Sea Otters

By James Bodkin

EDITOR'S NOTE: *Jim Bodkin is a research scientist with the Alaska Biological Science Center in Anchorage. He began his career with sea otters in California in 1980 and has studied them throughout the northern Pacific Ocean. He currently leads the Coastal Ecosystem Research Team whose work has focused on sea otters and nearshore marine communities.*

Introduction

Sea otters have been an important resource for people living along the North Pacific coast for thousands of years. At least two aspects of the sea otters' natural history have linked them with humans: their pelt and their food habits. Sea otter pelts, arguably the finest in the animal kingdom, were fashioned into garments, particularly in northern latitudes, while the presence of sea otters influenced the availability of some marine invertebrates, like snails, clams and abalone, that provided food for coastal people. In addition, sea otters spurred a growing fur trade after Vitus Bering's explorations of the North Pacific in the early 1700s revealed their widespread abundance. This commercial harvest was instrumental in European exploration and settlement of the Pacific Rim and led to the near-extermination of the sea otter, *Enhydra lutris*, in following centuries.

Largely because of their life history and their direct relations with coastal residents, sea otters are a comparatively well-understood marine mammal. During the past few decades, concern for sea otters has broadened to encompass an interest in global resource conservation and restoration, as well as community ecology. This more recent focus on sea otters now extends to humans far removed from marine environments.

Early sea otters evolved about 12 million years ago from Eurasian and African ancestors. They reached the North Pacific by way of two proposed migration paths, one along the Bering Land Bridge between northeastern Asia and northwestern North America and a second from the Atlantic Ocean that entered the Pacific through a channel in the central Americas. Modern sea otters occur only in the North Pacific and have occupied their current range for the past 1 million to 3 million years.

Environment, Food Habits and Movements

Sea otters are the only exclusively marine member of the Mustelidae (otter, weasel, badger and skunk) family, and are capable of spending their entire lives in the ocean. They are closely related to other otter species, such as the river, clawed, giant and smooth otters that occur on all continents and are mostly freshwater forms. One poorly known species, the marine otter (*Lutra felina*) of the west coast of South America, forages exclusively in marine habitat but acts out most other behaviors ashore along rocky coastlines.

Sea otters occupy nearly every coastal marine habitat in the North Pacific, from shallow estuaries to the exposed outer coasts. They are gregarious, and

FACING PAGE: *Sea otters inhabit shallow coastal waters with sandy or rocky bottoms that support crabs, mussels, urchins, clams and fish. (Patrick J. Endres)*

Sea otters haul out on an iceberg in Unakwik Inlet, northern Prince William Sound. When they come ashore, they usually form sex-segregated groups of a few to hundreds of animals. (Alissa Crandall)

often rest in groups numbering from a few to many hundreds. Kelps that form floating canopies are favored resting areas, but sheltered bays or offshore rocky areas that block wind and waves are also used for resting. Individuals may leave the sea to rest on ice floes, sandbars or intertidal rocks, but no aspect of a sea otter's life history requires such behavior and some never come ashore.

Although sea otters share adaptations found in other diving mammals such as collapsible lungs and hind feet modified for underwater locomotion, they are unique in that they feed almost entirely on benthic invertebrates such as crabs, clams and snails rather than the fish, squid or zooplankton many marine mammals eat. They also are known to chew open cans they find on the floor of California's Monterey Bay to reach octopus that hide inside. Sea urchins probably rank no. 1 on a list of more than 100 species of food items sea otters eat. Sea urchins range in maximum size from about that of a baseball to that of a softball.

Sea otters generally forage alone, but feeding individuals may concentrate where prey is most abundant. Although they are capable of diving to more than 325 feet, most feeding takes place in waters less than 150 feet deep. Because sea otters feed primarily on organisms living in, or on, the sea floor, their distribution offshore is limited by their ability to dive to the ocean bottom. And although they can be found far from shore where shallow waters occur, they are most common in waters adjacent to the coastline.

They are relatively sedentary compared to most marine mammals, and most individuals occupy home ranges that might include a few tens of miles of coastline. Juveniles and adult males tend to have slightly larger home ranges. Because of limits in their diving ability, effective barriers to movement exist in the form of deep and wide passages between suitable habitats, such as islands. Because of their limited movements, exchange of genetic material over long distances can require many generations.

Life Cycle and Reproduction

Sea otters mate at all times of the year, and young may be born in any season. In Alaska, most pups, averaging 3 to 5 pounds, are born in late spring. A

newborn pup is particularly vulnerable to predation and starvation, and requires almost constant care. If the mother is in poor condition when her pup is born, she may not be able to provide adequate care without risking her own life. Thus, most pup mortality occurs during the first 60 days after birth. If she is able to bring the pup through this period, the mother will likely raise it to weaning age. However, if she loses her pup at this early stage, she mates soon after and is able to produce another pup within the same year.

Sea otters can live more than 20 years, although the average life span for males is about 10, and 15 for females. A female reaches sexual maturity between ages 2 and 4. She is pregnant for about six months and produces a single pup, an adaptation to aquatic living common among marine mammals but not seen in other otter species. Population growth rates are constrained by the production of a single offspring. On rare occasions, twins are born. The reproductive rate increases with age, until by age 5 about 90 percent of females are giving birth to a pup per year. This annual reproductive output is maintained throughout adulthood with only a slight decline late in the female's life.

Pups depend on their mother for up to one year, during which the pup develops to near-adult size and acquires the skills it will need to live on its own. During their first year of life, pups are susceptible to various sources of mortality including hypothermia, predation, starvation and disease that can vary greatly and depend on the environmental conditions in which they were born. In areas where populations are at or near carrying capacity and food is relatively scarce, survival of pups can be as low as 45 percent, but where sea otter populations have abundant food supplies, the survival of pups can be as high as 85 percent. A second critical period of a pup's life comes at weaning and for several months afterward when the chance of mortality again rises. Survival rates can drop to 20 percent after weaning, although they may be as high as 85 percent under good

Grooming their thick fur is an important activity for sea otters. Unlike seals, which have a thick layer of blubber to insulate them, sea otters instead have the densest fur of any mammal. Air trapped between long guard hairs and soft underfur buoys them and helps keep their skin dry and warm. (Dan Parrett)

conditions. Survival generally increases following the first year of independence, approaching 90 percent for adult males and 95 percent for adult females.

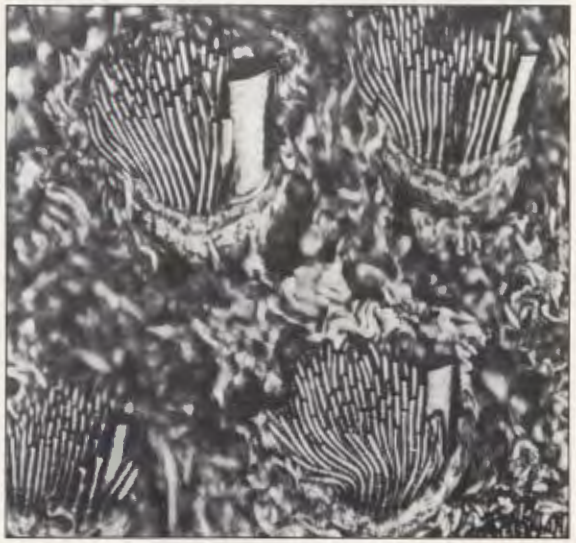
Sea otters are polygynous, with dominant males defending territories where females are present and excluding other males. The sexes are generally segregated, with the best habitat occupied by females and their young; most males, except those holding territories in female areas, concentrate in relatively small areas. The sex ratio at birth is about 1:1, but generally fewer males survive. The male-biased mortality results in a sex ratio among adults that is skewed toward females, which can comprise 70 percent of the population. Thus a reproductive system with more females than males in the population allows for higher population growth than if the sex ratio were equal.

Luxurious Fur: A Special Adaptation

Because water conducts heat more than 25 times faster than air, aquatic mammals, particularly those occurring in high latitudes, require advanced

LEFT: *In Kachemak Bay in lower Cook Inlet, a mother sea otter and her pup float, the pup resting on her stomach. The peak breeding season in Alaska is September through October, and females normally bear one pup in May. The offspring of first-time mothers have a lower survival rate than do the offspring of experienced mothers. (Alissa Crandall)*

BELOW: *Guard hairs and thick underfur, magnified 75 times, from the midback of an adult male sea otter show the density of the species' pelage. The circular areas represent the guard hairs, the squiggly areas the underfur. (Karl Kenyon, USDI)*



Sea otters bring their food to the surface to eat. A loose pouch of skin on each foreleg is used to carry food, so an otter can gather several pieces during one dive, then bring them all to the surface at once. Typically, a sea otter will use only the pouch on the left for storage, leading researchers to think most sea otters are "right-handed." (Tom Walker)

adaptations to maintain their constant body temperature. The adaptation employed by virtually all other marine mammals is one of a fat or blubber layer that encases the body and provides insulation.

Sea otters lack this blubber layer; instead, they produce the densest fur of all mammals to insulate themselves. This luxurious coat consists of two types of hair: a dense underfur that traps air and coarse guard hair that forms a protective outer layer. The up-to-1-million hairs per square inch of a sea otter's fur are quite capable of keeping the skin and underfur dry, insulating the otter with a layer of air, as opposed to fat.

The quality, or insulating properties, of a mammal's fur in large part depends on the habitat in which the animal lives. Species occupying the coldest habitats are considered to have the highest quality of fur. Humans initially valued mammal fur as a source of insulation. With proper clothing, people could occupy cold arctic habitats. Furs assumed additional value as a symbol of wealth and status, the finest furs having

Sea otters wrap themselves with kelp before sleeping to prevent drifting, though this is not necessary for survival. In places in the Bering Sea, they seem to sleep comfortably without secure kelp beds. (Chlaus Lotscher)

the highest value, both in insulating quality and social status. Thus the value of sea otter fur to both the otter and the human can ultimately be traced back to the biology of the animal.

Sea Otters and Humans: Indigenous Use

Researchers have little direct knowledge of the interaction between indigenous people of the North Pacific and the sea otter. However, we can draw some inferences from what exists in archaeological remains throughout the Pacific Rim as well as from written history following Bering's explorations.

Two lines of evidence support the premise that early coastal dwellers used sea otters. First, skeletal remains of these animals are common in coastal middens, the accumulated refuse at sites of human occupation. These middens exist throughout the Pacific Rim and provide insights into coastal people's lives and the resources they used. Second, and even more convincing, is that coastal people, particularly in northern regions of the Pacific, had apparently developed an elaborate and efficient method for hunting sea otters

long before acquisition of modern firearms. In particular, the Aleuts had developed a sophisticated hunting strategy prior to 1750. The hunt consisted of a well-coordinated effort that required specialized tools and the skills of many individuals. The Aleuts would take to the sea in small one- or two-man skin kayaks and paddle in formation searching for otter. The hunters likely concentrated on areas favored by sea otters for either resting or feeding. The typical response of sea otters to disturbance is to dive, and they can stay submerged for nearly five minutes, although average dive times are between one and two minutes. Upon locating one or more otters, the hunter in the kayak closest to the animal would raise his paddle to alert the others that an otter had dived. The remaining hunters would then form a broad circle around the location where the otter was last seen and wait for it to surface. This process would be repeated until the otter under pursuit surfaced sufficiently close to a hunter to be struck with a small spear propelled with a sling. A line attached to the spear was used to retrieve the animal; often more than one spear would be required to kill the otter. The development of such sophisticated, cooperative hunting is ample evidence of the importance of sea otters well into human history.

At least one other method was occasionally used to hunt sea otters and required an understanding of the close relationship between a female sea otter and her pup. At birth, a sea otter pup is largely defenseless, incapable of most behaviors other than nursing and floating on the water's surface. The mother is forced to leave the pup on the surface alone because she must still dive to the sea floor to forage. These separations create opportunities for predators, including the bald eagle and humans. The helpless pup is easily captured and handled without its mother and early hunters would entwine the pup with line and hooks. The pup would then become bait to lure the highly protective mother. While retrieving her pup, the female would

A sea otter eats a fish near Whittier in Prince William Sound. Sea otters use their front paws, which have retractable claws, for eating and grooming, but not for swimming. (Alissa Crandall)

become snared in the line and hooks and be subdued by the hunters. The pup depends on its mother for about six months and although pups of all ages can be readily captured without the protection of their mothers, they probably became less susceptible to this hunting technique with age.

Researchers have little knowledge of exactly why early coastal people hunted sea otters, but the hunters' elaborate methods confirm that they did indeed harvest them. We can, however, speculate on at least three potential reasons: one that is associated with management and protection of alternative resources and two that relate to resource acquisition, fur for clothing and as a commodity for trade.

Sea Otters as a Keystone Species

The concept of harvesting sea otters to protect other resources requires an understanding of the complex role this species can play in structuring coastal marine communities. Sea otters provide one of the best examples of the ecological "keystone species" concept. Simply put, a keystone species is one that has a proportionately greater effect on the community in which it exists than might be expected by its abundance.

The best evidence to support the sea otter as a keystone species comes from kelp forest communities of shallow rocky areas along the North Pacific coast. Within these habitats reside several species of sea urchins, marine herbivores that actively graze on algae, including the brown algae that form the often-conspicuous underwater kelp forests that occur along many coastlines. Where sea otters are abundant, they effectively control sea urchin populations by consuming most individuals larger than about 1 inch in diameter. Those larger sea urchins that escape sea otter predation do so by taking refuge in crevices that otters cannot reach. As a result, when sea otters are present, urchins generally do not have much of a grazing effect on algae and consequently kelp forests flourish.

Alternatively, in the absence of sea otters, sea urchin populations increase their numbers and average size. As this happens, the sea urchins exert greater grazing pressure on the kelp forest and can ultimately eliminate the forest and much of the associated animal community. An urchin-dominated community, sometimes called an urchin

Sea Otters as Tool Users

By Susan Beeman

Sea otters are the only mammal, other than primates, to use tools for eating. Most of the invertebrates sea otters eat have hard shells and must be cracked open to get at the meat inside. After bringing crabs or mussels or clams up from the ocean bottom, the sea otter rolls onto its back, and placing on its stomach a flat rock it has held under its arm, bangs the invertebrate on the rock several times to crack it open.

Pups learn from an early age the hammering skills they will use as adults. They begin by making chest-slapping motions at about 5 weeks, and at about 10 weeks, are rubbing pieces of shell together, or diving while holding a rock. By the time they are 5 months old, young sea otters seem adept at either biting into the shells of their prey or using a rock to help crack it open. ■

A sea otter carries a stone, used to help crack open shellfish, under its arm. (Frank S. Balthis)

An excavation of the Korovinski site on Atka Island in the Aleutians reveals thick volcanic ash covering layers of shells in a midden, or refuse pile, left by indigenous peoples. Researchers think that historical coastal Alaska Natives understood the effect sea otters had on local populations of shellfish, especially sea urchins. (Douglas W. Veltre)

barren, is characterized by abundant, large sea urchins, little midwater habitat provided by kelp and the absence of kelp-associated fauna.

Biologists have observed similar effects in other prey species in the absence of sea otter predation. For example, some species of crabs, abalone and mussels can also increase in abundance and average size once sea otters are removed. Those prey populations that flourish in the otters' absence can become more available for other predators, such as humans. While biologists cannot definitively answer whether early coastal people controlled sea otter populations to enhance populations of other invertebrates for their own use, they certainly possessed the knowledge, tools and abilities to do so. The presence of bones and other items these early people discarded in their village middens suggests that they may have done just that.

Excavated middens on Amchitka Island in the central Aleutians reveal distinct layers that apparently represent periods of time in which large sea urchins were abundant, as well as periods when they were rare. Although alternative explanations are possible, this finding coincides with periods of time when otter abundance may have been regulated by human harvest and resulted in distinct changes in the composition of coastal marine communities, as evidenced by the large sizes of sea urchins. A similar pattern can be seen in middens in islands off California, where the remains of shells of large abalone, mussels and urchins are present. The abundance and large size of these invertebrates, which are preferred sea otter prey, is inconsistent with the relative scarcity of large individuals of those same species in marine communities today where sea otters are present.

Although factors other than human harvest, such as starvation, disease or other predators may regulate sea otter populations, the midden remains and the well-developed hunting methods indicate that early coastal residents

Flourishing kelp beds in known sea otter territory may be a sign that the otters are keeping sea urchin populations down. (James Bodkin)

exploited sea otter populations as a tool to enhance desired invertebrate resources that could be used as food. It was in fact the hunting skills of coastal people within the sea otter's range that facilitated the commercial harvest of this species, a prowess that eventually led to the otters' near-extinction.

Sea Otters as a Fur Resource

Vitus Bering's discovery of abundant sea otters in the North Pacific and Bering Sea in the early 1700s spurred a commercial sea otter industry that lasted a century and a half and eventually reduced the number of sea otters from perhaps 300,000 to a few hundred. Initiated by Russians, the hunt began in the western Pacific, the Kuril and Commander Islands of Russia and the far western Aleutian Islands. Spanish, British and American fur hunters eventually joined in. The harvest progressed to the east as sea otters were removed from successive island groups in the Aleutians. Indigenous coastal hunters, primarily Aleuts, were employed, or in some cases enslaved, to conduct the hunt using those hunting methods described above. Eventually the Russians established trading centers at Kodiak and Sitka to handle the furs and other commerce. The primary market for sea otter pelts was Asia, where furs returned about $30 per pelt in the early 19th century. An estimated 500,000 to 900,000 sea otters were killed between 1742, when the commercial harvest began, and 1910, when the unsuccessful final hunt was held.

Despite the obvious value of the resource, there was apparently little effort to manage the harvest in any way that might assure its continuation. In fact, it is unlikely that the hunters knew how to harvest sea otters in a way to ensure the population, although historical records indicate that the Russians did make rudimentary efforts at conservation. A review of the commercial hunt in light of current understanding of a sea otter's life history may help explain how this species could have come so close to extinction.

Using advanced molecular techniques, researchers are able to distinguish genetic differences between populations as close together as Prince William Sound and Kodiak Island. The unique gene frequencies found within and among isolated sea otter

populations confirm their limited movement and geographic isolation. Thus the appropriate scale at which the commercial hunt could have been managed would have been over a much smaller area than the entire Pacific Rim. In other words, if the average harvest of 3,000 to 5,000 per year had been distributed in proportion to their overall abundance, rather than removing all otters from successive hunting areas, it is unlikely that the species would have approached extinction nearly a century ago. It is also possible that biologists would not have even been able to detect a decline in the overall abundance of the species during the period of commercial hunting.

Recovery of Sea Otter Populations

By the close of the 19th century it was clear that sea otter populations were too low to support a commercial harvest of any kind. Ironically, not until 1911, one year after the final hunt, did sea otters receive political protection under the

Fur color is one indication of age in sea otters. Adults range from dark brown to blonde; their head and neck lighten with age until they become white in old animals. Sea otters usually live 15 to 20 years. (Frank S. Balthis)

North Pacific Fur Seal Convention. Eleven geographically isolated sea otter populations — mostly in the Aleutians and Southcentral Alaska with a few in Russia and one in California — survived the commercial slaughter and formed the nucleus for recovery of the species.

During this period of low or no sea otter presence, profound changes occurred in marine communities formerly occupied by the otters, changes that provided cash and crops for humans but may have hindered the recovery of sea otters. In addition to increased sea urchin grazing, which reduced kelp biomass, a number of other species of mollusks, echinoderms and crustaceans were spared the effects of sea otter foraging. Over time, these species grew in number and size and attracted the attention of people, who recognized that these species could support a commercial harvest. During the 20th century, commercial fisheries developed for abalone, clams, sea urchins, crabs and spiny lobster. It is worth noting that most of these commercial harvests have also resulted in depletion of populations and fishery closures. In addition, a large number of recreational and subsistence fisheries have also developed in response to the large invertebrates present in the absence of sea otter predation. This modern scenario of increasing invertebrate populations and their use by humans following sea otter reductions may not be too much different from that described in the Aleutians during thousands of years, except in terms of geographic and economic scale.

Conflict has arisen where humans harvesting these invertebrates have met sea otters recolonizing their range. These conflicts have led to increased levels of illegal human kill of sea otters, either in frustration of suffering economic loss or in an effort to prevent that loss. In either case, the interests of people who oppose the recovery of sea otter populations today clash with the dramatically different interests of those concerned with conservation and restoration of natural communities. The latter view sea otters as an integral component of the coastal marine community, valued for

A biologist extracts a tooth from a sea otter during research eight years after the 1989 Exxon Valdez *oil spill, which left thousands of marine animals and birds dead or injured. (Roy Corral)*

Sea otters were hunted, almost to extinction, for their luxurious fur. The commercial harvest of Enhydra lutris *stopped in 1911, and populations now thrive in Alaska. (Tom Walker)*

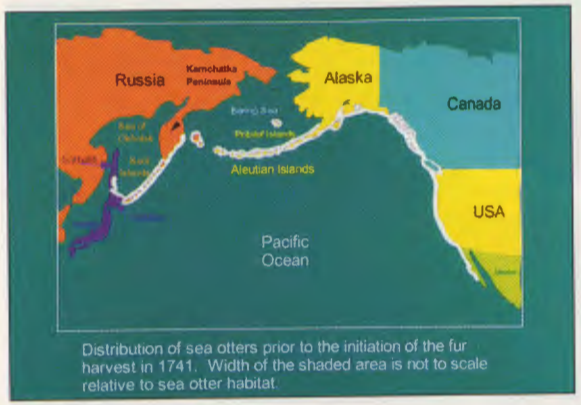
their presence rather than because of economic gain from their harvest or as an ecological consequence of their absence. Further, this perspective can be and is held by humans that do not reside along the coasts.

Recovery rates of remnant sea otter populations appear to have varied, particularly in the first few decades following protection. The Amchitka Island population grew the fastest, about 13 percent annually. Nearly all other remnant populations had average annual growth rates of 10 percent or less. The California population, numbering a few dozen in 1914, showed the slowest growth. Eighty-five years later, the population only numbers about 1,800. One explanation for the slow growth may be that the populations were so small that even the additional mortality of a few animals could offset the growth potential offered by reproduction in a given year. Arrests and the recovery of pelts prove that some illegal hunting occurred in the early 20th century. The sea otter's social and reproduction systems could have imposed a third limitation. Perhaps otters were so few and so sparsely dispersed, or sex ratios so skewed by the hunt, that reproductive rates were impaired.

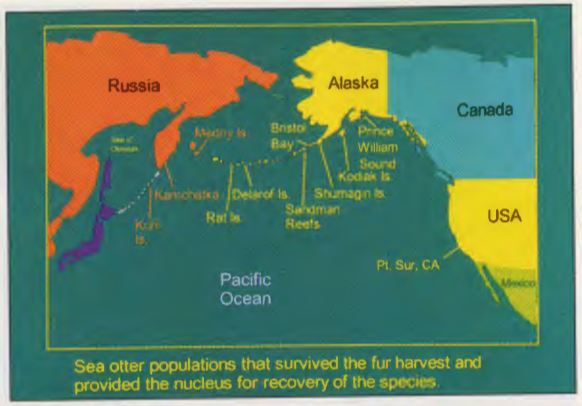
Whatever the reasons for the various growth rates, they were adequate to produce healthy and growing populations throughout much of Alaska, central California and Russia by the middle of the 20th century.

Translocations

By the 1960s and 1970s sea otter populations were sufficient to begin translocating animals from Amchitka Island in the Aleutians and Prince William Sound in Southcentral Alaska to



Distribution of sea otters prior to the initiation of the fur harvest in 1741. Width of the shaded area is not to scale relative to sea otter habitat.



Sea otter populations that survived the fur harvest and provided the nucleus for recovery of the species.

Current distribution of sea otters including locations of successful translocations

These maps show sea otter distribution at three stages: before the beginning of commercial hunting, remnant populations after the hunting stopped and current distribution. (Courtesy James Bodkin)

Oregon, Washington, British Columbia, Southeast Alaska and the Pribilof Islands. The goal of these translocations was to re-establish sea otter populations in their former range. These translocations would help the species recover and might also provide animals for a second commercial hunt. Accurate estimates of the current number of animals in each of the translocated populations are not available, but the Southeast Alaska population, founded with an estimated 150 animals in 1969, could exceed 20,000 animals in the year 2000.

The Oregon and Pribilof translocations failed; the Washington and British Columbia efforts succeeded, with current populations numbering in the thousands. Each of the translocated populations experienced high losses initially, either through mortality or emigration. During the mid-1980s, 142 sea otters were translocated from central California to San Nicolas Island off southern California. In 1999, a count at the island revealed 23 animals, the highest count in more than 10 years. The ultimate fate of this colony remains uncertain, but the lack of population growth demonstrates the high initial rate of loss of translocated otters. Despite more than 50 pups being born since the translocation, there has been no increase in population on San Nicolas, which confirms the existence of decline and a delayed growth phase after initial release.

The sea otter translocations gave biologists an opportunity to study another aspect of population dynamics, the effects of population reductions (or bottlenecks) on genetic diversity. Reduced genetic diversity can impair the ability of a population to recover by limiting reproductive rates or increasing mortality. Sea otters provide a good case study of the effects of population reductions on genetic diversity and population recovery rates because of the number of isolated remnant colonies and the number of translocations to isolated areas.

We recently used population and genetic data from four remnant and three translocated populations to test for relations between magnitude and duration of population declines and genetic diversity and population growth rates. We found that both the duration and magnitude of the decline correlated positively with genetic diversity, but did not find the expected relation between decreasing genetic diversity and reduced population growth rates. We also found that translocated populations experienced higher population growth rates than did remnant populations, and translocations using two different sources displayed increased genetic diversity. The reasons for differences in growth rates are unclear, but likely are

Caring for "Eyak"

By Pam Tuomi, D.V.M.

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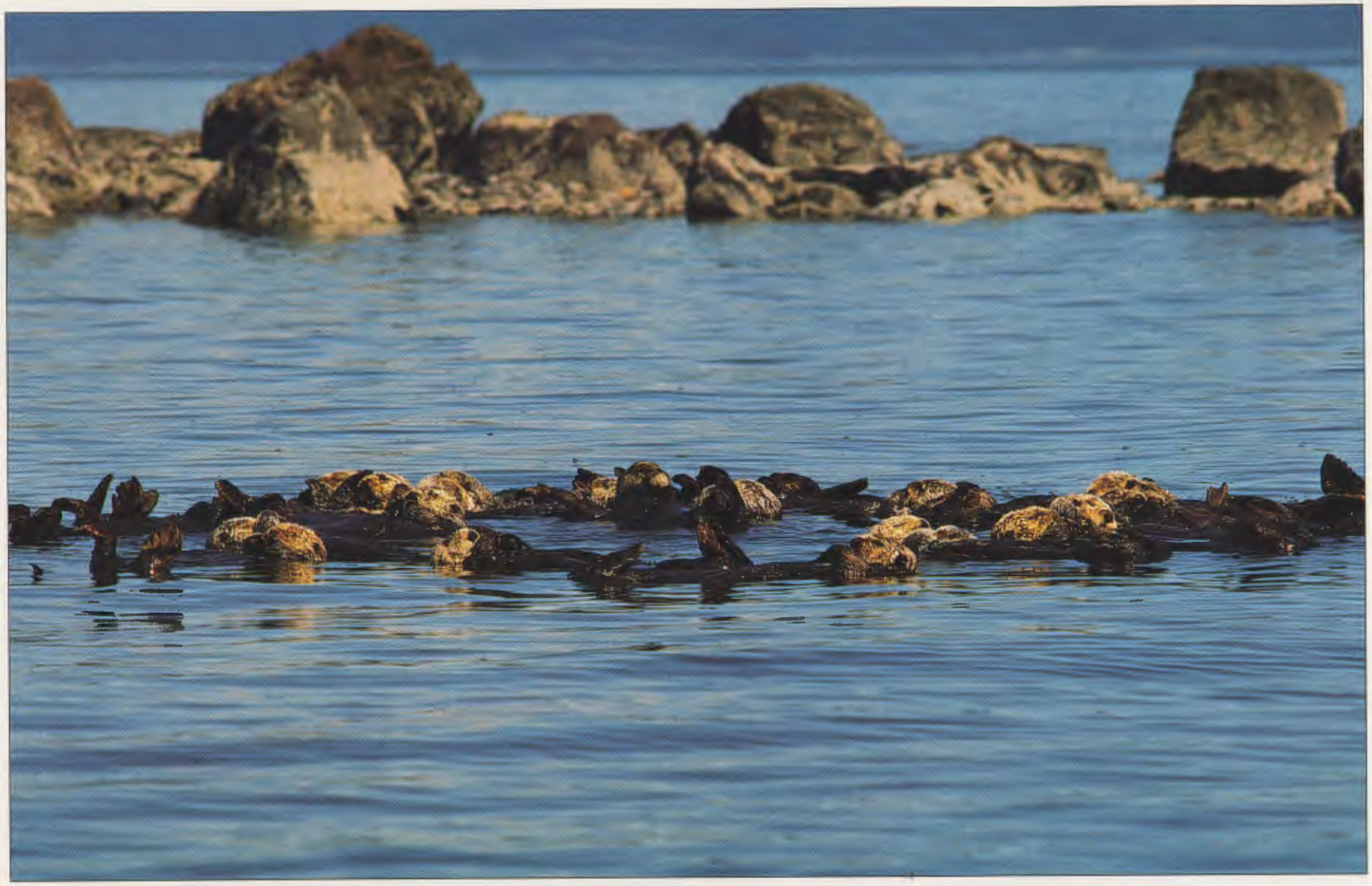
This sea otter pup weighed 5 1/2 pounds and was 3 to 4 weeks old when found July 8, 1996, drifting alone in northern Prince William Sound. A severe storm the preceding night had apparently separated the pup from its mother. The U.S. Fish and Wildlife Service, with management responsibility for sea otters in the United States, investigated. Unable to locate any other otters in the area, they brought the pup to the Alaska Wildlife Response Center in Anchorage, where a temporary nursery was set up. In August, the nursery moved to an outdoor site donated by the Alaska Zoo, and the orphan "Eyak" helped visitors learn about his species.

A sea otter pup is totally dependent on maternal care for five to six months. The mother must constantly groom her single pup to keep it meticulously clean and waterproofed. Properly aligned, the dense fur holds an insulating air layer next to the skin. The mother otter floats on her back and holds her pup on her stomach where it sleeps, nurses and stays warm and dry. While she dives for food, she releases the pup to float on the surface. Pups may appear "abandoned" during these dives but should always be observed from a distance. Usually, the mother surfaces to retrieve her pup and start the grooming process over again.

At a nursery, trained volunteers stay with an orphan 24 hours a day to provide a continuous cycle of feeding, swimming practice, grooming and sleeping. Formula is made from pureed clams, squid, half-and-half, electrolyte solutions, vitamins and cod liver oil. The pups are taught to nurse from a baby bottle and require 20 to 25 percent of their body weight each day in food. At 6 weeks, they start to eat small bits of shellfish meat and play with shells. They love to hold and manipulate rattles, balls, teething rings and other baby toys and to sleep on a cool waterbed mattress or in a hammock just above their swimming pool. Young pups must learn to roll over, swim and dive in a shallow saltwater pool and must be thoroughly combed and dried after each swim until old enough to groom themselves. Temperature control is critical, as sea otters can easily become hypothermic when wet or overheat when dry.

Captive-raised sea otter pups become dependent on humans and usually cannot be released into the wild. Lifelong homes must be found for them in one of a handful of zoos and aquariums with adequate facilities. In 1995, the Blijdorp Zoo in Rotterdam, The Netherlands, offered a permanent home to another Alaska orphan, "Chuluugi," the first sea otter to live in Europe. The U.S. Fish and Wildlife Service agreed to send "Eyak" to Blijdorp as a companion for "Chuluugi." On September 10, 1996, "Eyak," his veterinarian and a U.S. Fish and Wildlife Service representative made the long trip on a cargo jet by way of Frankfurt, Germany. Both otters have thrived in Rotterdam ("Eyak" now weighs 68 pounds) and are moving into a spacious new exhibit pool designed to educate visitors about life in polar regions. ■

Dean Rickerson, a volunteer at Anchorage's Bird Treatment and Learning Center, bathes and dries "Eyak," an orphan sea otter pup picked up by USFWS. Volunteers had to teach the pup how to dive by dropping baby toys to the bottom of his pool. (Harry M. Walker)



related to site specific differences in survival.

From most perspectives, the overharvest and near-extinction of sea otters should be considered a tragedy. However, from at least one perspective, this situation provided unprecedented opportunity in the study of large mammals. When biologists study captive populations of invertebrates, a larval beetle for example, it is relatively straightforward to manipulate population size and provide controls for those manipulations, allowing scientists to rigorously assign cause and effect (or

not) to the experimental manipulation they impose. For both practical and ethical considerations, large carnivores are difficult to experimentally manipulate. In the case of the sea otter, by selecting study areas with and without sea otters, or by selecting areas for study over time as recolonization occurs, biologists have been able to evaluate many aspects of the otter's ecology and natural history. Good examples of the results of this approach are demonstrated in the descriptions of the role of sea otters as keystone predators in coastal marine communities and the effects of sea otter reductions on population genetics and recovery rates.

The Future

Our view of coastal marine communities and the role of sea otters in those communities has been shaped to a large degree by what we observed during the 20th century, when sea otter numbers increased from a few hundred animals distributed over thousands of miles of shoreline to many tens of thousands of sea otters currently occupying more than half of their historic range. Suitable, unoccupied habitat remains, and it appears likely that sea otter populations will continue to recover. However, as local population densities reach equilibrium with food and space resources, we might expect rather large declines in local populations. Such a phenomenon was recently observed at Bering Island in Russia where the population experienced a large-scale die-off that led to a population decline from about 5,000 animals to 3,000 in a single year. Nearly 80 percent of the recovered carcasses were male, resulting in a surviving population with an increased proportion of females. Similar phenomena might be expected as recovery continues, particularly at islands where emigration might be limited or in mainland populations where the distance to unoccupied habitat exceeds the dispersal distance

FACING PAGE: *A raft of sea otters floats near Augustine Island, an active volcano in lower Cook Inlet. (Don Cornelius)*

RIGHT: *Sea otters are strong swimmers, and alternately roll onto their stomach and float on their back. (James L. Davis)*

of sea otters. As unoccupied habitat shrinks, it seems unlikely that we will continue to see the high growth rates in populations that we observed in the 20th century.

Future decisions regarding management and conservation of sea otter populations at or near equilibrium with their food and space resources may require a perspective quite different from that developed during the past century. Sea otters will likely remain important to humans. As they continue to recover previous habitat, conflicts can be expected where humans and otters compete for valuable invertebrate resources, particularly in Japan, Southeast Alaska, British Columbia, Pacific states of the United States and Mexico. Although we probably have adequate information on the life history of sea otters to conduct a sustainable harvest, social and ethical considerations from a geographical scale that extends well beyond the people and shores of the North Pacific must now be considered. ■

Sea otter fur spurred Russian hunters to cross the Bering Sea to the Aleutians. A thriving fur trade with the Chinese lasted more than a century. (Roy Corral)