitoring of marine mammal populations (fur seals, sea otters, harbor seals, and Steller sea lions). In 1995 he moved to Petropavlovsk-Kamchatsky and continues to work as a state inspector at Sevvostrybvod, and monitors marine mammal populations in the Kamchatka region.

Tim Tinker

University of California Santa Cruz/U.S. Geological Survey, Long Marine Laboratory, Santa Cruz, California

Tim has been conducting research on marine mammals for 15 years. In 1990 he completed his B.S. in zoology at the University of Guelph and in 1993 earned his M.S. at the University of Waterloo, Ontario, where he studied the mating behavior and energetic physiology of ice-breeding gray seals in eastern Canada. He is currently completing his Ph.D. at the University of California Santa Cruz. Since 1993, he has been involved with sea otter research in Alaska and California, studying both the causes and effects of the sea otter population decline in the Aleutian archipelago, as well as the foraging ecology and demography of sea otters in California.

Tim's research interests include quantitative conservation ecology, with a particular emphasis on modeling population dynamics and the ecological processes that regulate wildlife populations. He is also interested in individual behavioral strategies, particularly foraging specializations, and seeks to understand the ways in which variation in the fitness of individual strategies scales up to population-level and community-level dynamics.

Sergey Zagrebelny, Ph.D.

State National Reserve Komandorsky, Nikolskoe, Aleutian District, Kamchatka, Russia

Sergey was educated at the Far East State University in Russia where he received his Ph.D. in zoology in 1991. He is currently the vice director of the State Nature Reserve Komandorsky in the Aleutian District of Russia. His main interest is the ecology of terrestrial mammals in isolated systems such as the Commander Islands. His studies included the feeding ecology of arctic foxes, the ecology of reindeer, and the monitoring of sea otter populations in the Commander Islands, and he has also worked in the Kamchatka region in Russia.

Directory of Invited Researchers

Russ Andrews
Alaska SeaLife Center/
University of Alaska Fairbanks
PO Box 1329
Seward, AK 99664
(907) 224-6344
russ_andrews@alaskasealife.org

Shannon Atkinson
Alaska SeaLife Center/
University of Alaska Fairbanks
PO Box 1329
Seward, AK 99664
(907) 224-6346
shannon_atkinson@alaskasealife.org

James Bodkin
USGS Biological Resources Division
Alaska Science Center
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3550
james_bodkin@usgs.gov

Alexander Burdin
Alaska SeaLife Center
P.O. Box 1329
Seward, AK 99664
(907) 224-6332
alexander_burdin@alaskasealife.org

Kathy Burek
Alaska Veterinary Pathology
23834 The Clearing Drive
Eagle River, AK 99557
(907) 696-3704
fnkab1@uaf.edu

Vladimir Burkanov
Natural Resources Consultants, Inc.
National Marine Mammal Laboratory
7600 Sand Point Way N.E. F/AKC3
Seattle, WA 98115-6349
(206) 526-4298
vladimir.burkanov@noaa.gov

Douglas Burn
U.S. Fish and Wildlife Service, Region 7
Marine Mammals Management
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3807
douglas_burn@fws.gov

Don Calkins
Alaska SeaLife Center
PO Box 1329
Seward, AK 99664
(907) 224-6325
don_calkins@alaskasealife.org

Randy Davis
Texas A&M University at Galveston
Department of Marine Biology
5007 Avenue U
Galveston, TX 77551
(409) 740-4712
davisr@tamug.tamu.edu

Angela Doroff
U.S. Fish and Wildlife Service, Region 7
Marine Mammals Management
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3803
angela_doroff@fws.gov

Jim Estes
University of California Santa Cruz/
USGS
Long Marine Laboratory
100 Shaffer Road
Santa Cruz, CA 95060
(831) 459-2820
jestes@cats.ucsc.edu

Thomas Gelatt
Alaska Department of Fish and Game
Wildlife Conservation/Marine Mammals
525 W 67th Avenue
Anchorage, AK 99518-1599
(907) 267-2188
tom_gelatt@fishgame.state.ak.us

Verena Gill
U.S. Fish and Wildlife Service, Region 7
Marine Mammals Management
1011 E. Tudor Road, MS 341
Anchorage, AK 99507
(907) 786-3584
Verena_Gill@fws.gov

John Haddix
U.S. Fish and Wildlife Service, Region 7
Marine Mammals Management
1011 E. Tudor Road
Anchorage, AK 99507
(907) 786-3808

Charles Hamilton
U.S. Fish and Wildlife Service, Region 7
Marine Mammals Management
1011 E. Tudor Road
Anchorage, AK 99507
charles_hamilton@fws.gov

Lianna Jack
Alaska Sea Otter and Steller Sea Lion Commission
6239 B St. Suite 204
Anchorage, AK 99518
(907) 274-9799
ljack@gci.net

Carl Kava
Alaska Sea Otter and Steller Sea Lion Commission
6239 B St. Suite 204
Anchorage, AK 99518
(907) 274-9799
ckava@gci.net

Brenda Konar
University of Alaska Fairbanks
School of Fisheries and Ocean Sciences
PO Box 757220
Fairbanks, AK 99775
(907) 474-5028
bkonar@guru.uaf.edu

Sergei Kornev
Marine Mammal Laboratory
KamchatNIRO
18 Naberegnay Str.
Petropavlovsk-Kamchatsky,
Kamchatka, Russia, 683000
kornev@mail.iks.ru and
kornev@kamniro.ru

Lloyd Lowry
Marine Mammal Commission
73-4388 Paiaha Street
Kailua-Kona, HI 96740
(808) 325-6885
llowry@eagle.ptialaska.net

Daniela Maldini
Alaska SeaLife Center
PO Box 1329
Seward, AK 99664
(907) 224-6375
daniela_maldini@alaskasealife.org

Mikhail K. Maminov
TINRO Center
4 Shevchenko Tupik
Vladivostok Primorsky krai
690950 Russia
+7 4232-40-17-13
smperlov@tinro.ru

Dan Martinez
Alaska Sea Otter and Steller Sea Lion Commission
6239 B St. Suite 204
Anchorage, AK 99518
(907) 274-9799
danmartinez@gci.net

Craig Matkin
North Gulf Oceanic Society
60920 Mary Allen Way
Homer, AK 99603
(907) 235-6590
comatkin@xyz.net

Rosa Meehan
U.S. Fish and Wildlife Service, Region 7
Marine Mammals Management
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3800
rosa_meehan@fws.gov

Melissa Miller
University of California Davis Wildlife Health Center
California Department of Fish and Game
Marine Wildlife Veterinary Care and Research Center
1451 Shaffer Road
Santa Cruz, CA 95060
(831) 469-1746
mmiller@ospr.dfg.ca.gov

Dan Monson
USGS Biological Resources Division
Alaska Science Center
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3449
daniel_monson@usgs.gov

Victor Nikulin
Sevvostrybvod
Marine Mammal Service
58 Korolyova St.
Petropavlovsk-Kamchatsky
683024 Russia
+7 (415) 211-9009
v.nikulin@rybvod.kamchatka.su

Ken Pitcher
Alaska Department of Fish and Game
Wildlife Conservation/Marine Mammals
525 W 6th Avenue
Anchorage, AK 99518-1599
(907) 267-2363
ken_pitcher@fishgame.state.ak.us

Don Siniff
University of Minnesota
Department of Ecology, Evolution and Behavior
1987 Upper Buford Circle
St. Paul, MN 55108
(612) 625-5732
siniff@ecology.umn.edu

Leslie Slater
U.S. Fish and Wildlife Service, Region 7
Alaska Maritime National Wildlife Refuge
95 Sterling Hwy. Suite 1
Homer, AK 99603-7472
(907) 226-4607

LaVerne Smith
U.S. Fish and Wildlife Service, Region 7
Fisheries and Ecological Services
1011 E. Tudor Road
Anchorage, AK 99503
(907) 786-3493
laverne_smith@fws.gov

Nancy Thomas
USGS National Wildlife Health Center
6006 Schroeder Road
Madison, WI 53711
(608) 270-2463
nancy_thomas@usgs.gov

Tim Tinker
University of California Santa Cruz/USGS
Long Marine Laboratory
100 Shaffer Road
Santa Cruz, CA 95060
(831) 459-2357
tinker@biology.ucsc.edu

Glenn VanBlaricom
Washington Cooperative Fish and Wildlife Research Unit/USGS
University of Washington
School of Aquatic and Fishery Sciences
PO Box 355020
Seattle, WA 98195-5020
glennvb@u.washington.edu

Vladimir Vertyankin
Sevvostrybvod
Marine Mammal Service
58 Korolyova St.
Petropavlovsk-Kamchatsky
683024 Russia
+7 (415) 211-9009
vertyankin@mail.iks.ru

Sergey Zagrebelny
State National Reserve Komandorsky
Bering Street 18
Nikolskoe
Aleutian District
Kamchatka
684500 Russia
beringafox@mail.iks.ru

INTERPRETER
Marina Bell
1364 St. Gotthard
Anchorage, AK 99508
(907) 562-6922
marina@ak.net

Index