Restoration notebook

November 1997 *Exxon Valdez* Oil Spill Trustee Council

Photo courtesy Alaska Department of Natural Resources

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The sea otter, *Enhydra lutris,* is the largest member of the Mustelidae family and is the only one which lives entirely in marine waters. Sea otters are unique among marine mammals because, unlike whales, dolphins and seals, they do not have a layer of fat or blubber to keep them warm in the cool oceans of the North Pacific. Instead, sea otters depend on dense fur that traps tiny air bubbles to insulate them from the cold water. To stay warm, they also must maintain a very high metabolic rate, requiring the sea otter to eat about 25% of its body weight per day. Sea otters eat mostly invertebrates — clams, crabs, urchins, and mussels — found in shallow coastal waters.

Geographic Range and Species History

The historical range of the sea otter includes the shallow coastal waters of the northern Pacific rim, from central Baja California to the islands of northern Japan. About 250 years ago, Russian and European fur traders began hunting sea otters and trading with local Natives for sea otter pelts. Prior to the fur harvest, it's estimated that sea otters numbered 150,000 animals throughout their range.[1] Hunting brought the species close to extinction, but in 1911, sea otters came under protection with the passage of the International Fur Seal Treaty. At that time, remnant sea otter populations persisted in small isolated pockets in Alaska, California and Russia.[2] Although accurate population estimates are not available for that time period, anecdotal information and surveys suggest fewer than 100 sea otters remained in each population.[1,3]

During the 20th century, sea otter populations made a remarkable recovery, largely as a result of protection from harvest and successful translocations to Southeast Alaska, British Columbia and Washington. Today, nearly 75% of their historical range has been recolonized by more than 100,000 sea otters.[4] Annual growth rates among recovering remnant sea otter populations range from just over 5% along the California coastline to about 15% at Amchitka Island; translocated populations average nearly 20%.

Vital Statistics

Population
Approximately 100,000; 13,000 in PWS

Population Trend
Increasing or stable; recent declines observed in central Aleutians

Weight
males to 45 kg (ave. 30 kg); females to 35 kg (ave. 20 kg)

Length
to 140 cm (ave. 130 cm/males; 120 cm/females; measured from nose to tip of tail)

Lifespan
to 25 years (ave. 10-12 years)

Gestation
6 months

Number of offspring
one pup per year; pups remain dependent for about 6 months

Size at birth
about 70 cm and 2 kg.

Maturity
early as age 2 (ave. age 3-4)

Diet
clams, mussels, crabs, sea urchins, other benthic invertebrates, some fish

Predators
humans, sharks, bears, eagles (on pups), killer whales

Gulf of Alaska Populations

One of the remnant sea otter populations survived in the bays and coves of southwestern Prince William Sound (PWS). At least 150 otters were present at Montague Island in 1951.[3] Surveys in 1959 and 1973 provided counts of 545[3] and 2,015,[5] respectively. By 1985, when 4,747 were counted, sea otters were distributed throughout the sound.[6] These survey results are actual counts of animals observed, with an unknown proportion of otters present but undetected. An estimated 13,000 sea otters were present in the sound in 1995. Sea otters from PWS likely have been the source of animals now colonizing the Kenai Peninsula and the outer coast of the Gulf of Alaska, southeast of Cordova. An estimated 2300 sea otters resided along the Kenai Peninsula in 1989 and in 1995-96, nearly 300 were counted south of Cordova along the outer coast.

A remnant sea otter population apparently also persisted at Kodiak Island. A survey in 1951 located 82 sea otters in the northern portion of the Kodiak archipelago, and counts of 515 and 667 were obtained in 1957 and 1959, respectively.[3] By 1985, 2,811 otters were found at Kodiak[7] and in 1994, the population was estimated at over 6,000.[8] Much unoccupied habitat remains in the Kodiak region.

Habitat

Sea otters are gregarious and are most commonly found in nearshore waters, both along the outer coasts and within protected waters such as southeast Alaska and PWS. Sea otter habitat can be defined by two primary components: the sea floor, where prey are captured, and the sea surface, where prey consumption, grooming, resting and social interactions occur. Groups of resting otters, termed "rafts," often can be found associated with canopy forming kelp beds, such as *Macrocystis*, *Nereocystis* and *Alaria* . In the absence of kelp beds, groups of otters will frequently form rafts in the open water of protected bays or inlets.

Because sea otters feed exclusively on benthic prey, their distribution is limited by their ability to dive to the sea floor. Among marine mammals, sea otters are relatively shallow divers, and so their distribution is generally limited to a narrow zone extending out from the shoreline. Observations in Bristol Bay, Alaska, indicated that over 90% of the sea otters were found between the shoreline and the 40-m depth contour.[9] In PWS, about 85% of otters were observed between the shore and the 40-m depth contour.

Food Habits and Foraging Ecology

Sea otters forage in sedimentary and rocky habitats during daylight and at night. Maximum diving depth is believed to be about 100 m, based on one dead otter found in a king crab trap recovered from that depth in the Aleutian Islands. Until recently, it was generally accepted that most sea otter foraging occurs in waters less than 40-m depth. In 1996, use of pressure modulated sonic trans-

Photo by Roy Corral

Jennifer DeGroot, of the U.S. Geological Survey, holds a young sea otter captured near Ingot Island in Prince William Sound.

mitters showed that in Southeast Alaska, sea otters commonly dove to depths of 40-80 m. Swimming speeds while diving were about 1 m/second, and dive times averaged about 1-2 minutes.

More than 150 species of invertebrates, fish and seabirds have been identified as sea otter prey,[10] the most frequent being crabs, snails, clams, mussels, sea urchins, and sea stars.

Diets differ depending on the habitat. For example, in the primarily soft-sediment habitat of PWS it was found that clams and mussels comprised 60-70% and 10-20%, respectively, of the items identified. At Bering Island, Russia, a primarily rocky habitat, otters eat mainly urchins, snails, and crabs, with fish contributing to the diet as well. Consumption of seabirds has been observed, but rarely.

The use of tools by sea otters is unusual since tool use among mammals has been reported only in humans, chimpanzees, dolphins and occasionally, polar bears.[11] The tool most commonly employed by sea otters is the rock, which is used both for removing prey from the bottom and to open hard-shelled prey, such as large clams or sea urchins.

Sea otters have a large caloric requirement, consuming 10-25 pounds of prey per day.[10] Because of conflicts between otters and humans over prey resources, a lot is known about the impact of sea otters on populations of some shellfish, including mussels, abalones, and urchin. The near extinction of sea otters and their continuing comeback provide opportunities to study marine communities in the presence and absence of sea otters.

Reproduction and Behavior (Social Structure)

Female sea otters can become reproductively mature as early as age two, but the majority mature by age three.[12] While female sea otters can give birth at any time of year, they usually do so in the late spring and early summer. Pups are dependent on their mothers' care for about six months. The female lactates throughout the dependency period, although by the age of four months the pup is nourished primarily on solid food provided by the mother. Shortly after weaning her pup, the female will enter estrus and breed again, and thus is either pregnant or lactating for most of her adult life. Gestation lasts about six months, including a period of delayed implantation, leading to a reproductive cycle of one year. Like all marine mammals, sea otters give birth to a single pup.

Sea otters are polygamous and a single male breeds as many females as he can. Dominant adult males hold and defend territories where females are present, patrolling the boundaries on a regular basis. Territories range in size from a few to hundreds of acres, but average about 75 acres.[10] Individual males have been known to occupy the same territory for as many as nine years. While females are free to move among male territories, males will try to sequester adult females within their territories. Male sea otters become sexually mature at two or three years, but do not have the social maturity to hold a territory until age six to eight.

Photo by Roy Corral

One method of capturing sea otters is to catch them from underneath while they float on their backs. Divers, using rebreathers to prevent the release of air bubbles, swim under the sea otters and quickly capture them in a ring net.

Movements

Although sea otters have been observed traveling distances of more than 100 km, they tend to stay close to home. Typically, otters will travel several kilometers to forage, but otherwise remain in their resting area. Feeding activity peaks in the morning and afternoon.

Seasonal home ranges of females range from 10-25 km of shoreline, which may be the extent of their lifetime movements. Adult males, on the other hand, may occupy two distinct annual home ranges: one is their breeding territory, and the other is an aggregation of all-male otters. Distances between a territory and the all-male area may be 100 km or more. Not all males can defend territories and those that cannot, often the younger ones, may reside for long periods in male aggregations.

Non-territorial males can occur in large aggregations and are recognized as the initial colonizers in recovering populations. Range expansion, or population recovery, is usually the result of these male groups moving further into unoccupied habitat. Reproductive females establish themselves in what were formerly areas of male groups and dominant males establish territories within those female areas.[10]

Effects of the oil spill

Oil from the *Exxon Valdez* moved through prime sea otter habitat, with thousands of sea otters in PWS and the Gulf of Alaska in its path. Sea otters were particularly vulnerable to the oil because it destroyed the insulating qualities of the fur. In addition, the peak of pupping for sea otters in PWS occurs in late spring, so many animals were pregnant or were nursing pups when exposed to oil.

Those animals that found refuge from the oil in the backs of bays or inlets still may have been exposed to volatile components evaporating from the oil on the water. The risk of oiling of the fur would have continued over a longer period, as oil which had washed up on beaches was rewashed into nearshore areas.

Researcher Dan Monson takes measurements and samples from an anaesthetized sea otter. After processing the sea otter is awakened and released to the same waters where it was captured.

Photo by Roy Corral

Photo by Roy Corral

A sea otter's tooth reveals secrets about the animal's age and its health.

Immediate effects

Within days of the spill, sea otters in the path of the oil were being captured and brought in for treatment. Rehabilitation centers were established in Valdez and Seward, and during the spring and summer, more than 300 sea otters were caught in PWS, along the Kenai Peninsula, and at Kodiak.[13] Many animals were heavily oiled and did not survive. However, about 200 otters did survive the ordeals of oiling, capture, cleaning and captivity, and were released back to the wild in eastern PWS in late summer 1989.

A subset of the released otters was monitored for movements, reproduction and survival.[14,15] Researchers discovered that many of the otters (none of which was released back to the area where they had been caught) moved large distances, which has typically been observed in other translocations of sea otters.[16] Furthermore, survival and reproduction rates following release were relatively poor. This, combined with the high cost of operating the treatment centers, and recognition that the stress of capture and holding was in itself harmful to the otters, made the value of the rehabilitation process somewhat controversial.[17,18]

Estimated Mortality

Nearly 1,000 sea otter carcasses were recovered in oiled areas after the spill, creating a stark picture of the injury to sea otters.[19] About 500 carcasses were recovered from PWS; and from the Kenai Peninsula, Kodiak Island & Alaska Peninsula areas, about 400 carcasses were recovered. Another 123 died at the rehabilitation centers. An additional but unknown number of sea otters died from oil exposure, but their carcasses were never recovered. A small monitoring study, conducted during the cleanup activities at Kodiak, suggested that as few as 20% of the total number

of carcasses were recovered.[20] For a variety of reasons, however, it is difficult to apply this recovery rate to the larger spill area.

In some cases, carcasses were necropsied shortly after death, but many were frozen without further examination. In the summer of 1990, these carcasses were examined to provide insights into the mechanisms of oil injury to sea otters and to obtain teeth, reproductive tracts and tissue samples for further study. A high proportion of the carcasses were found to have pathologies (adverse changes in the tissue) of the lung, liver and kidney associated with oiling.[21]

Boat surveys were conducted after the spill to estimate numbers of sea otters in PWS. In 1984-85, boat surveys of sea otters counted nearly 5,000 sea otters in PWS,[6] and it was believed that otters had fully reoccupied all available habitat. Using similar methods, surveys were conducted in the summer of 1989[22] and repeated in the springs and summers of 1990, 1991 and 1993. Researchers found 14% more otters in unoiled areas of PWS (counting otters seen in the nearshore), and 35% fewer otters in oiled areas, compared to counts obtained prespill. Based on these survey data, an estimated 2800 (range of 500-5000) sea otters died acutely from the spill in PWS.[23] A different model resulted in an estimate of 750 otters lost due to the spill.[24]

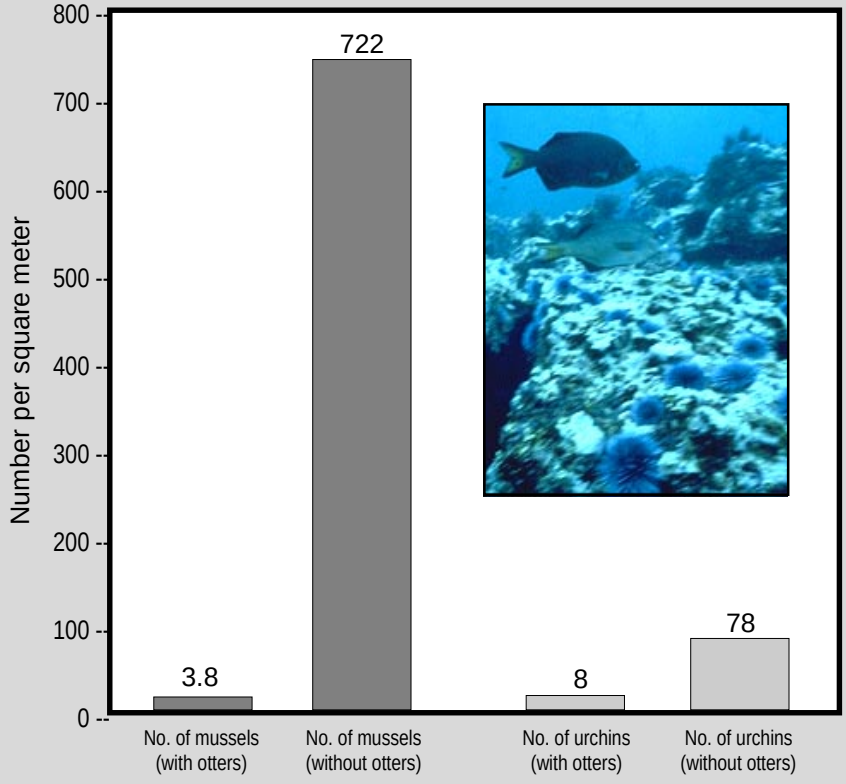
Although considerable effort was put into determining the total loss of sea otters in the months following the spill, baseline data are insufficient, thus limiting the ability to draw conclusions about total losses. It was not possible to arrive at a reliable, precise estimate of the total number of acute deaths, but a reasonable estimate is that the actual loss was in the range of several thousand sea otters.

Photo courtesy Department of Natural Resources

Longer-term effects

The immediate effects of the spill on sea otters were obvious and drastic. The extent of chronic damages has been more difficult to ascertain. Because of liver and kidney damage observed in otters that were exposed to oil and subse-

Densities of mussels and urchins in the presence *(Amchitka)* and absence *(Shemya)* of sea otters[25]



A large and expanding sea otter population often results in reductions of many invertebrate populations. Although predation of sea otters can conflict with human uses of clams, mussels, crab and other invertebrates, they also serve as a necessary control over some populations. In the absence of sea otter predation, sea urchins can proliferate and overgraze algal populations in kelp forests, resulting in what are now recognized as "urchin barrens." The consequence is an ecosystem of low species diversity, low algal biomass, and high densities and biomass of sea urchins. But in the presence of sea otters, large sea urchins are rare and small urchins are forced to seek refuge. When the pressures of overgrazing by large urchins are removed, kelp and associated algae proliferate, supporting increased abundance and diversity of a variety of species, including many marine invertebrates, kelp forest fishes and possibly other marine vertebrates such as some seabirds and seals.[26-30]

Estes, J.A., J.F. Palmisano, 1974, *Sea Otters: Their Role In Structuring Nearshore Communities.* Science 185:1059-1060.

quently died,[21] it seems likely that some otters which survived the spill would have been in poor health going into the next winter. There were also concerns about possible effects on the otters of continuing exposure to residual oil.

Studies conducted from 1990-93 suggested that oil-related injury to sea otters persisted, but the picture was far from clear.[19] Based on carcasses recovered in oiled areas of PWS in 1990 and 1991, mortality of prime-age sea otters (2-8 years of age) was abnormally high.[31] However, radiotelemetry studies of live otters suggested that reproduction and survival of adult female sea otters in western PWS was normal. Survival of sea otter pups in western PWS in the winters of 1990-91 and 1992-93 was poor and lower than that of their counterparts in eastern PWS.[32,33] Finally, data from the boat surveys which were initiated in the summer of 1989 and continued in subsequent years (1990, 1991, 1993, 1996) indicate that the sea otter population in oiled areas of PWS has not increased since the spill year.[22,34,35]

A sea otter is tentative about regaining its freedom after capture by Jim Bodkin and Brenda Ballachey of the USGS. While it checks out its options from the deck of the research vessel, Paul Snyder, Dan Monson, Jennifer DeGroot, and Ballachey encourage the sea otter to take the plunge.

Photo by Roy Corral

The general design of post-spill sea otter studies compared animals in unoiled areas of eastern PWS to those in oiled areas of the west. However, since the spill, the number of sea otters that could be found in the areas that were most heavily oiled has been low, and finding animals for the studies has been difficult. Thus, many of the sea otters caught in western PWS for post-spill studies were not from the locations hardest hit by the oil. This, combined with the likelihood that longer-term effects on the population likely were subtle and difficult to detect, may have compromised detection of chronic injury to the sea otter population. Nevertheless, the results cited above suggest that sea otters suffered from spill-related effects beyond the initial year of exposure.

In 1993-94, aerial surveys of western PWS confirmed that in areas which had received extensive oiling on much of the shoreline, sea otters were present at very low densities. For example, during the spill, 33 sea otters (22 dead and 11 alive) were removed from Herring Bay in northern Knight Island, but aerial surveys from 1992-1994 indicated otter numbers in that area remained low, with no more than six otters at a time observed in Herring Bay. These data led researchers to the conclusion in 1994 that sea otters had not yet recovered fully from the spill. Consequently, in 1995, the Nearshore Vertebrate Predator Project was implemented to investigate the recovery of four species of vertebrates, including the sea otter.

Restoration activities

Population survey methodology

As with other wildlife populations, accurately estimating sea otter populations in Prince William Sound and the Gulf of Alaska has long been a problem. In 1992, the Trustee Council and the Alaska Science Center cooperatively funded a three-year effort to design, test and implement an aerial survey method that could dependably provide a population estimate. An aerial survey method was implemented in PWS in 1993, and these surveys remain a part of the sea otter restoration program.

Photo courtesy Alaska Department of Natural Resources

Reproductive Biology and Population Modeling

The large number of sea otter carcasses recovered after the spill provided a unique opportunity for studies of otter biology. Teeth provided information about the age structure of the PWS sea otter population and that age distribution was use to to estimate survival rates of adult otters at the time of the spill.[36] Reproductive tracts (uterus and ovaries) provided information on the status of a female at the time of her death (e.g., pregnant vs. recently pupped) and the number of times she previously had been pregnant, and allowed estimation of the proportion of females of each age that reproduce annually.[12] Survival and reproduction rates are essential for understanding population dynamics, including growth and recovery subsequent to the spill. In combination with other available information on the western PWS sea otter population, they were used to develop a model of the sea otter population in the area of the spill.[36] This model has been used to predict potential recovery of the sea otter population in western PWS. Depending on assumptions made, the model predicts a range of 10-23 years before the sea otter population in oiled areas recovers to its prespill abundance. This result should be considered with caution as the amount of uncertainty associated with some of the information required for the model (e.g., pre- and post-weaning survival rates of sea otter pups) is large.

The Nearshore Vertebrate Predator Study

In 1995, a restoration project entitled "Mechanisms of Impact and Recovery of Nearshore Vertebrate Predators" (NVP) was initiated. The project addresses the question of ecosystem recovery by examining four top-level predators: sea otters, river otters, harlequin ducks and pigeon guillemots. The approach is to compare demographic, physiological and trophic measures for each species in oiled and unoiled areas of western PWS as indicators of the ecosystem's status.

For the sea otter component of the NVP project, abundance, reproduction, body condition, blood parameters, immune response, foraging success and prey selection are being compared between oiled and unoiled areas. If populations are similar between oiled and unoiled areas of PWS, this will suggest recovery of sea otters has occurred. Additionally, the size of sea otter prey are being compared between oiled and unoiled areas. Similar size distribution of prey items in oiled and unoiled areas will be another indicator that sea otter populations have recovered.

Conclusion

A significant proportion of the sea otters exposed to oil from the T/V *Exxon Valdez* died within several months of the spill. The number of deaths has been estimated at several thousand. However, because baseline data were minimal and appropriate studies were not implemented immediately following the spill, an accurate estimate cannot be made. Although many sea otters in the path of the spill died, the number of deaths was small relative to the size of the overall Alaska sea otter population. In the most heavily oiled areas of PWS, however, the sea otter population apparently has not returned to its prespill abundance. Through the NVP project, continued monitoring of sea otters in oiled areas will provide additional insight into possible long-term effects of oil exposure on sea otters as well as the process of recovery.

The Restoration Notebook series is published for educational purposes. Persons wishing to cite this material in scientific publications should refer to the technical reports and literature listed at the end of each account.

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