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School of Natural Resources and Environment
THE UNIVERSITY OF MICHIGAN

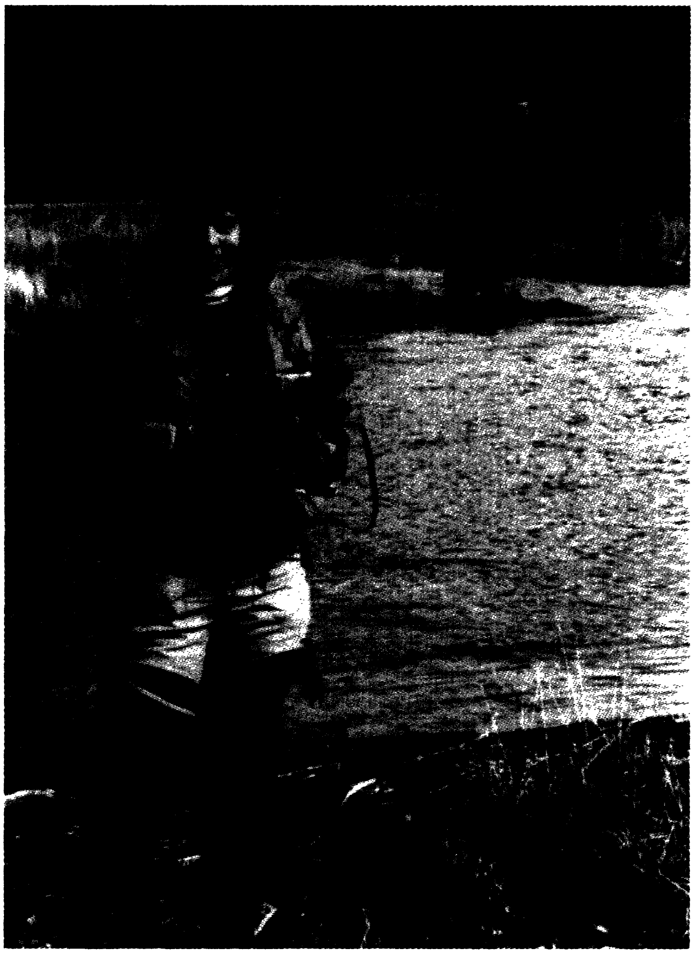
Special Issue:
Conservation and Management of the Southern Sea Otter

This Special Issue is Dedicated to:

Mollie H. Beattie

U.S. Fish and Wildlife Service Director, 1993-1996.

"She combined her role as the chief steward of America's fish and wildlife programs with her compassionate belief that people were an inseparable part of the natural environment" (Rep. Don Young, R-Alaska).



Photograph by Walter O. Stieglitz, U.S. FWS

Mollie H. Beattie had a vision of how to forge a stronger conservation plan for our Nation: seek first to identify the common ground and then to build a partnership between the government and the American people. When she became Director of the U.S. Fish and Wildlife Service she turned her vision into a reality, and became one of the Service's most effective leaders. During her brief tenure, 15 wildlife refuges were added to the Nation's list of protected areas, over 100 conservation habitat plans between landowners and the government were developed, and the gray wolf was reintroduced into Yellowstone National Park. She courageously defended the reauthorization of the Endangered Species Act, blocked efforts to open the Arctic National Wildlife Refuge to oil exploration, and battled Congress over funding cutbacks aimed at crippling environmental programs. And, most notably, she guided the Service in adopting an ecosystem approach to conservation.

It was Mollie Beattie's vision that inspired the design of this Special Issue of the *Endangered Species UPDATE.* We began with the premise that the conservation of the threatened sea otter population off the California coast will rely on the ability to establish effective partnerships, to manage the threats to this population, and to resolve the conflicts over the uses of marine resources. In partnership with the Monterey Bay Aquarium, we then assembled a list of authors, experts in their field of sea otter biology or on the issues surrounding the species' conservation, and invited them to contribute to the publication. Each author was encouraged to identify key issues surrounding the conservation of the sea otter and to present a list of research and management recommendations within their area of expertise. We hope that the resulting publication will serve as the first step in developing strong conservation-oriented partnerships, and we dedicate it to the memory of Mollie Beattie.

Mollie H. Beattie served as Director of the U.S. Fish and Wildlife Service from September 10, 1993, until she was forced to resign due to ill health on June 5, 1996. A few weeks later she died after a year-long battle with cancer. In recognition of her accomplishments, President Clinton signed an act designating eight million acres of the Alaska Arctic National Wildlife Refuge as the Mollie Beattie Wilderness Area. "It ensures that future generations will recall the lasting contributions Mollie made to conserving our Nation's priceless natural heritage," said President Clinton.

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MONTEREY BAY
AQUARIUM

This Special Issue of the Endangered Species UPDATE has been developed in a partnership with the Monterey Bay Aquarium. The purpose of the non-profit Monterey Bay Aquarium is to stimulate interest, increase knowledge and promote stewardship of Monterey Bay and the world's ocean environment through exhibit, education, and research programs.

Production of this issue was made possible in part by support from the Monterey Bay Aquarium.

Introduction to the Special Issue: Why Southern Sea Otters?

John F. Watson and
Terry L. Root

Many casual environmentalists, wildlife enthusiasts, and animal lovers view the sea otter (*Enhydra lutris*) as the precise type of animal that the Endangered Species Act (ESA) was designed to protect: a highly charismatic, cute mammal that is easy to observe. Additionally, many conservation advocates view the sea otter as a flagship species around which to rally support for protection of the marine environment, for the ESA, and for other regulations that limit environmentally harmful or risky practices. Those designing and implementing sea otter conservation management plans must address the complex biological needs of a species, while planning and implementing complex regulations that seek to balance the interests of the otter, of people advocating different levels of preservation, and of people who see their jobs and industries threatened.

We chose to focus this Special Issue of the Endangered Species UPDATE on the southern sea otter for a number of reasons. A large amount of information exists on southern sea otters, especially compared to other marine organisms, making the sea otter a good species for which to examine management concerns. The southern sea otter population, while currently listed under the ESA, is growing. Therefore, we can expect that the population will be delisted under the ESA, making other laws such as the Marine Mammal Protection Act (MMPA) and state laws applicable to future sea otter management. Finally, as with many other species, conservation of sea otter populations necessitates managing conflicts between species protection and industry. Our hope in putting together this issue is to provide a broad base of the best knowledge we have on southern sea otters to help facilitate future conservation management.

The southern sea otter

Sea otters are one of twelve species of otters worldwide and belong to one of four groups of marine mammals. They are members of the mustelid family, which includes other species such as weasels, minks, and skunks. Two subspecies of sea otters have been commonly recognized, the Asian (*Enhydra lutris gracilis*) and Alaskan (*Enhydra lutris lutris*) sea otters, and some biologists consider the southern sea otter (*Enhydra lutris nereis*) to be a third subspecies (see Anderson et al., this issue).

Alaskan and Asian sea otters are widely distributed across the North Pacific from Washington State to the Kuril Islands and Kamchatka Peninsula in Russia, with a total population estimated at over 100,000 (U. S. Fish and Wildlife Service 1996). Southern sea otters live along a stretch of less than 400 kilometers (250 miles) of the California coast around Monterey Bay. This population, of roughly 2,400 individuals, is believed to be increasing at approximately 5 to 7 percent per year (U. S. Fish and Wildlife Service 1996). A translocated population of roughly 20 individuals is located at San Nicolas Island, which is located about 110 kilometers (70 miles) west of Los Angeles (see Benz, Attempts to Reintroduce, this issue).

Sea otters are found along rocky, sandy, and mixed shores, but are most common along rocky shores and prefer habitat with kelp (see DeMaster et al., this issue). They generally remain close to shore in areas where the water depth is 20 meters (65 feet) or less, which facilitates their foraging along the ocean floor. Sea otters eat a variety of marine invertebrates, including such items as crabs, mussels, clams, abalones, and sea stars. They also will catch and eat fish and marine birds on occasion (Riedman and Estes 1990). Otters are believed to have a significant effect on their marine environment by reducing prey populations that feed on kelp (U.S. Fish and Wildlife Service 1996). Their effect on local fisheries has been a contentious issue in California (see Wendell, this issue).

Female sea otters typically give birth to a single pup each year. Females are believed to reach sexual maturity after three years, and males after five years. In California most births occur between late February and April, although births do occur throughout the year. Otters live between 12-20 years, and chief causes of mortality have not been determined (see Thomas and Cole, this issue).

Sea otter protection

Sea otters have been classified as threatened under the ESA, depleted under the MMPA, and as a "fully protected mammal" under California state law. Each of these levels of protection is significant for different reasons. Protection under California state law, which preceded federal protection under the MMPA or ESA, involves balancing the needs of otter conservation with economic interests, especially fisheries along the California coast. Protection under the ESA is of special interest at this time because the ESA is up for reauthorization in Congress and has been the subject of contentious debate. Protection under the MMPA is currently superseded by the listing under the ESA. The MMPA listing will become relevant only after the southern sea otters' population and range expands to the point that it is delisted under ESA (see Baur; VanBlaricom, this issue).

For a number of reasons the southern sea otter is an excellent species for exploring policy issues under each of these laws and jurisdictions. The sea otter is well studied and relatively well understood, especially compared to other marine species. Its population history, of being hunted to near extinction for its fur and then rediscovered in California, is well known and documented. Consequently, we have a lot of information necessary to help determine whether the southern sea otter is a separate subspecies (see Anderson et al., this issue). This question of subspecies is representative of similar debates under the ESA, which currently protects threatened subspecies of animals that have unthreatened populations elsewhere (for example, the bald eagle, rare and protected in much of the contiguous United States but common in parts of Alaska). Additionally, issues of habitat protection have been especially troublesome in the ESA debate, and our knowledge of southern sea otters provides valuable insights into protecting marine habitats.

Sea otters are charismatic and a favored target for protection, yet their protection has created large conflicts with two major industries, oil transportation and fishing. How we deal with conflicts between conservation and industry is, of course, an ongoing debate, and is the subject of several papers in this issue (e.g., Bonnell; Saunders; Wendell).

Finally, the otter is a good subject for study because its population is recovering and we can expect it to be delisted under ESA in the forseeable future. The need for management of the population will not end, however, with the delisting under ESA. Issues of conflict will remain in managing the population as it grows and protection shifts to MMPA and then possibly to California state law. Indeed, preparing for the future management of the otter as an unlisted species is critical in order to be able to successfully manage the population throughout the future.

Special Issue format

The Sea Otter Special Issue is divided into four sections. The first focuses on the biology and status of the otter. Articles in this section look at the distribution of the otter through its entire range; how the California population relates to other populations; methods for monitoring these populations; the otter as an indicator of pollutants in the marine community; and risks of disease that wild populations face.

The second section focuses on the recovery of the sea otter under the ESA. The first article in this section provides background on the ESA, with subsequent articles examining Recovery Plans and attempts to implement a translocation as recommended by the first Recovery Plan; the threat of oil spills to the otter's recovery; the history of the National Marine Sanctuary that encompasses much of the otter's habitat; and the role of non-governmental organizations in the listing and protection of the otter.

Treatment and rehabilitation of sea otters have played a prominent role in conservation, and the third section looks at these efforts. Questions addressed include the efficacy of rehabilitation efforts, and the role of captive otters in the larger sea otter conservation plans.

The final section is based on an assumption that the otter will continue its recovery and eventually be delisted under the ESA, making the MMPA the relevant statute for future otter conservation plans. This section provides background on the MMPA, examines the critical issue under MMPA of estimating the carrying capacity of the habitat off the California coast, and looks at the concept of zonal management as a possible basis for management in the future. The concluding article looks to the future of otter conservation efforts.

Conclusion

Conservation planning must be based on the best science available, and our goal in putting together this issue is to compile a broad base of the best knowledge we have on sea otters today. Undoubtedly there are readers who will disagree with some of the points made, who would have preferred to see some issues left out or others highlighted. These questions and possible disagreements reflect the reality of managing for the conservation of a complex species: there are no easy answers, and the problems will remain contentious even as conservation planning and implementation moves forward. We hope, however, that in publishing this issue we provide a strong basis for future thought on sea otter conservation, and also that we provide a model for looking at other species that must be managed for conservation.

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Front and back cover: Sea otters (*Enhydra lutris*). Photographs by Jeff Foott. For information on ordering prints see the advertisement on page 27.

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Sea Otter Systematics and Conservation: Which are Critical Subspecies?

C. Gregory Anderson, John L. Gittleman,
Klaus-Peter Koepfli, and Robert K. Wayne

The sea otter (*Enhydra* sp.) is a charismatic carnivore. As an aquatic, crustacean feeder possessing four incisors in the lower jaw, having webbed feet, and spending most of its life on its back, this is not your typical carnivore! Although all otters have adaptations for living in an aquatic environment, sea otters have carried this approach to an extreme and are unique in many respects. Indeed, in tracing the history of sea otter taxonomy some early authorities confused the many aquatic adaptations of the sea otter with its phylogenetic heritage. As a result, the sea otter was even misplaced with the pinnipeds, which include seals and sea lions, rather than with the mustelids, which include river otters, weasels, and badgers. Nevertheless, species designation and much of the phylogenetic history of the sea otter have been remarkably consistent and accurate (see Table 1). The main systematic difficulties rest with whether subspecific units are meaningful evolutionarily and how to manage these units from a conservation standpoint. In this paper, we review the history of sea otter systematics, summarize morphological and molecular studies of subspecies, comment on the implications systematics have for conservation efforts, and provide suggestions for future areas of study.

Historical ranges and extirpations

Like many carnivores, the history of sea otter distribution is one of an initial contiguous range followed by periodic extirpations, leaving present-day population ranges patchily distributed (see Figure 1). Historical records of distribution are reasonably reliable, as *Enhydra* was known to the indigenous peoples who hunted them, and trade in sea otter pelts to the Spanish began in California at least by and probably prior to 1733 (Ogden 1941). The historical range of the sea otter extended across the Pacific rim in a wide arc from Morro Hermoso in Baja California to the island of Hokkaido in northern Japan (Ogden 1941; Barabash-Nikiforov 1947). Population estimates for this historical range vary from between 100,000-150,000 (Kenyon 1969) to 300,000 (Johnson 1982).

According to Barabash-Nikiforov (1947), intensive hunting of the sea otter in the northern part of its range began almost immediately upon the return of Steller from the Bering Expedition (1741-1742), which collected over 700 pelts. This expedition provided one of the first detailed descriptions of the sea otter from Bering Island, but ironically also led to its extirpation there. By 1762, after thousands of pelts were exported from Bering Island by commercial hunters, there were too few sea otters in the area to justify commercial expenses in hunting them. This pattern was repeated throughout the range of the sea otter, exterminating population after population around the Pacific rim from Kamchatka to Alaska, British Columbia, Washington, Oregon, California, and Baja California. Estimates for the total number of sea otters killed from 1740 to 1911 range from 500,000 (Kenyon 1969) to well over 800,000 (Lensink 1960). The result of such unregulated hunting was a patchwork of roughly 11-13 isolated populations from what was once a continuous distribution (Kenyon 1969). It is estimated that only about 1,000 individuals survived the onslaught of commercial hunting (Kenyon 1969), between 1 and 2 percent of the original estimated population.

In California, estimates of historical population numbers range from 16-

Name	Author	Comments
Lutra marina	Steller (1751)	Binomial but pre-Linnaean and therefore considered to be unacceptable according to the International Commission of Zoological Nomenclature (ICZN)
Mustela lutris	Linnaeus (1758)	Partially based on Steller's account (1751), *Mustela* was used for all members of the Mustelidae recognized at that time.
Phoca lutris	Pallas (1811)	An attempt to ally *Enhydra* with the Pinnipeds.
Pusa orientaliis	Oken (1816)	An attempt to give *Enhydra* its own generic appellation but Oken's names are not available according to the ICZN (and has been synonymized. with *Phoca*).
Enhydra marina	Fleming (1822)	Oldest available valid Genus name.
Latax lutris	Gloger (1827)	Renaming of *Pusa* Oken, which was preoccupied.
Enydris marina	Lichtenstein (1827)	Emmendation of *Enhydra*.
Enchydris	Lesson (1842)	Emmendation of *Enhydra*.
Enhydris lutris	Lesson (1842)	Emmendation of *Enhydra*.
Enhydra lutris	Gray (1843)	First use of current name combination.
Sutra marina	Elliot (1874)	Junior synonym of *Enhydra*.

Table 1. History of the taxonomy of the sea otter, *Enhydra lutris*.

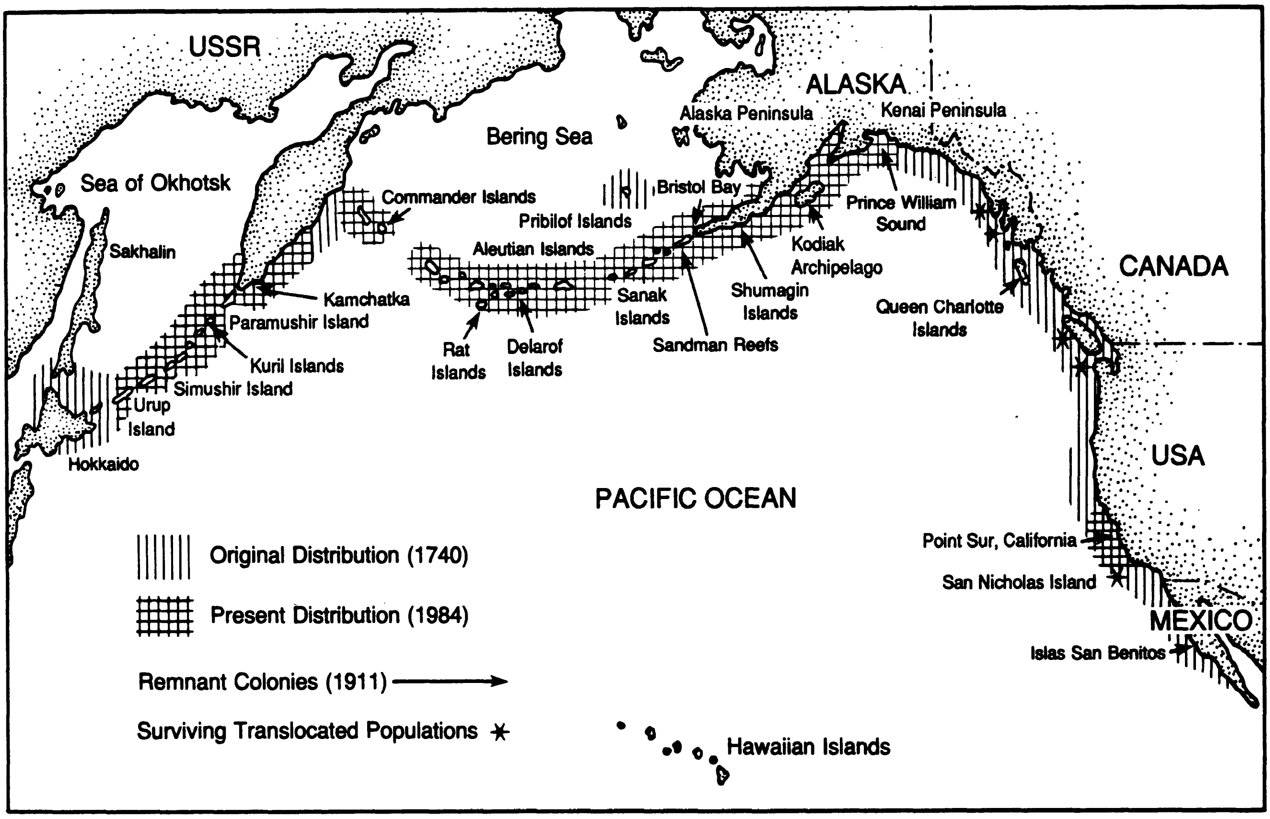


Figure 1. Present distribution of the sea otter.

20,000 (Ralls et al. 1983; see DeMaster et al., this issue). Commercial hunting began in 1784 and ended in 1840 when it became unprofitable due to the low number of available sea otters (Ogden 1941). The population was thought to be extinct by the turn of the century, but a small group of between 32-50 were observed in 1914 (Bryant 1915). Subsequent rediscoveries of sea otters in California elicited much excitement. When a rancher and his wife found a small population off the coast of Big Sur in 1938 (Bolin 1938), one marine biologist remarked that reporting dinosaurs would not have caused more surprise (Wolkomir 1995)!

Under protection of the International Fur Trade Treaty of 1911, sea otter populations around the Pacific began to recover, slowly at first and mainly in areas with little human disturbance. Today, it is estimated that sea otters inhabit most of their historic range west of Prince William Sound (Riedman and Estes 1988, 1990; Estes 1990), but populations have not yet fully recovered in Southeast Alaska and British Columbia and are very limited south of British Columbia.

Subspecific status

Subspecies are defined as a geographical or ecological population within a species which differs from any other such population within the same species. The difficulty arises in what we mean by "differs." Variation within a species often differs among individuals, varieties and subspecies; the problem lies in determining how much of this variation represents a legitimate subspecies. Subspecific delineations involve a continuous process of refinement with a subspecies proposed, then reanalyzed and refined, until relative stability is reached. Recently emphasis has been placed on taxonomically identifying subspecies by concordant characters which are consistent with explicit phylogenetic partitioning (Avise and Ball 1990; O'Brien and Mayr 1991). The following is a review of how the above subspecific delineations for *Enhydra* have been refined over the years and provide a consistent phylogenetic picture.

Morphological data

Barabash-Nikiforov (1947) was the first to suggest that the Commander Island subspecies was not sufficiently different from the Aleutian Island form and so designated the Northern American form as *E.l. lutris*, the Kuril-Kamchatkan race as *E.l. gracilis*, and the Southern Californian group as *E.l. nereis*. Barabash-Nikiforov based these findings on measurements from 5 specimens from the Aleutian Islands and Alaska, 3 specimens from the Commander Islands, 7 from Mednyi Island, 5 from the southern tip of the Kamchatka Peninsula, and 1 from Bering Island. No specimens were available from either the Kuril Islands or California. The separation of *E.l. gracilis* was based primarily on pelage differences described from pelt scraps (Barabash-Nikiforov 1947) and the description of this form was later refuted by Stroganov (1962) because it is a composite of other subspecies (but see below).

The subspecific taxonomy of the southern sea otter (*E.l. nereis*) was not contested until Scheffer and Wilke (1950) reexamined the specimen used by both Merriam (1904) and Grinnell et al. (1937) as well as new material from western (n=46) and southeastern (n=2) Alaska, Washington (n=1), Oregon (n=2), and California (n=5, including the type-specimen). They concluded

Subspecies name	Author	Common name	Status
E. l. lutris	(Linnaeus 1758)	Asian sea otter	CITES Appendix 2
E. l. kenyoni	(Wilson, 1991)	Alaskan sea otter	CITES Appendix 2
E. l. nereis	(Merriam 1904)	California sea otter	CITES Appendix 1 U.S. ESA Threatened

Table 2. Commonly recognized subspecies of sea otter.

that several of Merriam's characters were flawed and there was insufficient evidence to support the existence of a southern subspecies of sea otter. Despite these assertions, most authors were not convinced because of small sample sizes and therefore continued to recognize the southern subspecies (e.g., Murie 1959).

In 1969, Kenyon critically reviewed the southern subspecies question, specifically in regard to Scheffer and Wilke's (1950) analysis. Kenyon summarized his position as follows: "...it is not possible, without further study, to distinguish racially distinct populations which might exist" (Kenyon 1969, p. 5). Later, Kenyon (1982) reiterated the conclusion of Roest: "...all sea otters from the Pacific coast of North America represent a single clinally varying population, *Enhydra lutris lutris*" (Roest 1979, p. 14). The precise study called for by Kenyon was performed by Wilson et al. (1991), with one ironic result being an accepted subspecies designation bearing Kenyon's name, *Enhydra lutris kenyoni*. This study examined 236 specimens from the former Soviet Union, 84 from northwestern North America and Alaska, and 48 specimens from California (total n=368), using a sequential discriminant function analysis. They found clear support for the recognition of three subspecies of sea otter, with the greatest distinction existing between the two extreme populations in the USSR and California, and mandibular length generally being the best morphological character for subspecific recognition. Currently there are three recognized subspecies of *Enhydra lutris* (Reeves et al. 1992; Wozencraft 1993), as shown in Table 2.

In summary, morphological analyses have consistently supported subspecies designations. However, further phylogenetic studies of these subspecies are needed to clarify the systematics at the subspecific level.

What new analyses would improve our understanding? As stated, most phylogenies across species have been morphological, with major emphasis on cranial and dental characters. Consistency among studies is hampered by selection of different characters, subjective evaluations of characters, variation in phylogenetic methods, and nonrepresentation of some taxa (see Table 1). We are now correcting some of these problems (Anderson and Gittleman, in preparation) by analyzing across all lutrines a broader suite of morphological and other characters (e.g., behavioral and life history traits) than has been previously used. In addition, as many complications of phylogenetic study undoubtedly rest with convergence due to the effects of aquatic living, molecular analyses will play a critical role in better understanding systematic relationships.

Molecular data

Molecular analyses will serve as an independent test of the results obtained from morphological analyses. Most molecular studies to date have only examined higher level relationships among carnivore families (Wayne et al. 1989; Vrana et al. 1994; Ledje and Arnason 1996); few have dealt with relationships within the Mustelidae (but see Masuda and Yoshida 1994). However, a project examining the phylogenetic relationships among otter species using DNA sequences of the mitochondrial DNA cytochrome *b* gene is currently underway (Koepfli and Wayne, in preparation).

Molecular techniques are quite useful for delineating systematic relationships among populations and subspecies (Avise 1994). Much molecular work is ongoing with the sea otter, particularly in evaluating the subspecific question (Scribner et al., in press).

Lidicker and McCollum (1981, cited in Riedman and Estes 1990, and Scribner et al., in press) used allozymes to determine levels of heterozygosity and genetic differentiation between the Californian and Alaskan populations. Their findings indicated that five of 30 loci were variable and no alleles were site specific; they hypothesized that the absence of rare alleles in the California population was due to population bottleneck effects, although this is not completely accepted.

Rotterman (1992) also used allozymes to assess genetic variability between three Alaskan populations and the California population. Of 41 loci examined, only three were variable, and only two of these were sufficiently variable to be informative. Genetic distances for these populations were also small (0.001-0.006), revealing a high degree of genetic similarity (Nei 1978) that would not confirm subspecific status for the California population. An intriguing result from the genetic distance analysis was that the California population showed a higher genetic affinity to several of the Alaskan populations than among the Alaskan populations themselves.

Recent analyses of mitochondrial DNA (mtDNA) employing restriction fragment-length polymorphisms (RFLPs) assessed relationships among populations in Prince William Sound, the Kuril Islands, and central California (Sanchez 1992). The California population was most divergent from the Prince William Sound population, followed by the Kuril Island and Prince William Sound populations, and lastly the Kuril Island and California populations, revealing total genetic divergences of 0.0008-0.0060. Sanchez concluded that the mtDNA haplotype distribution generally supported the morphological classification of Wilson et al. (1991), although there was also indication of recent common ancestry, high gene flow and reduced effective population sizes. To date, analyses of mitochondrial DNA (mtDNA) have only approximated divergences among otters and other mustelids using linear fragments from different parts of the mtDNA molecule without mapping restriction sites (Cronin et al. 1996); therefore, caution must be taken because single-locus phylogenies may not be accurate.

Most recently, Cronin et al. (1996) used RFLPs of several large segments of mtDNA, amplified using the polymerase chain reaction (PCR) technique, to investigate genetic differentiation within and among subspecies. Results indicate that only *E.l. nereis* has monophyletic mtDNA, not found in either populations of *E.l. lutris* or *E.l. kenyoni.* Cronin et al. (1996) propose an explanation that there was pre-exploitation divergence between the following four groups: California, Prince William Sound, Kodiak-Adak-Amchitka-Attu-Medney islands, and Kuril island populations. In examining these results it appears that these divergent populations correspond to the four most frequently proposed subspecies (*E.l. nereis*, *E.l. kenyoni*, *E.l. lutris*, and *E.l. gracilis*, respectively).

Conclusion and recommendations

Molecular studies consistently support differentiation among populations along subspecific lines. The California subspecies (*E.l. nereis*) appears to have monophyletic haplotypes of mtDNA, which do not overlap with other populations; in contrast, *E.l. lutris* and *E.l. kenyoni* have frequencies of haplotypes which are similar to some extent. Four problems should receive future molecular work.

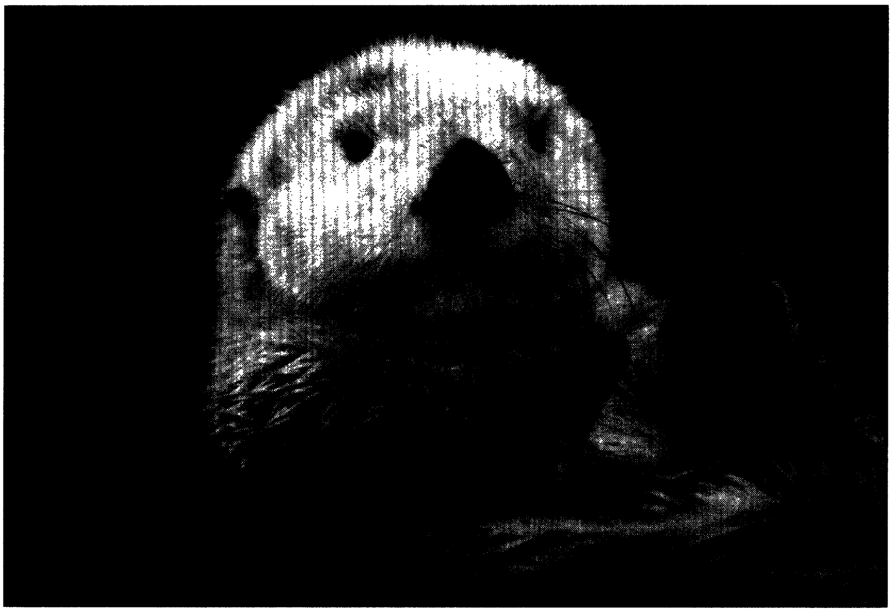
(1) The California haplotypes, though monophyletic, are not unequivocal and therefore phylogenetic analysis should be performed alongside other genetic and morphological studies (Cronin et al. 1996).

(2) Genetic sequence analysis using the mitochondrial DNA control region and nuclear microsatellites should be used to distinguish populations within subspecies which may be important for identifying populations that may be managed as independent units (currently being carried out by Koepfli and Wayne).

(3) Much of the studies using mtDNA (e.g., Cronin et al. 1996; Sanchez 1992; Koepfli and Wayne, in preparation) have shared samples. An independent analysis is needed to assess whether some concordance among molecular results is affected by sampling biases.

(4) Although allozymes have been used previously (see review in Scribner et al., in press), additional nuclear markers with higher variability need to be employed to assess concordance with mitochondrial DNA results. Koeplfi and Wayne are currently conducting such a study using hypervariable nuclear microsatellite markers.

Without question, bad taxonomy is detrimental to conservation efforts. An increasing number of studies show that endangered and threatened species must be rigorously defined by explicit phylogenetic units (Avise and Ball 1990; O'Brien and Mayr 1991). Present data indicate validity of named subspecies for the sea otter and therefore current protection measures should remain in place to ensure the survival of threatened populations. (*E.l. nereis* is listed as threatened under the Endangered Species Act and under CITES Appendix 1, all other subspecies are listed under CITES Appendix 2; see Baur et al.; Clark, this issue). Further systematic work is needed, however, to bring into line subspecific recognition with regard to phylogenetic units. First, phylogenetic analyses of different phenotypic characters and molecular gene markers should resolve the history of natural population distinctions. Second, phylogenetic population clusters should then be identified in relation to phylogeographic boundaries. Conservation efforts involving captive management and breeding programs as well as reintroduction plans must demand such results from systematics.



Photograph by Jeff Foott

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Comparative Demography of Sea Otter Populations

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Population trends are poorly documented and demographic information is typically lacking for many carnivorous mammals. The sea otter (*Enhydra lutris*) has a well known history of decline and recovery, and while many other species have declined as precipitously, few have recovered so spectacularly. Generally speaking, northern populations (remnants within the range of *E. l. lutris* and *E. l. kenyoni*) have recovered at high rates while recovery of the southern sea otter (*E. l. nereis*), which is listed as legally threatened under the Endangered Species Act (ESA), has progressed more slowly. Our purpose is to contrast trends in abundance and demographic patterns between southern (California) and northern (Washington, British Columbia, Alaska, and Asia) sea otter populations. Specifically, we provide (1) a brief review of the main findings to date; (2) a summary of ongoing and planned studies; and (3) recommendations for future research. A more detailed account of these and other issues concerning the conservation and management of sea otters is provided in the U.S. Fish and Wildlife Service's Recovery Plan for the California Sea Otter (U.S. Fish and Wildlife Service 1996).

Summary of past research

Demographic information on sea otters comes from several sources. Population monitoring programs have been conducted mostly by state and federal agencies. Information on reproduction and mortality comes from work conducted by scientists from state and federal agencies, academia, and the private sector. Although there have been several long-term monitoring programs, most information on population trends, and much of what is known about reproduction and mortality, comes from the *post hoc* assembly of data that were collected for other purposes. In some cases recognition of patterns is confounded by the different methods used in existing research. More recently, there has been a concerted effort to apply consistent techniques in studies of reproduction and mortality in different parts of the sea otter's range. Nonetheless, varying conditions and purposes of work in different areas have inevitably influenced the comparability of available data.

Trends in abundance

The earliest comprehensive reports of status and trends in sea otter populations were written by Barabash-Nikiforov (1947) and Lensink (1960). Karl Kenyon's (1969) monograph summarized information through the mid-1960s and reports by Rotterman and Simon-Jackson (1988), Riedman and Estes (1990), and Estes (1991) provide the most recent updates.

By the early 1900s sea otters had been hunted to near extinction throughout their range (Lensink 1960). When prohibition against further take was enacted in 1911, a dozen known colonies remained, none of which are thought to have contained more than several hundred individuals (Kenyon 1969). These colonies recovered at varying rates in the ensuing decades, although not in unison. The sea otter population at Amchitka Island in the western Aleutian archipelago was one of the first to recover, apparently reaching equilibrium numbers by the late 1930s or early 1940s. In other areas recovery lagged behind by as much as a half century.

Sea otters were hunted to extinction in several isolated areas of the Aleutian archipelago and along the west coast of North America between eastern Prince William Sound and central California. They were reestablished in the late 1960s and early 1970s to southeast Alaska, British Columbia, and Washington via relocations (Jameson et al. 1982), and in the mid-1960s a small colony naturally recolonized Attu Island, western-most of the Aleutians (Jones 1965). The subsequent growth of these colonies has been documented through repeated surveys. These data are informative because (1) founding population sizes are known in all cases; (2) each area was surveyed using consistent methods; and (3) the populations are sufficiently isolated that movement among populations is unlikely to have affected their population growth rates. All 4 populations increased at 17-20% per year, which is near the sea otter's theoretical maximum rate of increase, r_{max} (*sensu* Cole 1954), based on known or estimated values of key life history parameters (Estes 1990). Furthermore, these growth trajectories have shown no indication of density compensation, even though the population in southeast Alaska contained greater than 1500 individuals at the time of the last survey. However, the most recent information from Washington (R. Jameson, unpublished) indicates that the population growth rate there has declined somewhat in the past few years.

Although there has been less consistency in the census techniques used to survey California sea otters, this population clearly has grown more slowly than the northern populations. Except for the mid-1970s to the early 1980s, when the California sea otter declined (Estes 1990) in apparent response to incidental mortality in a coastal set net fishery (Wendell et al. 1985), the rate of increase has consistently been about 5% per year. This comparatively low rate of increase, coupled with its small size, limited range, and concern over possible catastrophic losses from oil spills, led the U.S. Fish and Wildlife Service to list the California sea otter population as threatened under the ESA in 1977.

Demographic patterns

The strikingly different growth rates between sea otter populations in California and more northern regions is attributable to different demographic schedules. That is, the populations differ in some aspect of their age-specific probabilities of reproduction, survival, or some combination thereof. Differences in mortality are thought to be the main factor explaining divergent rates of population growth, as explained below.

Most females conceive and give birth for the first time at age 3, and since the lengths of gestation and post-partum dependency are each about 6 months, females that successfully wean their pups reproduce on roughly an annual cycle

(Jameson and Johnson 1993; Riedman et al. 1994). Females usually come into estrous within a few days of separating from their pup. Therefore, when pups are lost prematurely, the reproductive cycle is shortened. Although most pregnancies probably are carried to term, many post-partum losses occur shortly after birth. Despite this, age of first reproduction and the age-specific probability of females giving birth appear to be largely invariant among populations, irrespective of whether they are increasing, at or near equilibrium, or in decline (Jameson and Johnson 1993; Bodkin et al. 1993; Monson and DeGange 1995; Monson et al., unpublished manuscript; Tinker and Estes, unpublished data).

In contrast to reproductive rates, age-specific mortality schedules vary considerably among sea otter populations. Maximum longevity of wild sea otters is about 20 years (Bodkin, unpublished data). Beach-cast carcasses are rarely found in areas where populations are growing rapidly, and most of those that are recovered are aged (Kenyon 1969). This observation, and the analysis of population growth potential based on life history data indicate that very low mortality between birth and senescence is the rule in populations that are increasing at rates near r_{max} (Estes 1990). In contrast, the age-specific mortality schedule of resource-limited populations, such as those at Amchitka Island or western Prince William Sound, features an increased probability of mortality among dependent and recently weaned juveniles. Therefore, the age-structure of beach-cast carcasses from resource-limited populations is bimodal, with peaks at the very young and old age classes. Mortality rates of individuals between about 3 and 8 years are very low, regardless of population status. A third pattern, in which probability of mortality is relatively high for all post-weaning ages, produces a carcass age structure similar to that of the living population. This pattern was seen following the *Exxon Valdez* oil spill (Bodkin et al. 1993) and is also typical of the California population (Pietz et al. 1988). The reason for this mortality pattern is still poorly understood, although there appear to be a wide range of possible causes.

Ongoing and planned research

Population monitoring of sea otters in California and Washington is part of the U.S. Department of the Interior's research program, and is expected to continue indefinitely. Elsewhere, population surveys probably will be done opportunistically, or as the need arises.

A large-scale comparative study of sea otter demography and behavior was initiated in the early 1990s. This project is being conducted as a series of 2 to 3 year studies of populations that are either small and growing rapidly or large and at or near equilibrium density. Similar methods, centered on information obtained from a sample of individuals equipped with surgically implanted radio transmitters, are used in each study. Information on diet, activity-time budgets, distribution and movements, reproductive success, and mortality is being gathered. In addition, surveys of pre-determined coastal segments are conducted at monthly intervals to obtain samples of beach-cast carcasses, and to determine trends in abundance and reproduction. There is ongoing or recently completed field research at Amchitka and Adak islands (populations near equilibrium density), and Shemya Island and Washington State (growing populations). A similar study is planned for California where the data will be added to those obtained in the 1980s by Siniff and Ralls (1988). The ultimate goals of this program are to relate population status to demographic and behavioral patterns, and in particular to better understand the status and factors limiting growth of the California population.

Conclusion and recommendations

The above-described activities will form an empirical backbone for the long-term conservation and management of sea otters. Continued population monitoring is probably the most fundamental need, although information on demography and behavior is also necessary if there is to be any hope of understanding the observed trends. Three additional areas of research could enhance this goal.

(1) Synthesize available data. A great deal of information already has been gathered on the abundance and trends of sea otter populations, and on the demography and behavior of individuals within these populations. Most of this information has not been published and some of it was obtained by people no longer working with sea otters. We recommend that all of the relevant demographic data be identified, assembled into a comprehensive data base, and analyzed and synthesized. At the very least, this will clarify what information is available and what more is needed.

(2) Population modelling. A rigorous analytical effort is needed to help field researchers focus their efforts on the most revealing populations, age and sex classes, and demographic/behavioral parameters. Properly done, population modelling can serve as a reality check for preconceptions and interpretations that have become accepted without benefit of rigorous analysis. For instance, we have argued that elevated mortality, as opposed to depressed reproduction, is responsible for the regulation of sea otter populations as they approach equilibrium density. While this argument is supported by the available data and may be correct, recent work on another carnivore species, the cheetah, suggests that a more careful look is needed. In the case of the cheetah, cub mortality is highly variable and this variation has been assumed to be responsible for the growth or decline of local populations (Caro and Laurenson 1994). However, iterated simulations of cheetah population trends using the available life history data show that observed levels of cub mortality have relatively little effect on population growth or decline, and that adult mortality is the likely causal variable (Crooks et al., in review). The case of the cheetah is relevant to sea otters because (a) we have also assumed that mortality of young animals is the major driving variable in population trends, and (b) sea otters, like cheetahs, come into estrous immediately after becoming separated from their young. Thus, it may be that elevated pup mortality, especially that which occurs shortly post-partum, produces an elevated rate of fecundity, in turn buffering the population against decline. Preliminary analyses of data collected from a declining population at Adak Island, Alaska suggest that variation in adult mortality rates may be a critical regulating factor in sea otter populations (Tinker and Estes, unpublished data).

(3) Develop a better understanding of linkages between sea otter population biology and community- and ecosystem-level processes. Ultimately, most population trends are driven by some aspect of the habitat. Food, predators, space, and other physical aspects of the habitat are common limiting factors for other species. Sea otters strongly depress their prey populations (Estes and VanBlaricom 1985; VanBlaricom and Estes 1988) and thus food limitation is often assumed to be the main factor regulating sea otter populations. While this is likely true, recent findings suggest that the interaction can take complex and unexpected forms. For instance, while organic carbon production from kelp beds may ultimately fuel the maintenance and growth of sea otter populations (Duggins et al. 1989; Estes 1990), poorly known relationships between coastal currents and prey recruitment appear to modulate the linkage between macroalgal-derived organic carbon production and sea otter abundance. These relationships, in turn, may explain why high density sea otter populations have persisted in some areas but not others (Estes and Duggins 1995; Estes 1996; Estes, unpublished data). Similarly, recent work at Amchitka Island has shown that episodic food subsidies from the oceanic realm can strongly influence the behavior and population biology of sea otters (Watt et al., submitted). Predation on newborn pups by bald eagles (Sherrod et al. 1975) or on adult sea otters by killer whales (Hatfield et al., in preparation) is another potentially important variable, and while predation may be negligible in many populations, it should not be overlooked. Finally, there is growing evidence that environmental contaminants may be responsible for reduced growth rates and declines of local sea otter populations (Estes et al., in press; see Jarman et al., this issue). These examples, while still equivocal, point out that any real understanding of the sea otter's demography must include community- and ecosystem-level interactions.

One broad goal of wildlife research is to develop strategies that help minimize the likelihood of extinction on relevant time scales. Except for the rare effects of environmental catastrophes, perspectives built around years or even decades are too short, especially for long-lived organisms like sea otters. Similarly, very long time scales (e.g., millennia) are too long to worry about because it is virtually impossible to forecast environmental, social, and political changes over these time scales. We should probably be concerned with developing conservation strategies for sea otters over periods of roughly 50 to 100 years. The sea otter's future appears bright at the moment, but one must be mindful of how misleading the short-term perspective can be. For instance, even 100 years ago a concerned resource manager would have viewed the prospects for grizzly bears or gray wolves in North America in much the same way as we view sea otters today. However, the ensuing century has demonstrated how wrong that perspective would have been, and how fragile species and populations can be over long periods of time.

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Monitoring the Status of the Wild Sea Otter Population: Field Studies and Techniques

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Fundamental to the conservation and management of wildlife resources is an understanding of a population's status, both in terms of abundance relative to its naturally occurring equilibrium level or carrying capacity, and rate of change (Caughley 1977; Eberhardt and Siniff 1977). A variety of criteria for determining the status of wildlife populations have been suggested (Eberhardt and Siniff 1977; Hanks 1981; Fowler and Siniff 1992), and are summarized in Table 1. Proposed criteria include both direct measures, such as the ratio of current abundance to carrying capacity abundance, and indices, such as time-activity budgets or body condition, that may be indicative of population status. Routine monitoring of population status improves management capabilities and may be particularly relevant to resource conservation.

Due to the recent history of exploitation and recovery (see Anderson et al.; Estes et al., this issue) and the resulting spatial separation of populations, sea otters in the north Pacific provide a unique opportunity to evaluate techniques for monitoring population status. Within the current range of sea otters, populations exist that have been at or near equilibrium density for as long as 50 years (e.g., Architka, Alaska; see Figure 1). Other populations have recently attained equilibrium density (e.g., Bering Island, Russia and Prince William Sound, Alaska) while others remain below (e.g., Olympic Peninsula, Washington; Vancouver Island, British Columbia; and Southeast Alaska). The status of the mainland California population apparently remains uncertain. The known variation in status among populations, a well described natural history, and the relative ease of enumerating sea otters provide a solid foundation for testing techniques to estimate sea otter population status. The results of research aimed at evaluating sea otter population status may be transferable to other wildlife populations, including endangered species, which are not as readily studied. Our purpose in this paper is to describe those measures of population status that have been applied to sea otters (see Table 1), discuss their relative merits, and recommend directions for research that may improve our ability to accurately monitor sea otter population status.

Population parameters

Distribution

Observations of animals reoccupying areas they had historically inhabited, or of vacant habitat where they were previously present, is a clear indication of population change. Available information suggests that the distribution of otters remains fairly stable over decadal time scales in equilibrium populations such as Amchitka, although abundance may vary, but that seasonal shifts may be pronounced and possibly predictable. Change in distribution in growing populations appears less predictable, particularly in areas of complex coastal physiography, such as southeast Alaska, compared to populations occupying more linear coastlines, such as California. Accurately describing changes in distribution requires systematic population surveys that should include areas adjacent to occupied habitat.

Rate of change

Population status may be inferred from the direction and rate of change in numbers in a population. Rate of change, resulting from the balance between recruitment and mortality, likely reflects a response to prior conditions rather than present, or future conditions. However, alterations in the rate of change might provide some predictive power (e.g., a population that continues to grow, but at a decreasing rate, may be approaching equilibrium). Generally, remnant populations have experienced slower growth rates than translocated populations, or naturally recolonized islands (Estes 1990a; Bodkin, unpublished data). Annual growth rates observed from several remnant populations range from about 5% (California) to 6-8% (Prince William Sound and Kodiak) to 13% at Amchitka, compared to about 20% consistently observed for translocated populations in Southeast Alaska, Washington and British Columbia.

Several types of data can be used to calculate rate of change. These are summarized below, with assets and liabilities noted for each.

Measures of abundance

Estimates of relative abundance. Counts of sea otters have been made from shore, skiffs, larger boats, a variety of fixed-wing aircraft, and helicopters, or a combination of these. It has been generally recognized that some proportion of the population is not observed during surveys. In Prince William Sound, Udevitz et al. (1995) demonstrated that 30% of the sea otters present were missed during skiff surveys, because of avoidance by otters and failure to observe otters present.

It is likely that detection probabilities differ among surveys, even if methods are similar. Average sea otter detection probabilities from fixed wing aircraft were <0.50 and varied widely both within and among observers (Bodkin and Udevitz 1996; Bodkin, unpublished data). Consequently, if indices of abundance are to provide unbiased estimates of the proportional change in a population, the probability of detecting otters must be known for each survey. However, estimating detection probability can be difficult, and most surveys do not account for undetected otters, complicating comparisons among surveys.

Estimates of absolute abundance. Estimating absolute sea otter abundance through systematic sampling requires a method to estimate the proportion of animals not detected while sampling. Bodkin and Udevitz (1996) have developed an aerial survey method consisting of a strip transect design where all otters observed in a 400 m wide strip on one side of an aircraft are counted. The proportion of otters not seen is estimated by conducting intensive searches within the strip transects. A similar procedure was at-

Population Parameters	Physiological Parameters	Behavioral Parameters
1. *Distribution*	1. *Growth rates and individual size*	1. *Time activity budgets*
2. *Rate of change*	2. *Serum chemistry and hematology*	2. Territory size
3. *Measures of abundance*	3. Deposited fat (kidney, bone marrow, fat mobilization)	3. Group size
4. *Reproduction*	4. Disease	4. Agonistic behavior
5. *Survival rates*	5. Parasites	5. *Food habits*
6. *Age/Sex structures*	6. *Immune response*	6. Infanticide
	7. Adrenocortical hypertrophy	
	8. Urinary excretion of hydroxyproline	
	9. Developmental stability (asymmetry)	

Table 1. Summary of indices proposed to estimate the status of a population relative to an equilibrium level (after Hanks 1981; Fowler and Siniff 1992). Techniques applied to sea otters are in italics.

tempted from helicopters in Alaska (DeGange et al. 1995). The aerial methodology should be validated in a population of known size, and may provide additional information on the California population.

Estimates of absolute abundance can be important in population management. For example, sea otter abundance data would have been of great value in determining the magnitude of mortality from the 1989 *Exxon Valdez* oil spill (Ballachey et al. 1994; see Bonnell et al., this issue).

Population census. Counts of sea otters from the shore have generally been recognized as the most accurate means of enumerating sea otter abundance. Estes and Jameson (1988) estimated the detection probability of sea otters using standardized shore counts at 94.5%. This was the first rigorous evaluation of this survey method, and provided a baseline against which other methods could be tested. Due to access constraints, however, shore-based counts have limited application over the large areas occupied, or potentially occupied, by many sea otter populations.

In California, a combination of a census (ground count) and index of abundance (aerial counts) are combined to provide annual minimum counts. These counts are biased low to the extent that each method does not account for animals not detected. To retain comparability over time (assuming relative abundance remains constant), it will be important to continue using each method proportional to its use in previous surveys.

Population density. Assuming equilibrium densities are similar among similar habitats, density estimates should provide an objective and direct measure of population status. Following complete reoccupation, about 50 years ago, a decline in density was observed at Amchitka Island (Kenyon 1969). In 1991 at Bering Island, a 40% reduction in sea otter density was observed following complete reoccupation of the island during the 1980s (A. Burdin, unpublished data). Estes (1990a) used densities to evaluate the recovery of sea otters at Attu Island. Comparison of densities between Attu and Amchitka Island led Estes (1990) to develop a hypothesis regarding multiple equilibria, where sea otter densities reached a second, higher equilibrium density, following a diversification of diet. The possibility of multiple equilibria should be considered in interpreting trends in population density.

Estimation of density requires delineating suitable habitat accurately. Potential sea otter habitat can be defined from the high intertidal to a bathymetric contour beyond which sea otters cannot forage due to diving limitations. Our data from Prince William Sound suggest that sea otters between the shoreline and the 200 m contour interval are not evenly distributed. Approximately 80% of the otters observed on surveys between the shoreline and the 200 m contour were within the 40 m contour interval, which is about a third of the total area. Until the relation among the distribution of substrate depths, habitat characteristics, and sea otter density is defined, the use of density to compare populations should be limited to areas of similar bathymetry and habitat. Data on the distribution of dive depths of individual otters may prove useful in describing this relation. Additionally, a potential relation between diving depths and population status may exist.

Indices of density will result if the survey method does not estimate the proportion of sea otters not detected (Udevitz et al. 1995). Valid comparisons across or within populations using an index require the assumption that detection probabilities do not differ among surveys. It is unlikely that this assumption is valid. If detection probabilities can be estimated, unbiased estimates of abundance will result. The results of a complete census or an unbiased estimate of abundance will result in unbiased density estimates that should be comparable within and among populations.

Reproduction

Two specific reproductive attributes have been proposed as indices of sea otter population status: age at first reproduction and age-specific reproductive rates. Most studies to date have found relatively consistent results among populations in these variables. Generally, a small proportion of female sea otters reproduce at age 2, most are mature by age 4, and age-specific rates are relatively high and consistent among mature females (Riedman and Estes 1990; Jameson and Johnson 1993; Bodkin et al. 1993; Monson and DeGange 1995; Monson 1995).

Reproductive characteristics in female sea otters have been studied through analysis of reproductive tracts and monitoring known individuals. Tract analysis requires carcasses in good condition, which usually are not available in large numbers. Monitoring known individuals

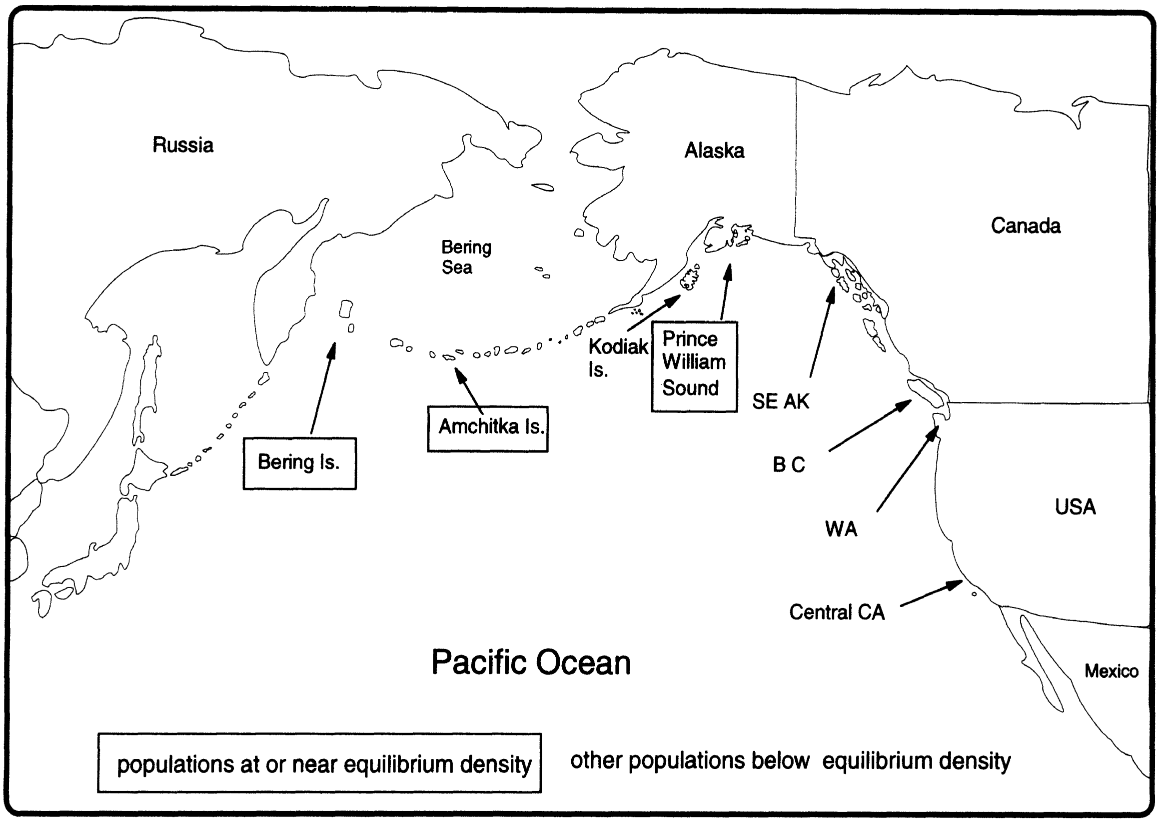

Figure 1. Map of the northern Pacific Ocean showing some sea otter populations near equilibrium density and others below equilibrium density.

has been accomplished most efficiently with the aid of radio telemetry. Adult female reproductive rates are generally high (0.80-0.94) among those populations sampled (Schneider 1973; Jameson and Johnson 1993; Siniff and Ralls 1991; Bodkin et al. 1993; Monson and DeGange 1995; Monson 1995), and include estimates from populations of differing status (California, Amchitka, Prince William Sound and Kodiak). However, reproductive rates appear to vary among ages, leading to the need to restrict comparisons to similar ages. Much less work has been done on aspects of male reproductive biology, although sperm samples collected in Prince William Sound indicate that males may attain maturity as early as age 3 (Ballachey, unpublished data). In summary, it appears that the reproductive characteristics studied to date are relatively invariant, and therefore unlikely to provide a sensitive index to population status.

Survival rates

Survival rates, particularly of juveniles, have been suggested as the life history variable most sensitive to environmental conditions (Eberhardt 1977; Hanks 1981). Annual survival rates among adult sea otters are generally high (0.75-0.96) and have been obtained from monitoring known animals in California, Kodiak and Amchitka (Siniff and Ralls 1991; Monson and DeGange 1995; Monson 1995), and through analysis of age structure of carcasses collected at Amchitka (Eberhardt and Siniff 1988) and in Prince William Sound, following the *Exxon Valdez* oil spill (Udevitz et al. 1996). Most studies have found higher survival rates in adult females, compared to adult males.

Juvenile sea otter mortality can be evaluated in two components: through dependency, and after weaning. Dependent juvenile survival has generally been estimated by following known females from pupping through weaning. Comparisons of pre-weaning survival rates suggest variability among populations. Estimates from California are 0.46 (Siniff and Ralls 1991), 0.64 (Jameson and Johnson 1993) and 0.60 (Riedman et al. 1994); and from Alaska are 0.85 at Kodiak Island (Monson and DeGange 1995), and 0.29 and 0.54 at Amchitka (Monson 1995).

Post-weaning juvenile survival rates estimated from Prince William Sound are 0.32-0.51 for males (Monnett 1988). Post-weaning survival was an estimated 0.08 (males) and 0.21 (females) in 1990/91 (Rotterman and Monnett 1991) and 0.47 (males) and 0.59 (females) in 1992/93 (National Biological Service, unpublished data) in western Prince William Sound. During the same periods of study survival rates in eastern Prince William Sound were 0.33 (males) and 0.43 (females) in 1990/91 and 0.42 (males) and 0.89 (females) in 1992/93. At Amchitka, only 2 of 11 (0.18) pups survived one year post-weaning (Monson 1995). These data suggest that juvenile survival rates are lowest in populations that may be considered at or near equilibrium, and highest in growing populations such as Kodiak. Post-weaning juvenile survival appears to be highly variable among years, as well as within sub-populations, based on the Prince William Sound data. The Prince William Sound data are difficult to interpret because, in studies to date, potential oil effects cannot be separated from potential area effects related to differences in length of occupancy. However, if we assume no chronic oil spill effect, the comparisons between western and eastern Prince William Sound suggest juvenile survival may be a sensitive index of population status. Additionally, the large inter-annual variation observed in juvenile survival suggests we question the assumption of a stable age distribution in sea otter populations (Eberhardt and Siniff 1988; Monson 1995).

Ideally, a monitoring program would include both periods of dependency and independency. If pre- and post-weaning survival of pups are equally good estimators of population status, monitoring pre-weaning survival may prove more feasible for several reasons: (1) following females through years may control for variability in pup survival among females; (2) up to three annual estimates could be gathered from a single transmitter; and (3) potential effects of surgical implants (if any) should be less in adults than in pups. However, given the variability in post-weaning survival, and the possibility of nearly complete failure of a cohort, we suspect that post-weaning survival may be a more sensitive estimator of current population status.

Physiological parameters

Although physiological measures of population status have been considered for many years (Hanks 1981; Fowler and Siniff 1992), the 1989 *Exxon Valdez* oil spill in 1989 in Prince William Sound provided a major impetus to evaluate health of (1) individual sea otters captured for treatment and release and (2) the wild population, for indications of continuing deleterious effects of the spill. Examinations of oiled sea otter carcasses demonstrated that exposure to oil (based on contamination of the fur) was associated with liver and kidney damage (Lipscomb et al. 1993, 1994). The question remained, however, whether sea otters in oiled areas would have poorer survival rates and, if so, the time until health and survival rates returned to pre-spill, normal values. To evaluate oil-related population damage and recovery, a series of studies on sea otters were implemented, primarily in Prince William Sound (Ballachey et al. 1994). These studies are still ongoing (see the NVP project, below), and may provide insight into new approaches for assessing population status.

Growth rates and individual size

Kenyon (1969) first described differences in weights and lengths of sea otters from growing and equilibrium sea otter populations. Results of recent research in Russia, Amchitka and Prince William Sound suggests that body condition (generally measured as the ratio of weight to length) may be useful as an indicator of population status. For example, between 1980 and 1989 the Bering Island population grew at >20% annually, but by 1990 it had apparently exceeded carrying capacity, as a large scale mortality event occurred during 1990/91. During this period of population growth, the mean weight of adult male carcasses declined significantly at Bering Island (Bodkin and Burdin, unpublished manuscript). In 1990, weights of adult males at Bering Island did not differ from weights of adult males collected in Prince William Sound, a population at or near equilibrium density. The number of otters at Bering Island has apparently stabilized at or near the number that persisted following the 1990/91 mortality event.

Although sample sizes were small, Monson (1995) found differences in the condition of adult female otters between 1993 and 1994 at Amchitka Island. Corresponding differences in pre-weaning survival were also observed, with females in better condition experiencing greater weaning success. In eastern Prince William Sound, weights of mothers of pups surviving at least 1.5 years were significantly greater than those of mothers of pups that died prior to 1.5 years. Additionally, capture data suggest that animals in more recently occupied areas in the eastern Sound are slightly heavier than those in areas of the western Sound (National Biological Service, unpublished data). However, we cannot discount the potential of an oil spill effect in observed differences.

Review of the studies presented above suggest that the condition of animals in growing, as well as equilibrium populations may be a fairly sensitive index to short term changes in ecological conditions experienced by the population, and may vary on time scales suitable for predicting change in population growth. Measuring body condition is a relatively non-invasive and simple procedure. Additional research relating body condition to survival rates and changes in abundance may be justified.

Serum chemistry and hematology

Prior to the 1989 oil spill, blood values (hematology and serum chemistry) of California sea otters had been reported (Williams and Pulley 1983; Williams et al. 1992). Subsequently, blood data have been obtained on additional populations, primarily in Alaska (Rebar et al. 1995, 1996; National Biological Service, unpublished data). Differences have been identified between sea otter subpopulations in Prince William Sound (in western and eastern areas) in serum enzymes and levels of certain white blood cells (Rebar et al. 1996; National Biological Service, unpublished data), but the biological significance of these differences at either the individual or population level is equivocal. Blood samples have been collected from several other sea otter populations in different stages of expansion. Comparison of blood values among populations, and relations with other measures of population status, should provide clarification of the utility of blood analyses for assessing populations.

Immune response

Immunological measures have been developed to screen populations for effects of toxic chemical exposure (Weeks et al. 1992). However, these techniques have not been applied to monitoring the status of wild populations when contaminants or disease are not a concern. Recent work in Prince William Sound demonstrated the feasibility of an *in vitro* lymphocyte proliferation assay using cells isolated from blood of wild-caught sea otters (P. Snyder, unpublished data); the technique is currently being applied to samples collected from Prince William Sound subpopulations to evaluate potential differences in status.

Other

Other body fluids (urine, semen) have been collected from sea otters in southeast Alaska, and Prince William Sound (Ballachey 1995; National Biological Service, unpublished data) but have not been analyzed in terms of their relationship to population status.

Parasites have been frequently observed in necropsies of sea otters, including infestations in carcasses recovered from high density areas at Amchitka

(Rausch 1953) and Prince William Sound (National Biological Service, unpublished data). Although it may be anticipated that parasite loads might increase as densities increase, no published data exist on parasite levels in sea otter populations of differing densities, or on the effect of parasite loads on survival and, consequently, population growth.

As yet, the value of individual physiological measures as estimators of population status, and their variability across populations in different stages of growth, are undetermined. Although measures evaluated to date may not prove to be useful tools for predicting population status, they nevertheless should be valuable for assessing health of individuals and provide a tool for understanding factors that may be limiting population growth.

Behavioral parameters

Time activity budgets

Considerable effort has been allocated in evaluating time activity budgets as an index of sea otter population status (Loughlin 1979; Estes et al. 1982; Ribic 1982; Estes et al. 1986; Garshelis et al. 1986; Ralls and Siniff 1988; Estes 1990b; Garshelis et al. 1990; Ralls and Siniff 1990; Gelatt 1996). Although conclusions have been equivocal, there does appear to be a general positive relation between length of occupancy and the proportion of time individuals allocate to foraging. However, local environmental and seasonal effects potentially may confound comparisons among populations. Differences in activity budgets among age/sex and reproductive status, as well as, local environmental conditions, should be considered in comparisons among populations. Both the apparent lack of sensitivity as an index and the extensive effort required in its estimation will likely limit the application of time activity budgets as an index of sea otter populations.

Food habits

Relatively little work has been done relating sea otter food habits to population status. However, some generalizations may be warranted. Sea urchins appear to be a preferred prey item of otters reoccupying former habitat, and the proportion as well as the mean size of urchins in the diet apparently decline as length of occupation increases. Similar changes may occur with clams in soft sediment communities. Foraging on fish appears to be an attribute primarily of populations limited by resources, but may be observed throughout the Aleutian Islands. And lastly, there may be an increase in prey species diversity, as populations become food resource limited.

The "NVP" approach

In 1995, we (along with a large number of other scientists) initiated a study entitled "Mechanisms of Impact and Potential Recovery of Nearshore Vertebrate Predators" (the NVP study). The primary objective is to determine the status of the near-shore marine ecosystem in western Prince William Sound affected by the *Exxon Valdez* oil spill of 1989. Our approach is to compare population, physiological and behavioral parameters in four vertebrate predators, the harlequin duck, pigeon guillemot, river and sea otter, in oiled and nearby, unoiled portions of Prince William Sound, as indicators of the ecosystem's status. For sea otters, we are estimating abundance and reproduction, body condition, blood chemistry and immune response, and foraging success and prey selection. In addition, we are comparing sizes of sea otter prey in areas where otter populations were reduced and in areas where they were not. Sea otter predation is widely recognized as limiting the larger size classes of some invertebrate prey, such as sea urchins and mussels (Riedman and Estes 1990). If sea otter populations are reduced, prey populations might be expected to respond by increasing in size. We are using this knowledge as a way to measure if the affected sea otter population in Prince William Sound has recovered. Assuming sea otter densities, relative to carrying capacity, are similar between oiled and non-oiled areas, we expect to see similar size distributions of prey. Sea otter recovery may be indicated by similar prey sizes.

The NVP study and other ongoing efforts analyzing and comparing measurements taken in sea otter populations in different stages of expansion (expanding vs. at equilibrium) will provide further assessment of the array of measures potentially available to monitor population status.

Conclusion and recommendations

Contemporary sea otter populations are generally recognized by their geographic isolation. Although a population may be perceived as "single" because of geographic considerations, it may not be homogeneous in terms of population status, particularly if available resources vary by location. Considerable variation in survival may exist among individuals if, for example, juveniles born in the center of a population's distribution had a greater distance to travel to unoccupied habitat than juveniles born in areas closer to the boundaries of the populations's distribution (assuming that a greater distance traveled decreases the likelihood of survival). Consequently, when evaluating or implementing measures of population status, it may be prudent to consider the potential for within population variation in status, particularly as remnant populations increase in numbers and distribution. With this in mind we make the following recommendations.

(1) Continued monitoring of population trends is critical. Standardized survey methodologies will accommodate comparisons across populations. Survey methodologies should be evaluated by sampling populations of known size. Unbiased estimates of abundance provide benefits in documenting magnitude when change occurs, particularly declines from events such as oil spills.

(2) Our review of available data suggest that a relation exists between body condition and vital demographic variables, such as juvenile survival, that may predict change in population abundance. This potential relation warrants additional consideration.

(3) At least three attributes of an index of status are desirable:

a. the method should be sustainable over time;

b. the index should predict change, both direction and magnitude; and

c. the index should indicate cause of change (e.g. intrinsic vs extrinsic).

(4) Develop an understanding of the fundamental processes that are structuring sea otter populations, including the

potential relation between dispersal distance and population growth rates in expanding populations and factors constraining growth in equilibrium populations.

(5) Continue evaluation of the relation between population status and indices using populations in differing stages of recovery as well as within populations over time. Consideration should be given to combinations of indices to improve our ability to assess population status.

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Organochlorine Contaminants in Sea Otters: The Sea Otter as a Bio-Indicator

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Sea otters (*Enhydra lutris*) were once distributed throughout the North Pacific Rim from the Kuril Islands to Baja California, with estimates of the worldwide population between 150,000-300,000 individuals (Marine Mammal Commission 1992; see Anderson et al., this issue). Fur harvesting during the eighteenth and nineteenth centuries nearly exterminated the species, and by the early 1900s the total world population had been reduced to an estimated 1,000-2,000 individuals; the California population was estimated at fewer than 50 animals (Kenyon 1969). Since sea otters were legally protected in 1911 by the International Fur Seal Treaty these remnant colonies, and others established by relocations, have increased (Estes 1990).

The rates of recovery, however, have differed among areas or populations. The California sea otter population has increased at a rate of about 5% per year, compared with 17-20% per year for more northerly populations (Estes 1990). The explanation for the depressed rate of increase in the California sea otter population is ambiguous and most likely complicated. Potential factors are (1) emigration; (2) reduced fecundity; and (3) increased mortality, possibly caused at least partially by environmental contaminants (Estes 1990).

Although the effects of environmental contaminants on sea otters is unstudied, confamilial species, such as minks (*Mustela vison*) and ferrets (*Mustela putorius furo*), have been shown to be extremely sensitive to several of these compounds (Platanow and Karstad 1973; Jensen et al. 1977; Wren et al. 1987). For example, experimental exposure of mink to PCB levels as low as 0.64 parts per million (ppm) in their feed caused nearly complete reproductive failure (in these animals liver PCB levels averaged 1.2 ppm) (Platanow and Karstad 1973). Sea otter livers from central California were found to have levels of PCBs which exceed 1.2 ppm (Hofman and Risebrough 1985). PCBs have also been suggested as having a role in the decline of river otters throughout much of Europe (Mason 1989).

The purpose of this study was to determine if organochlorine contaminants could be contributing to the depressed rate of increase in the California sea otter population. Unlike most previous contaminant studies involving marine mammals, sea otters provide good subjects for ecotoxicological studies because they are non-migratory. Contaminant burdens in sea otters should reflect their local habitats, in combination with metabolic factors.

Our approach was to compare organochlorine contaminant levels in sea otter tissue among three separate populations across the North Pacific Rim to determine if California sea otters have significantly higher tissue organochlorine levels when compared with populations in Alaska. Liver tissue from sea otters in California, Southeast Alaska, and Aleutian Islands (Adak and Amchitka, Alaska) were analyzed for organochlorine pesticides (e.g., DDT and related compounds), polychlorinated biphenyls (PCBs) including non-*ortho* congeners (NOPCBs), polychlorinated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and polychlorinated terphenyls (PCTs).

Sample collection

Biologists affiliated with the California Department of Fish and Game located in Monterey, California routinely perform necropsies on sea otters. Mortality categories are assigned and tissue samples are collected and archived. Liver samples for this study were chosen according to the sea otter's sex, condition, year of death, and mortality category. California sea otter tissues were selected primarily from adult male sea otters in relatively good condition collected between the years 1988-1991, with one female sea otter included for comparison. Adult, male sea otters were chosen to reduce variability involved with reproduction and age when analyzing for organic contaminants in female marine mammals (Addison 1989). Seven sea otters died from uncertain causes, one was shark bitten, and one died of mating wounds.

Samples from Southeast Alaskan otters were acquired by Native Alaskan hunters at Middle Island, Sitka Sound and Ogden Bay, Alaska, during May 1991. Otters were shot, pelts removed, and tissue samples were taken within 8 hours of death. Samples were collected from adult male sea otters exclusively. Aleutian Island sea otter samples were obtained from beach-cast carcasses at Adak and Amchitka islands; one specimen was obtained in July 1992 from an individual who drowned during capture operations. Aleutian samples were collected during 1991-1992 and include 3 adult males and 4 female sea otters of varying ages.

Results and discussion

Polychlorinated biphenyls

Average total PCB levels (ΣPCB; sum of individual congeners) in sea otter livers were highest in the Aleutian Islands (310 μg/kg), intermediate in California (170 μg/kg), and lowest in Southeast Alaska (8 μg/kg) (see Figure 1). ΣPCB levels in both California and Aleutian sea otters were significantly higher than those in Southeast Alaska ($p<0.05$; all statistical results presented in this text based on one way ANOVA). Though Aleutian sea otters had the highest ΣPCB levels, this difference is not significant when compared to ΣPCB levels in California sea otters ($p>0.05$). ΣNOPCB levels were highest in sea otters from California (33 μg/kg), however, the three populations could not be shown to differ significantly ($p>0.05$).

The California sea otter population is located close to industrial activities. High levels of organic xenobiotics have been documented in the mid-latitudes of the northern hemisphere and reflect extensive use and production of these chemicals in these densely populated areas (Tanabe 1988; Bacon et al. 1992; Norstrom and Muir 1994). Otter populations at Adak and Amchitka were chosen for comparative study because of the extreme remoteness and presumably pristine nature of the western Aleutian Islands. Thus, the relatively high ∑PCB levels in otters from the Aleutians are surprising.

There are two potential sources of PCBs to the islands of Adak and Amchitka: (1) local contamination sources (point-source input), and/or (2) atmospheric and oceanic currents which supply the Aleutian Islands. Both islands are located approximately 2,000 miles from the Alaskan mainland and 1,000 miles from the Kamchatka Peninsula of Russia, along the Pacific Ocean and Bering Sea division. Adak and Amchitka have a history of limited post-industrial revolution human activity, primarily serving as military bases during and since World War II. Portions of these islands are currently "restricted" because of the presence of explosives and chemicals, including PCBs. Therefore, the source of PCBs to Adak and Amchitka sea otters could be derived from local military activities.

Organochlorine pesticides

In contrast with PCBs, ∑DDT (p,p'-DDT+p,p'-DDE+p,p'-DDD) levels were highest in California sea otters (see Figure 1). Levels of ∑DDT in California otters (850 μg/kg) are significantly different ($p<0.05$) than those for Aleutian otters (40 μg/kg) and Southeast Alaska (1 μg/kg). Relatively high ∑DDT levels reported for California sea otters most likely reflect the extensive use and production of DDT in California during the 1950s through the early 1970s (MacGregor 1976; U.S. Fish and Wildlife Service 1993).

∑DDT levels reported for California sea otters are not exceptionally high when compared to environmental levels in the literature. DeLong et al. (1973) associated ∑DDT levels in blubber of 820 ppm with premature births in California sea lions, and LeBoeuf and Bonnell (1971) reported extraordinary concentrations of DDT (911 mg/g wet weight) in blubber from the same species. Studies involving mink, however, have not conclusively demonstrated extreme reproductive effects related to DDT exposure. Minks exposed to large doses of DDT did not experience significant decreases in the number of whelps (Jensen et al. 1977).

Levels of Chlordane are very low in sea otters from both California and Alaska (see Figure 1); the levels are highest in California sea otters, then Aleutian, and lowest in the Southeast Alaskan sea otters.

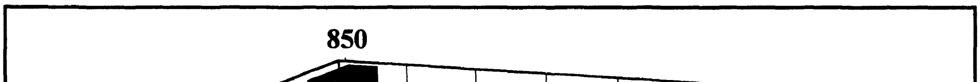
Polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans

Unlike PCBs or DDTs, dioxin and furan congeners occurred at very low to undetectable levels in otters from all three regions (see Figure 1). Levels of dioxin and furans were not significantly different between otters in California and the Aleutian islands ($p>0.05$). The Southeast Alaskan sea otter population was not included in statistical comparison since extremely low or undetectable levels of PCDDs and PCDFs are reported. These results are consistent with data showing that PCDDs and PCDFs are distributed differently than other organic contaminants in marine mammal samples from the Canadian Arctic (Norstrom et al. 1990).

Polychlorinated terphenyls

The mean PCT level in otters from California was about 1.3 times (46 μg/kg dry weight) that in the Aleutian Islands (35 μg/kg), however, these levels were not statistically significant ($p>0.05$) (see Figure 1). PCTs were not measured in the Southeast Alaska sea otters. Possible sources of PCTs to the environment involve either atmospheric/oceanic transport and/or point-source contamination. Risebrough et al. (1990) speculated that the source of PCTs in Winter Quarters Bay was local machine shops located at the military facility or machine shops on ships. Furthermore, de Lappe et al. (1989) associated PCT residues in San Diego Bay with local shipyards, and Gallagher et al. (1993) associated PCTs with a suspected outfall site in Chesapeake Bay.

Similar PCT levels in otters from California and the Aleutian Islands indicate similar atmospheric deposition to each environment, comparable point-source input, or a combination of the two factors. Similar PCT/∑PCB and PCT/∑Chlordane ratios indicate an atmospheric source of PCTs to California and the Aleutian Islands.



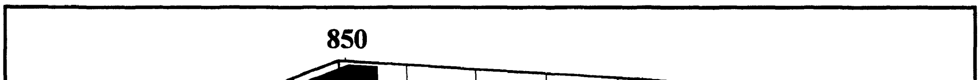


Figure 1. Levels of PCTs, ∑PCB, ∑DDT, and ∑Chlordane in sea otter liver tissue from California and Alaska, collected in 1988-1992.

Yet the islands of Adak and Amchitka have a history of military presence and PCTs have been associated with a military base (Risebrough et al. 1990); therefore, exposure at these islands could be local. The central California coast has substantial ship traffic, and since PCTs have been associated with shipyards (de Lappe et al. 1989), the source of PCTs to the central California coast could be related to shipping activities.

Conclusion

Though ΣPCBs are not significantly different among otter populations in Adak and Amchitka compared with California, they are still of concern to both California and Aleutian populations. Firstly, reproductive problems and reduced kit survival in minks have been correlated with PCB exposure at environmental levels. (Platanow and Karstad 1973; Aulerich and Ringer 1977; Jensen et al. 1977; Bleavins et al. 1980). Secondly, comparing PCB levels in Aleutian otters with those in California may be misleading because the possibility exists that the introduction of these compounds is comparatively recent to the Aleutian environment as opposed to California. Their introduction to the Aleutians may be so recent that population effects have not been fully recognized. Recent ecological data suggests that high pre-weaning pup mortality accounts for the impaired growth rate of the California sea otter population (Riedman et al. 1994). Furthermore, while sea otter populations in the Aleutian Islands appear healthy and thriving, Monson (unpublished data) has noted a high rate of pup mortality at Amchitka.

Lastly, in addition to PCBs, sea otters from both California and the Aleutian Islands had detectable levels of many other organochlorines which could be acting synergistically to impair the health of these otter populations. Synergistic effects of PCB exposure with compounds such as HCB and dieldrin, accompanied by environmental stresses (e.g., severe cold or food limitations) are documented in mink (Bleavins et al. 1984; Wren et al. 1987; Cobb et al. 1994).

We have shown that sea otters are valuable in the study of contaminants for several reasons. They are (when compared to other marine mammals) relatively sedentary, and tend to reflect localized contamination. As high level predators they tend to biomagnify ambient contamination, making detection easier. Their role as a "keystone species," and their relationship to mink (a species very sensitive to environmental contaminants) make the sea otter a species worthy of study as a bio-indicator.

Acknowledgments

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The Risk of Disease and Threats to the Wild Population

Nancy J. Thomas and
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The growth of the southern sea otter population has been steady, but slow in comparison to Alaskan subspecies, and range expansion in California has faltered. Slower growth is occurring in California despite birth rates comparable to those in Alaska, so biologists have reasoned that mortality is hindering the growth of the California population (Riedman and Estes 1990; see Estes et al., this issue). In order to investigate this issue, research efforts have been directed toward identifying the causes of death in southern sea otters.

Several major causes of mortality in the southern population were recognized in the past and are currently being addressed. These include protections from overharvesting and accidental entanglements in fishing gear, as well as oil spill prevention and contingencies. Still to date, the problem of slow population growth and expansion persists.

The California Department of Fish and Game has studied sea otter mortality since 1968. A salvage network, maintained through the cooperation of State and Federal agencies and scientific institutions, verified beach-cast carcasses and examined them to estimate the causes of death. By 1989 nearly 1700 dead sea otters had been documented (see Table 1; Ames et al. 1983, unpublished data; Riedman and Estes 1990). Substantial mortality from net drownings was identified and the prevalence of trauma from predators, shooting, fighting and mating activities were documented. Pup abandonment and a variety of miscellaneous conditions and diseases were recorded. Since 1992, laboratory diagnostic efforts at the National Wildlife Health Center (NWHC), Madison, Wisconsin, supplemented the stranding network's activities in California, so that knowledge about the causes of mortality has been further refined. It is these recent perspectives on the causes of mortality in the southern sea otter that are outlined here, along with consideration of their implications for sea otters and the Pacific marine ecosystem.

Causes of mortality

Since 1992 approximately 50 southern sea otter carcasses per year were examined at the NWHC as part of a 5 year intensive necropsy study. Carcasses were selected for the NWHC study on the basis of good post mortem condition from the approximately 110 to 160 carcasses found per year in California. At the NWHC, microscopic examination supplemented gross examination of the carcasses and a variety of laboratory techniques in bacteriology, virology, parasitology, and toxicology were conducted to arrive at a diagnosis. By this means a greater proportion of the animals with inapparent causes of death were diagnosed. Only a preliminary analysis of the 1992-95 data has been done, but some interesting patterns are emerging from the 195 cases studied (and additional samples have been collected through 1996).

The proportionate causes of mortality identified at the NWHC bore similarities to past data but also had interesting differences (see Figure 1). Various parasitic, fungal, or bacterial diseases caused the deaths of 38.5% of the sea otters examined at the NWHC. Twenty percent died from traumatic injuries. Another 10% were emaciated at death and no specific cause for their debility could be identified. Miscellaneous conditions, such as neoplasia, or gastrointestinal or urinary obstructions, accounted for 13% of the mortality. In 18.5% of the animals no cause of death could be ascertained.

Trauma		18.9%
shark attack	12.0%	
gunshot	4.6%	
mating	2.3%	
Fishing net/line		4.6%
Dependent animals		16.5%
Natural causes		4.0%
Undetermined		56.0%

Table 1. Sea otter mortalities from 1968-1989 (n=1,680), taken from Ames 1983 and Riedman and Estes 1990.

Traumatic causes, emaciation and a variety of miscellaneous conditions were similar to those described in sea otters in the past. Ames summarized the causes and distribution of traumatic injuries in sea otters examined from 1968 to 1989 (as presented in Riedman and Estes 1990). The most frequently identified cause of trauma in the past was shark attack (Ames and Morejohn 1980); the shark-bitten sea otters were collected throughout the range but the largest proportion were found north of Point Sur. In the recent study shark attack was also the most frequently diagnosed source of trauma (7% of all mortality, n=14), and more than 70% of the shark-bitten sea otters were found north of Point Sur. In the past, gunshot injuries were documented predominately south of Cambria. Ames speculated that the frequency of shark attacks in the northern extent of the range and gunshot mortalities in the south may have an impact on range expansion (as presented in Riedman and Estes 1990). Gunshot was diagnosed in 4% (n=8) of the sea otters in the recent study but these cases were equally distributed between the range south of Cambria and north of Point Sur.

Infectious disease

The high frequency of infectious diseases (38.5%, n=75) was unexpected. Many of these diseases were reported but uncommon in the past. Peritonitis induced by acanthocephalan parasites (see below) was the diagnosis for 14% (n=27) of the sea otters examined at the NWHC, comprising the single most fre-

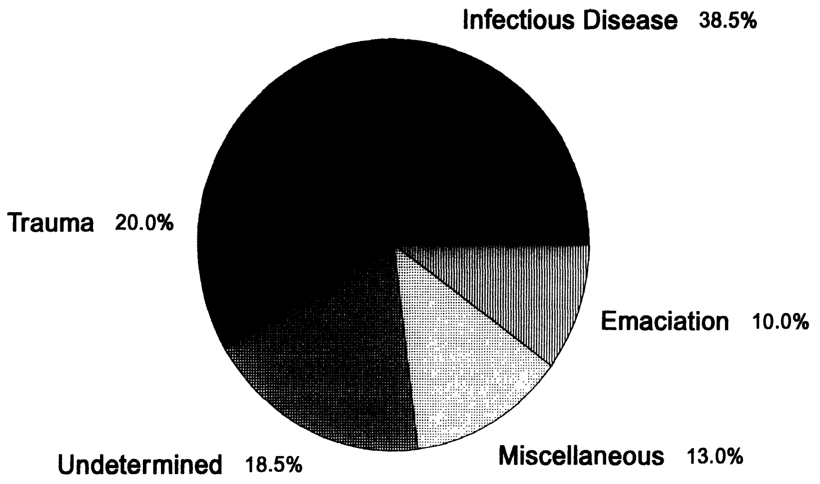

Figure 1. Causes of mortality in southern sea otters from 1992-1995 (n=195).

quent cause of death, as well as the most frequent infectious disease. Most (67%, n=18) cases of acanthocephalan peritonitis occurred in pups or juvenile sea otters. Peritonitis occurs when larval acanthocephalan parasites that reside in the intestine aberrantly migrate through the intestinal wall allowing bacteria to infect the abdominal cavity. Additionally, in many of these cases, thousands of acanthocephalans were embedded in the intestinal wall, and there was profuse bloody enteritis. The parasite causing this condition, *Polymorphus* spp., belongs to one of two genera of acanthocephalans found in southern sea otters (there is a current taxonomic dispute on the *Polymorphus* species identification). The other, *Corynosoma enhydri,* was found frequently but caused no detectable deleterious effects. Acanthocephalans are transmitted to sea otters through invertebrate intermediate hosts. The spectrum of invertebrate hosts of *Polymorphus* spp. is unknown. *Polymorphus* spp. were reported in small numbers (2-206 per otter) in 10% of the southern sea otters examined by Hennessy and Morejohn (1977). Both the prevalence and intensity of *Polymorphus* spp. infections appear substantially greater in recent years.

Protozoal encephalitis was the cause of death in 8.5% (n=17) of the sea otters examined at the NWHC. This is the first report of this organism or disease in sea otters. Most (88%, n=15) of the affected otters were adults or subadults. Otters with encephalitis had no gross evidence of the condition but, microscopically, inflammation in the brain was associated with intermediate stages of protozoal parasites. The characterization of this disease syndrome was confounded by the fact that the protozoan *(Toxoplasma gondii)* was isolated from the brains of sea otters with and without encephalitis. Immunohistochemical tests indicated that a second protozoan was present in some of the cases, suggesting that two agents may be involved. In each year of the recent study, encephalitis cases were restricted to the spring and summer. The means of transmission of these agents to sea otters is unknown. The typical infectious stage, the oocyst, of *T. gondii* is shed in the feces of a species-specific definitive host, the cat. Intermediate stages of several protozoan agents are found in animal tissues and may also be directly infectious if ingested. The intermediate stage of *T. gondii* is found in a wide variety of vertebrates including humans world wide, but serious illness from the infection is sporadic. Illness is more common in the very young, aged, or as a complication of impaired immune function.

Eight cases of coccidioidomycosis (4% of all mortality), a systemic infection caused by the fungus, *Coccidioides immitis,* were diagnosed from 1992-95 (Thomas et al. 1996). Only one case had been reported previously, in 1976 (Cornell et al. 1979); this may be an emerging problem. The affected sea otters were adult or subadult. All 8 sea otters, and the prior case in 1976, were found at the southern end of the range at San Luis Obispo County. The disease, also known as San Joaquin Valley fever, is endemic in certain arid regions of the Southwest U.S., notably the Central Valley of California. This fungus grows in soil to form arthrospores that produce disease when inhaled by susceptible individuals. Coccidioidomycosis most often manifests itself in the respiratory tract, but many organs, including the brain, may be affected. A wide variety of species, including humans, are susceptible to coccidioidomycosis. The results of exposure vary, depending on both species and individual factors, from no ill effects to death. In all sea otter cases the infection was widely disseminated to affect multiple organs.

The deaths of 12% (n=23) of the otters were attributed to various bacterial infections. The affected sea otters were all adult or subadult. Bacterial infections were manifested primarily as pneumonia, heart valve infection, abscess or septicemia. The origins of infection were likely to be inhalation or traumatic injuries, but were inapparent in most cases. Bacterial infections occurred as individual cases with no apparent links among them, so direct transmission between sea otters was unlikely. The most frequently isolated bacteria were different strains and species of *Streptococcus,* but the agents varied widely and mixed infections in the same individual were common.

Significance of disease

The implications of the recent necropsy results appear complex. Past mortality surveys suggested that the influences of "natural" (that is, not directly human-inflicted) mortality might be significant (Ames et al. 1983). The preliminary data presented here corroborate that mortality from natural causes, specifically infectious diseases, is occurring at a high rate. Disease mortality is not only frequent but some diseases appear to be on the rise while others are newly reported. Several of the diseases are predominately affecting prime age, breeding adults. Taken in total, the findings regarding infectious disease mortality appear to bear some disturbing implications for sea otters. The immediate questions are whether this frequency is truly unusual and whether it is remediable.

In comparison to endangered terrestrial top-level predators, these results are unusual, and, at the moment, there is no comparable data available for other, more vigorous sea otter populations. The NWHC is carrying out similar mortality studies on gray wolves (*Canis lupus*) in the Great Lakes Region and for the red wolf (*Canis rufus*) reintroduction program. In these terrestrial species the greatest proportion of mortality (55% for gray wolves and 42% for red wolves) is accidentally or intentionally human-inflicted by shooting, trapping, poisoning, or vehicle trauma. Infectious diseases cause a relatively minor proportion of the mortality in these species, at a rate of 9% in gray wolves and 8% in red wolves.

The question of whether the sea otter's disease mortality has a remedy is not readily answered in our current state of knowledge. Missing details about the transmission cycles of the more frequently encountered diseases may provide the keys to effective control measures. Before focusing on the transmission cycles of individual diseases, it may be useful to consider the underlying significance of a high rate of infectious disease from a broad perspective. In order to exhibit a high frequency and variety of infectious disease mortality, are southern sea otters highly vulnerable to many diseases or are they undergoing high rates of exposure?

A state of general susceptibility is suggested by the variety of infections encountered in sea otters. Unusual vulnerability is also suggested by the fact that otter deaths are repeatedly attributed to diseases that are expected to cause only sporadic mortality in other species. Generalized vulnerability to infections implies that immune function is ineffective. Although assessing and understanding the exact mechanisms of immune function impairment is complicated, in general, immunologic defects may be congenital or have a genetic basis, or arise from certain viral infections, environmental toxins, or malnutrition.

The factors that affect the rates of infectious disease exposure in sea otters differ among the different diseases encountered. The potential sources of the disease agents and means of exposure differ, as do the reasons why an apparent increase or emergence might be taking place. Exposure rates may be linked to population density for certain diseases but density-independent for others. Identification of the key factors that affect exposure and the significance of each disease in relationship to population dynamics will be important distinctions to make if we are to arrive at effective mortality-reduction strategies.

Polymorphus spp.

Over the last 5 years the prevalence and intensity of *Polymorphus* spp. infections in otters and the frequency of extraintestinal migration of acanthocephala has increased. In order to understand this increase in deleterious *Polymorphus* spp. infections in sea otters, we need to examine the predator-prey dynamics of the definitive host species (sea birds) and probable intermediate hosts (crabs). It is this predator-prey relationship that the *Polymorphus* spp. depend upon for completion of the life cycle. Preliminary data suggest that *Emerita analoga* and *Blepharipoda* sp. of crab are two intermediate hosts for this acanthocephalan, however there may be more invertebrate species involved. Birds such as gulls, scoters and sea ducks prey upon infected crabs and harbor the egg-producing adult *Polymorphus* spp. The eggs are deposited with feces into the environment. Sea otters can become infected with the *Polymorphus* spp., by eating the infected crabs, however, the sea otter is a dead-end host and no egg-producing acanthocephalans have been found. Abiotic or biotic factors that influence the population densities and predator-prey interactions of the bird, invertebrate hosts, or sea otters could affect the risk of infection in sea otters.

There are three broad facets to examine to determine why increases may be occurring in otters.

(1) Factors impacting bird populations. A larger infected bird population (as higher prevalence and/or higher acanthocephalan burdens) could be due to factors that caused an increase in certain sea bird populations, or factors inducing bird aggregations (for example, beach utilization by humans, distribution and management of landfills, aggregation of crab species or other food items).

(2) Factors influencing intermediate host populations. A larger infected intermediate host community (as increased prevalence and/or larval acanthocephalan burdens) could be related to an increase in infected birds that contaminate the beaches with feces and acanthocephalan eggs. Add to this the complicating fact that some acanthocephala species alter their intermediate host's behavior, thereby increasing the risk of predation so that birds prey disproportionately on infected crabs. Certain conditions such as a rise in water temperature and phytoplankton proliferation can favor the survival of crab offspring, thereby providing a larger intermediate host community for potential infection.

(3) Factors affecting the sea otter population. A food habit change by some sea otters could increase their predation on infected crustaceans. This prey selection might occur if more optimal prey items were unavailable or they may be taken by inexperienced or incapacitated sea otters that seek easier prey such as *Emerita* and *Blepharipoda*.

A combination of two or more of the above factors may be interacting to cause an increase in the parasitism of the sea otter. Given the complexity of the ecology influencing the predator-prey dynamics, several species of invertebrates and vertebrates need to be considered in order to identify the factors influencing the sea otter's *Polymorphus* spp. infections.

Eradicating *Polymorphus* spp. from the normal bird and invertebrate hosts would be impossible. However, a reversal of the sea otter's current mortality trend from *Polymorphus* spp. is feasible if we could reduce the prevalence of this parasite. Effective management strategies may be to disperse the responsible bird species or increase the availability of alternate uninfected prey species to sea otters. However, before such management strategies can be developed basic questions must be answered, including which crab species act as intermediate hosts, which beaches have highly infected intermediate or definitive host communities, and what factors correlate with the distribution of infected sea otters.

Toxoplasma gondii

The source of *Toxoplasma gondii* exposure to sea otters is most likely oocysts from cat feces. Transmission by preying on infected intermediate hosts is unlikely because only warm-blooded animals have been reported as intermediate hosts, and the sea otter is reported only rarely to eat birds. Sea otters could ingest oocysts in water contaminated with cat feces through run-off from beach soils, or possibly by eating filter feeding invertebrates that are transporting oocysts in their alimentary tracts. If oocysts are entering the water via sewage effluent, the contamination of the marine ecosystem could be much greater than just that from beach or adjacent shoreline run-off. This would be an important source to identify and is potentially manageable. To investigate the connection between sewage disposal and otter exposure, the survivability of oocysts through local sewage treatment systems and the viability of oocysts in sea water should be evaluated. Temporal studies could determine whether peaks in contamination correlate with seasonal patterns of disease. Laboratory studies could be designed to investigate whether crabs and other crustaceans could act as phoretic agents in the transmission of *T. gondii* to sea otters. Vertical transmission of *T. gondii* from mother to offspring can cause abortion in sheep, goats, and humans. Toxoplasmosis in the very young sea otter may be under-represented in post mortem sampling because carcasses of fetuses or neonates are less likely to be found (Riedman and Estes 1990).

Toxoplasmosis, may be more than the other diseases, raises concern about the sea otter's general ability to resist disease. Infection with *T. gondii* does not always cause disease in the host. Disease and death more often occurs in animals that are vulnerable due to age, immuno-compromise, or in species (e.g., Australian marsupials or arboreal New World monkeys) that evolved isolated from felids or their feces. Subadult and adult sea otters, not just the young or aged, had protozoal encephalitis, so age does not appear to be an important factor. Sea otter immune competence has not been well studied, so its status to date is unknown. Regarding the species experience with *T. gondii,* there is little information. Most reports of *T. gondii* infection of marine mammals are from captive animals. However, reports of this protozoan causing disease in the wild northern fur seal (*Callorhinus ursinus*) (Holshuh et al. 1985), the West Indian manatee (*Trichechus manatus*) (Buergelt and Bonde 1983) and five species of dolphin (Di Guardo et al. 1995) indicate that other wild marine mammals are also exposed to *T. gondii.* Regardless of whether resistance to toxoplasmosis is an individual or species phenomenon, we can evaluate the sea otter's degree of susceptibility by evaluating the frequency of exposure. Such studies would help discern if most otters are exposed to *T. gondii* and resist disease or if the few that are exposed break with disease.

Coccidioides immitis

The occurrence of infections by the soil-associated fungus, *Coccidioides immitis*, in the marine environment is puzzling. The means of transmission to sea otters presumably is similar to that in other species, specifically by inhalation of airborne arthrospores. Recurrent dry winds from the east may disperse the spores from the soil in endemic sites around the city of San Luis Obispo or in the San Joaquin Valley. Coccidioidal spores survive and may even grow in salt water, so the accumulation of spores in the marine environment has also been postulated (Dzawachiszwili et al. 1964). The apparent increase in prevalence of coccidioidomycosis in sea otters since 1992 may be due to the application of more sensitive diagnostic methods, but it coincides with a marked increase in human cases in 1991 to 1993. The human outbreak was tentatively attributed to unusual weather and environmental conditions rather than human-related factors, so occurrence in sea otters may lend support to that hypothesis. Prospects for control of this disease in sea otters are not promising, but knowledge about coccidioidomycosis prevalence has predictive value that may particularly apply to the population in the southern extent of range.

Many of the infectious diseases of concern in southern sea otters are not species specific; they may affect other marine mammals, sea birds and human beings. Some of the epizootiologic factors that potentially play a role in promoting disease emergence or frequency in otters also may have broad effects in the marine environment. The successful recovery of the southern sea otter population is of immediate concern, but obstacles to their recovery could have wider implications for the marine ecosystem. The sea otter could be a sensitive indicator of the health of the Pacific near-shore marine ecosystem.

Conclusions and recommendations

The following series of recommendations are proposed as means to assess the impact and implications that have arisen from investigations into sea otter mortality.

(1) *Complete the 5 year intensive necropsy study.* The 5 year database under development at the NWHC will be completed at the end of 1996. The recent health and mortality data have undergone only preliminary evaluation. Further analyses for age, gender, and temporal and geographic differences are necessary to distinguish significant patterns and compare with previous data.

(2) *Analyze the population data.* Further examination of recent necropsy data by integration with other mortality and demographic data may provide valuable insight into the significance of disease and the role of mortality in population recovery. The relationship between the various infectious disease conditions and population dynamics needs to be explored. Identification of mortality factors with the greatest potential for limiting population growth should guide research priorities.

(3) *Identify key factors in the disease cycles.* The key to reducing mor-

tality in the southern sea otter may be found by identifying critical points at which important disease transmission cycles can be interrupted by knowledge-based management strategies. The greatest gaps involve the transmission of acanthocephalan peritonitis and protozoal encephalitis. Elucidation of disease cycles may also provide a measure of the role of human intervention or human responsibility in the emergence of sea otter disease.

(4) *Develop comparative data.* Comparison with similar data from a more vigorous sea otter population would provide another means to assess the significance of mortality and various mortality factors to the southern sea otter population. The best comparison would include both the causes and rates of mortality.

(5) *Continue mortality monitoring.* Continuation of a mortality monitoring system is the basis for identifying trends, investigating, and interpreting the patterns in sea otter mortality. The activities of the sea otter stranding network are critical to that end.

(6) *Evaluate the rates of disease exposure.* By comparing the rates of disease exposure to the rates of disease mortality we can evaluate the general vulnerability of the southern sea otter to infectious disease.

(7) *Assess immune function.* Evaluation of the adequacy of the wild southern sea otter's immune function is a means to investigate whether generalized vulnerability to infectious disease exists.

(8) *Assess environmental contaminant exposure.* Otter tissue analyses for organochlorine compounds and heavy metals were discontinued in 1980. No serious threats to sea otter health were revealed in these early analyses. Evaluation of recent environmental contaminant burdens in sea otters in correlation with mortality factors is a means to assess the current role of toxic contaminants in sea otter disease vulnerability, debility, or neoplasia.

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Overview of the Legislative Mandates and the Agencies Responsible for Implementation of Southern Sea Otter Protection Under the Endangered Species Act

Jamie Rappaport Clark

When Congress passed the Endangered Species Act (ESA; 16 U.S.C. 1531 et seq.) in 1973, it set clear public policy that we were to act to prevent the destruction of nature's diversity. The ESA is one of the most comprehensive pieces of environmental legislation ever enacted by Congress, calling for the conservation of threatened and endangered species, and, more importantly, the ecosystems upon which they depend. The ESA also established a strong leadership role for the federal government in the conservation of species at risk of extinction. To accomplish the objectives of the ESA, Congress envisioned a network of international, national, federal, state, and private organizations working toward common goals. Coordination among these agencies and organizations, private individuals, and major land users is perhaps the most essential ingredient for the successful implementation of the ESA.

Fundamentally, the ESA is habitat-oriented. It seeks to conserve "the ecosystems upon which endangered species and threatened species depend." This orientation has been embraced by the federal government in its increased efforts to address listing and recovery on a multi-species, ecosystem-wide basis wherever possible. It is doubtful that anyone anticipated in 1973 what a large, complex, and sometimes contentious job this would become. However, there has been a continuing underlying commitment throughout society and its various institutions that the goal of protecting species is important for the Nation.

Under the ESA, the Secretary of the Interior, acting through the U.S. Fish and Wildlife Service (FWS), oversees the protection and conservation of fish, wildlife, and plants found to be in serious jeopardy. The Secretary of Commerce, acting through the National Marine Fisheries Service (NMFS), is given similar authority for most marine life. NMFS is generally responsible for most marine species, except birds, and the FWS is generally responsible for birds and terrestrial and freshwater species. The southern sea otter is an exception, however, and along with the West Indian manatee and sea turtles (on land), remains under the FWS's jurisdiction.

Protecting endangered and threatened species and restoring them to a secure status in the wild is the primary objective of the endangered species program. Endangered species responsibilities for both NMFS and FWS include listing, reclassifying, and delisting species; providing biological opinions to federal agencies on activities that may affect listed species; enforcing species protection; providing technical assistance to the states and other non-federal applicants in the development and implementation of habitat conservation plans; overseeing recovery activities for listed species; providing for the protection of important habitat; and providing grants to states to assist with their endangered species conservation efforts.

Listing

The listing process is one of the basic functions performed by the FWS in carrying out its responsibilities under the ESA. Species are classified as either endangered or threatened. The ESA defines endangered species as any species in danger of extinction throughout all or a significant portion of its range. Threatened species include any species likely to become endangered in the foreseeable future throughout all or a significant portion of its range. A species is added to the list when its survival is found to be threatened by one or more of the following factors: the present or threatened destruction, modification, or curtailment of the species' habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; the inadequacy of existing regulatory mechanisms; or other natural or man-made factors affecting the species' continued existence.

In order to list a species, the FWS must follow a strict legal process known as a "rulemaking procedure." Changes or additions to the list are accomplished through a rulemaking process involving publishing a proposal in the Federal Register, allowing opportunity for public comment (including holding public hearings) and adoption of a final determination. To ensure that all potentially interested parties are made aware of the proposal, the FWS issues news releases, conducts special mailings, and directly informs the scientific community and other federal and state agencies. A final rule listing the species as endangered or threatened must be published within one year of the proposal, with a possible six-month extension to gather more data if there is scientific conflict, or the proposal must be withdrawn. The ESA provides that listing decisions must be based solely on the basis of the best scientific and commercial data available.

The southern sea otter was listed as threatened in 1977 due to its small population and limited distribution, and to threats from oil spills, pollution, and competition with humans. A major oil spill from a tanker in the vicinity of the southern sea otter is considered the most serious threat (see Bonnell et al., this issue). Drowning in gill and trammel nets was a significant cause of sea otter mortality in the past until the State of California banned the use of these nets within the otter's range (see Wendell, this issue).

Recovery

Recovery, the ultimate purpose of the endangered species program, is the process by which the decline of an endangered or threatened species is arrested or reversed, or threats to its survival neutralized so that its long-term survival in nature can be ensured. This process requires the

Photograph by Jeff Foott

maintenance of secure, self-sustaining wild populations of species with the minimum necessary investment of resources. The primary objectives of the recovery program, while working in close cooperation with our partners, are to: (1) identify those ecosystems and species that face the highest degree of threats; (2) determine tasks necessary to reduce or eliminate the threats; (3) apply the limited resources available to the highest priority recovery tasks; and (4) reclassify and delist species as appropriate.

The first step in the recovery process is to initiate recovery actions needed to stop the species' decline. At the same time, species-specific recovery goals are developed and species information and management needs are identified and ranked in terms of their relative importance. This information is typically set forth in a recovery plan. A recovery plan delineates, justifies, and schedules the research and management actions necessary to support recovery of the species, including those that are likely to permit the reclassification or delisting of the species. These plans are comprehensive documents that identify all known recovery actions for a species and associated costs by all cooperating partners. They serve as blueprints for private, federal, and state cooperation in the implementation of recovery actions.

A recovery plan for the southern sea otter was developed and finalized by the FWS in 1982. This plan identified as the primary management actions the need to minimize the risk of tanker accidents and minimize the possible effects of oil spills. Establishing one or more sea otter colonies outside their present range was identified as the primary task since population growth was minimal. In the mid-1980s, however, federal and state biologists determined that the accidental entanglement and drowning of sea otters in gill and trammel nets was the likely factor limiting population growth. Since then the state of California has effectively restricted within sea otter habitat the use of nets that accidentally drown sea otters, and population growth has subsequently resumed. In 1989, the FWS reconstituted the Southern Sea Otter Recovery Team (SSORT) and requested the team to review and recommend changes to the existing recovery plan. In 1996, the FWS released a draft revised recovery plan for public review (cited in this issue as US Fish and Wildlife Service 1996). The main objective of this revised plan is to "passively allow" the currently increasing sea otter population to continue to grow to a size that otters will likely persist following any natural or human-caused disturbance (see Benz, Recovery Plan, this issue).

Coordination among federal, state, and local agencies, conservation organizations, appropriate experts, and major land users is a key ingredient for effectively implementing a recovery program. The recovery planning process is designed to allow potentially affected segments of the public to participate in planning and implementation and to provide comments to facilitate coordination between groups. Such coordination allows the special local knowledge of affected communities to be fully considered. This understanding can serve to reduce or eliminate human use conflicts with listed species and their habitats. The FWS recognizes that public support is vital to long-term survival and recovery of threatened and endangered species, and the public is invited to provide comments on draft recovery plans.

The revised recovery plan was drafted by the SSORT. Leading the team is Dr. Douglas DeMaster, NMFS; Dr. David Duggins, University of Washington; Dr. James Estes, National Biological Survey; Dr. Michael Martin, California Department of Fish and Game; Dr. Katherine Ralls, National Zoological Park; Dr. Calos Robles, California State University, Los Angeles; Dr. Ulysses Seal, Veterans Administration Medical Center; and Dr. Donald Siniff, University of Minnesota. Carl Benz from the FWS's Ventura Field Office serves as the SSORT's Executive Secretary. The SSORT also received assistance from technical consultants, experts in science, and representatives from other federal and state agencies and non-government interests, among them, environmental groups, fishing interests, and the oil industry. In addition, the FWS held public hearings on the revised plan to solicit additional comments.

The tools available for recovery of listed species are numerous and may include reintroduction of species into formerly occupied habitat, land acquisition, captive propagation, habitat restoration and protection, population assessments, research, law enforcement, and technical assistance for landowners and public education. These efforts must allow time for an endangered species to respond biologically to the activities and protective efforts implemented on its behalf. Recovery activities conducted by the FWS and its partners include: defining threats through research on biological requirements, managing threats through habitat protection and restoration, and achieving a stable or upward population trend for an endangered species.

Development and implementation of a translocation plan was considered one of the FWS's primary recovery tasks in the 1982 southern sea otter recovery plan. By establishing a second breeding colony of sea otters into unoccupied habitat within their historic range, the FWS's goal was to reduce the probability that more than a small portion of the otter population could be decimated by a single natural or human-caused disaster. Translocation and subsequent management actions required Congress to broaden the FWS's authority. Pub. Law 99-625 was enacted in 1986 allowing the FWS to develop and implement a translocation plan. This law required the FWS to establish a management zone surrounding the translocation zone. Any sea otters found in this management zone were to be removed using non-lethal means and returned either to the translocation zone or the range of the parent population. In addition, any sea otters found in the management zone would be considered to be a part of an experimental population, and, as such, would not be afforded the same stringent protection as otters found in the parent population. A total of 139 sea otters were translocated from central California to San Nicolas Island in the Channel Islands between 1987 and 1990 (see Benz, Attempts to Reintroduce, this issue).

Ban on takings and other statutory prohibitions

Once a species is officially listed as endangered or threatened, it is given full legal protection under the ESA. The ESA prohibits the import, export, or interstate or foreign sale of listed animals and plants (including their parts and products) without a special permit. Section 9 of the ESA prohibits specified acts which directly or indirectly harm listed species. Unlike other major ESA provisions, section 9 restrictions apply not only to federal agencies and permittees, but to all persons subject to United States' jurisdiction. Also, the protection afforded to plants differs from the protection extended to fish and wildlife, and provisions applicable to endangered species differ from those applied to threatened species. Section 9 of the Act prohibits "taking" of endangered animals. Taking is defined to include "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in such conduct." Also prohibited by section 9 is the transportation and sale of protected wildlife and the importation or exportation of any listed endangered species or products derived from them.

There is a significant legal distinction between threatened and endangered species with respect to the ESA's prohibitions. This difference provides a measure of administrative flexibility. The ESA's general prohibitions are applied by statute for endangered species but not for threatened species. ESA section 4(d), however, requires the issuance of regulations deemed necessary and advisable to provide for the conservation of threatened species. Regulations may be as restrictive as the section 9 prohibition for endangered species, or may be less restrictive if the full range of protection is not believed to be needed.

The ESA provides for broad statutory exceptions to the taking prohibitions. Provisions of section 7 allow for the issuance of an incidental take statement to federal agencies, which must identify measures to minimize the impact of incidental take on the species. Section 10 outlines a permit process to allow the FWS to grant the permits for taking of listed species. These permits are granted in accordance with the terms of an approved habitat conservation plan, and must meet a number of requirements to mitigate effects on listed species. Taken together, these provisions are designed to allow economic development that will not "appreciably reduce the likelihood of the survival and recovery of species in the wild."

Cooperation with the states/territories

State agencies often possess scientific data and valuable expertise on the status and distribution of endangered, threatened, and candidate species. State agencies, because of their authorities and their close working relationships with local governments and landowners, are in a unique position to assist the FWS in implementing all aspects of the ESA. Section 6 of the ESA authorizes the FWS to enter into cooperative agreements with states that establish and maintain a program for the conservation of endangered and threatened species. Under section 6, the FWS provides 75 percent of project funds (90 percent when two or more states cooperate on the same species) that can be used for tasks covering all phases of ESA implementation, from candidate conservation to recovery and delisting. Although chiefly a federal undertaking, the sea otter translocation was accomplished under State of California permits as well as federal permits and with the assistance of biologists and law enforcement personnel from both the FWS and the California Department of Fish and Game.

Conclusion

As Mollie H. Beattie, former Director of the FWS, said, "Our fate and that of our economy are linked to natural systems. We cannot eliminate species and expect our own to survive. I would have liked to have stopped the ridicule about the conservation of snails, lichens, and fungi and instead move the debate to which ecosystems are the most recoverable and how we can save them, making room for them and ourselves."

The southern sea otter's struggle for survival has helped raise public awareness of the plight of endangered species in the United States and worldwide. The ESA obliges us to maintain our commitment to conserve imperiled species for the benefit of future generations as well as our own. The ESA has been responsible for improving populations of declining species throughout the United States and has served as a model for international conservation efforts. Implementation of the ESA, by building stronger partnerships with states, local governments, private industry, and individuals; by exercising greater administrative flexibility to minimize socioeconomic effects; and by reducing delay and uncertainty for states, governments, private industry, and individuals will preserve ecosystem health and sustainability into the future.

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Evaluating Attempts to Reintroduce Sea Otters Along the California Coastline

Carl Benz

The U.S. Fish and Wildlife Service (FWS) listed the southern sea otter, *Enhydra lutris nereis*, as threatened in 1977 under the Endangered Species Act of 1973 (ESA) after consideration of its small population size, greatly reduced range, and the increasing risk from oil spills. The ESA requires the FWS to develop and implement recovery plans for listed species. The recovery plan for the southern sea otter was initiated in 1979 and approved in February 1982. During development of this plan, the Marine Mammal Commission recommended the FWS consider the ultimate need for zonal management of sea otters and fisheries in California (see Wendell, this issue). Contemporary issues addressed in the plan were the (1) taxonomic status of the California population, (2) effects of sea otters on shellfish fisheries, and (3) effects of outer continental shelf oil development, production, and transportation.

At the time the plan was being developed, available information suggested that the sea otter population was not growing, and some biologists believed that the population was declining. This information greatly influenced the recommendation that translocating southern sea otters to a new site within their historical range was necessary to enhance population growth and distribution. At the time the otter was listed, and when the recovery plan was approved, the magnitude of the threat to sea otters from incidental entanglement and drowning in commercial halibut gill and trammel nets was not recognized. It was not until later that an analysis of data obtained between 1982 and 1984 indicated that an average of 80 sea otters per year, or about 6 percent of the population per year, had been accidentally drowned in commercial fishing nets. State and federal biologists concluded that these losses were large enough to have prevented the population from growing from the early 1970s to the mid-1980s (Wendell et al. 1985).

The goals cited in the 1982 recovery plan were to: (1) minimize the risk of oil spills from tanker accidents and other sources; (2) establish at least one additional breeding colony outside the present range; (3) minimize vandalism, harassment and incidental take; (4) monitor recovery progress; and (5) integrate the recovery plan into plans of local coastal community governments. This paper reviews the events leading up to the translocation, the process guiding it and the results. The success of these efforts is also evaluated.

Translocation as a recovery goal

In 1982, the FWS considered oil spills as the primary threat to the continued existence of the sea otter. Although some management efforts were underway to improve capture techniques and rehabilitation of oiled sea otters, the FWS believed that these tools alone would be ineffective in protecting the sea otter population in the event of a large oil spill. The recovery plan also recognized that the sea otter population had not significantly changed in size since 1973. The California Department of Fish and Game (CDFG) proposed that the population was at carrying capacity, which accounted for the reduced growth rate (Miller 1980); the FWS suggested that the problem was due to high mortality. Because the ability to protect sea otters from oil once a spill occurs is inadequate and the sea otter population was not increasing in size, the FWS determined that translocating sea otters was the most effective and reasonable recovery action. The purpose of translocation was to enhance range expansion by establishing a new colony within the historic range which would ultimately result in a larger continuous distribution and population size. Translocation was viewed as paramount to achieving recovery and establishing a data base for identifying the optimal sustainable population level for the southern sea otter as required under the Marine Mammal Protection Act (MMPA) of 1972 (see Baur et al.; DeMaster et al., this issue).

Translocations of listed species are authorized under the terms of section 10(j) of the ESA, which addresses the establishment of experimental populations. However, prior to the amendments of 1988, there were no provisions under the MMPA to translocate sea otters for conservation purposes. To resolve this dilemma, in 1986 Congress passed legislation (Pub. Law. 99-625) that specifically authorized and set the ground rules for translocation of California sea otters. The key points were that by regulation the FWS must develop a translocation plan that includes the following: (1) the number, age and sex of sea otters to be translocated; (2) the methods for capture, translocation, release, monitoring, and protection; (3) the specification of a "translocation zone" where otters will be relocated, plus a buffer area, with formal section 7 consultations (see Clark, this issue) required in the zone for all Federal activities except those that are defense-related; (4) the specification of a "management zone," which would surround the translocation zone but would not include the existing sea otter range or adjacent areas where expansion is needed for the species recovery; (5) measures to isolate and contain the experimental population, backed up by an adequate funding mechanism; (6) a detailed description of the relationship of translocation to the status of the species and to future section 7 determinations relative to either the parent population or the experimental population; and (7) a provision that the plan should be administered in cooperation with the state. The management zone is to be kept free of sea otters using non-lethal means, no formal section 7 consultations will be required (only conferences), and incidental take of sea otters resulting from otherwise legal activities will not be a violation of the ESA or MMPA.

In June 1984, the FWS published a Notice of Intent to prepare an Environmental Impact Statement (EIS) and proposed rule for establishing an experimental population of southern sea otters. All major interest groups, including environmental organizations, the oil industry, and sport and commercial fisheries interests, were represented at the public scoping meetings. As suggested by the Council of Environmental Quality, the FWS established an interagency project review team made up of representatives from the CDFG, Marine Mammal Commission, and Minerals Management Service. Their assistance was solicited to participate in the scoping process and consult with the FWS in the preparation of the EIS. All meetings of the interagency project review team provided for the participation and involvement of interested members of the public. The FWS also established an Expert Review Team consisting of recognized experts in the fields of benthic ecology, marine mammal biology, marine resource economics, physical oceanography, and the physics and chemistry of pollutant transport, to provide impartial comments to the FWS on major sections of the EIS.

The draft EIS considered all data and information available up to the time of its publication and evaluated potential effects of the action on the marine environment, the southern sea otter, and the socioeconomics in the area. The draft EIS was made available for public review, and public hearings were held in Brookings, Oregon, and Monterey and Ventura, California. After release of the draft EIS, the President signed into effect on November 7, 1986 Pub. Law 99-625, which broadened the FWS's authorization for long-term management of an experimental population. Therefore, the final EIS was prepared to meet the requirements of Pub. Law 99-625, which was the sole authority under which translocation was proposed. The final EIS also incorporated comments received during the public review period and the final rule (50 C.F.R. Part 17) that governed the translocation under the new legislative authority (Pub. Law 99-625).

Implementing the translocation

Authority for implementing the translocation was given to the FWS pursuant to Pub. Law 99-625. The FWS requested and received assistance and cooperation from the CDFG for implementation of the translocation plan. Under an existing Cooperative Agreement, the FWS and the CDFG signed a Memorandum of Understanding addressing respective responsibilities, funding, contingency plans to handle funding, containment and logistical problems, and other items.

The FWS had lead responsibility for all management and research activities. The sea otter containment program, law enforcement, sea otter protection, review of Federal activities that may have affected the colony, and issuance of all permits related to the translocation was handled by the FWS's Fish and Wildlife Enhancement Program. Assistance in translocation activities and subsequent research was provided by the FWS's Research Group.

The Research Group designed and conducted the translocation of sea otters, including all aspects of capture, holding, veterinarian care, transport, release and baseline ecological studies. These studies were continued after the translocation and included an assessment of the effect(s) of translocation on the parent population.

The successful implementation of the translocation plan depended on an adequate commitment of funding and

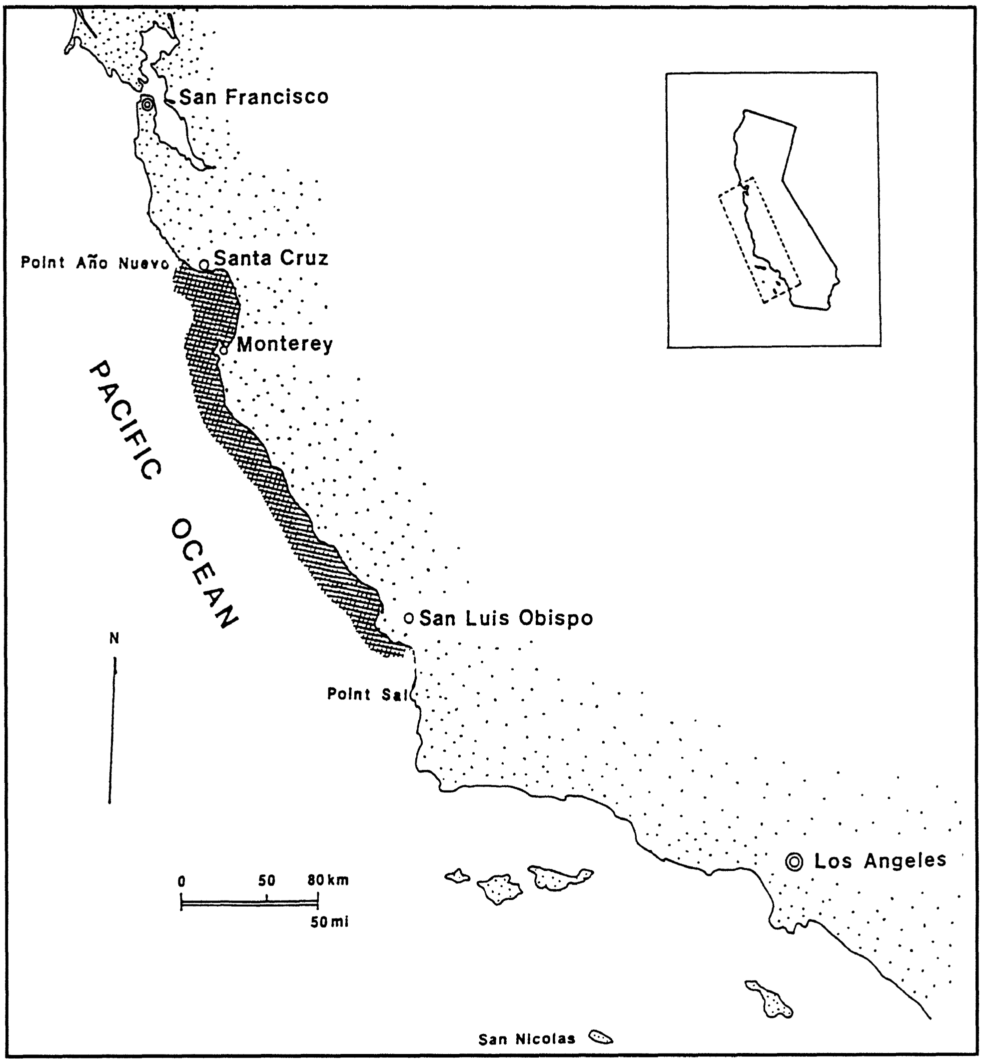


Figure 1. The Channel Islands, roughly 70 miles (110 km) west of Los Angeles and significantly south of the current sea otter habitat, were chosen as the translocation site.

Category	Year 1	Year 2	Year 3	Year 4	Years 5-9	TOTAL
Total Captured	124	104	23	1	0	252
Released at Capture	50	43	8	0	0	101
Died During Translocation	4	2	1	1	0	8
Released During Translocation	1	3	0	0	0	4
Translocated to SNI	69	56	14	0	0	139

Table 1. Summary of total number of sea otters captured for translocation to San Nicolas Island, August 1987-August 1996.

personnel. The FWS requested funding through its normal congressional appropriations process. Federal funding was administered through the FWS's Fish and Wildlife Enhancement Program. Monies were distributed to management and research. The CDFG received operational funds through the ESA section 6 (grant-in-aid to states) program.

On August 11, 1987, the FWS published a final rule (50 C.F.R. 17.84) to establish an experimental population of the southern sea otter at San Nicolas Island, located about 70 miles west of Los Angeles (see Figure 1). The final rule established the boundaries of a translocation zone to which otters would be translocated and given protection similar to that of the source population, and a management zone to be maintained otter-free by removing sea otters by non-lethal means. The intent of designating a management zone was to limit sea otter impacts on existing fisheries and other marine resources (see Wendell, this issue). The management zone encompasses the entire southern California bight south of Point Conception, except the translocation zone surrounding San Nicolas Island (see Figure 2). Between 1987 and 1990, 139 sea otters (31 males, 108 females; 63 adults, 76 juveniles) were translocated to San Nicolas Island from the mainland population. No sea otters have been translocated to San Nicolas Island since 1990 (see Table 1).

Results of translocation efforts

The purposes of the translocation program were to: (1) implement a primary recovery action for a Federally listed threatened species; (2) obtain data for assessing capture, transport, reintroduction, and containment techniques; (3) gather data on population dynamics, ecological relationships of sea otters and their near-shore community; and (4) determine the effects on the donor population of removing sea otters for translocation.

Reproduction at San Nicolas Island was first observed during the initial translocation year, when two pups were observed. As of September 1996, 40 pups are known to have been born at San Nicolas Island, of which 6 died as pups, 11 were weaned, and the fate of 23 remains undetermined. Pre-weaning mortality within the mainland population in California is about 40 percent. In past years, a higher mortality rate (66%) has been documented at San Nicolas Island. This rate may be misleadingly high because the number of identifiable otters at the island has declined due to tag loss, thus tracking individual otters is almost impossible.

Of the 139 sea otters translocated to San Nicolas Island, the fate of 61 is known. Thirty-seven sea otters are known to have returned at least once to the range of the parent population. Eleven have been captured in the designated management zone and released in the range of the mainland population. Three were found dead at San Nicolas Island shortly after they were released. Three have been found dead in the management zone. At least seven are believed to have taken up residency at the island. The status of the remaining sea otters is unknown. The cause of the continuing attrition of tagged animals over the past several years remains unknown. The question of the final fate of the original animals becomes less relevant as many of the translocated animals are reaching the expected natural lifespan of a sea otter in the wild.

The lack of growth of the colony has been attributed primarily to poor recruitment and, to a lesser extent, emigration and adult mortality. Although reproduction has been observed every year, the fate of most pups is not known and few have been observed to be over 135 days of age. Food resources are abundant and should be readily accessible to young sea otters. Predation is not known as a factor, although great white sharks do occur in the area. Incidental take in the lobster fishery may contribute to the lack of population growth. Hundreds of pots are set around San Nicolas Island each season, and the opening into the pots may be large enough for a small to medium sized sea otter to enter. Entrapment of sea otters in lobster pots has not been documented at San Nicolas Island. However, a dead sea otter was found near Santa Cruz, Santa Cruz County, in an abandoned crab pot with similar dimensions to those of lobster pots. A few records exist of Alaskan sea otters entrapped in crab pots. With only five to six pups born each year and high pre-weaning mortality, incidental take and natural mortality factors could threaten the long-term persistence of the population.

Zonal management

The containment program is intended to prevent sea otters from colonizing the management zone through a cooperative effort between the FWS and the CDFG. The containment operation, as outlined in the translocation plan and the FWS's Containment Plan, consists of three interrelated and interdependent activities: surveillance of the management zone, the capture of sea otters in the management zone, and the relocation of captured sea otters to the range of the mainland population.

Captured sea otters are released in the northern portion of the mainland population range to reduce the likelihood of returning to the management zone. Early in the containment program, sea otters captured in the management zone were released at their original capture location along the mainland. Travel time to the more remote locations was lengthy; therefore, the

FWS and CDFG decided to reduce stress to captured sea otters by releasing them in accessible locations. To avoid releasing a disoriented female sea otter into an area that may contain aggressive male sea otters, the decision was made to release female sea otters into female dominated areas. Male sea otters were released into male dominated areas.

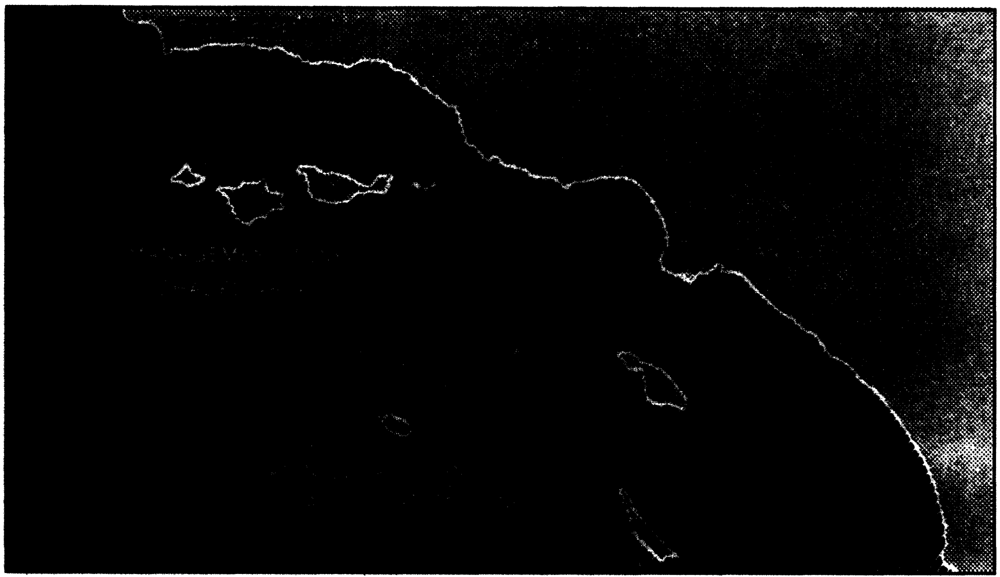


Figure 2. San Nicolas Island translocation and management zone.

Since 1987, 20 independent sea otters (10 males, 10 females) and 4 dependent pups have been captured in the management zone. Eleven of the otters had been translocated to San Nicolas Island, four had apparently swam down from the mainland range, and nine either swam down from the mainland range or were born in the management zone or at San Nicolas Island. Two of the sea otters mentioned above were captured and removed from the management zone twice.

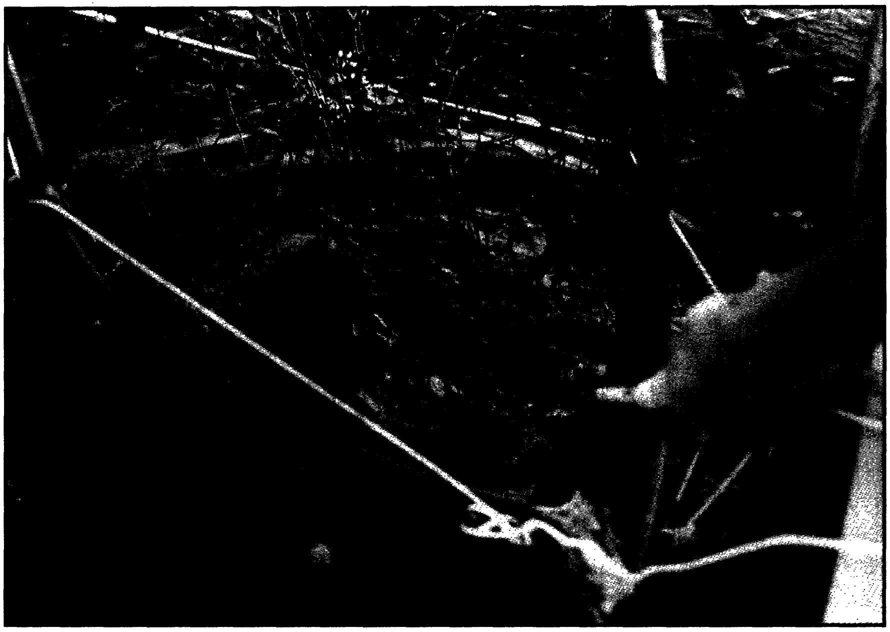
In February 1993, all sea otter containment activities were halted following the deaths of 2 independent otters shortly after their release at a predetermined site at the northern end of the range. Concern was raised whether sea otter containment activities were being conducted by non-lethal means. An evaluation of containment techniques proved to be inconclusive, and recommendations were made to continue sea otter containment activities with minor modifications that included improved post-release monitoring activities. However, subsequent sea otter containment activities were limited due to the unavailability of funds within both the FWS and the CDFG. No sea otters have been removed from the management zone since early 1993.

Evaluation of the success of the translocation effort

From 1980 until the initial translocation period, the southern sea otter recovery program was considered a high priority FWS program based upon the combination of species vulnerability and political controversy associated with recovery needs. The southern sea otter population size was small and growth was minimal, at best. Small populations are vulnerable to a variety of perturbations. For the sea otter, the impact associated with oil spills was the greatest threat, and there were increasing risks of oil spills from expected increases in offshore oil and gas development and from increases in coastal tanker traffic. Recovery of the sea otter also would most likely conflict with both shellfish fisheries and oil related activities. Consequently, implementation of the translocation effort involved diverse political attention and a highly regulated process.

By the end of the first year of translocation, the rate of dispersal of sea otters from the island was higher than expected and appeared problematic to establishing a colony. However, a review of another reintroduction effort, that to Washington State, provided insight that translocation to San Nicolas Island may ultimately be successful. For the Washington effort, 59 Alaskan sea otters were released during 1969 and 1970. At least 16 of 29 sea otters released in 1969 died within 2 weeks. No data are available on deaths after the second release of 30 sea otters in 1970. Very few data on this reintroduction were recorded until 1977, when FWS biologists conducted the first intensive survey. At that time only 19 sea otters, including 4 pups, were observed. However, population surveys during the 1980s suggested that the Washington population was slowly increasing. Total counts in 1981, 1983, 1985, and 1987 were 36, 52, 65, and 94, respectively. The high count for the 1996 survey was 430 sea otters indicating that the population is established and should continue to grow. These observations suggest that post-translocation dispersal of sea otters occurs and can reduce the population to a very small founder population. However, if left undisturbed and protected, the founder population can become established. The major differences between the Washington population and the San Nicolas Island population are the active lobster trap fishery at the island and the presence of the management zone. Although sea otters found within the management zone were to be removed, as many were, there are no data suggesting that sea otter containment activities create a sink effect on the island population. The dynamics of the management zone surrounding San Nicolas Island is not believed to negate a comparison to the Washington State example.

At the end of the third year of the post translocation phase of the program (August 1993), the FWS evaluated the status of the translocated San Nicolas colony, containment efforts and failure criteria. Population surveys confirmed that the numbers of sea otters were continually declining, and therefore, the program as a whole should be evaluated. The FWS could not identify any deterministic causes as to why the San Nicolas Island colony was not increasing as expected, and therefore took a "wait and see" position while continuing monitoring efforts.



Sea otter being captured for translocation to San Nicolas Island. Photograph provided by Carl Benz, U.S. Fish and Wildlife Service.

Over subsequent years, bi-monthly sea otter counts at San Nicolas Island ranged between 12-16 independent otters. The population has not changed significantly in size. A small colony (12-16 individuals) of southern sea otters still persists at San Nicolas Island. Based on the results of the translocation effort in Washington State, additional years of monitoring are necessary to determine if the San Nicolas Island colony will become established.

From a management perspective, the translocation as implemented failed to achieve the anticipated results for expediting recovery. As discussed in the EIS, the FWS expected that most of the sea otters would remain at the island and the colony would become established in about 5 years. Carrying capacity was expected to be reached after a minimum of about 10 to 15 years.

Actual implementation of the translocation plan was significantly hampered because any change to translocation procedures required a change in the enacting federal regulation and concurrence by the California Fish and Game Commission. At times this process exceeded 6 months. The requirement of Pub. Law 99-625 that the fine procedural details be defined in federal regulation prohibited the FWS from efficiently, and therefore possibly more effectively, implementing the translocation.

Lessons from the translocation

The political and public scrutiny of daily events, often resulted in a "small picture" mentality focusing attention on issues that in the "big picture" were insignificant. The deaths of three animals translocated to the island, the ability to track animals that disperse from the island, and the fate of missing animals are examples that required extensive attention by the FWS (briefing commissions, drafting reports, etc.). This attention tended to discredit the program, compromising the public's understanding and support. In turn, this influenced decisions on how the translocation efforts would proceed. In the big picture, and over time, these issues were not significant, but the impacts on the program were.

As the translocation program advanced, the political-environmental conditions changed. The FWS faced ever increasing budget demands to list and recover endangered species, the number of listed species more than doubled between 1980 and 1990. The amount of recovery dollars available did not keep pace with recovery need. New high-profile controversies of a much broader scale surfaced demanding attention by the FWS (e.g., spotted owl, delta smelt, California gnatcatcher). The CDFG was experiencing similar problems.

At the same time, our knowledge base regarding the southern sea otter and recovery needs grew. The restrictions on entangle net fishing virtually eliminated the accidental drowning of sea otters, and growth of the mainland population resumed. The ability to establish a colony was proving to be difficult and the translocation effort was expensive. Furthermore, the *Exxon Valdez* oil spill in 1989 demonstrated that oil spills can affect a large area, the effects of which can persist over a prolonged period, and the ability to protect sea otters once a spill occurs is insignificant.

In combination, these changing conditions affected the FWS's focus and priority on the translocation effort. The purpose of the translocation initially was to establish a sea otter colony and to obtain information valued for the long-term management of sea otters. As evidence grew indicating that the colony would not easily become established, most consideration seemed to shift away from the success of the entire project. In light of our present understanding of the recovery needs for the southern sea otter, including an analysis of oil spill risk to coastal California and the mainland population growth rate, it appears that recovery will likely be achieved by the natural growth of the mainland population and the San Nicolas Island colony will not contribute significantly. Attention and efforts therefore have shifted to other higher priority needs, with only minimal attention remaining at San Nicolas Island.

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The Second Southern Sea Otter Recovery Plan

Carl Benz

The original recovery plan for the southern sea otter (*Enhydra lutris nereis*) was developed and approved by the U.S. Fish and Wildlife Service (FWS) in 1982. This plan identified the need to minimize the risk of tanker accidents, but recognizing the inevitable possibility of an oil spill, it also recognized the need to minimize oil spill effects. The primary recovery method outlined was increasing the sea otter range to decrease the probability that a oil spill would impact a large percentage of the sea otters' habitat. At that time population growth was minimal and translocation was considered necessary to expedite range expansion and population growth.

The original recovery plan did not quantify criteria for delisting. The stated objective was to restore the southern sea otter to a non-threatened status and to maintain this population at its optimum sustainable level. Optimum sustainable population (OSP) level for the southern sea otter was considered to be a population size and distribution greater than the listing threshold under the Endangered Species Act (ESA). In the original recovery plan, the FWS recommended that delisting be considered when the population is stable or increasing at sustainable rates in a large enough area of their original habitat that only a small proportion of the population would be decimated by any single natural or man-caused catastrophe.

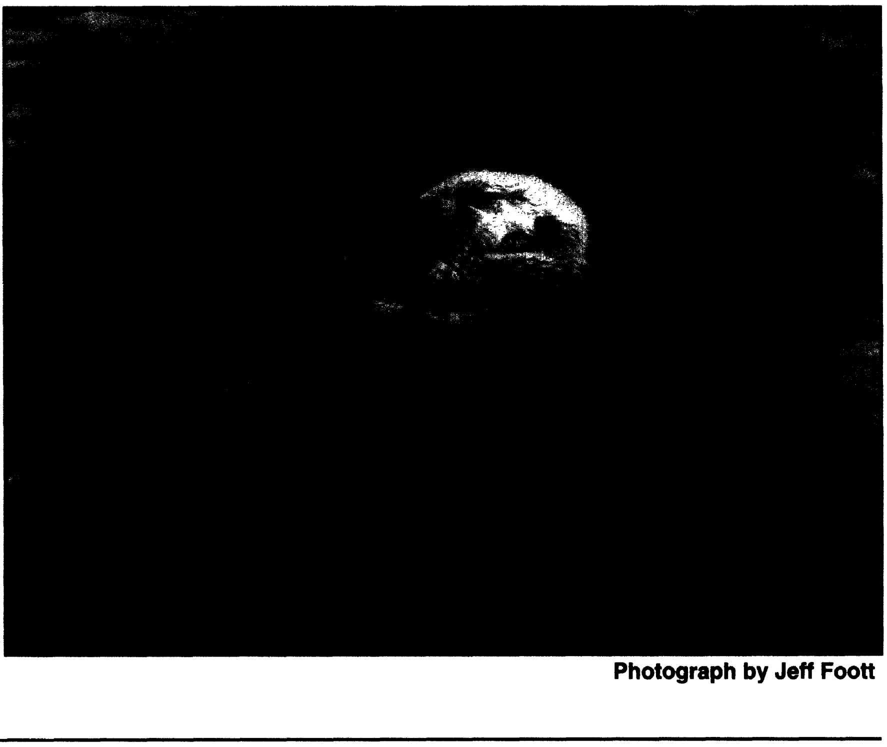
In 1989, the FWS established a Southern Sea Otter Recovery Team (SSORT) and requested that the they review the 1982 plan, determine if it still satisfactorily addressed the recovery needs for the southern sea otter, and decide whether the plan should be updated or revised. The SSORT recommended revision. In 1993, the FWS established a team of Technical Consultants (representatives from State agencies, environmental organizations, commercial and recreational fishing interests, and the oil industry) to provide information and comments to the SSORT.

The Recovery Team's approach

Because the likelihood of sea otters persisting in California is currently determined primarily by whether or not a major oil spill occurs within the otter's range, two approaches have been identified that would lead to delisting the southern sea otter under the ESA: (1) increasing the range of otters in California to reduce the risk of a single oil spill event reducing the otter population below a level that is viable, and (2) decreasing the risk to otters that a major oil spill event will occur within their range. In developing criteria to delist under the ESA, the SSORT used an approach that incorporates elements of population viability analyses, which, when applied to this population of sea otters, required information on the probability of an oil spill occurring within the range of the southern sea otter, the likelihood of a spill of a particular size occurring, and the expected level of mortality associated with an oil spill event of a particular size. The FWS responded to the SSORT's request to contract experts to provide this information (U.S. Fish and Wildlife Service 1996, Appendix B and C; see Bonnell et al., this issue). The SSORT acknowledges that the data provided are equivocal. The FWS in determining a course of action to recover the southern sea otter, therefore, used as its standard a "preponderance of evidence" rather than the standards normally applied in publishing scientific literature.

Assumptions

The southern sea otter population was listed as threatened in 1977 because (1) its population size was small and distribution limited, and (2) the remaining habitat and population was potentially jeopardized by oil spills, pollution, and competition with humans (42 Federal Register 2965). A major spill of oil from a tanker in the waters in the vicinity of the range of the southern sea otter is still considered the most serious potential threat to the species. Approximately six spills greater than 1,000 barrels that are likely to impact the southern sea otter have been estimated to occur over the next 30 years (see Bonnell et al., this issue). The expected number of otters that will die as a result of contact with oil following a spill is likely to be no less than 50 percent. Rehabilitation of oiled sea otters is expensive, may be detrimental to some individuals, and is of questionable benefit to the population (Estes 1991).



Photograph by Jeff Foott

The 1982 recovery plan identified the need to establish by translocation one or more colonies to enhance range expansion. Three major events have occurred subsequent to the translocation efforts to establish a colony of southern sea otter at San Nicolas Island which alter the need and rationale for that translocation plan. First, state restrictions and closures on gill and trammel nets throughout the range of the southern sea otter has resulted in a subsequent resurgence in population growth (see Wendell, this issue). Second, the Alaskan *Exxon Valdez* oil spill of 1989 confirmed many of the worst fears about the consequences of such events. The spill was uncontrollable and quickly spread over an area greatly exceeding the present range of the sea otter in central California plus that of the translocated colony at San Nicolas Island, and efforts to save and rehabilitate oiled sea otters were of little or no value to the population (see Williams and Williams, this issue). Third, the translocation to San Nicolas Island has been less successful than originally hoped in establishing a viable population (see Benz, Attempts to Reintroduce, this issue). Therefore, the current strategy for recovering the southern sea otter population is to increase the number of sea otters in California, such that following a major oil spill in the waters off central California, the remaining otters will constitute a surviving population. The FWS recommends against additional translocation to accomplish the objective of increasing the range and number of southern sea otters.

Overview of revised recovery plan

The current draft revised southern sea otter recovery plan retains the same primary management actions, but it does not recommend translocation. Sea otter population growth and range expansion will be passive, i.e., not augmented by translocation. Delisting criteria have also been identified: the southern sea otter population should be delisted under the ESA when, based on standard survey counts, the average population level over a three year period exceeds 2,650 animals (U.S. Fish and Wildlife Service 1996).

The minimum population size that can be considered viable is one that is large enough to accommodate adaptive changes and allows the population to be resilient to changes in the environment. A genetically effective population of 500 (Franklin 1980) is considered adequate such that the loss of genetic variation due to small population size is balanced by the gains of mutation. However, the number of individuals in a population required to achieve a genetically effective population size of 500 may be several times greater than 500 individual animals (Frankel and Soulé 1981). Until better information is available, the estimate that 27 percent of the census population reproduces, as proposed by Ralls et al. (1983), will be used. Therefore, an actual minimum viable population of approximately 1,850 sea otters are required to maintain a genetically effective population of 500. The SSORT proposed that this number be used as the threshold population level for endangered status.

The population level at which delisting of the sea otter should occur was based on the modeling efforts referenced earlier (see Bonnell et al., this issue). As many as 800 southern sea otters could contact oil following a 250,000 barrel oil spill event in central California. Because data are not available to precisely predict the level of otter mortality which will occur, the FWS took a conservative approach and assumed that all otters contacted by oil within 21 days of a spill will die. Therefore, to meet the standard that in the event of a major oil spill, the population should not be reduced below the level of 1,850, the southern sea otter population should not be delisted under the ESA until the average population level over a three year period exceeds 2,650. Based on the expected rate of population growth (approximately 5 percent per year), delisting under ESA could occur by 1999.

The following are the primary tasks identified in the draft revised recovery plan: (1) monitor existing and translocated populations; (2) develop and implement a plan to reduce the probability of an oil spill occurring in the sea otter range and a plan to minimize the effects of an oil spill on the otter population, in the event that one occurs; (3) develop and implement plans to reduce or eliminate the incidental take of sea otters and other sources of take in California; and (4) evaluate assumptions used to estimate the population level at which southern sea otters could be considered recovered under the ESA.

What's next

The FWS announced the availability of a draft revised recovery plan for the southern sea otter on June 26, 1996. The public was invited to provide comments on the draft revised plan. In addition, two public hearings were held in Monterey, California on July 18, 1996. The public comment period was opened for 90 days, closing on September 24, 1996.

Public and agency comments will be reviewed by the FWS. The SSORT and Technical Consultants will be asked to review and address technical questions and comments. The SSORT will ultimately be responsible for providing the FWS with their recommendations for a final document. Scheduling of meetings with the SSORT and Technical Consultants, and completion of the final Southern Sea Otter (Revised) Recovery Plan, depend upon FWS budget and priorities established for fiscal year 1997.

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Assessing the Threat of Oil Spills to Southern Sea Otters

Michael L. Bonnell, R. Glenn Ford,
and Allan J. Brody

The California population of sea otters was listed as threatened under the Endangered Species Act in 1977 due to its small size, isolated and limited geographic range, and vulnerability to oil spills (Federal Register 42:2965-2968). Today the population, although increasing slowly, is still small, and its range has not appreciably increased. Consequently, its vulnerability to oil spills remains high.

The threat of oil spills to the California population has been underscored in recent years by three vessel accidents with release of oil or bunker fuel that had the potential of contacting sea otters. These were a leaking barge towed south from San Francisco (the *Apex Houston*, February 1986), the explosion of a tanker off San Francisco (the T/V *Puerto Rican*, October 1984), and a barge taking on water off Cape San Martin (the *Spartan 120*, May 1983). Additionally, there have been two near-groundings of deep-draft vessels along the central California coast (the *Sealift Pacific* in April 1984 and the T/V *Austin* in April 1980); both groundings were narrowly averted after the vessels drifted to within a few kilometers of the sea otter range.

The *Exxon Valdez* oil spill clearly demonstrated the sensitivity of sea otters to oiling. Approximately 11,000,000 gallons (42,000,000 liters) of crude oil were released into Prince William Sound when the vessel grounded in March 1989; subsequent winds carried oil southwestward to contaminate waters off the Kenai and Alaska peninsulas and Kodiak Island. Best estimates of mortality range from 2,650 (Garrott et al. 1993) to 3,905 sea otters (DeGange et al. 1994).

The California population of sea otters has, thus far, escaped significant impact by oil spills. However, most researchers (including the authors) believe that a spill is inevitable and therefore planning a response is essential. Based on spills that have occurred, the greatest threat to sea otters is from tanker and barge accidents. Spills at oil production platforms and pipelines are far less likely to have a major impact on sea otters because of the location of platforms in relation to the sea otter range and the typical pattern of winds and currents along the coast.

The magnitude of the threat can only be estimated as the probability of future events based on the occurrence of past events. To extrapolate from historical data, the assumption must be made that improvements in tanker safety, navigation, and construction are inconsequential. This assumption is probably suspect; clearly such improvements should have a beneficial effect and be encouraged. However, safety improvements may not be enough; given the sophisticated tracking/warning systems in place, the *Exxon Valdez* spill in Prince William Sound should never have occurred.

Historical data can be used to credibly estimate the number and size of spills that might occur over a given time period. Although small spills occur much more often than large ones, most are at marine terminals during transfer of oil or refined product. Consequently, small spills are less likely to reach sea otters and, when they do, result in limited mortality. In contrast, most spills from vessels at sea are large (many thousands of gallons).

While the probability of such accidents is low, large spills along the open coast can have large impacts. Substantial threat to sea otters exists from all vessels in transit past the central California coast due to quantities of bunker fuel. Tankers, which account for about 28% of all vessel traffic to or from ports in San Francisco Bay, pose an exceptional threat; relative to other vessels, tanker spills may be five time as large (U.S. Coast Guard 1996).

Learning from history

From analysis of tanker oil spills in U.S. waters between 1974 and 1989, it has been estimated that spills of 1,000 to 100,000 barrels (bbls; 42 gal/bbl) have an occurrence rate of 0.19 per billion bbls transported, and spills greater than 100,000 barrels have an occurrence rate of 0.13 per billion bbls (Minerals Management Service 1994; see Anderson and LaBelle 1990). A reasonable approximation of the quantity of oil and petroleum product transported per year can be obtained from commodity flow statistics for waterborne commerce of the United States, developed by the U. S. Army Corps of Engineers, and import-export statistics compiled by the Bureau of the Census. Using these numbers, the total quantity of oil and petroleum product transported into San Francisco Bay or past the sea otter range in 1989 was 450 million bbls (U. S. Coast Guard 1996). Assuming that the same volume is transported each year, the projected quantity over 10 years is 4.5 billion bbls and, over 30 years, 13.5 billion bbls.

Based on the history of oil spills in U. S. waters and the volume of oil and petroleum product transported, we might expect at least one oil spill of 1,000 bbl or greater in the next 10 year period, and three in the next 30 year period. These are minimum expectations—because each oil spill is an independent event, the occurrence of one oil spill does not diminish the likelihood of subsequent spills. It should be recognized that these spills could theoretically occur anywhere along the tanker route. However, most spills off the Pacific coast in the last 30 years have occurred close to land and particularly as tankers make their approach to port (U. S. Coast Guard 1996).

Modeling contact of sea otters by oil spills

Although we cannot be sure of when or where oil spills will occur, we can use statistical models to examine their potential impact on the sea otter population. This can be done by conducting many computer simulations of oil spill events, with random selection of spill origin, size, and date, followed by examination of the results.

In an analysis of potential impacts of oil spills on the southern sea otter population for the U. S. Fish and Wildlife Service (FWS), Ford and Bonnell (1995) simulated the movement and spread of oil spills using a database of actual winds recorded from the National Oceanic and Atmospheric Administration meteorological buoys and seasonally averaged surface current vectors from a curvilinear grid provided by the Minerals Management Service. Spills of 31,250 to 1,000,000 bbls were simulated, where each spill was represented as a cluster of independently moving points (Lagrangian Elements, or LEs), each representing a portion of the entire spill volume. Spreading was simulated using a random diffusive factor based on the areal extent of oil slicks over time documented in past spills (Ford and Casey 1985). For each size category of oil spill (31,250, 62,500, 125,000, 250,000, 500,000, and 1,000,000 bbls), 200 model runs were conducted, each consisting of 100 LEs. The date (for selection of a time-series of winds) and spill origin were assigned using a random number generator. The position of sea otters was defined using a digital distribution from 1992 data provided by the FWS. The movement of each LE was tracked in 2-hour time steps; contact was scored if an LE passed within 5 km of sea otters. This radius was chosen as an approximation of the areal extent of a 2,500 bbls spill (Ford and Casey 1985). The model was relatively insensitive to this parameter—a 100% increase in size increased number of contacts by only 3.6%.

The number of sea otters contacted by simulated spills of 250,000 bbls (the size of the *Exxon Valdez* spill) at randomly selected locations within 25 nautical miles (nmi; about 46 km) suggests that spills of this size result in greatest contact with sea otters when occurring from the Gulf of the Farallones off San Francisco to about Lopez Point (see Figure 1). This is not surprising given the typical movement of drifting oil in a southeasterly direction and the distribution of sea otters. What is surprising is that spills farther from shore might produce a greater impact than groundings.

To examine this pattern, Ford and Bonnell (1995) conducted simulations of spills evenly spaced along lines orthogonal to shore and extending to a distance of 110 km (about 60 nmi). The results suggested that the greatest number of contacts with sea otters in a 21-day period would typically occur from spills north of the present range and relatively far from shore. The consequences of spills in waters off San Francisco were greatest 60-70 nmi offshore because oil would drift into the center of the range along the Big Sur coast. Off Point Año Nuevo, the number of sea otters contacted remained high for oil spills within about 30 nmi from shore. On other lines farther to the south, spills within 10-20 nmi produced the most contacts. These results are easily understandable considering that oil from spills close to land must be deposited in areas of high density to contact many sea otters. Large spills offshore, especially to the north, can contact a more extensive portion of the range as they drift southeastward with winds and currents.

Not unexpectedly, the number of contacts increased with the size of the simulated spill. However, the relationship of sea otter contacts and spill size proved to be nonlinear. At the 95th or even the 90th percentile (i.e., only 5-10% of model runs resulted in a greater number of contacts), roughly two to three times as many sea otters were contacted by a 1,000,000 bbl spill as by a 31,250 bbl spill despite a 32-fold increase in spill volume. For a 31,250 bbl spill, the 95th and 90th percentile simulation resulted in 552 and 456 sea otters contacts, respectively. The worst case of 200 model runs for a spill of 31,250 bbls resulted in 1,119 sea otter contacts, representing nearly one-half of the existing population. The lesson is that even a relatively small spill of 31,250 bbls can

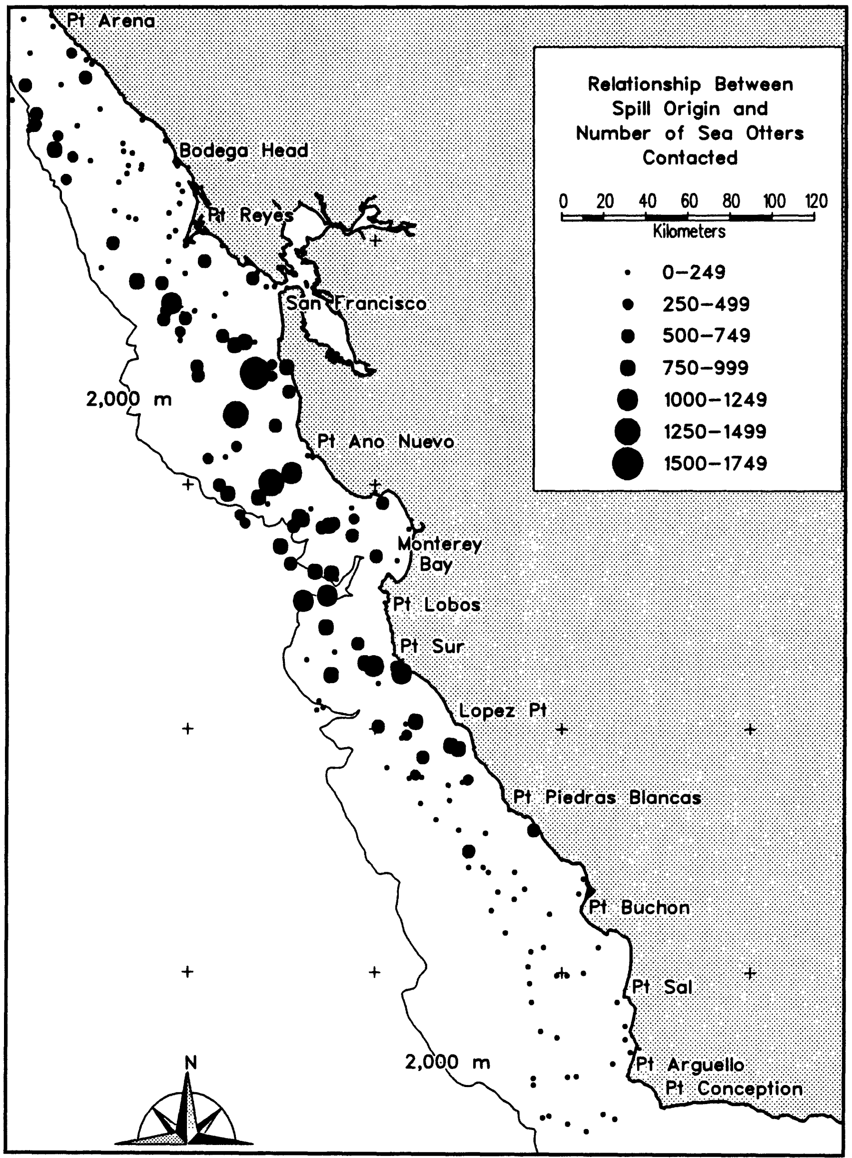

Figure 1. Spill origins scaled according to number of sea otters contacted for 200 simulations of 250,000 bbl spill at randomly selected sites within 25 nmi of land.

cause a major and perhaps irrecoverable impact on the sea otter population.

Mortality of sea otters

Given that a substantial number of sea otters are contacted, what might be the mortality? This is a difficult question to answer because mortality of each individual sea otter is determined by the degree of oiling and this, in turn, is affected by the amount of oil in sea otter habitat and how long it remains. Sea otters may survive initial contact but succumb in following days due to repeated exposure to oil. Working in favor of sea otters is weathering of oil as it drifts, and the opportunity provided for clean-up and use of dispersants.

Many factors influence direct mortality of sea otters once they are contacted by spilled oil. Oil is toxic to sea otters in at least three distinct ways: lung damage from inhaled volatile components, gastrointestinal damage and perhaps systemic toxic effects from oil ingested while grooming, and hypothermia following oiling of pelage. Sea otters dying from oiling may evince all three. However, the basic data needed to construct a mechanistic model of individual sea otter mortality during a spill, which would allow modeling of spill impacts "from the bottom up," simply do not exist. One of the missed opportunities of the *Exxon Valdez* spill was that such data were not collected. In the event of another spill affecting sea otters, such studies should receive highest priority.

The question of mortality has therefore been addressed in perhaps the only way it can—with a statistical analysis. Using data collected following the *Exxon Valdez* spill, Brody et al. (1996) examined the validity of the assumption that the overall toxicity of oil to sea otters should decrease as spilled oil ages, weathers, and spreads. As oil weathers, volatiles evaporate, caustics degrade, and the oil itself becomes diluted. In the absence of other data, they tested the assumption that distance from the spill origin to point of contact with individual sea otters might serve as a reasonable surrogate for detailed data on the state of oil and the degree of exposure—the greater the distance that oil drifted, the less likely that oiled sea otters would die. For nearly 300 sea otters captured in rescue efforts following the spill, a survival rate was calculated as a function of the distance from the spill origin to capture sites along the trajectory of oil. The survival rate function provided a good fit with the data, indicating that no sea otters would survive at the spill origin, about 50% would survive at a distance of 150 km, and survival of sea otters at greater distances would asymptotically approach 100%.

This relationship presumed that survival of captured oiled sea otters is representative of a population of oiled animals observed but not removed from their contaminated habitat. It seems likely that many sea otters left to their fate would additionally have become oiled over time until they ultimately died of toxic effects and hypothermia. Thus, estimates of mortality derived from the relationship should be viewed as minimum values. It is also important to remember that these estimates are of mortality from direct contact with oil; should oil remain and degrade sea otter habitat, additional and long-lasting im-

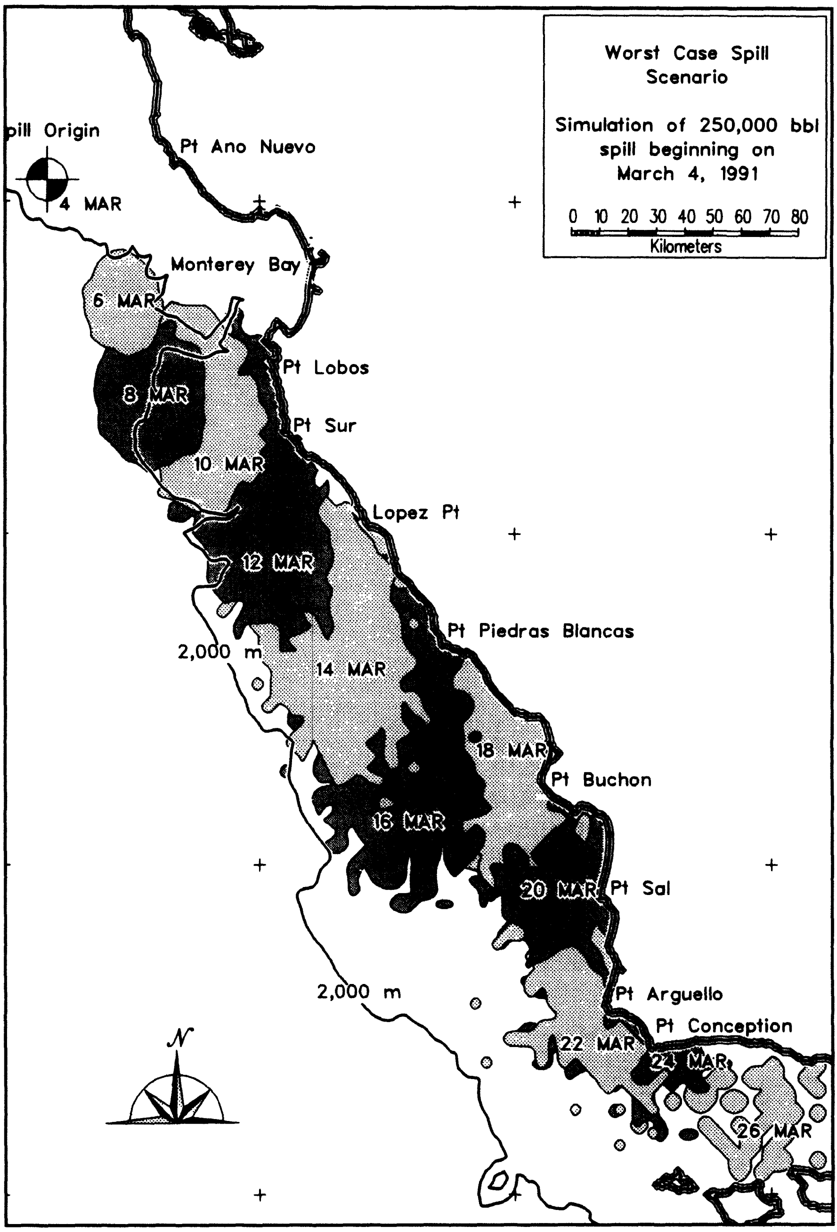

Figure 2. Time-course of movement and spread of oil from the 100th ranking simulation of a 250,000 bbl spill. This simulation resulted in the greatest number of sea otters contacted out of 200 simulations at randomly selected sites within 25 nmi from land.

pacts on the population may result.

Detailed scenarios were produced for the 100th and the 90th percentile contacts of a 250,000 bbl spill (about the size of the *Exxon Valdez*) on the California population. In each of these simulations, 2,500 LEs were tracked to determine distance of drift prior to contact with sea otters. The 100th percentile spill contacted 1,820 sea otters of which 777 ultimately would die using the relationship of Brody et al. (1996; see Figure 2 and Table 1). Unfolding of the spill episode is illustrated by the following time-course. The simulated spill occurred 36 km (19.5 nmi) west of Point Año Nuevo with oil driven by real-time winds recorded from March 4 through 25, 1991. Over a three-week period, northwest winds were interrupted repeatedly by the passage of storms. South and southwest winds associated with low-pressure cells slowed southward movement of the slick and allowed it to move closer to shore. Contact with sea otter habitat first occurred six days following the release when oil beached near Point Lobos. Oil continued to enter sea otter habitat over the next three days under variable west and northwest winds to about 20 knots and resulted in heavy contamination of near-shore waters to about Pfeiffer Point. The main body of the slick resumed its southward drift on day 9 after the spill under northwest winds of 20-30 knots, sparing parts of the sea otter range between Point Sur and Point Lopez. On day 12, south, southwest, and west winds of 20 knots or more again pushed oil toward shore, initially resulting in heavy oiling of sea otter habitat near Point Piedras Blancas. Over the subsequent four days, variable winds kept oil close to shore, first spreading northward to Lopez Point and then southward to Point Sal. By day 17, northwest winds of 15-25 knots resumed and oil was driven southward. Oil not yet beached rounded Point Conception by about day 20, and slicks became increasingly fragmented as oil drifted into the Santa Barbara Channel. In this simulation, mortality was about 37% of the spring 1992 population; in heavily contaminated portions of the coast from Point Lobos to Point Sur, the local population suffered mortality approaching 55%.

Day	Number Contacted	Mortality	Cumulative Contacted	Cumulative Mortality
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	362	202	362	202
7	4	2	366	204
8	277	152	643	356
9	98	45	741	401
10	129	54	870	455
11	9	3	879	458
12	673	245	1552	703
13	48	14	1600	717
14	87	25	1687	742
15	72	19	1759	761
16	25	6	1784	767
17	0	0	1784	767
18	0	0	1784	767
19	36	10	1820	777
20	0	0	1820	777
21	0	0	1820	777

Table 1. Number of sea otters contacted and estimated mortality resulting from 100th percentile worst case scenario of a 250,000 bbl oil spill.

Using the 90th percentile worst case resulted in contact of 881 sea otters and, using the relationship of Brody et al. (1996), resulting in mortality of 456 animals. This spill originated about 36 km (19.5 nmi) northwest of Point Año Nuevo. The simulated spill was driven by real-time winds of August 11 through 31, 1990. Initial contact with sea otters in the vicinity of Point Año Nuevo occurred on the day after release. Over the next two days, oil moved southward along the shore under northwest winds of 15-20 knots. Four to five days following the simulated spill, oil entered Monterey Bay resulting in heavy contamination of near-shore waters in the southern part of the Bay and then moved southward along the Big Sur coast to about Point Lobos. Five to six days after release, oil drifted south in a compact 10 km wide slick contacting sea otters along the Monterey Peninsula to beyond Point Sur. Oil then moved 3-5 km offshore still remaining somewhat compact in the light winds and seas, and next contacted shore in the vicinity of Lopez Point about 13 days after the spill. Under the influence of variable winds from the south and west, oil continued to contact sea otter habitat from Lopez Point to near Point Piedras Blancas until about day 17, and thereafter drifted offshore leaving most of the range south of Point Piedras Blancas untouched.

Conclusions and recommendations

Oil spills may be an unavoidable consequence of tanker transport of oil. Historical data suggest that it might be prudent to prepare for one or more spills of 1,000 to 100,000 bbls in the near future. Spills in this range can have a significant impact on the sea otter population. How can the threat be reduced? The U. S. Coast Guard (1996) states that implementation of the Oil Pollution Act of 1990 (OPA 90) regulations over the next several years is expected to greatly reduce the probability of vessel casualties and associated oil spills. Some lessening of the occurrence rate of oil spills may indeed result; however, it would be unrealistic to hope that OPA 90 regulations will eliminate all threat of large oil spills.

It appears unlikely that the U. S. Coast Guard will achieve, in the near future and with concurrence of the International Maritime Organization, a new Traffic Separation Scheme in and out of San Francisco Bay. Nor will a Shipping Fairway be established along the central California coast. However, this does not mean that tankers must take the most direct route. The Western State Petroleum Association (WSPA; as cited in U. S. Coast Guard 1996) has recommended a stand-off distance of at least 50 nmi in agreement with the State of California. If adhered to by the oil companies and their tankers, this would result in a substantial decrease in risk of oil spills to sea otters.

Based on the results of Ford and Bonnell (1995) it is clear that a change in tanker routing would be the most effective way to reduce potential of impact of oil spills on southern sea otters. The recommended route (see Figure 3) skirts the edge of the one-percent contour for contact with the sea otter range (Ecological Consulting, Inc. 1990; see Saunders, this issue). Small, almost negligible, costs would be incurred by tankers due to extra time at sea. These additional costs pale in comparison to those incurred should a spill occur within these bounds. WSPA and oil companies do not have to wait for mandate from the U. S. Coast Guard—take initiative now and choose the route that best reduces the potential for impact on sea otters.

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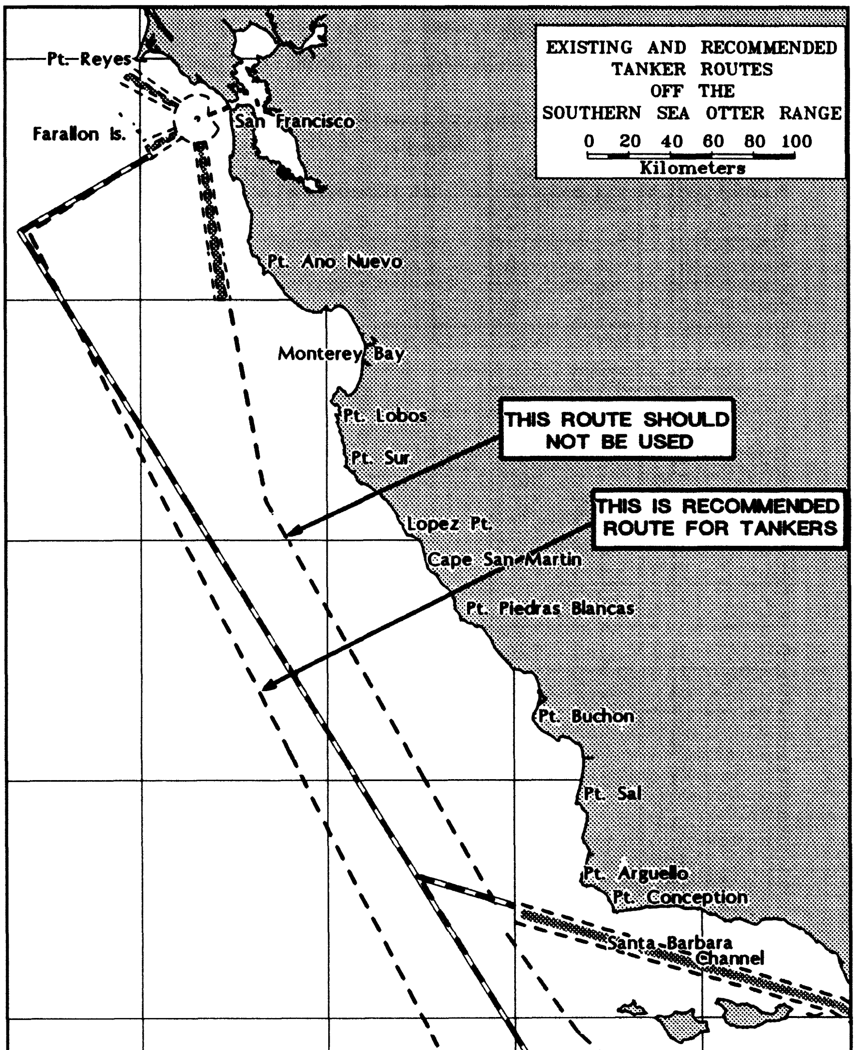

Figure 3. Suggested changes to tanker routes around sea otter habitat.

Does 'Sanctuary' Mean Secure?

Rachel T. Saunders

The Monterey Bay National Marine Sanctuary off central California is the only U.S. marine sanctuary that has a naturally occurring population of sea otters. Indeed, it is in these waters that the California sea otter made its acclaimed comeback from near extinction. Today, the sanctuary continues to serve as the sea otters' life-support system, while the well-being of the otter serves as an important indicator of the sanctuary's health.

The creation of the Monterey Bay National Marine Sanctuary in 1992 was the culmination of more than 15 years of unwavering public support and tireless efforts of government officials and environmental groups to provide one of this nation's most beautiful and bountiful marine areas with a special and long-lasting level of protection.

But what does it really mean to give 'sanctuary' to a part of the ocean? Perhaps most importantly it is an act of foresight, a recognition of the value of our marine heritage, and an acknowledgment that we have an obligation to maintain these public waters, like public lands, for future generations.

The National Marine Sanctuary program is a unique federal program created in 1972 to protect entire marine ecosystems, rather than individual components such as fish or marine mammals. The aim is to safeguard healthy marine environments, rather than restore damaged ones. Administered by the Department of Commerce's National Oceanic and Atmospheric Administration (NOAA), sanctuaries are managed through an integrated approach of enhanced resource protection, scientific research, and public education efforts. While the word sanctuary is associated with a place of refuge, national marine sanctuaries are developed with the purpose of achieving conservation while still allowing human uses. "Sanctuary" does not mean that we remove ourselves from the system, but that we honor the life within it. Importantly, however, while sanctuaries do recognize the contribution of marine resources to the economic vitality of coastal communities, their use must be compatible with the program's primary goal of resource protection. Human activities that would harm sanctuary resources are regulated.

Closing the door to oil drilling

The core of the sanctuary designation process is the issuance and review of the Draft Environmental Impact Statement and Draft Management Plan. Much of the discussion is focused on sorting out questions regarding the compatibility of existing and future uses and protection of sanctuary resources. In some cases this tug-of-war over issues has seriously stalled the designation process. In 1983, the Reagan Administration published a notice declaring that Monterey Bay was to be removed from the list of active sanctuary candidates (48 Federal Register 56253). This prompted an intense campaign to counter the sanctuary's abrupt delisting, which many viewed as an orchestrated attempt to prepare the area for the oil-drilling auction block. With the backing and activism of environmental organizations and local governments in 1988, former Congressman Leon Panetta pushed through legislation requiring sanctuary designation no later than December 31, 1989 (Pub. Law 100-627, section 205). While this congressional mandate got the designation process back on track, it was repeatedly delayed due to the continuing controversy over proposed oil and gas activities. Ultimately it was the outpouring of public support for the sanctuary that sent a message that political leaders could not ignore. A comprehensive ban on offshore oil and gas activities was eventually supported by the Bush Administration and included by NOAA in the sanctuary's final regulations.

It's not what you see, it's what you don't

Given the well-documented vulnerability of sea otters to oil, the sanctuary's prohibition of offshore oil and gas activities provides California's threatened sea otter population with an important measure of protection. Taken together with the adoption of the most comprehensive boundaries for the sanctuary (encompassing more than 5,300 square miles), California sea otters are now protected from this threat throughout most of their range. Only through an act of Congress would the specter of oil rigs again loom on the horizon of this special area.

Additional sanctuary-imposed safeguards include a prohibition on the establishment of new dump sites for the disposal of dredged materials within sanctuary boundaries and a prohibition on the discharge of primary-treated sewage. A sanctuary permit is required for activities such as (1) the discharge or deposit of materials (except those incidental to routine fishing and vessel operations); (2) the moving, removing or injuring of a sanctuary historical resource; (3) alteration of the seabed (except routine anchoring, fishing, navigation or other harbor maintenance activities); (4) "taking" of marine mammals, sea turtles, or seabirds (except as permitted under existing federal wildlife laws); (5) the operation of motorized aircraft below 1,000 feet in certain areas; and (6) possession of any historical resource, marine mammal, sea turtle, or seabird. Permits granted under local, state or other federal authorities *prior* to sanctuary designation still stand, although NOAA does have the authority to make them more protective of the sanctuary. Any new permits, granted by local, state, or other federal authorities *after* sanctuary designation must be reviewed by the sanctuary program and comply with terms and conditions necessary to protect sanctuary resources (U.S. Department of Commerce 1992).

A court decision in the spring of 1995 upheld a sanctuary regulation limiting the operation of motorized personal watercraft (e.g., jet skis) within the Monterey Bay National Marine Sanctuary (Personal Watercraft Industry Association; A. Mason Killebrew, Jr; Derek Coppersmith. v. Department of Commerce, National Oceanic and Atmospheric Administration, U.S. Court of Appeals, March 3, 1995). This regulation designates four zones and access routes for the operation of these craft. As noted in the court's decision, the intention of the regulation is to provide enhanced resource protection by prohibiting operation of motorized personal watercraft in areas of high marine mammal and seabird concentrations, kelp forest areas, rivermouths, estuaries, lagoons and other similar areas where sensitive marine resources are concentrated and most vulnerable to disturbance and other injury from personal watercraft. The court found that NOAA was acting well within its authority in setting down rules for the sanctuary that it determined were necessary and reasonable and that the record amply supported NOAA's judgement on this issue.

The coast is still not clear

Although the comprehensive boundaries and management plan adopted for the sanctuary provide meaningful protection against threats from offshore oil drilling, large-scale dumping proposals within its borders, and other potentially harmful activities within its boundaries, at this point it does little to *directly* elevate the protection needed from vessel-related oil spills, and point and non-point source pollution.

Most troubling is the sanctuary's failure to put forth specific regulations to keep oil tanker and barge traffic further away from sensitive areas, sea otters, and other living resources of the sanctuary. The devastating impacts of the *Exxon Valdez* spill—and the array of spills and close calls along the California coast and elsewhere in the world—should serve as potent reminders that an ounce of prevention is worth a pound of cure. Yet despite public outcry and concerns raised by environmental organizations and government agencies such as the California Coastal Commission, no immediate measures were put forth as part of the Monterey Bay National Marine Sanctuary designation or its management plan to control the thousands of vessels which pass through and near the sanctuary annually. As a result of citizen and environmental group advocacy, the U.S. Congress did require NOAA and the U.S. Coast Guard to prepare a report,

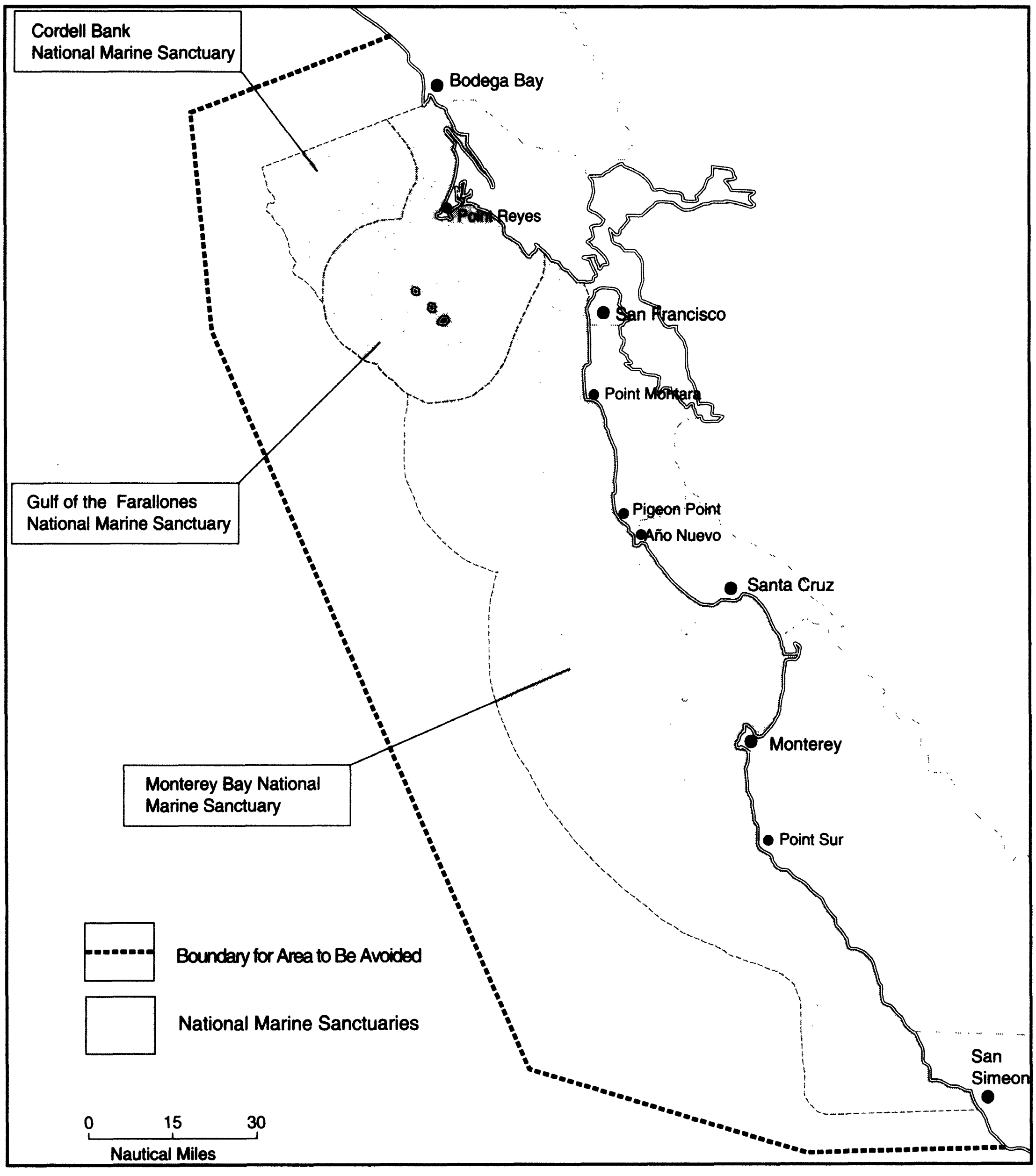

Figure 1. Boundary for proposed area to be avoided (ATBA).

within 18 months from the time of the site's designation, evaluating measures needed to regulate vessel traffic (Pub. Law 102-587). Despite the congressional mandate, the report has still not been released as of January 1, 1997. Meanwhile, the threat of a tanker and barge spill remains (see Bonnell et al., this issue).

In 1994 the Center for Marine Conservation released its own independent analysis of vessel traffic oil spill risks and possible solutions. *Safe Passage: Preventing Oil Spills in Our Marine Sanctuaries* (Townsend and Glazer 1994) sets forth ten detailed recommendations which, taken together, seek to:

(1) create a management regime that includes areas to be avoided (ATBA) that keep vessels further offshore, providing more time for response vessels to reach a disabled ship before it drifts ashore and/or giving spill responders time to mobilize vessels and other equipment in the event of a spill (see Figure 1);

(2) lessen the risks posed by vessels approaching San Francisco by employing a new traffic separation scheme that has all vessels using a common point outside of the ATBA as a staging area when entering or leaving the San Francisco Bay Area (see Figure 2), in an effort to minimize collisions and maximize the distance from the mainland and island hazards;

(3) establish a means to respond quickly to aid a disabled vessel and control its movements by strategically stationing rescue vessels with emergency towing capability; and

(4) improve tracking of vessel movements by upgrading radar monitoring capabilities, employing state-of-the-art surveillance technology and other information gathering programs and giving vessel traffic managers more authority to track and direct vessel movements within San Francisco Bay and in the approaches to the Bay.

The recommendations presented in *Safe Passage* have generated much discussion and have garnered support from congressional members, the Monterey Bay National Marine Sanctuary Advisory Council, and from individuals within the U.S. Coast Guard and maritime shipping industry. However, the U. S. Coast Guard continues to fail in its responsibility to make a determination about oil spill prevention for the region. It steadfastly refused to recommend oil tanker buffer zones in its recent report *Evaluation of Oil Tanker Routing* (U.S. Coast Guard 1996), despite information contained in the report that shows that this region has environmental sensitivity equal to or greater than two other sanctuaries that now have buffer zones (southern California's Channel Islands and Washington's Olympic Coast). It has also engaged in a tug-of-war with NOAA over the strength of recommendations to be contained in the congressionally-mandated report on vessel traffic within the sanctuary. This struggle and the resulting wall of delay in the report's release cannot bode well for resource protection. The fact remains, however, that oil spill prevention and natural resource protection *should be* at the forefront of vessel traffic management. New efforts to prevent oil spills in or near sanctuaries *must* be taken; once the oil hits the water, the battle has been lost. Until meaningful measures are in place, the coast cannot be con-

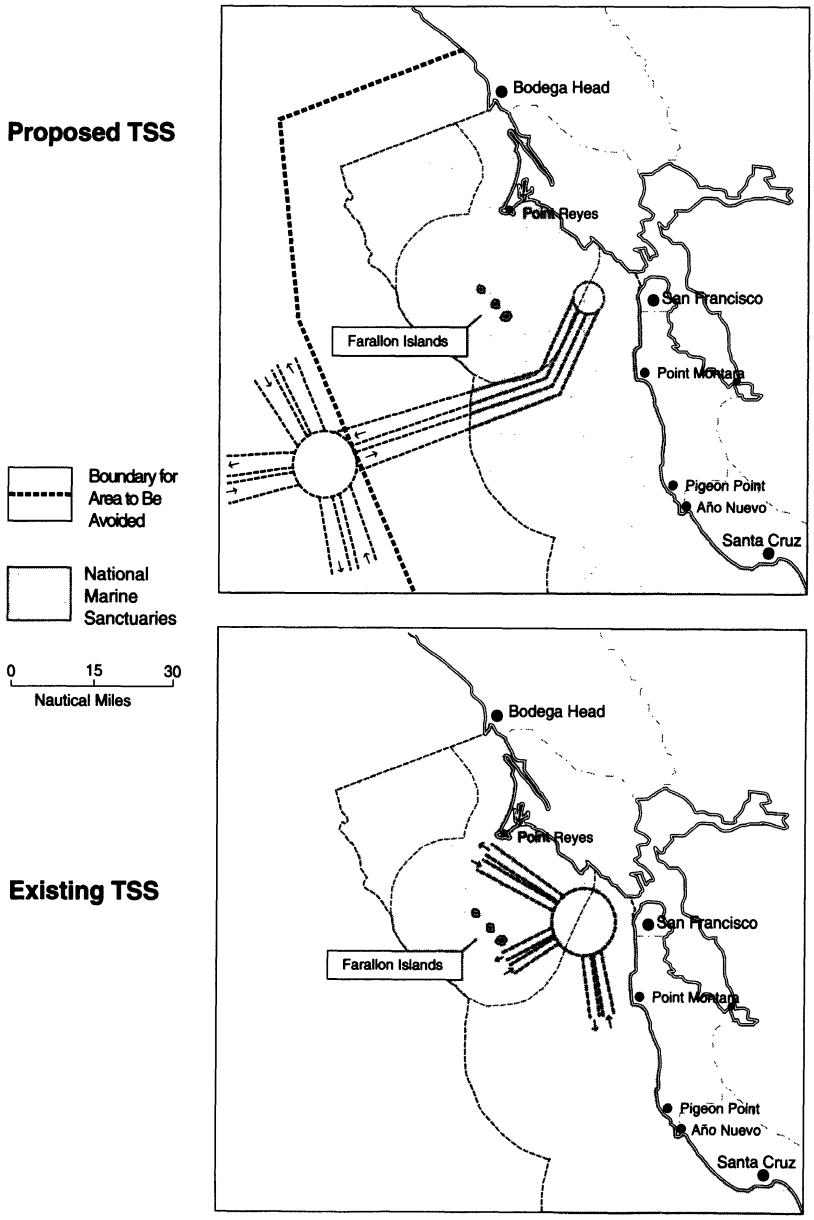

Figure 2. Proposed new traffic separation scheme (TSS) for vessels approaching and departing the San Francisco Bay Area.

sidered clear for the recovering California sea otter population or the other living resources of the Monterey Bay National Marine Sanctuary.

Pollutants don't respect sanctuary boundaries

Clean water is the sanctuary's life support system. Aside from oil spills, inadequately treated sewage and industrial discharges, storm drain overflows, and pesticide runoff can also compromise the sanctuary. Sanctuary activists advocated an active role for sanctuary management in protecting water quality. However, at the completion of the designation process, the State of California had retained prime authority on most water quality issues.

Moreover, a 71 square nautical mile area near San Francisco was also excised out of the sanctuary, potentially weakening the sanctuary's control over activities within it (such as high volume discharges from the San Francisco outfall).

Thus far it does appear that the sanctuary program has forged productive working relationships with existing state and federal water quality agencies and has effectively weighed in on behalf of sanctuary resources. The sanctuary has also taken a promising, proactive posture in initiating a comprehensive water quality protection program for the sanctuary and its watersheds. The Monterey Bay National Marine Sanctuary's Water Quality Protection Program is leading a core group of over two dozen representatives of public and private agencies and organizations at the federal, state, and local level in examining water quality problems and designing and implementing conservation strategies. These strategies will address issues such as urban runoff, marina and boating activities, and point-source pollution. The Program has also initiated the development of a regionally consistent water quality data base and a regional monitoring program, and is forging a stewardship approach to reduce pollution associated with the agricultural sector.

Conclusions and recommendations

It is clear that while drawing a boundary line on a map and proclaiming an area a sanctuary is an essential first step, boundaries alone do not guarantee protection. Management and regulation of potentially detrimental activities are also vital.

Today, as throughout the designation process, the sanctuary has been a focal point for important issues and healthy debate on the management of our coastal and marine resources. However, if the sanctuary is to be held up as a model for marine conservation, existing weaknesses in the sanctuary plan will need to be addressed. Crucial to protection of the sanctuary and the recovery of California's threatened sea otters is the creation and enforcement of tangible oil spill prevention policies. Given that a large proportion of the existing sea otter population is located within the boundaries of the sanctuary and that vessel-related oil spills remain a threat, it is incumbent upon the U.S. Fish and Wildlife Service (FWS) to immediately start working with the sanctuary program, the U.S. Coast Guard, and sanctuary advocates to secure these long-overdue protections. Specifically, the FWS should:

(1) provide a rigorous review and critique of the congressionally-mandated U.S. Coast Guard report on reducing the spill threat to sanctuary resources;

(2) request that public hearings be held on the report within each county adjoining the sanctuary so that report findings may be presented and public comments made;

(3) request the U.S. Coast Guard to provide a timeline for implementation of tangible oil spill prevention measures (such as those identified in the Center's *Safe Passage* report); and

(4) support the adoption of a specific buffer area large enough to adequately protect sea otters and other sanctuary resources. The FWS would also do well to coordinate with sanctuary management on their Water Quality Protection Program and on enforcement and monitoring issues of mutual concern, as the sanctuary is still in the early stages of constructing and implementing a more comprehensive enforcement plan.

Sanctuary designation marked the beginning—not the end—of a long-term commitment to conserve and effectively manage a world-class resource. It is a work in progress. Ensuring a truly protected future will require that all of us who use and enjoy sanctuary waters continue to carry the sanctuary torch, stay involved, and speak out. As Brooks (1985) once said about Rachel Carson, we must be "stonemasons who never lose sight of the cathedral."

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The Role of Friends of the Sea Otter in Resource Protection

Ellen Faurot-Daniels and
Donald C. Baur

Non-governmental organizations (NGOs) can make significant contributions to research and management discussions, planning, plan implementation, negotiations, political lobbying, funding procurement, education, and legal and citizen actions. Because they are not bound by the legal and regulatory encumbrances that government agencies often work under, NGOs are uniquely positioned to catalyze action, suggest and promote solutions to problems, and use the political process to achieve goals that often cannot be achieved by those working within government agencies.

This paper will focus on how Friends of the Sea Otter (FSO), as one example of an NGO, has operated in its effective and singular role as a conservation advocate. The paper looks briefly at the history of the organization, how it operates, and FSO's accomplishments and current focus.

How and why Friends of the Sea Otter was started

Friends of the Sea Otter began in 1968. It was born of the commitment of two people, Margaret Owings and Jim Mattison, Jr., to protect the southern sea otter against the threat of further endangerment or extinction. In the late 1960s the southern sea otter population was small, located only along a 150 mile band of central California coastline, and subject to strong competition from the commercial abalone fishery. There was a lack of knowledge about the behavior and biology of sea otters, and the range and seriousness of perceived threats to their populations. The focus of FSO's founders was to alert the public and elected officials to the pressures sea otter recovery was facing. The founders thought that the organization would be able to complete the task of sea otter protection within two years. What started as a two-person, grassroots effort has grown over the years into a well-established, highly respected conservation organization and the only advocacy group in the world exclusively dedicated to sea otters.

FSO currently has a staff of 5 full-time professionals, a 10 member Board of Trustees, a 15 member Scientific Advisory Council, and a membership of 4,000 that represents all 50 states and 20 foreign countries. In addition to work in the conservation policy realm, FSO has established an educational outreach program, responds to requests for information on sea otters, sponsors work with university interns studying sea otters, operates a retail/education Sea Otter Center, and operates a program for the identification and training of oil spill response volunteers (the COAST program).

Many of the issues that led to the formation of FSO have persisted in type and intensity, although varying in specifics. While the sea otter population is recovering in numbers, their range along the central California coast is still limited, and the threats from oil spills, human interactions, and environmental contamination are still very much present.

General operating principles

As a result of all the communications and actions required to put together cogent policy positions, FSO commonly is in the middle of a communications "node." This access to information and issues allows us to function effectively as a citizen-based action group.

Because FSO's focus is on the marine environment, for which the state and federal governments are the sole "landlords," it tends to look toward affecting government policy. FSO also puts a premium on collaboration with other non-profit organizations, government agencies, and scientific institutions. FSO can and does enlist the help of environmental lawyers in determining the best possible policy course to take; while lawsuits are used as a last resort, FSO will pursue that avenue if necessary.

FSO is sometimes consulted by institution and agency scientists and managers, and asked to participate in construction of management policy. Without exception, these instances of cooperative work have always benefited all parties. Because of this, there seems to be a slow awakening by other management agencies and institutions to the positive role NGOs can play if they are approached early in the decision-making process. Many conservation NGOs have access to excellent scientists, policy makers and lawyers, all of them conscious of the need to utilize the best possible evaluative tools available in reviewing a contentious issue.

FSO's contributions to sea otter conservation

Friends of the Sea Otter examines issues of fisheries utilization and conservation, plans for oil spill prevention and response, follows research on environmental contaminants, and endeavors to increase scientific and public understandings of fluctuations in sea otter numbers, distribution, and habitat utilization. FSO is involved in a variety of sea otter science and policy issues throughout the North Pacific, in negotiations of national and international environmental legislation, and in consultations for recovery planning for the southern sea otter. Some policy actions have been almost exclusively the province of FSO action, for example the listing of southern sea otters under the federal Endangered Species Act (ESA), and lobbying for restrictions on California coastal gillnets. Without the efforts of a focused advocacy group such as Friends of the Sea Otter, many of those accomplishments could not have been achieved. More important, perhaps, NGOs can choose to identify and implement appropriate solutions, not stopping with a simple acknowledgment and notification of a problem.

Over the years, the specific tasks and accomplishments of FSO have fallen into several different categories. The first is scientific research and monitoring. Examples include:

- establishing a scientific advisory council (including representatives from U.C. Santa Cruz and Stanford University);
- initiating studies on sea otter biology and behavior by providing financial support to field scientists;
- tracking fisheries monitoring and enforcement efforts of California Department of Fish and Game (CDFG) and U.S. Fish and Wildlife Service;
- participating in sea otter censuses on the mainland and San Nicolas Island; and
- establishing COAST (a volunteer oil spill response program).

A second area of FSO tasks and accomplishments is in the area of advocacy and lobbying, for example:

- testifying on California commercial fisheries legislation;
- providing Congressional testimony on marine mammal protective legislation;
- participating in reauthorizations of the Marine Mammal Protection Act, Endangered Species Act, Clean Water Act, and Magnuson Fisheries Act;
- providing legal challenges to Native Alaskan hunting rights;
- acquiring restrictions on use of coastal gill and trammel nets; and
- supporting establishment of the Monterey Bay National Marine Sanctuary.

Establishing funding for sea otter protection is another area of tasks, which include:

- procuring ongoing funding for CDFG marine enforcement programs;
- securing salary and operating funds for Russian sea otter biologists; and
- securing reallocation of federal funds to National Biological Service biologists.

Finally, FSO is involved with public education efforts, including:

- working with film producers, photographers and authors to relay the sea otter story;
- writing and circulating sea otter issue papers; and
- meeting with resource interest groups, industry, environmentalists, scientists, agency managers, politicians to discuss issues related to sea otter population or habitat protection.

Photograph by Jeff Foott

Extensive effort is often expended on a particular issue. For instance, the 1977 listing of southern sea otters as threatened under the ESA and the 1986 restriction on use of coastal gill nets both involved extensive petitioning and meetings with agencies and politicians, in addition to preparation of political briefing and public education materials. The translocation of sea otters to San Nicolas Island (see Benz, Attempts to Reintroduce, this issue) involved 3 years of meetings, report reviews, and numerous phone and meeting conversations in addition to actual participation in the translocation effort and follow-up activities, which continue today. Work on designation of the Monterey Bay National Marine Sanctuary (see Saunders, this issue) involved a steady 10 year effort, and continues today with ongoing participation in conservation working groups, and review of Sanctuary regulations and proposed exemptions. The 1994 negotiations over the reauthorization of the Marine Mammal Protection Act involved several multi-day meetings, drafts and redrafts of language, conference calls to negotiation participants, and action alerts to members. Similarly, work involving the second southern sea otter recovery plan requires extensive efforts on the part of our science, policy, and legal experts spanning months or even years; efforts to implement our recommendations take even longer.

FSO's current focus

The recently released draft revised southern sea otter recovery plan (U.S. Fish and Wildlife Service 1996; see Benz, Recovery Plan, this issue) provides a timely example of how FSO identifies and resolves issues. FSO has a number of concerns with the second recovery plan, which fall into the following two categories.

Technical concerns

These are primarily based on the narrow focus of the recovery plan. The emphasis on calculating the number of sea otters needed to provide a margin of safety following a major oil spill downplays or ignores several other important considerations that need to be comprehensively addressed. These include the limited range and remaining threats within the range. Also, better oil spill prevention policies are needed to protect essential habitat. FSO believes that finding at least one tangible and significant oil spill prevention technique to formalize and implement will be the only way to effectively protect the coast and its resources.

A second area of concern is with the sea otter population health. Data from the past 5 years indicate that nearly 40% of the dead sea otters examined had an infection at the time of death (see Thomas and Cole, this issue). While the types of diseases have been catalogued, we know little about how sea otters encounter these diseases, if they are encountering them at greater rates than in the past, or whether their resistance to natural or new types of infections has changed. Research is necessary to determine sea otter infection rates, how and to what degree infections are communicable, and the incidence and impact of environmental contaminants, toxins, and parasites on sea otters and their critical habitat.

The second recovery plan recognizes the need to research the impact of sea otters on shellfish resources, but there is no identification of a similar need to study the abundance, distribution, and quality of food resources available to the sea otters. If sea otters within their current range become food-limited as a result of human overharvest of shellfish, or as a result of contamination of the food supply, then recovery levels sufficient for ESA delisting, and ongoing population stability, cannot be assured.

Legal concerns

The chief legal concern with the second recovery plan is the failure of the oil spill risk analysis to adopt the conservative approach required by the ESA. The efficacy of the second recovery plan relies upon the prediction that a 250,000 barrel oil spill would contact sea otters at least 10% of the time and result in no more than 800 otter deaths. This estimate does not comport with the legal intent that the ESA be administered in a conservative manner (i.e., to give the benefit of the doubt to the species).

A second area of concern is that the second recovery plan does not adequately address the full range of threats that caused the species to be listed as threatened in 1977. The risk posed by oil spills clearly was the greatest threat at the time. But all of the following threats also were identified: (1) increasing chemical, bacteriological and metal pollution; (2) inadequate habitat protection under existing law; (3) direct killings by shooting and collision with boats; and (4) restricted genetic diversity due to the severely reduced state of the population. As a matter of law, even if the second recovery plan established delisting criteria to address all of the original threats, the species could not be determined recovered unless any new threats also had been fully analyzed, addressed, and resolved.

Conclusion and recommendations

The next five years will be pivotal for sea otter research and recovery. The southern sea otter population has apparently done just well enough in terms of population growth to move it down the priority list in terms of U.S. Fish and Wildlife Service (FWS) management efforts and dollars. Ironically, federal management tends to be reduced just as species are on the brink of full recovery. With the ESA under attack, federal mandates for species' recovery at an all time high, and budgets for recovery efforts being cut, we are concerned that FWS involvement with sea otters has been lessened. However, FSO believes that we can utilize persistence, creativity and cooperative efforts among state and federal agencies, academic institutions, research facilities, industry, and conservation groups to successfully complete the task of southern sea otter recovery under the ESA.

We recommend two broad actions. First, the ESA needs to survive its next reauthorization with its basic protective tenets intact. This will involve extensive negotiations over at least the next year. FSO expects to be intensively involved in this effort.

Second, the most recent draft of the second southern sea otter recovery plan needs to be updated significantly as it moves toward its final form, and must be made to reflect new concerns over sea otter population health, and the need to provide more definitive habitat protection from oil spills. Equally important, mechanisms for implementing the final recommendations of the second recovery plan must be identified. Given the greatly decreased resources and efforts of the FWS directed toward southern sea otter recovery, cooperative linkages with other responsible research and policy partners must be forged and supported by the FWS. Toward that end, FSO will over the next year be working with institutions and agencies to (1) identify ESA pre-delisting goals; (2) identify policy development linkages; (3) conduct strategic planning for future research, keyed to the pre-delisting goals; (4) lobby to have consensus-based strategic planning and timetables become part of the second southern sea otter recovery plan; and (5) procure additional funding and policy support to achieve these goals.

Implementing these revisions would not only set the southern sea otter on a track for recovery on a reasonable schedule, but could serve as an example for other recovery plans on how to achieve agreement among interested parties. We encourage FWS to take advantage of this opportunity to demonstrate just how effectively a recovery planning process under the ESA can work when a consultative process is used and proper consideration is given to the needs of the affected species. The second southern sea otter recovery plan can illustrate the necessity of a well-managed, adequately funded recovery planning process that calls upon the expertise of all affected parties.

It is in just these types of endeavors that NGOs such as FSO can be extremely effective. Partnered with the efforts of agencies and institutions, FSO can serve to ally disparate entities and catalyze positive change.

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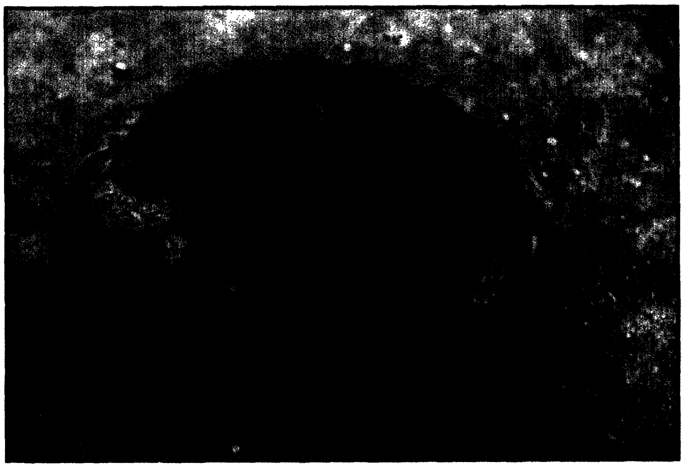
The Role of Rehabilitation in Sea Otter Conservation Efforts

Thomas D. Williams and
Terrie M. Williams

Rehabilitation programs for sea otters, as well as other wildlife, are supported by arguments based on psychological impacts on the public, practicality, knowledge enhancement, and the value of the individual animal as well as the species. Conversely, potential deleterious effects upon the gene pool, stress to individual animals, the potential spread of disease, and inappropriate use of limited resources argue against rehabilitation efforts. A good example of this conflict was the rescue of sea otters following the *Exxon Valdez* oil spill. Rehabilitation efforts were disappointing, with nearly one quarter of the rehabilitated and released sea otters presumed to have died soon after release, based on post-release monitoring of radio instrumented animals (Monnett et al. 1990). Furthermore, the potential contribution of the rehabilitation effort has been questioned in view of the fact that although a large number of sea otters were impacted (estimated at 1000 to more than 5000 individuals) this number does not represent a significant portion of the total Alaskan population of 150,000 - 200,000 otters (Garrott et al., 1993). This paper will look at the lessons of the Exxon Valdez spill and will examine the questions: how will these issues influence the role of rehabilitation programs in future sea otter conservation?



Dead oiled sea otter pup, resulting from the *Exxon Valdez* oil spill. Photograph courtesy of Friends of the Sea Otter.

Public perception of rehabilitation and conservation

The U.S. Environmental Protection Agency (EPA) has recognized the dichotomy between public perception and scientists' understanding of environmental problems. Action and priorities are often tempered by the influence of public concerns on national legislation and funding. As a result, the EPA budget and staff are often directed at environmental problems perceived as serious by the general public but not necessarily justifiable at the population conservation level (Environmental Protection Agency 1990). For example, oil spills were considered a relatively low risk problem due to the resiliency of ecosystems to such short-term insults. Despite this, considerable resources have been directed towards the mitigation of the impact of oil spills on wildlife. In the aftermath of the *Exxon Valdez* oil spill, for example, 225 sea otters were rehabilitated at a cost of $18.3 million, or over $81,300 per otter.

Historically, wildlife rehabilitation efforts in the United States have reflected the public's desire to serve as stewards of the environment. The reverence for life that evolved from our historic traditions is denigrated if the needs of fellow human beings or animals are ignored. The moral issue becomes an even more compelling force for rehabilitation if animals are endangered as a result of a human-caused disaster. Our society willingly assumes responsibility for the mitigation of such disasters.

Psychological factors are closely tied to moral issues as compelling forces for rehabilitation. Strong human/animal bonds result in people being negatively impacted when confronted by animals in distress. Preventing rescue attempts would increase the feelings of helplessness among those sensitive to animal issues. In contrast, people experience a psychological boost through the sense that they are returning something to the world by caring for distressed animals.

Rehabilitation programs broaden community ownership of problems in the environment and empower people to act and learn about those problems. Educational programs are crucial for linking the immediate satisfaction of caring for an individual animal with larger conservation issues. Programs at the public aquaria and rehabilitation facilities provide opportunities to view animals not easily seen in the wild, resulting in a sense of caring and respect for the animals. Public education on the value of these animals towards conservation of the population is necessary in developing cooperative conservation programs involving the public, researchers, rehabilitation facilities, aquaria, government officials, and animal interest groups.

The institution of a cooperative conservation program will require a fundamental change in thinking by the general public, which should be based on a foundation of scientific fact. Rather than focus on the individual animal as has been the case to date, attention must be redirected toward the species and population levels. Thus, the scientific and rehabilitation community need to develop a more responsible attitude toward the relationship between basic biological research and its application to environmental problems.

The individual versus species conservation

One of the primary criticisms of rehabilitation programs has been their focus on the individual animal rather than the needs of the population or the species. This is complicated by media-

Sea otter being washed as part of the rehabilitation effort after the *Exxon Valdez* oil spill. Photograph courtesy of Friends of the Sea Otter.

created "personalities:" such as Lazarus, the sea otter who made a convenient on-camera recovery during the *Exxon Valdez* spill, and April, the rehabilitated sea otter released by the Monterey Bay Aquarium who was the subject of periodic cover stories in local papers for months. Public empathy for sea otters and the promotion of rehabilitated animals as personalities creates a fertile environment for financial, popular, or political gain.

Debates concerning rehabilitation programs often reveal a basic misunderstanding by the general public of species conservation and the role of scientific research and rehabilitation in the preservation of biodiversity. They also illustrate the problem of trying to reach consensus amid the conflicting goals associated with individual animal rights and the conservation of an entire species or population. In reviewing the costly sea otter rehabilitation programs following the *Exxon Valdez* oil spill, Estes (1991) questioned the value of efforts focussed on individual animals when resources are limited and a population or species is not threatened with extinction.

The individual sea otter in a rehabilitation program, however, provides much more than a human interest personality. These animals represent an invaluable link between the scientific community and wild populations. Combining the expertise and resources of zoological parks, rehabilitation personnel, and environmental scientists is an important dimension to the timely conservation of the species.

Individual otters as representatives of the species

The sheer number of species facing extinction far outweighs our capabilities to either house or study them (Soulé et al. 1986). In addition, there is a paucity of information on the basic physiology, behavior, immunology, genetic diversity, interactions and environmental requirements of sea otters and their prey. Unfortunately, this basic information is critical for identifying the environmental demands of a population and for developing intelligent management plans (Ralls and Brownell 1989). Rehabilitation programs offer innumerable research opportunities, and the knowledge gained may have significant long-term importance for the survival of the population as a whole. Work on individual sea otters allows researchers to develop effective capture, transportation, treatment and husbandry techniques. Rehabilitating animals often provides biomedical and physiological standards regarding exposure to pathogens, parasites and toxins.

Carefully planned and executed rehabilitation programs can advance our understanding of the basic biology of a species, and thus improve the scientific foundation for conservation programs. This may serve as the only research option for species that do poorly in captivity or whose populations have declined to the point that disturbance by scientists would be detrimental. For example, the sea otter may provide clues about a variety of other endangered mustelids including semi-aquatic (i.e. Amazonian otters (*Pteronura brasiliensis*)) and terrestrial (i.e. black-footed ferret (*Mustela nigripes*)) species.

Individual otters as part of secure populations

Natural or anthropogenic factors may create habitats that are temporarily untenable for a species (Foose 1989). Captivity offers safe haven for preserving biodiversity until the environmental threat is removed. The sea otter and the California condor (*Gymnogyps californianus*) are good examples of such environmentally threatened species. Inadequate food resources, habitat loss and toxins have created an unsuitable environment for supporting the California condor (Verner 1978). To alleviate environmental pressures, the few remaining wild California condors were captured and placed in a captive breeding program. Likewise, pre-emptive capture and long-term holding may be the only alternative for the California sea otter in the event of a catastrophic oil spill (Degange et al. 1995; see Brennan and Houck, this issue). Such critical measures may be needed until habitats can be matched to the environmental requirements of the animals.

Individual otters as members of future wild populations

New methods and technologies for captive breeding and reintroductions to the wild offer a lifeline for endangered populations. When coordinated with habitat preservation, programs involving rehabilitated animals serve as a powerful tool for restoring communities and ecosystems (Stanley Price 1989). The black-footed ferret (*Mustela nigripes*) in Wyoming (Seal 1989), the Arabian oryx (*Oryx leucoryx*) in Oman (Stanley Price 1989) and the California condor in southern California (Verner

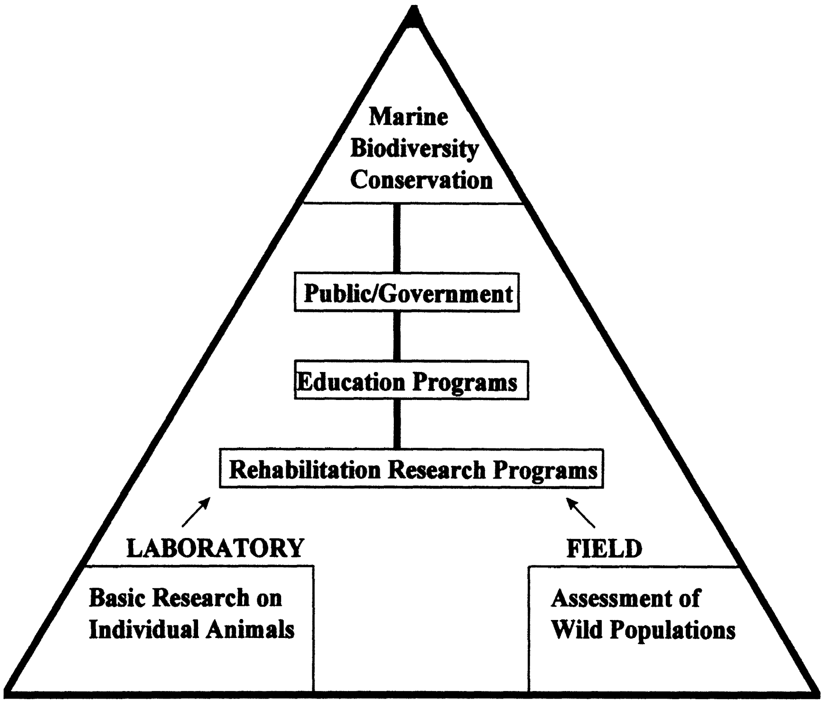


Figure 1. A theoretical Biodiversity Pyramid. Key elements in achieving conservation goals from rehabilitation programs are a foundation of research on individuals and populations followed by education of the public and government agencies.

1978) are recent examples of scientific programs designed to "seed" the environment with wildlife from captive populations. Similar considerations should be given to the southern sea otter population. Hallmarks common to these programs were captive breeding and a comprehensive knowledge of the biology of the species. By guaranteeing the success of the individual, the programs were able to enhance population levels in the wild.

Turning rehabilitation into conservation—the Biodiversity Pyramid

Conservation of biodiversity can be thought of as a pyramid, with knowledge as the base (see Figure 1). This foundation requires information about the needs of individual animals and the requirements of wild populations. It relies on basic research conducted on animals under human care as well as an assessment of the numbers and environmental challenges faced by animals in their native habitats. Research supported by rehabilitation programs and aquariums can provide the vital link between these research objectives. With planning, the result will be a direct application of research data to the conservation of wild populations. When linked to education programs, research findings can be used to shape public perception about conservation issues. Public empathy for the environment and animals can then translate into action by state, federal and international agencies. The cooperative goal should be to develop sound conservation measures for marine biodiversity based on scientific fact.

Admittedly, the challenge will be in the development of multi-disciplinary strategic plans for rehabilitation that incorporate research, education and conservation. The optimum conservation strategy for any species will incorporate captive and wild populations as interactive components (Foose 1989). Otherwise, rehabilitation programs will be limited to serving the emotional needs of the public rather than the species affected.

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Oiled Wildlife Care for Sea Otters and Other Marine Animals in California: A Government, University, Private Sector, Non-Profit Cooperative

David A. Jessup,
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The draft revised southern sea otter recovery plan released by the U.S. Fish and Wildlife Service (FWS) for public review and comment of June 1996 states that "...the likelihood of sea otters persisting in California is currently determined by whether a major oil spill occurs within the sea otters range...." (U.S. Fish and Wildlife Service 1996. p. vii). It further states that "...two approaches have been identified that would lead to delisting the southern sea otter under the Endangered Species Act (ESA): (1) increasing the range of otters in California to reduce the risk of a single oil spill event reducing the otter population below a level that is viable, and (2) decreasing the risk to otters that a major oil spill event within their range will occur" (U.S. Fish and Wildlife Service 1996. p. vii).

Efforts to increase the range of the southern sea otter (the first approach) have met with limited success. Reasons for this, for the slow rate of expansion of the sea otter population, and for the apparently high rate of mortalities in adults, are poorly understood. Efforts to decrease the risk of a major oil spill (the second approach) include moving all Trans-Alaska Pipeline System tanker traffic (but not all non-oil carrying vessels and barges) beyond 50 miles off the coast. These efforts are under the leadership of the California Department of Fish and Game-Office of Oil Spill Prevention and Response (CDFG-OSPR) and the U.S. Coast Guard.

A third approach toward improving the likelihood that sea otters would survive a major oil spill, the development of state-of-the-art centers for sea otter care and research, is not mentioned in the draft revised southern sea otter recovery plan. That may be because, given the relatively high costs and mortality rates for oiled sea otters in Alaska following the *Exxon Valdez* incident, this approach to sea otter management is somewhat controversial. However, while treatment and recovery programs for the non-threatened, expanding sea otter population in Alaska may be controversial, the California situation is very different indeed. California sea otters are state and federally listed, the population is only slowly recovering, and a single large oil tanker spill could contaminate a major portion of the entire sea otter range.

This paper will discuss the Oiled Wildlife Veterinary Care and Research Center (OWVCRC) in Santa Cruz, California, that will serve as a focus for oil spill response and sea otter biomedical research, and a larger Oiled Wildlife Care Network (OWCN) that serves all species along the California coast, including its development, current status, and potential contributions to species conservation.

Although the plight of the southern sea otter was not the driving force behind the development of an Oiled Wildlife Care Network (described below) in California (see Figure 1), it was certainly a major consideration. Every effort has been made in the development of the OWCN, and OSPR's other programs, to identify methods by which impacts of oil spills in the sea otter range can be reduced. In addition, the OWCN will ensure that any sea otters that do become oiled will receive the best achievable treatment and that their potential for survival and release will be maximized. Thus, the OWCN and associated monitoring, research and management efforts by the CDFG and cooperating agencies and organizations may hasten the recovery of the southern sea otter and may help document their health and status in support of federal delisting.

The Oiled Wildlife Care Network

Although state wildlife agencies are trustees for wildlife resources, few wildlife agencies actually provide care for wildlife compromised by oil spills or other human activities. The establishment of a large and complex network for the care of oiled wildlife *before* a major oil spill is unprecedented. But, the spectacle of dead and dying Alaskan sea otters repeatedly shown on national television throughout the spring of 1989 subsequent to the *Exxon Valdez* spill, followed shortly by the *American Trader* spill off Huntington Beach near Los Angeles, California, galvanized public and political support in California for action. In 1990 the legislature of California enacted the Lempert-Keene-Seastrand Oil Spill Prevention and Response Act (SB 2040), which established the OSPR within the CDFG, and placed a $.04 per barrel fee on oil transported or processed in California, the proceeds of which are to be used, among many other things, for care of wildlife affected by oil spills. SB 2040 requires that oiled wildlife receive "best achievable treatment" and "the establishment of rescue and rehabilitation stations for sea birds, sea otters, and other marine mammals." The first of these stations was to be built within the range of the southern sea otter.

OSPR is currently building this station (OWVCRC) at the University of California, Santa Cruz (UCSC). When completed in the summer of 1997 at a cost of approximately $5 million dollars, it will be capable of caring for 125 sea otters, but flexible enough to care for other species of marine animals and house ongoing joint and cooperative research projects. By locating this facility adjacent to California's premier marine ecotoxicology laboratory (the Joseph L. Long Marine Laboratory on the UCSC campus), and by committing to support appropriate research, OSPR has assured that its OWVCRC will play a prominent role is sea otter and marine mammal research and management when not being used for oil spill response.

In 1993, a second piece of legislation, SB 775, which was amended by AB 1549 in 1995, allowed OSPR approximately $9 million dollars over a 4 year period to help build the other mandated "rescue and rehabilitation stations" in the OWCN, and allow the OWCN to serve all marine species along the entire California coast. These additional centers are being developed in San Diego, Orange County, Los Angeles, Santa Barbara, the San Francisco Bay Area and Humboldt County. Most of these centers should be completed by the end of 1997. Each of these centers is being developed in conjunction with an existing marine park, wildlife rehabilitation program, educational institution, or combination of compatible programs. The programs at each center have separate and additional sources of financial, political, and personnel support. This approach again assures that all OWCN centers will provide useful and appreciated services to the people of California when not in use for oil spill response (see current programs section below). Two centers, one at Sea World in San Diego and one at The Marine Mammal Center in Sausalito, are being designed and built to provide additional facilities for the care of oiled sea otters should the capacity of the Santa Cruz OWVCRC be exceeded or should it be medically expedient to treat oiled sea otters at separate locations.

To assure that oiled wildlife would immediately begin receiving "best achievable treatment," OSPR developed working relationships assured by a Memoranda of Understanding with 15 existing private non-profit wildlife rehabilitation organizations in 1995 and incorporated them into the OWCN. These organizations have agreed to assist OSPR with personnel and small facilities to respond to the needs of oiled wildlife. Essentially all of the organizations that currently provide care for marine mammals as part of the California Marine Mammal Stranding Network under the jurisdiction of the National Marine Fisheries Service (NMFS) are part of the OWCN. OSPR and NMFS have negotiated a Memorandum of Agreement to confirm this state and federal agency cooperation during and between oil spills. OSPR has, in turn, equipped and supplied these 15 additional existing organizations with whatever they have needed to deliver "best achievable treatment" to oiled wildlife and has conducted, and will continue to conduct, training courses and symposia on state-of-the-art medical care and washing procedures, sample collection, record keeping, etc. In some cases the physical facilities have been improved or expanded at these existing private wildlife rehabilitation centers.

These smaller wildlife rehabilitation organizations can provide a pool of trained volunteers for oiled animal care that may be utilized at more distant locations in the event of a catastrophic spill requiring large amounts of

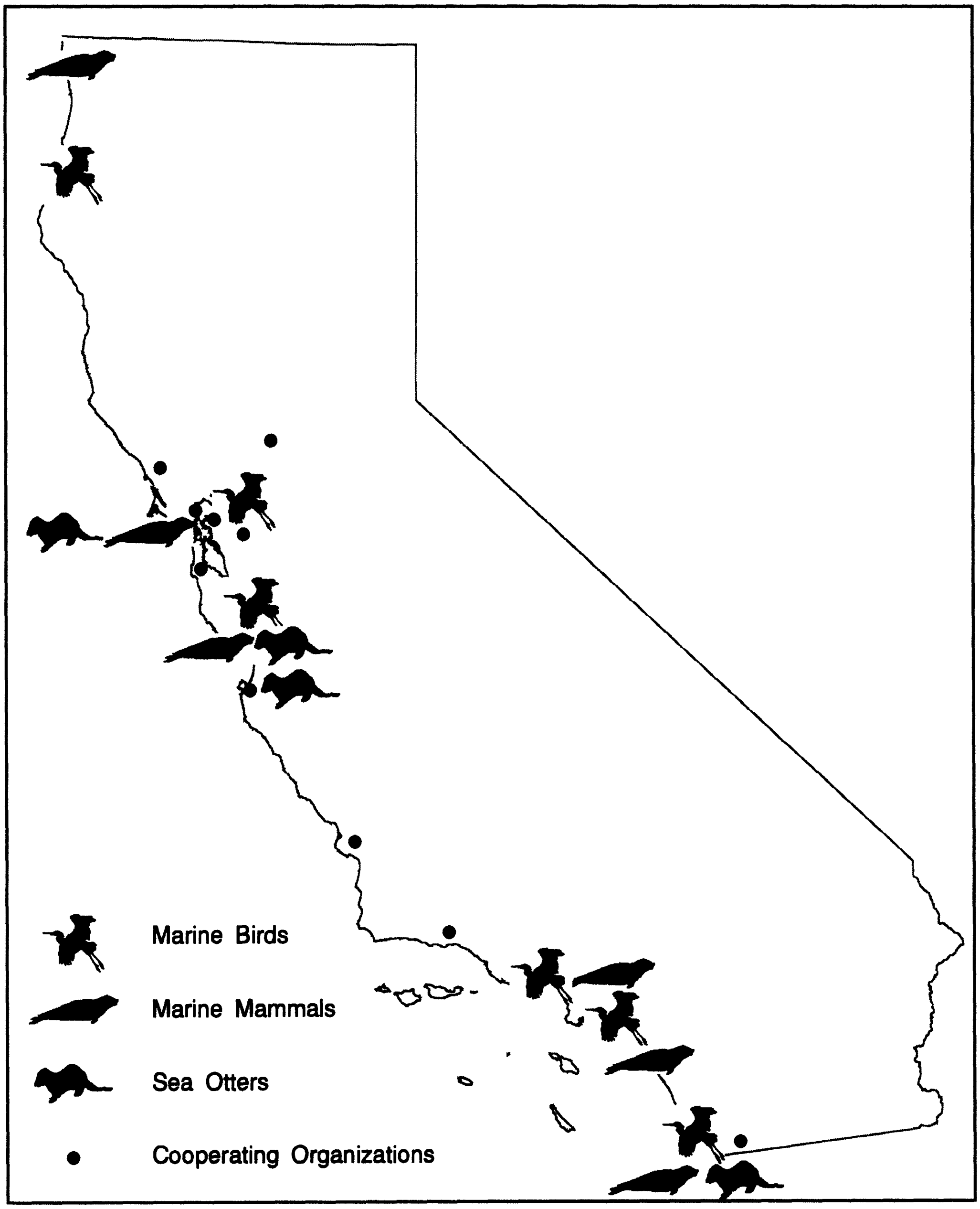

Figure 1. Location and focus of oiled wildlife care network (OWCN) facilities.

person power. The cooperation and mutual respect that develops when private, community-supported organizations and government work together results in community (thus political) support for the overall program. It is also hoped that this type of cooperation and assistance will encourage the continued improvement and professionalization of wildlife rehabilitation organizations.

Current program status

To meet the mandate for immediate veterinary response capabilities for oiled wildlife, the OWCN has developed a veterinary team that includes individuals from government agencies, private practice, universities, research institutes, wildlife rehabilitation centers, and marine parks. Participants share pertinent information, improve and standardize treatment protocols, and cooperate in research. OSPR has built and outfitted a pair of mobile veterinary laboratories and animal transport, washing, and care trailers that can be mobilized to reach anywhere in California within 24 hours. A trailer specifically designed to rapidly transport large numbers of oiled birds to or between centers has been designed and built. Small trailers which contain hazing equipment and supplies needed during the first few hours following an oil spill and which can transport all-terrain vehicles needed for wildlife surveillance and pickup have been constructed and deployed. The large "18 wheeler" mobile oily bird care and washing trailer (MOBCART), which was designed by International Bird Rescue and Research Center (IBRRC) and built by Chevron and Clean Seas, will soon be available for response in California as well. The development of regional OWCN facilities will substantially improve local wildlife veterinary care capability as well as reduce the cost of oiled wildlife rehabilitation, which has traditionally included the development of interim facilities (see Williams and Williams, this issue).

A third piece of legislation introduced in 1995, AB 1549, expanded the OWCN mandate to include operations and maintenance of the OWCN, and support of appropriate technology development and research allows OSPR to accomplish these aspects of the program through the Wildlife Health Center at the University of California, Davis. After 1998, U.C. Davis will be the principal operator of the OWCN. The OWCN program clearly provides a service to the State and its wildlife resources and is supported by top university administration at three campuses. The program represents a unique collaboration between scientific, educational, non-profit, and government organizations, and has attracted some of the nation's best veterinary and wildlife health professionals into the oiled wildlife care and response arena. A competitive grants program has been established that is open to proposals from any agency, company, university or research institution. The first request for proposals has been published and $100,000 became available in 1996. The level of funding will increase to $200,000 in 1997 and to $325,000 in 1998 and beyond. Research that may benefit sea otters is very likely to be supported and advanced as a result of this initiative.

Currently, other OSPR funded research at California universities and Hubbs Sea World Research Institute are addressing the effects of oil on sea otters, harbor seals, and key marine bird species. Specific research programs address: (1) the effects of oil on various organ systems in sea otters; (2) immediate detection of trace amounts of oil in the fur and feathers of live animals; (3) characterizing the potential effects of oil on the immune response of sea otters; (4) characterizing the immune response of harbor seals including differentiating the effects of the rehabilitation process from exposure to oil and other health hazard; (5) establishing baseline health information for pinnipeds; (6) updating information on the status of marine mammal populations and delineating populations at greatest risk of exposure to oil; and (7) establishing baseline health information on key marine bird species. An additional effect of this commitment to research has been support of at least four individuals pursuing doctoral degrees and support for the post-doctoral research of three other individuals.

All of this research is designed to improve our ability to provide care for oiled marine wildlife, and to improve our ability to determine the immediate and the sublethal effects of oil pollution on marine animal populations. It may also enable federal and state trustee agencies to complete comprehensive wildlife injury assessments as part of the Natural Resource Damage Assessment or joint injury determination. Settlements with responsible parties will enable trustee agencies to undertake restoration of injured wildlife resources.

The OWCN allows the petroleum industry to meet its legal requirements (under SB 2040) to provide for the care of potentially oiled wildlife in all locations where they do business in California. The OWCN provides this in a cost-effective and highly professional manner. Because a portion of the interest on the State Oil Spill Response Fund mandated by SB 2040 is being used to build and support the OWCN, no company or potential responsible party has to pay additional fees out-of-pocket unless or until they are responsible for an oil spill. However, responsible parties which cite the OWCN in their oil spill contingency plans (currently this is essentially all contingency plan holders in California) will utilize the OWCN under OSPR's guidance, and will pay all costs of caring for oiled wildlife. Industry has representatives on the OWCN Advisory Board and the OWCN Scientific Review Board. As may be imagined, this type of cooperative approach has received very broad support in the regulated private sector.

The OWCN is one of the first government, private industry, non-profit, professional educational/research institution partnerships of its kind. This program also represents a State government commitment to integrate wildlife care with resource management and ongoing research. This paradigm shift, from concern only about populations to concern for individual animals as well as populations, has proven a challenge to resource agency personnel and their traditional way of thinking and operating. The OWCN's development has been difficult and complicated, but it has the potential to provide optimal care for oiled wildlife, and to also make tremendous contributions to sea otter and marine animal conservation.

Conclusions and recommendations

In California the prevention of and response to oil spills will remain the focus of OSPR. To the extent these programs are effective, they will improve the likelihood of recovery for the southern sea otter. Inspection of petroleum facilities, pipelines, and transportation vessels, and enforcement of marine safety regulations, may become more intense. Further restrictions on petroleum shipping could be considered. Such technological innovations as Vessel Traffic Identification System may help reduce the risk of shipping accidents.

If the OWCN, with all its various programs and partners, is to succeed in lowering the risk that a major oil spill will reduce the southern sea otter population (and other sensitive marine birds, mammals and turtles) below viable population levels, as well as generally improving our understanding of the health of sea otters and other marine species, this cooperative program must be sustained and supported by CDFG-OSPR. With current legislation which allows OSPR the use up to $1.3 million per year of the interest off the Emergency Response Fund to operate and maintain the OWCN through the U.C. Davis Wildlife Health Center when the building phase is completed in 1998, support for that program seems assured. As noted, there is excellent potential for cooperating with wildlife care programs, educational programs, and marine research in general, as long as these types of activities, and any additional compatible activities at the various OWCN centers unrelated to oil spills, find additional and separate sources of funding.

OSPR and the OWCN are already contributing to the potential recovery of the southern sea otter under the Endangered Species Act (ESA), through activities directly related to oil spill prevention and response. If the southern sea otter is to be delisted, however, it appears that substantial efforts will need to be made to continue tracking morbidity and mortality, to better understand the effects of environmental contaminants, diseases and parasites, as well as the immune response of southern sea otters and factors that may compromise it. With joint funding this type of program would be welcome at the Santa Cruz OWVCRC and/or other OWCN centers. The Santa Cruz OWVCRC could become a world center for sea otter research and management, but FWS and the former National Biological Service (NBS) will need to facilitate and contribute.

Beyond reducing the potential impacts of an oil spill on sea otters and other marine animals, the OWCN and OSPR's Veterinary Services Unit could do much more. Because it brings substantial fiscal and physical resources to bare, the OWCN could facilitate the real implementation of the Federal Marine Mammal Stranding and Response Act in California. The OWVCRC at Santa Cruz could assist in understanding the effects of human activities on sea birds and marine life within the National Marine Sanctuaries of Northern California. If that is to happen, however, National Marine Fisheries Service (NMFS) and National Oceanic and Atmospheric Administration must seek, facilitate, and support those programs.

To date the majority of the funding, equipment, and some key personnel for the OWCN have come from CDFG-OSPR. Non-governmental organizations and other agencies such as the FWS, NMFS, and NBS may all have a vested interest in collaboration with and development of compatible programs. Their support may be in the form of joint research projects, facilitating permits, or continuing support for sea otter and other marine animal demographic, mortality and health studies. Projects related to sea otter recovery and health may be ideal candidates for funds identified in the draft revised southern sea otter recovery plan to "protect population and reduce or eliminate identified potential limiting factors related to human activities including managing petroleum.... (and to) conduct research to understand factor or factors limiting current growth rate of the California population...." (U. S. Fish and Wildlife Service 1996. p. x) or for section 6 (ESA) funds.

The OWCN is a real change from past government-led programs that only gave obligations to the private sector and non-governmental organizations and provided few opportunities. Funds, supplies and training are flowing from a government program to the private sector, and the private sector and universities have input into the program's operations. The OWCN is an example of a truly cooperative approach to research, governance, and public service. Recently cooperative efforts to develop a comprehensive southern sea otter research program, which includes CDFG, FWS, NBS, UCSC, The Marine Mammal Center, and the Monterey Bay Aquarium have begun. Large multi-organizational cooperative programs have been relatively uncommon in the past. They represent a recognition that no single agency, organization or university has all of the resources or political will, all of the best personnel or ideas to provide optimal conservation of sensitive or listed species. There is also a recognition that government and non-governmental organizations need to try to be less insular, more flexible and more cooperative; that universities can provide service along with their research programs; and that in the future we will increasingly need to pool our financial and personnel resources. It may be difficult for some to embrace these changes and new realities. We should remember, however, that the Chinese symbol for "change" also means "opportunity."

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Safeguarding Diversity: Challenges in Developing a Genome Resource Bank for the California Sea Otter

Julie A. Long, Shawn E. Larson, and Samuel K. Wasser

The U.S. Fish and Wildlife Service (FWS) estimates that there are currently 2,400 California sea otters (*Enhydra lutris nereis*) with a range of only 240 miles along the central California coast. The relatively low number and small range of the California sea otter is cause for great concern about the fate of this unique marine species because of the potential for oil spills within the region (see Bonnell et al., this issue). In fact, a major oil spill (>1,000 barrels) within the range of the California sea otter is considered to be the most serious threat to the survival of this species (U.S. Fish and Wildlife Service 1996).

The threat of lost genetic diversity

In the event of a major oil spill, the California sea otter population may lose not only a large number of animals, but also a significant proportion of existing genetic diversity. For any species, the potential for inbreeding increases when the total number of animals in a population is reduced. In naturally outbreeding species, such as the sea otter, inbreeding depresses reproductive fitness by decreasing genetic variation. In fact, inbreeding depression is a major influence on the cycle of extinction where lowered reproductive fitness results in fewer offspring that, in turn, further increases the chances of inbreeding (see Figure 1). Recent evidence indicates that endangered species actually may give little warning of impending crises due to inbreeding because of a threshold relationship between inbreeding and extinction rates (Frankham 1995). Additionally, inbreeding is more likely to contribute to population decline for species with low reproductive rates. The reproductive rate of the sea otter is characteristically low, with an estimated annual birth rate of 0.9 pups per female in California (Riedman et al. 1994). The reproductive efficiency of the California sea otter is compromised further by a relatively high level of pup mortality. For example, in the Monterey area, a 40% pre-weaning pup mortality rate was estimated for 1985-1991 (Riedman et al. 1994).

The viability of wildlife depends, in part, on the level of genetic variation within species, populations, and individuals (Wildt et al. 1993). Because the possibility of an oil spill within the California sea otter's habitat is a constant threat to the continued viability of this population, conservation efforts should include the development of a Genome Resource Bank.

Genome Resource Banks

A Genome Resource Bank (GRB) is the systematic collection, cryopreservation and use of biological materials (gametes, embryos, tissues, blood products, and DNA) from a given species. Because cells can endure storage at low temperatures (-196°C), cryopreservation of gametes and/or embryos extends the generation interval of an individual indefinitely. GRBs essentially are frozen repositories that provide insurance against loss of genetic diversity by retaining viable germ plasm from founder animals for future generations (Wildt 1992). In the case of the California sea otter, a GRB would safeguard existing genetic diversity against not only environmental disasters, but also other unpredictable incidents like disease epidemics (see Thomas and Cole, this issue).

For several reasons, a GRB can be a powerful conservation tool. Most importantly, a GRB offers a high degree of security against loss of genetic diversity by providing an avenue for

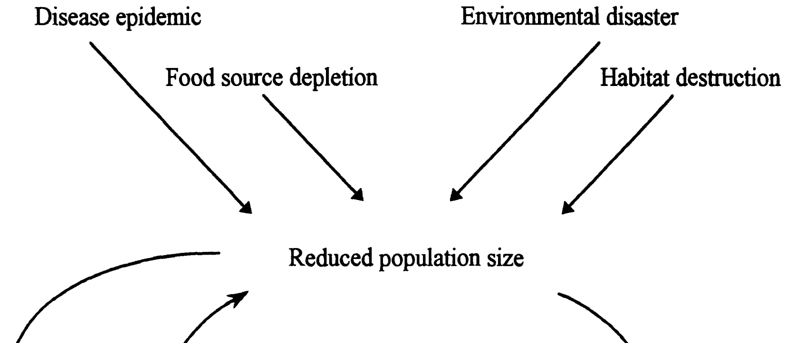

Figure 1. A potential scenario for extinction. Small population size, resulting from either one or a combination of factors, increases the opportunity for incestuous matings. Inbreeding depression is expressed by reduced reproductive fitness and increased susceptibility to disease. Each subsequent reduction in population size further limits genetic variation, eventually leading to extinction (adapted from Wildt 1994).

long-term storage of genetic material. Once established, a GRB can be used as a strategic method for managing exchange of genetic diversity among wild populations. In fact, successful cryopreservation of semen from free-ranging animals suggests that sperm banking also may be a viable approach to promoting genetic diversity in captive populations (Wildt 1989), as well as between captive and wild populations. Additionally, biomaterials stored in a GRB can be used for basic and applied research in genetic, disease and reproductive studies. For example, cryopreserved embryos can provide precise standards for quantifying subtle processes like genetic drift (Mazur 1984).

The effective use of a GRB requires an organized, systematic approach. The Genome Resource Banking Advisory Group, a scientific advisory group under the auspices of the American Zoo and Aquarium Association, serves to guide and facilitate the development of GRBs. Recently, the GRB Advisory Group developed a Resource Guide designed to assist in the formulation and implementation of GRBs. Issues to be considered when developing a GRB include: (1) current knowledge of life history and reproduction; (2) status in the wild; (3) type and amount of germ plasm to preserve in the context of management and genetic goals; (4) technical aspects of germ plasm collection; (5) storage, use and ownership; and (6) available resources and funding (AZA Genome Resource Bank Advisory Group 1996).

Genome Resource Banking and assisted reproductive technology

The potential benefits of GRBs for maintaining genetic diversity and preserving species depend heavily upon adequate usage of stored genetic material through assisted reproductive technologies such as artificial insemination, *in vitro* fertilization, and embryo transfer. Successful assisted reproductive technology, however, relies on knowledge of species-specific reproductive characteristics, including annual reproductive cycles, seminal traits, and timing of ovulation. Therefore, practical application of assisted reproductive technology and, ultimately, the GRB, requires a solid reproductive database.

Female reproduction

Much of the documented information about reproductive biology in the female California sea otter has been derived from comprehensive field studies (Kenyon 1969; Wendell et al. 1984; Siniff and Ralls 1991; Jameson and Johnson 1993; Riedman et al. 1994), as well as direct examination of reproductive tracts (Sinha et al. 1966; Sinha and Conaway 1968; Kenyon 1969; Schneider 1973; Bodkin et al. 1993). Females reach sexual maturity at 4-5 years of age and 75% of 14-15 year old females have been found to still be reproductively active (Bodkin et al. 1993). Females less than 3 years old have immature ovaries (Schneider 1973) ranging in size from 7-11 mm (Sinha and Conaway 1968.) In mature females, ovaries are 11-23 mm in length and enclosed within a bursa. Typically, a single preovulatory 8 mm follicle is present on the ovary; polyovular follicles are rare. Fresh ovulation sites, or corpora lutea, measure 5-8 mm in diameter; whereas corpora lutea of the preimplantation period and pregnancy range in size from 5-11 mm and 9-17 mm, respectively (Sinha and Conaway 1968). The period of delayed implantation appears to be variable and may account for the range of differences in gestation length (Jameson and Johnson 1993). On average, gestation is 6 months and is considered to consist of a 2-3 month pre-implanted and 4 month implanted phase. The peak pupping period for the California sea otter in the southern part of the range near Morro Bay occurs from January to March, with a smaller peak in the late summer to early fall (Siniff and Ralls 1991); whereas, in the Monterey area, seasonal trends in pupping are less pronounced (Riedman et al. 1994). Females return to estrus 1 day to several weeks after pup weaning. Interestingly, females that lose their pups prematurely soon return to estrus; thus, spring pupping mortality and subsequent mating may account for the second pupping peak in the fall. Estrus length, based on pair-bond dissolution, is estimated to be 3-4 days (Riedman and Estes 1990). Even though there appears to be a seasonal trend in pupping, births can take place throughout the year (Jameson and Johnson 1993).

Although a substantial amount of information about female reproductive biology has been accumulated, little is known about sea otter endocrinology. Biologists do not know for certain if females are (1) induced ovulators; (2) seasonally polyestrus or monoestrus; or (3) how to distinguish between pregnant and nonpregnant states. Such information is critical for the application of assisted reproductive technologies. The Seattle Aquarium and the Center for Wildlife Conservation, in cooperation with public aquariums and marine mammal biologists, are conducting a long-term project on sea otter endocrinology using a non-invasive hormone monitoring technique that measures steroid metabolites extracted from fecal samples. Over 350 samples have been collected from 2 female Alaskan sea otters spanning 1 year. Preliminary data reveal, for the first time, annual estrogen and progesterone profiles in a captive female (see Figure 2). Cyclic estrogen spikes occurred at 45-60 day intervals, increasing in magnitude until the largest spike, which was associated with full estrus behavior. Ovulation was confirmed by a 10-fold rise in progestins within 10 days following the estrogen spike and continued to rise until 30 days post estrogen spike. Both estrogens and progestins fell off slightly by day 50, and then showed a dramatic and sustained rise (3-fold increase for estrogens and 20-fold increase for progestins) 90 days post estrogen spike of a presumed pregnancy. These data suggest that the preimplantation period in this female lasted for 3 months. With the addition of more females to the dataset, it may be possible to fully characterize the period of delayed implantation in sea otters. Additionally, fecal cortisol metabolites also have been monitored successfully and show promise as an index of physiological stress in this species.

Male reproduction

In contrast to female sea otters, limited information is available about the reproductive biology of male California sea otters. Male Alaskan sea otters reach sexual maturity at 5-6 years of age (Schneider 1978; Garshelis 1983); however, the onset of sexual maturity in California males has not been established (Riedman and Estes 1990). Reproductive tracts from "old" (exhibiting well-worn teeth) Alaskan males show no signs of diminished sperm production (Kenyon 1969). It also has been suggested that Alaskan males produce sperm throughout the year (Lensink 1962); however, testicular histology indicates that a mild periodicity is associated with spermatogenesis (Kenyon 1969). In California, mating activity of territorial males increases during September through November, and copulation occurs exclusively in the water (Riedman and Estes 1990). Only one report documents ejaculate traits in sea otters (Ballachey 1995); this study was conducted to assess damage in male Alaskan sea otters after the 1989 *Exxon Valdez* oil spill in Prince William Sound. Overall, ejaculates from adult male sea otters exhibited low sperm concentrations and contained an average of only 13.8% morphologically normal sperm cells per ejaculate. The most prevalent structural defects included mid-piece and tail abnormalities. More alarming, however, is the fact that high numbers of abnormal sperm were found in both oiled and unoiled (control) males, indicating that this may be characteristic of the species. It is clear that a comprehensive study of reproduction in the male sea otter needs to be conducted.

Conclusion and recommendations

Present realities require focusing on basic research to determine critical reproductive parameters for both female and male sea otters, including the timing of ovulation, number of normal sperm produced and optimal methods for cryopreserving sperm, before attempting artificial breeding or long-term storage of genetic material. Ideally, protocols for ovulation detection, semen collection and artificial insemination are developed using a model species before applying the technology to the endangered species. This approach has been successful for a critically-endangered mustelid species, the black-footed ferret (*Mustela nigripes*). Semen cryopreservation and artificial insemination techniques were developed first for the domestic ferret (*Mustela putorius furo*; Howard et al. 1991). Determining optimal methodology in the model species enabled the production of black-footed ferret offspring by artificial insemination with frozen-thawed sperm (Howard et al. 1996). For the sea otter, the non-threatened Alaskan subspecies would be an excellent model for the threatened Californian subspecies. Additionally, the relative abundance of Alaskan sea otters in captivity provides a unique opportunity to develop these technologies for use in the field without disturbing wild populations.

GRBs, in combination with assisted reproductive technology, have enormous potential for conserving endangered species. There is a general consensus that GRBs will be contributing significantly to the conservation of rare wildlife

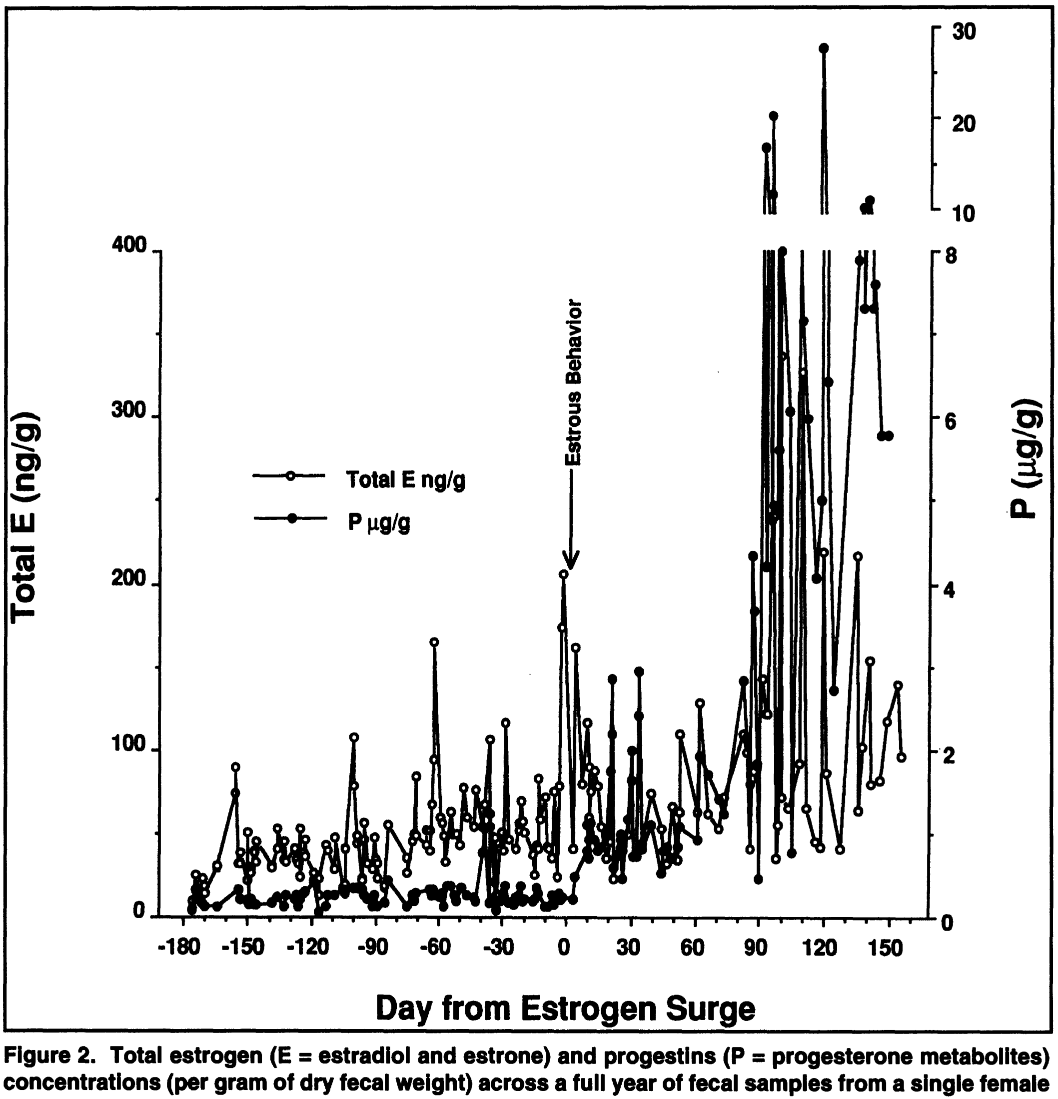

Figure 2. Total estrogen (E = estradiol and estrone) and progestins (P = progesterone metabolites) concentrations (per gram of dry fecal weight) across a full year of fecal samples from a single female sea otter at the Seattle Aquarium. Day 0 reflects the time of the estrogen spike which, for this female, occurred in January. Estrus behavior refers to overt and frequent female-initiated mating behavior with the male. This behavior was observed only during the single event indicated on the graph.

species as we enter the 21st century (Wildt 1992). For the California sea otter, the availability of stored gamete and/or embryo samples is particularly relevant in the event that the current population experiences a drastic decline in number. Storing gamete samples, however, should not be viewed as the solution to sea otter conservation, but rather as one of many tools that will enable this species to thrive. All reasonable approaches should be explored and used to help conserve and understand the California sea otter while maximizing the efficient use of limited resources.

For wildlife populations that are susceptible to catastrophe, an organized effort to collect, evaluate, cryopreserve, store and use germ plasm should rank high on the list of conservation priorities. Because of the likelihood that an oil spill could dramatically affect the California sea otter population, there is an urgent need to establish a GRB before such a crisis occurs. Development of GRB will require a concerted effort from aquariums, reproductive biologists, field biologists and policy-makers, as well as funding commitments. In summary, the following reproductive studies are recommended to facilitate the development of a GRB: (1) conduct a comprehensive study on male reproduction that characterizes ejaculate traits and seasonality; (2) determine unknown aspects of female sea otter endocrinology, including estrous cycle length, timing of ovulation and seasonality; and (3) develop semen handling and cryopreservation protocols. Because of the precarious status of the California sea otter, these reproductive studies should be initiated as quickly as possible. A GRB, together with conservation activities such as improved pollution control, diligent habitat maintenance and protection, captive breeding/reintroduction programs and public awareness campaigns, promises to be an effective strategy for conserving the California sea otter.

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Sea Otters in Captivity: The Need for Coordinated Management as a Conservation Strategy

E. Jean Brennan and
John Houck

Sea otters in captivity serve an important role in conservation, specifically in the education of the public and the maintenance of biological diversity. Historically, education has been the primary focus. This is because many aquariums adopt a regional approach to both their exhibit collection and interpretive programs, and use the sea otter to teach the visitor about local coastal habitats. In the last decade more aquariums have tried to educate the public about broader conservation issues; for example, the effects of over-harvesting by commercial and sport fisheries, and the effects of human-caused environmental disasters such as oil spills. Aquariums have the potential, however, to play a more active role in sea otter conservation by linking the management of the captive population with the conservation needs of the wild population. This would require that the captive population be genetically and demographically managed to form a self-sustained population. The creation of a genetically healthy and stable captive population would serve, not only as a genetic reservoir to use in population recovery or restoration attempts in the wild, but also to eliminate the need to collect sea otters from the wild to fill their exhibits (Soulé 1980; Foose 1980; Wildt et al. 1991). Realizing this potential will challenge animal husbandry techniques (see Long et al., this issue) but, more importantly, will require a change in captive management philosophy (i.e., to manage the captive sea otters cooperatively rather than independently, which has historically been the practice).

The management of the captive sea otter population must be directed toward anticipating the need to respond to environmental or human-caused threats to the wild population. The primary objective therefore must be to preserve within the captive population an adequate representation of the genetic diversity and presumably the adaptive traits that are found in the wild population (Foose 1980). Our success at achieving that objective can be measured with the use of computer simulations that model the trends in the population under various management strategies. In this paper we present the results of such an analysis and, based on the sensitivity of the model, we identify ways to modify the captive management program in an effort to enhance the contribution the captive sea otter population can make in the conservation of this species.

History in captivity and husbandry requirements

In the 1930s and 1940s, Russian investigators were the first to identify critical physiological requirements and basic husbandry techniques required to successfully meet those requirements in captivity (Barabash-Nikiforov 1947). Their findings were later corroborated by U.S. investigators in Alaska during the 1950s (Kenyon 1969). The most critical requirements reflect the animal's unique physiological and behavioral adaptations to the cold marine environment (Kirkpatrick et al. 1955; Kenyon 1969), specifically, the fact that the sea otter, unlike other marine mammals, lacks a fat or blubber layer to insulate it from cold water temperatures. The animal relies on its fur which must be clean and well-groomed if it is to be effective at trapping a layer of air next to its skin, thus preventing the cold ocean water from penetrating to the skin. To prevent the breakdown of the natural oils in the fur, the sea otter must have access to large quantities of clean sea water maintained at a cool temperature. Without these essential elements provided in the captive environment, the fur cannot be maintained and the animal quickly becomes hypothermic and dies. The animal also relies on its high metabolic rate to generate heat internally to help maintain core body temperature. This requirement demands that a sea otter receives large quantities of food, approximately 20% of its body weight per day, at an annual cost of $10-14,000.

The first sea otter to be successfully maintained in a public facility was housed for six years at the Wood-

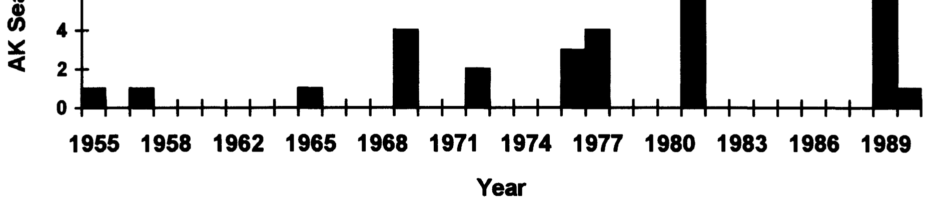

Figure 1. Chronological history showing the number and year wild Alaska sea otters joined the North America captive sea otter population. Figure does not include animals that died within the first month after capture.

land Park Zoo in Seattle, beginning in 1955 (Vincenzi 1962). Since then, the professional staff and associates working in zoos and aquarium have worked to improve husbandry techniques (Johnson et al. 1967; Pollard 1969; Johnson 1972; Nightingale 1981; Glazier 1984; Ramirez et al. 1996; Powell 1994) and to learn more about sea otter behavior (Kenyon 1969; Whitt 1971), nutrition (Crandall 1964; Mattison and Hubbard 1969; Nightingale et al. 1978, 1979; Hoffer 1973; Fausett 1976; Antonelis et al. 1981; Williams et al. 1991), reproduction (Brosseau et al. 1975; Jameson et al. 1975; Antrim and Cornell 1980; Hewlett 1983; Casson et al. 1987; Nakajima et al. 1988; Hanson et al. 1993), and health (Kenyon et al. 1965; Stetzer et al. 1981; Giddens et al. 1984; Williams 1986, 1990; Joseph and Spraker 1989; Williams et al. 1990; Casson 1990; Brown et al. 1994). Integrating these findings into exhibit design results in an exhibit that is very costly to build and to maintain, due to the sophisticated sea water systems and high level of filtration required. As a result, the number of "homes" in captivity, defined as the captive carrying capacity, has been very limited. This has forced captive managers to limit captive reproduction (or even prevent breeding entirely), and to transfer captive-born offspring to Japan or Europe due to space limitations. Based on a recent meeting among members of the captive zoo and aquarium community in May of 1996, it is estimated that the North American carrying capacity will not exceed 47 over the next five years.

Population status and life history data of sea otters in captivity

Two recognized subspecies, commonly referred to as Alaska (*Enhydra lutris kenyoni*) and California (*E. l. nereis*) sea otters, are managed by wildlife agencies in North America; both are exhibited in aquariums. There are more than 150,000 Alaska sea otters in the wild (Riedman and Estes 1990), in contrast to the estimated 2,400 in California (U.S. Fish and Wildlife Service 1996). The Alaska population is secure in the wild, its members are collected by commercial animal dealers for aquarium exhibits, and are hunted by native-peoples under state and federal permits. The California sea otter population has been designated threatened under the Endangered Species Act due to its small numbers, slow growth rate, and risk of oil spills (U.S. Fish and Wildlife Service 1996). Currently there are 24 Alaska sea otters maintained in aquariums in North America, 113 in Japan, and two in Europe. There are only thirteen members of the California subspecies in four U.S. aquariums, all of whom were rescued as stranded orphaned pups that would otherwise have died. California sea otters are not exhibited outside the U.S. and their export is prohibited due to their threatened status. In this paper we refer to the collective captive members of each subspecies as a "subpopulation" of the entire captive sea otter population in North America.

Probability of female producing 1 pup	33
Probability of female producing 2 pups	1.5
Sex ratio at birth (males)	0.6
Female mortality (0-1 yr of age)	0.727
Female mortality (1-2 yr of age)	0
Female mortality (2-3 yr of age)	0.5
Female mortality (adult, 3-25)	0.091
Male mortality (0-1 yr of age)	0.5
Male mortality (1-2 yr of age)	0
Male mortality (2-3 yr of age)	0
Male mortality (adult, 3-25)	0.099

Table 1. Life history rates of sea otters in captivity.

Since 1955, a total of 92 Alaska sea otters have been exhibited in North America zoos and aquariums, of which 30 were wild-caught, 22 were non-releasable wild sea otters placed in captivity following the *Exxon Valdez* oil spill of 1989, and 44 were captive-born. Five of the wild sea otters died within one month of their arrival in captivity (these are not included in the demographic calculations presented in this paper). Alaska sea otters have generally come into captivity from the wild as a result of environmental disasters or failed translocation efforts (Hewlett 1983). The result has been the formation of an unstable age-structure of this subpopulation due to the large number of same-age animals that enter captivity at random intervals. This is particularly evident as a result of the 1989 oil spill (see Figure 1). The age-structure of the Alaska subpopulation follows: females (2 yr. n=1; 6 yr. n=1; 7 yr. n=7; 8 yr. n=3; 12 yr. n=1; 16 yr. n=2; 17 yr. n=1; 18 yr. n=1; 25 yr. n=1) and males (6 yr. n=1; 7yr. n=2; 13 yr. n=1; 17 yr. n=1).

Continued reliance on punctuated recruitment is unreliable, perpetuates the unstable age-structure and thus hinders the ability to form a demographically stable, self-sustaining population. This pattern is exacerbated by the low recruitment level due, in part, to the practice of transferring captive-born Alaska sea otters out of the breeding population. Fifty percent of the captive-born offspring that survive their first year have been sent to aquariums in Japan. The current Alaska subpopulation represents 10 wild-caught, 11 non-releasable wild sea otters rescued during the *Exxon Valdez* oil spill (one is a castrated male), and three captive-born. Only two of the five institutions that maintain Alaska sea otters in North America are attempting to breed their animals (representing wild-caught females and two captive-born males).

An analysis of the historic records was used to calculate life history data for Alaska sea otters in captivity (see Table 1). Annual survival rates were calculated using all available survival data from dead, living, and transferred sea otters. Adult mortality are more commonly observed in males between the ages of 10 to 13, and females be-

Number of simulations	1,000
Number of years	24
Breeding system	Polygynous
Age at first reproduction	3
Maximum lifespan	25
Maximum number young per litter	1
Density independant reproduction	Yes
All males in the breeding pool	Yes
Assume carrying capacity non-limiting	Yes
Population supplementations	As specified
Initial population size	Current

Table 2. Assigned values used in Vortex© model.

tween the ages of 13 to 18. The longest lived animal is still alive at age 25 yr., which exceeds the previous longevity records of 23 in females and 18 in males. Reproductive rates were calculated using the historic records of 17 reproductive-aged females: 12 produced a total of 40 single pups, one produced twins, and four were non-reproductive. The first female sea otter to be successfully maintained in captivity was not included in our reproductive rate estimates due to abnormal reproductive tract development (Vincenzi 1962). The youngest female to reproduce was 3 years old when the pup was born, and the oldest was 12. The sex ratio of captive-births is slightly biased towards males (0.6). Observed annual female reproduction in this study equal 0.34, with a lifetime average of 2.65 (range 1-8 pups/female). These rates should be considered a production measure rather than a measure of female reproductive potential however, since managers have the option to limit captive breeding. In the wild, Alaska sea otters exhibit higher reproductive rates (see Bodkin and Ballachey, this issue).

California sea otters have been maintained in captivity since 1969. Complete records are available for a total of 32 animals, exhibited in four aquariums. Twelve were wild-caught, 18 were rescued from the wild as orphaned pups (Harrold et al. 1996), and two were conceived in the wild but born in captivity. Eighteen additional captive-born California sea otters were born at one institution as the result of breeding between eight females and a single male. Due to chromosomal abnormalities found in the breeding male however, none of these pups survived (see Duffield et al., this issue). The oldest California female in captivity is 12 years of age. A complete historic record for California sea otters has not been assembled, thus it is not possible to compare life history traits of the two subpopulations. There are currently 13 California sea otters maintained in four U.S. aquariums, representing the following age-structure: females (1 yr. n=2; 2 yr. n=1; 3 yr. n=1; 4 yr. n=1; 12 yr. n=2) and males (2 yr. n=1; 3 yr. n=1; 4 yr. n=2; 5 yr. n=1; 10 yr. n=1).

Population viability analysis and management options

We present the results of computer simulations that model demographic and reproductive outcome as a measure of the captive population's long-term viability under current management practices. The Vortex© Monte Carlo computer program was used for this purpose (see Table 2) (Lacy and Kreeger 1992; Lacy, in press). The age-structure of the starting population matched the current profile of each subpopulation. The model generates a Leslie matrix using the observed life history data, simulates a series of steps that represent events in the life cycle (reproduction, litter size, sex determination, death) and assigns the outcome of each step based on observed probabilities. Each simulation was repeated 1,000 times. The results of these simulations predict the most probable outcome and demographic trends in both the Alaska and California sea otter subpopulations through the year 2020.

It should be noted, however, that the model assumes coordinated, cooperative management to maximize reproductive output and genetic founder representation and to minimize inbreeding (i.e., unrestricted movement between institutions). Current management practices violate the model's assumptions however because many aquariums limit or prevent reproduction and rarely exchange animals because they operate independently. Thus, the actual population numbers will be less than those predicted in the simulations presented. The results, therefore, are presented as a heuristic tool, to help evaluate how management strategies may influence population trends, not to predict exact numbers in any given year. The results of these simulations are presented graphically in Figures 2-4.

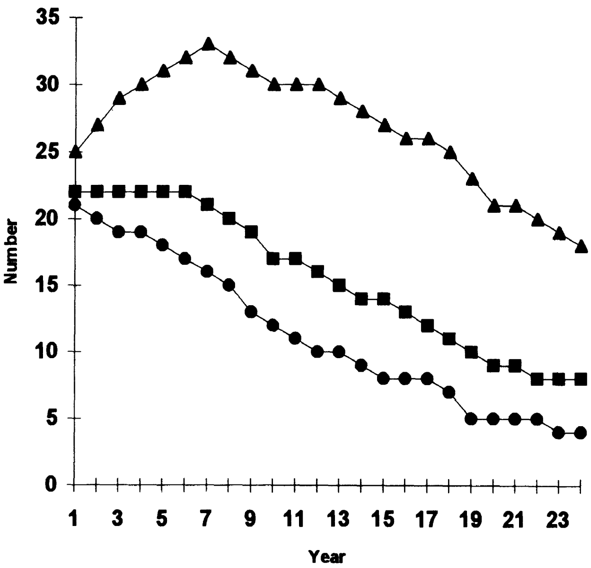

Figure 2. Most probable outcome based on computer simulations of the captive Alaska sea otters in North America under three different management strategies: [circle] continue to limit female reproduction and transfer half of the offspring out of the breeding population; [square] continue to limit female reproduction but keep all captive-born offspring in the breeding population; [triangle] double reproductive rate while retaining all captive-born offspring in the breeding population.

Modeling the Alaska subpopulation

The Alaska subpopulation was modeled under a variety of management scenarios. The first examined the effects of adding wild-caught adults (1 male and 6 females, ages 3 years old) every other year for 10 years to the captive subpopulation. A second simulated the possible effects of adding a large number of same aged animals (3 males and 10 females, ages 3 yr. old) to the population at year two of the simulation (i.e., to simulate the possible effects of another major oil spill). In both cases, the simulations failed to produce a stable population. The only way a stable population was achieved, relying on supplementing the population with wild-caught sea otters, required a population size so large it was meaningless (given the current and anticipated carrying capacity in North American aquariums).

Several other, more realistic, management strategies were simulated: (1) continue the current practice of limiting female reproduction and transferring half of the captive-born offspring out of the population; (2) continue to limit female reproduction but allow all captive-born offspring to remain in the breeding population; and (3) encourage female reproduction, doubling the rate, and allow offspring to remain in the breeding population. Figure 2 show the results of these simulations. Despite the feasibility in implementation, these management strategies failed to produce a self-sustained population. The results, however, help to illustrate: (a) that the model is sensitive to an increase in reproductive output (whether it be through increase reproductive rate or increase recruitment); (b) that captive breeding alone does not produce the level of recruitment to maintain the Alaska subpopulation (presumably due to the unstable age-structure); and (c) continued reliance on infrequent and unreliable events to provide additional replacement animals will further hinder the process of becoming self-sustaining.

Modeling the California subpopulation

Figure 3 presents the simulation results of the captive California subpopulation. We used the life history values observed in the captive Alaska sea otters since specific data for California sea otters are lacking. Four different management strategies were simulated: (1) continue the current practice of non-reproductive management; (2) encourage female reproduction to achieve the same level as observed in the Alaska female; (3) double the female reproductive rate and add two wild year-old orphan females to the captive population each year for 7 years; and (4) double the female reproductive rate and add two wild year-old orphan females to the captive population each year for 15 years. Again, because current management practices violate many of the model's assumptions, the choices of 7 and 15 years and supplementing with only females is intended to be illustrative, not prescriptive. The simulation results further illustrate the need to increase reproductive output in captivity and to supplement the captive population with animals from the wild before a self-sustaining population can be achieved.

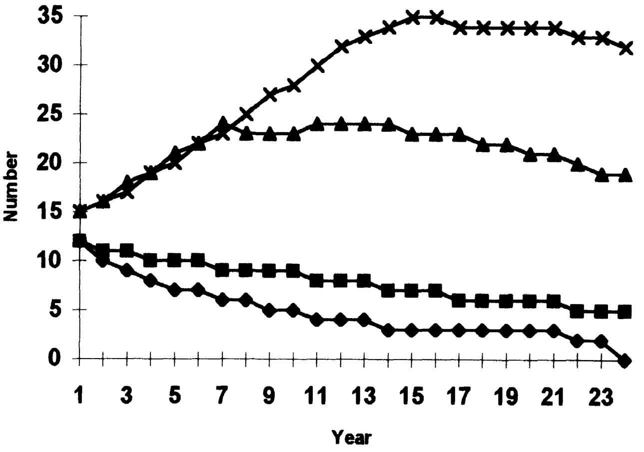

Figure 3. Most probable outcome of computer simulations of the captive California sea otters in North America under four different management strategies: [diamond] continue to manage as a non-reproductive population; [square] female reproductive rate equal to that observed in the Alaska subpopulation; [triangle] double female reproductive rate while adding two yearling females every year for seven years; [cross] double female reproductive rate while adding two yearling females every year for 15 years.

Shifting the emphasis over time to manage a single subspecies in U.S.

Figure 4 illustrates one possible strategy: to simultaneously manage both subpopulations while over time shifting to manage a single subpopulation. The overall goal would be to maintain only California sea otters as a way of optimizing the conservation value of limited carrying capacity. This represents a shift in management philosophy in recognition of the threat to the wild California population, and the fact that Alaska sea otters are adequately represented in aquariums in Japan and in the wild. In this strategy, the Alaska sea otters currently in the U.S. would be replaced with California sea otters as they age and die. It is important to remember that the Alaska sea otters in captivity serve as the biological model to use in studying and refining captive reproductive techniques. Thus, reproduction of Alaska sea otters need not necessarily be eliminated, but rather be controlled to produce surplus animals only if they are guaranteed to be transferred out of the U.S. breeding population. This functionally represents a zero reproductive rate. The California subpopulation would be simultaneously managed to increase its reproductive output while adding orphaned animals to the captive breeding population until a self-sustaining population could be established.

Conclusions and recommendations

The results of computer modeling indicate that current management practices (i.e., limited reproduction, limited recruitment, and restricted

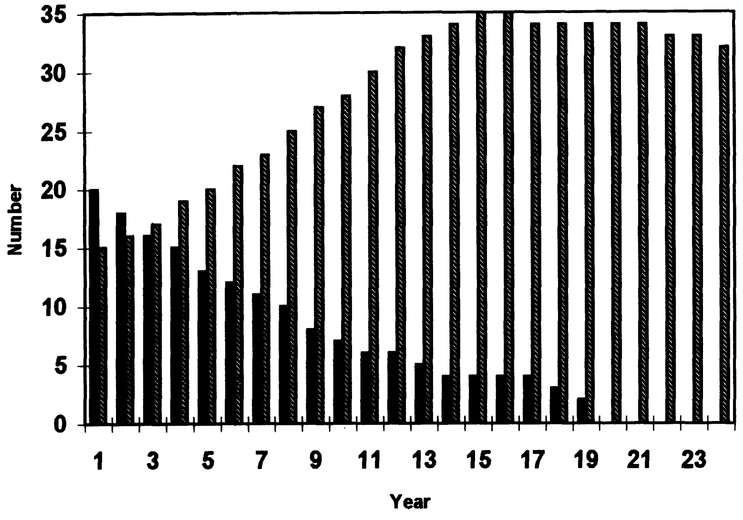

Figure 4. Graphic illustration of a management strategy to exhibit both Alaska and California sea otters in North America while gradually replacing Alaska sea otters with California sea otters.

exchange of animals between institutions) will fail to produce a self-sustaining population. Based on a population viability analysis using Vortex,© the carrying capacity in North America is too limited to maintain members of both the Alaska and California subspecies without relying on replacement animals from the wild. The following recommendations are offered to help zoos and aquariums make a more significant contribution to sea otter conservation.

(1) Increase carrying capacity. Efforts to increase the carrying capacity through the construction of new sea otter exhibits will be minimal due to the high exhibit construction and annual animal maintenance costs. Certainly zoos and aquariums may be more willing to dedicate exhibit space to California sea otters if it promotes their conservation mission. Institutions that decide to build new sea otters exhibits should be encouraged to maintain California sea otters. In addition, several steps may be taken to increase captive carrying capacity including: (a) encourage institutions to increase the carrying capacity of their existing facilities; (b) explore the feasibility of exhibiting sea otters with other marine mammals in mixed species exhibits; and (c) support cryopreservation and assisted reproductive efforts. (This would allow the introduction of genetic materials into the gene pool at a future time if the current limited carrying capacity prohibits breeding.) In order to realize this latter approach, aquariums are encouraged to support studies of both male and female reproductive biology and behavior, to initiate the collection of semen, and to promote studies to optimize cryopreservation and utilization of this material (see Long et al., this issue).

(2) Increase reproductive and survival rates. Reversing the projected decline in the captive North America sea otter population will require a coordinated management effort to increase the number of females that are allowed to breed, increase annual recruitment and, over the next few decades, supplement the captive population with animals from the wild. Reproductive rates can be increased in two ways: by increasing the number of females that reproduce, and by increasing the survival rates of the offspring. Every effort should be made to house captive sea otters in reproductive groups and to manage the animals to facilitate breeding. Currently, only two of the four institutions that maintain California sea otters in reproductive breeding groups (representing five wild females and two wild males), and none have reproduced.

Increasing annual recruitment can be achieved by decreasing pup mortality. High infant mortality has been reported in other captive species (e.g., Ralls et al. 1979,1980) and are often attributed to inbreeding. This is an unlikely explanation in the case of captive Alaska sea otters, however, since the majority of the recorded births have been between wild, presumably unrelated pairs. Captive managers should therefore examine husbandry and management practices that may contribute to pup mortality such as: (a) conditions under which the parents were reared (especially in the case of sea otters that were acquired as stranded orphan pups); (b) stressful environmental factors such as those produced by the sight and sounds of human activities (Brosseau et al. 1975; Antrim and Cornell 1980; Nightingale 1981; Graham and Hewlett 1988); (c) sexual receptivity as a function of social groupings; and (d) how potential mates are introduced to one another for mating (Graham and Hewlett 1988).

(3) Link the captive population with the problem of stranded California pups. As in the case of the Alaska sea otter population, it will be necessary to supplement the captive California population with additional animals from the wild until a demographically stable age-structure is established. The difference between the Alaska and California sea otter subpopulations is the predictable supply of animals from the wild, due to the number of orphan pups that strand each year. In 1986, the Monterey Bay Aquarium in central California began efforts to raise stranded sea otter pups for release back into the wild as a humane endeavor. Not every animal could be successfully rehabilitated, and those that were deemed non-releasable have been added to the captive population. Historically, the number of pups that are orphaned each year ranges from two to eight (see Figure 5). As a result, the captive California subpopulation has a more stable age-structure because of this annual recruitment. Adopting a strategy to incorporate orphaned pups into the captive population, or to preferentially select animals to establish a self-sustaining captive sea otter population would not prohibit rehabilitation efforts since the number in need of rehabilitation exceeds the number of spaces in captivity. It is the U.S. Fish and Wildlife

Service recommendation that orphan pups remain on the beach. These animals will undoubtedly die. Thus, placing such animals in captivity has no impact on the population's natural recovery in the wild.

(4) Utilize the existing infrastructure to implement management objectives. Many of the key elements and organizational structure needed to design and implement a more active sea otter conservation program are already in place. Eight of the nine North American institutions currently exhibiting sea otters are fully accredited members of the American Zoo and Aquarium Association (AZA), a professional organization that promotes cooperative efforts among its member institutions to effectively manage species in need of conservation efforts. One of the principle mechanisms of fostering cooperative efforts is the Taxon Advisory Group (TAG), a group composed of experts that are knowledgeable about the particular group of animals. The AZA Marine Mammal TAG has already been formed, and regional studbooks, which provide a complete demographic analysis of the historic and living population, already exist for sea otters in North America and Japan. We recommend that the industry professionals meet and identify common goals, define management objectives, and to constantly measure their success in achieving conservation goals. Hopefully, the results presented in this paper will prompt such a meeting.

(5) Work on an international scale. A closer working relationship between country representatives will greatly facilitate the transfer of surplus captive-born Alaska sea otters pups, provide captive homes to stranded or non-releasable sea otters in the event of another major oil spill off the Alaska coastline, and would minimize the need to collect Alaska sea otters from the wild. Improved communication outside of North America, especially between the U.S., Canada, and Japan, is needed.

(6) Work closely with federal agencies. Captive managers need to work more closely with federal agencies to identify ways aquariums can best serve sea otter conservation. Aquarium professionals are already working with the U.S. Department of Agriculture in a method known as "negotiated rulemaking" to update and upgrade standards for the display and care of sea otters on public display. A similar approach should be adopted between the captive community and the U.S. Fish and Wildlife Service. Their common goal should be to enhance the captive breeding program, and the transfer and management of California sea otters to maximize and retain genetic diversity. The legal tool that would facilitate this level of coordinated management is an enhancement permit (U.S. Fish and Wildlife Service, Ventura Office, personal communication). This type of permit must be written jointly if the relevant issues and obstacles are to be identified and addressed. The permit would clearly identify the various management options and would grant captive managers the latitude to work more quickly and effectively. Captive managers should therefore consider working with the U.S. Fish and Wildlife Service in this endeavor to be their highest priority because it will serve as the legal foundation upon which to build the captive management program.

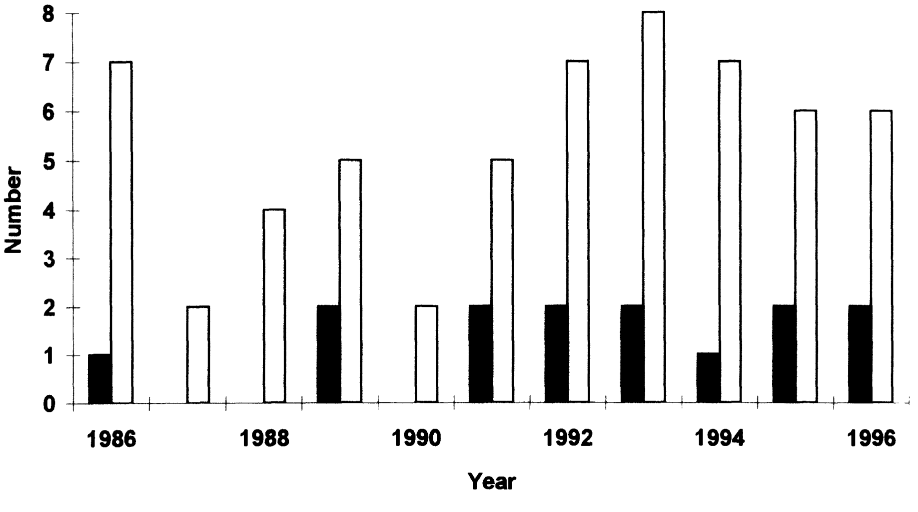

Figure 5. Chronological history of stranded California sea otter pups: [white] number that stranded; [black] number of non-releasable pups that were added to the captive population.

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A Complex Chromosome Rearrangement in the Karyotype of a Wild-Caught Male Sea Otter

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Jan Chamberlin-Lea, and James E. Antrim

California sea otters have been maintained at Sea World, San Diego, California since 1972. The sea otters studied here had been integrated into a sea otter breeding program in 1973 (Antrim and Cornell 1980). The early pupping history of this breeding colony, when it consisted of the original male and eight females, was characterized by a pattern of stillbirths, anomalous offspring and spontaneous abortions. The congenital anomalies expressed included a heart defect, the absence of the digestive tract from mouth to intestines with other instances of parts of the digestive tract missing (e.g., liver, pancreas), incomplete diaphragm and the presence of facial anomalies, such as severe cleft palate and absence of eyes. The severity and array of the abnormalities were, to us, highly suggestive of the types of birth malformations seen in the segregation of chromosome anomalies in humans (Yunis 1977; Smith and Jones 1982). Chromosome studies were, therefore, undertaken on the male and three of the females in the breeding colony to investigate the possibility that there was a chromosomal abnormality segregating in this breeding colony. We report here the results of chromosome studies undertaken on a male and 3 female California sea otters in the Sea World sea otter breeding colony. We also discuss possible implications of these findings to conservation efforts.

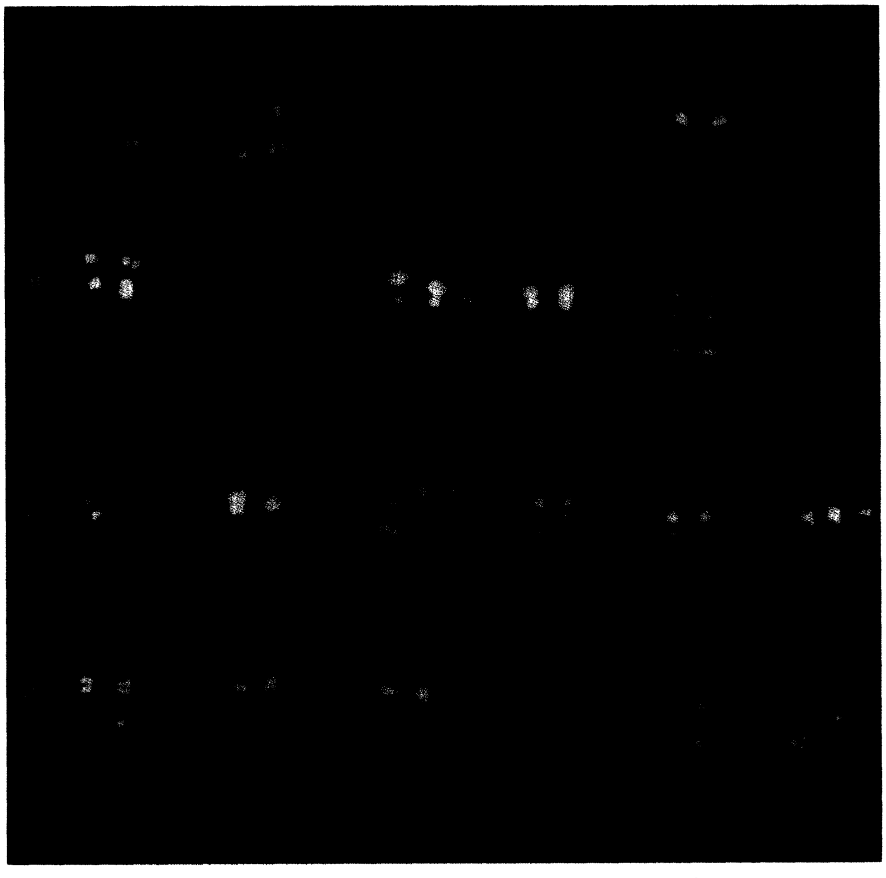

Figure 1. An R-banded karyotype of a female sea otter (2N = 38). Chromosomes are grouped A through D and numbered based on size and centromere position. The X chromosomes are indicated.

Materials and methods

Karyotypes were established from blood and fibroblast cultures in the male, and from blood cultures in the females. At the time of this study, no pups were available for examination. Blood was drawn by femoral venipuncture. Tissue and blood samples were refrigerated and shipped by one-day air to Portland State University for culturing. Blood samples were cultured in RPMI-1640 media (Gibco), supplemented with 25% fetal calf serum, antibiotics and phytohemagglutinin (Duffield and Chamberlin-Lea 1990). These cultures were grow for 4 days, synchronized for one to two hours with colcemid, followed by a second 6-10 minute colcemid synchronization 21 hours later. The cells were harvested, exposed to 0.075M KCL hypotonic, and fixed. Subsequent to the initial blood sample, the male died of septic endotoxemia and corneal fibroblasts were cultured. The fibroblast culture was grown in Hams F-10 (Gibco), supplemented with 15% fetal calf serum, antibiotics and a fungicide, as per Duffield et al. (1991).

A variety of staining techniques were used to construct karyotypes. These included standard Giemsa staining, G-banding, C-banding (Hack and Lawce 1980), and a fluorescent R-banding technique using chromomycin A3 and distamycin A (Sahar and Latt 1978; Schweizer 1980; Duffield and Chamberlin-Lea 1990; Duffield et al. 1991).

Results

Chromosome irregularities were seen in the male California sea otter karyotype when compared with the three females. The chromosomal differences in the male were consistently present in all of his cells, both leucocyte and fibroblast, and were not seen in any of the cells of the

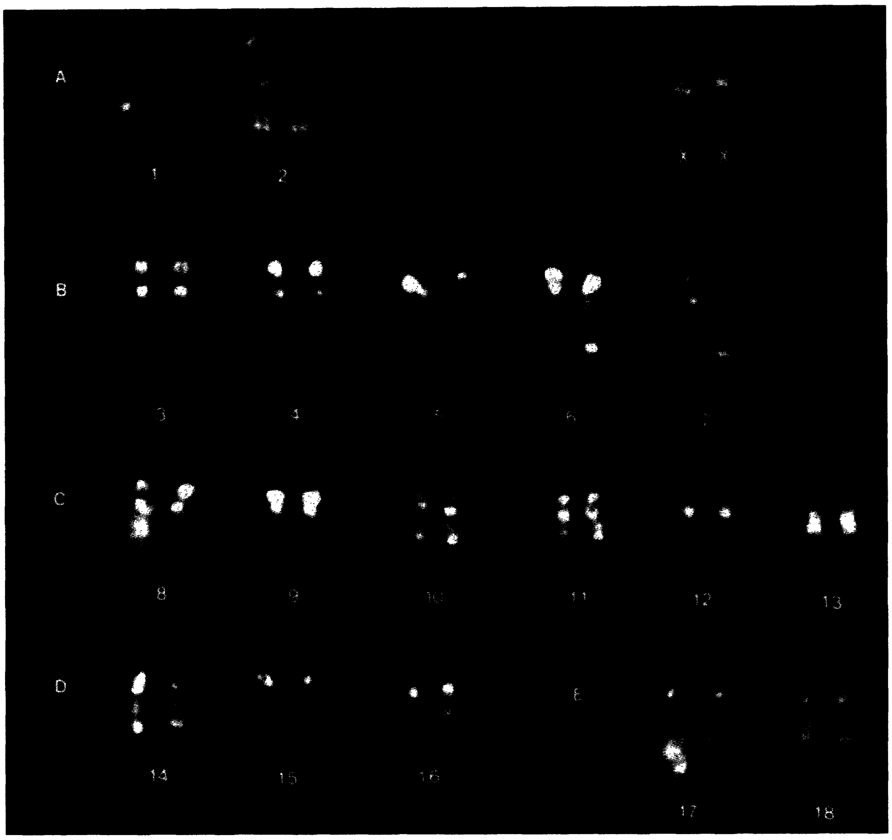

Figure 2. An R-banded karyotype of the male sea otter in question in this study (2N = 38). The chromosome pairs exhibiting consistent irregularity are indicated by arrows.

females examined. A representative female R-banded karyotype is shown in Figure 1; the male is presented in Figure 2. The three pairs of chromosomes exhibiting a consistent irregularity in the male (b5, c10 and c13) are marked. The differences between the chromosome pairs in the male and in the three females is illustrated in more detail in Figure 3. The rearranged b5 homologue in the male is missing a faint-staining or 'dull' area in the short arm. The c10 rearrangment represents a possible inversion of the short arm of the chromosome (see Figure 4) and there is an apparent difference in the short arm and centromere region of one of the chromosomes of pair c13, as compared to the other homologue and to the chromosomes of the females.

Discussion

The precise nature of the chromosomal changes in the male California sea otter are not easy to resolve without chromosomal evaluation of the abnormal offspring. Many species of marine mammals have variable fluorescent R-band regions, referred to as heteromorphisms (Duffield and Chamberlin-Lea 1990; Duffield et al. 1991). These variable regions can differ between individuals within populations and are considered to be normal variants in the chromosomes . The apparent inversion in chromosome c10 could, indeed, be an example of normal R-band differences in the centromeric and short arm telomeric region of this chromosome. However, this variant was not seen in any of the females, nor in another male karyotyped subsequent to this study (this male was chromosomally similar to the three females and did not exhibit any karyotypic irregularities). It was judged to be an inversion because of the way it visually matched an "inversion" produced by physically inverting the short arm of chromosome c10 in the females (see Figure 4). However, only a small number of California sea otters have been examined and future karyotyping of more animals would help to resolve the normal vs. abnormal interpretation of this particular chromosome. The types of changes in the other two chromosome pairs have not been seen as normal chromosome variants in other marine mammal species studied with R-banding, and from the anomalies seen in the pups sired by this male, it would seem likely that there was, indeed, a complex chromosomal rearrangement in the karyotype of the breeding male. Since this wild-caught male was phenotypically normal, it was presumed that he was a balanced carrier for this rearrangement. Balanced complex *de novo* chromosome rearrangements have been reported in humans (e.g., Magenis et al. 1981).

The pupping history in the sea otter colony for the period involved the breeding of this male and the eight females. Eighteen pups, all sired by the one male present in the breeding colony, were born from 1975 to 1982. There was one set of twins. Eleven pups were stillbirths or abortuses. Several of these exhibited congenital anomalies. The anomalies were not confined to particular matings, but appeared in offspring of several of the females. Of the live births, five pups lived only 1-2 days. One was congenitally abnormal, the others were either under normal birth weight (as compared to values of 1.4 - 2.3 kg reported for successful births in wild sea otters: Kenyon 1969; Estes 1980) and congenitally weak, or appeared malnourished and died of maternal neglect. There were three pups of good birth weight, who lived for a longer period of time. One female pup lived for approximately two weeks and died of a respiratory infection. Another female pup died after 21 days of malnutrition and maternal neglect. One male pup lived for four months, dying of congestive heart failure resulting from an apparent congenital heart defect. Interbirth intervals ranged from 7 months 25 days to over 31 months, with a median interbirth interval of 11 months. Therefore, in this breeding colony where there was

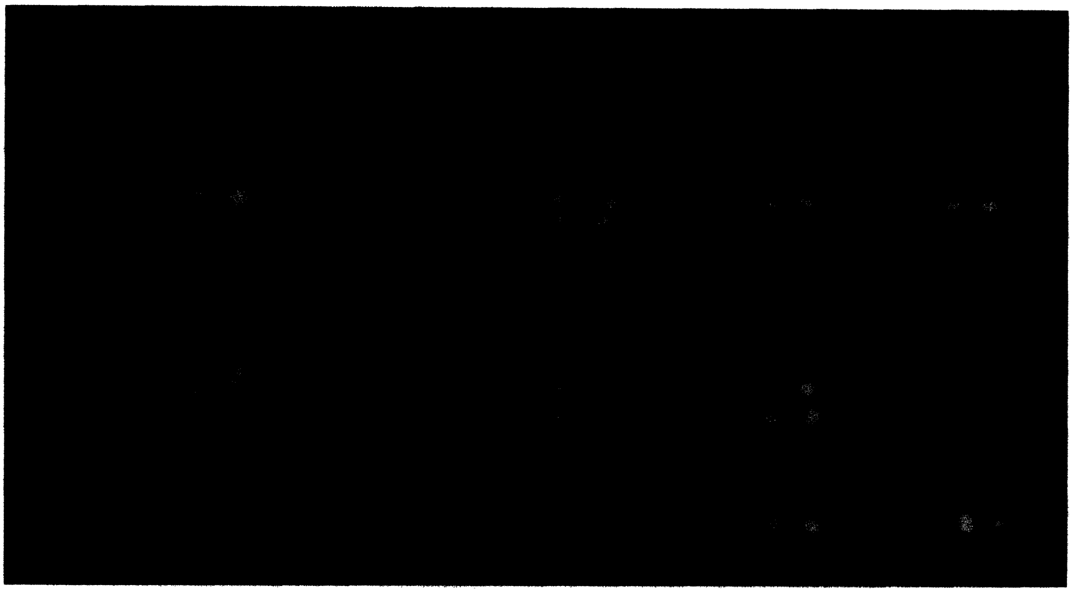

Figure 3. The abnormal homologues in the breeding male compared with the homologues of those same chromosome pairs in the three females examined in this study. The areas indicate regions of irregularity.

continual access to a male, there is the possibility of additional undetected pregnancies and spontaneous abortions during the apparently longer interbirth intervals.

Given the normal chromosome pairs seen in the karyotypes of the females examined, the existence of the chromosomal irregularities in the male karyotype suggested that he was a major contributor to the reproductive problems in the breeding colony. Numerous examples of chromosomal rearrangements producing multiple congenital anomalies are described in humans (Yunis 1977; Smith and Jones 1982). With the increased chromosomal resolution made possible by chromosome banding techniques, many cases of fetal and newborn abnormalities and malformations, and of increased rate of spontaneous abortion and stillbirth, have been associated with families carrying balanced chromosome rearrangements, including both simple and complex translocations and inversions (Budberg et al. 1982; Buchinger et al. 1981; Anderson et al. 1981; Cohen et al. 1983; Ostovics et al. 1982; Palmer et al. 1987; Gadow et al. 1991). The occurrence of late pregnancy abortions, failure to thrive, maternal neglect and the range of abnormalities seen in the offspring in this breeding colony would be consistent with a chromosome rearrangement involving small chromosome segments.

Interpretation of the observed congenital anomalies as directly resulting from genetic missegration of a complex chromosome rearrangement in the male is complicated by two factors. At the time of this study, the offspring could not be karyotypically examined to associate specific chromosomal duplication or deficiencies with the presence of anomalies. Furthermore, there is evidence both from captive breeding of sea otters (Antrim and Cornell 1980) and from the wild (Kenyon 1969), that first-time births have a lower success rate and are often characterized by stillbirths or failure of the pups to thrive. These effects would have also contributed to the pupping history in this breeding colony. To this latter point, however, the consistent pattern of congenital anomalies, stillbirths and spontaneous abortions throughout the breeding history of a number of the females, argues against this being the only explanation for the breeding problems. The most common signs of autosomal chromosome aberrations, which include increased spontaneous and stillbirth rates, and in live offspring, low birth weight, failure to thrive, mental retardation, head and facial anomalies and heart and abdominal defects (Vogel and Motulsky 1979; Gadow et al. 1991), certainly characterize the pupping history in this colony.

Implications for conservation efforts

Congenital malformations can also be caused by a number of environmental factors. The possibility that the birth anomalies were caused by a teratogenic agent cannot totally be ruled out in the absence of verification of karyotypic abnormalities in the anomalous offspring. However, it can be argued that given the range of congenital defects, as well as the presence of apparently phenotypically normal offspring in this colony, one would not expect the problem to be related to a single teratogenic agent, nor to any single, consistent factor in their environment. A study of the water environment of this sea otter colony was undertaken, subsequently to the chromosome study, to see whether the water quality treatment or filtering of water in this particular system produced a teratogenic-like effect on in vitro cells (Nicholas and Duffield, unpublished observation). Cells were grown in water from a variety of sources and were scored for chromosome damage; such as, breaks, rearrangements and sister chromatid exchanges. The highly treated water of the sea otter filtration system, compared with other sources, which included purified water, local bay water and local drinking water, was ranked as having no added effect on chromosomal change in culture when compared to the purified water control. It is interesting, as an aside, that the local drinking water had a statistically significant effect on chromosome breakage and rearrangement in the cultures.

Potentially, there is also the possibility that the apparent "irregularities" in the chromosome pairs of the male resulted from a cross

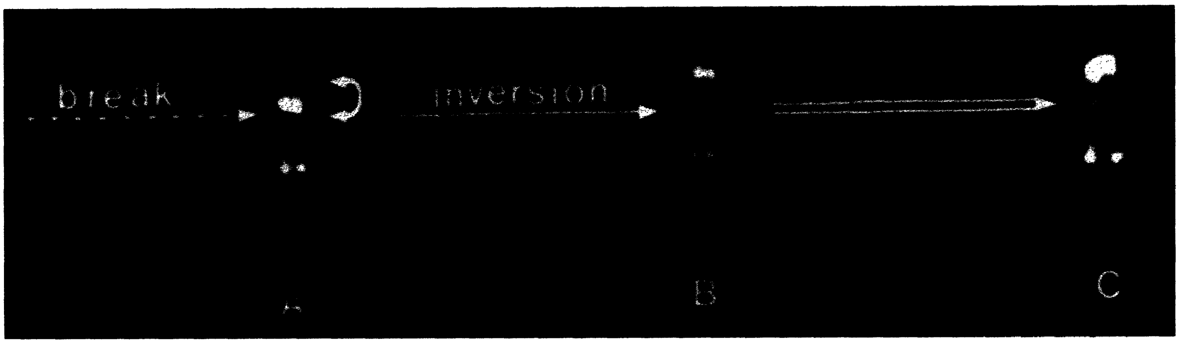

Figure 4. A proposed inversion explaining the rearrangement in c10 in the male sea otter. The inversion was modeled by inverting the equivalent part of the short arm of one of the c10 chromosomes in a female karyotype (A - B) and comparing it visually to the "rearranged" chromosome in the male (C).

between parents from stocks of wild sea otters which were chromosomally differentiated. For example, there has been continuing controversy over the discreteness of Alaskan and Californian sea otter populations (Kenyon 1969; Lidicker and McCollum 1981; Wilson et al. 1991; Cronin et al. 1996). The male in question came from Monterey Bay, California. However, with the occasional introduction of Alaskan sea otters along the Oregon and Washington coasts (see Jameson et al. 1982), there is a possibility, although thought to be remote, that some of these have been integrated into the California population. If these two populations were chromosomally distinct, a cross between them would certainly give rise to an individual exhibiting irregular pairing of chromosomes. An R-band karyotype has not yet been done for the Alaskan sea otter to test this possibility. Either source, structural rearrangement or population difference, could have resulted in the production of anomalous offspring by the carrier animal.

Ralls et al. (1983) predicted that despite the population bottleneck in the California sea otter population caused by fur hunting in the 18th and 19th centuries, 77% of the original genetic diversity would be expected to be retained and that the bottleneck would, therefore, not have had much impact on loss of genetic variation. Genetic variation in both allozymes and mtDNA has been subsequently demonstrated in various sea otter populations (see Cronin et al. 1996; Scribner et al., in press). This would imply that deleterious effects, such as, increased mortality in young animals and reduced fertility expected as a result of loss of genetic variability, would not be an anticipated consequence of the near extinction of the California population (Ralls et al. 1983; Cronin et al. 1996). On the other hand, from a genetic drift argument, if one of the subsequent founders of the current population, i.e. one of the survivors, was carrying a chromosome rearrangement, the frequency of that rearrangement in the recovered population could be fairly high based on chance contributions of individual founders. In time, selection would be expected to lower the frequency of the chromosome rearrangement, but in the interim, because of its effect on reduced fertility (Tupler et al. 1994) as well as on lowered pup production through spontaneous abortion and failure to thrive, it might have a significant impact on the observed rate of recovery of the population. This would be true, as well, if the source of chromosome irregularity were the consequence of breeding between individuals of chromosomally differentiated subspecies subsequent to sea otter translocation efforts.

The frequency with which balanced chromosome rearrangements occur in the wild is not known for most species. In man, the frequency of balanced autosomal rearrangements estimated from prenatal cytogenetic studies ranges from 0.224% (Hook et al. 1983) to 0.4% (Van Dyke et al. 1983). Chromosome abnormalities are reported for cattle (Swartz and Vogt 1983; Bongso and Basrur 1976), sheep (Bruere 1969), pigs (Akesson and Henricson 1972; Henricson and Backstrom 1964) and horses (Hughes and Trommershausen-Smith 1977). These have been associated with physical anomalies, fetal death and reproductive inefficiency. Balanced translocations have been reported for wild-caught cetaceans (Duffield 1977; Worthen 1981). The presence of a carrier of a chromosomal rearrangement in a wild sea otter is, therefore, not in itself, surprising. However, in a population which has suffered the degree of genetic bottlenecking and reduction in numbers seen with the California sea otter, it might be useful to further evaluate the frequency of chromosomal rearrangements in the current population.

In terms of the impact on captive breeding programs, the finding of a phenotypically normal, but karyotypically abnormal wild-caught male in the Sea World breeding colony, emphasizes the importance of screening potential breeding animals for chromosomal rearrangements which could lead to costly risk of abnormal births and compromised breeding success in captive breeding programs. This is especially important in breeding colonies built around a single male or a single breeding pair of animals.

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The Law Governing Sea Otter Conservation

Donald C. Baur, Allison M. Meade, and Lisa M. Rotterman

The sea otter has the distinction of being one of the first animals protected under federal law. In 1911, the United States joined Great Britain, Japan, and Russia to execute the Convention for the Preservation and Protection of Fur Seals, a treaty prohibiting pelagic sealing and the taking of sea otters on the high seas. The United States implemented this Convention, and imposed a prohibition on high seas sea otter taking, by the Fur Seal Act of 1912 (Chap. 373, 37 Stat. 499, 1912).

At the time it was imposed, this protection was of little value for sea otters. The once prolific species, which had occupied a range from Japan, across the Pacific rim, down the Pacific coast of North America, and into Mexico was on the brink of extinction. Its numbers ravaged by the fur trade of the 18th and 19th centuries, the sea otter survived, not because of the 1911 treaty or its implementing U.S. law, but because the animals were simply too scarce to justify the cost of searching them out and killing them for their skins. In addition, the prohibition on take applied only on the high seas (beyond three miles), a delineation that was insufficient to protect a mostly near-shore species such as the sea otter.

This pattern of legal protection-after-it-was-almost-too-late is not uncommon for many marine mammals and other protected species. Until the early 1970s and the enactment of the Marine Mammal Protection Act in 1972 and the Endangered Species Act amendments of 1973, sea otters and other wildlife species at risk from human activities had little or no legal protection. As Congress observed in 1971 when it took up the MMPA for consideration:

> *Recent history indicates that man's impact upon marine mammals has ranged from what might be termed malign neglect to virtual genocide. These animals, including whales, porpoises, seals, sea otters, polar bears, manatees and others, have only rarely benefited from our interest; they have been shot, blown up, clubbed to death, run down by boats, poisoned, and exposed to a multitude of other indignities, all in the interest of profit or recreation, with little or no consideration of the potential impact of these activities on the animal populations involved* (H.R. Rep. No. 707, 92d Cong., 1st Sess. 11-12, 1971).

As a result of the resulting legal protection, the status of the sea otter has significantly improved. Sea otters now occupy a number of areas within their historic range: Alaska, British Columbia, Washington, and California. The population of animals in California is currently designated as a separate subspecies (see Anderson et al., this issue). Each of these populations is subject to varying degrees of legal protection. As a result, separate policy and management issues arise in connection with each.

The two major federal laws governing sea otters are the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). Marine mammal populations listed either as endangered or threatened under ESA are by default categorized as depleted under MMPA. Removal from lists defined by ESA also automatically removes the depleted designation as defined by MMPA. An approved petition is required for populations not listed under ESA to be listed as depleted under MMPA. The provisions of the ESA are discussed elsewhere in this issue (see Clark, this issue), and this paper will summarize the Marine Mammal Protection Act and discuss the resulting conservation issues associated with sea otters in California.

The Marine Mammal Protection Act

Having found that "certain species and population stocks of marine mammals are, or may be, in danger of extinction or depletion as a result of man's activities" (16 U.S.C. § 1361(1)), Congress set forth in the MMPA a mandate that marine mammals "should be protected and encouraged to develop to the greatest extent feasible commensurate with sound policies of resource management and that the primary objective of their management should be to maintain the health and stability of the marine ecosystem" (Id. § 1361(6)). Federal agencies thus were directed that "such species and population stocks should not be permitted to diminish beyond the point at which they cease to be a significant functioning element in the ecosystem of which they are a part, and, consistent with this major objective, they should not be permitted to diminish below their optimum sustainable population" (Id. § 1361(2)).

Pursuant to the MMPA, jurisdiction over the sea otter is vested in the Secretary of the Interior and administered by the U.S. Fish and Wildlife Service (FWS). Oversight is provided by the Marine Mammal Commission and the Committee of Scientific Advisors on Marine Mammals (Id. § 1402).

The MMPA established four innovative concepts of wildlife protection and management that are relevant to the sea otter: (1) preemption of state control over marine mammals; (2) imposition of a moratorium on the taking and importation of marine mammals; (3) establishment of the species and population stock recovery goal of reaching and maintaining optimum sustainable population (OSP) levels; and (4) recognition of marine mammals as vital components of the overall marine ecosystem and establishment of ecosystem health and stability as the primary goal of marine mammal management.

State control of marine mammals

Having removed states from direct control over the taking of marine mammals, Congress also set forth in the

MMPA mechanisms whereby states could regain some or all of that authority.

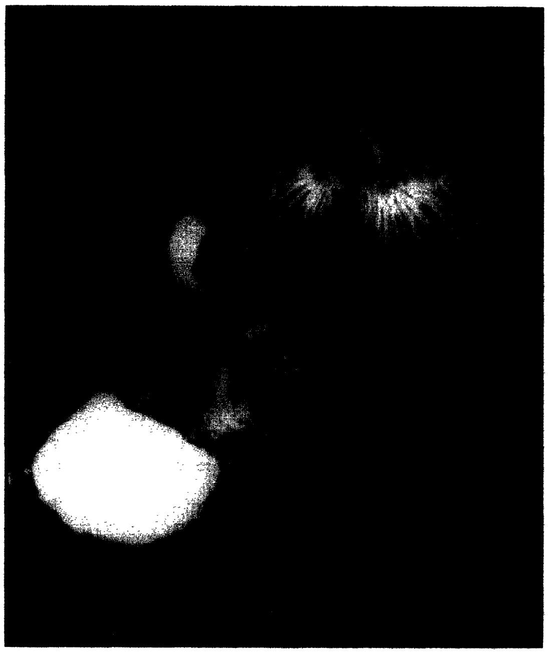
In 1974, California invoked this procedure and filed a request for a waiver of the moratorium and a transfer of management for sea otters. Pursuant to that request, the state sought to establish a management regime that would have restricted sea otters to their then current range along the central California coast. By mid-1976, however, the California Department of Fish and Game (CDFG) recognized that many of the goals it sought to achieve pursuant to a management transfer, including testing of the effectiveness of translocation as a method of regulating sea otter distribution, could be accomplished under an MMPA scientific research permit. Consequently, the waiver request was withdrawn and a research permit application filed.

Described as "an experimental management plan," the research permit was requested in order to "provide an adequate number of sea otters for maintenance of a healthy self-sustaining population" and to "restrict the distribution of the sea otter to protect the State's remaining recreational and commercial shellfish fisheries and to enable possible development of marine aquaculture in coastal waters." The FWS issued a two-year permit on August 26, 1977 (42 Federal Register 44,314, Sept. 2, 1977). As issued, the permit authorized CDFG to capture, tag, weigh, measure, and blood sample up to 100 animals from the northern end of the sea otter range. It also authorized the translocation of up to 40 sea otters from southern to the northern end of the range. As federal efforts to achieve zonal management intensified, the state declined to further pursue the research effort, and a return of management was not pursued again.

Moratorium on taking

In conjunction with the preemption of state authority, Congress imposed a moratorium on the taking and importation of all marine mammals (16 U.S.C. § 1371(a)(1)). The expansive scope of this moratorium is established by the definition of "take," which means "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal" (Id. § 1362(13); 50 C.F.R. § 18.3). The prohibition on taking, unless subject to an MMPA exception, is absolute, and takings that are incidental to otherwise lawful activities are prohibited to the same degree as intentional takes.

The Act, as amended over the years, sets forth several exceptions to the moratorium. These exceptions are for: (1) scientific research; (2) public display; (3) photography for educational or commercial purposes; (4) enhancing species survival or recovery; (5) incidental take in commercial fishing operations; and (6) incidental take of small numbers of marine mammals in non-commercial fishing activities.


Photograph by Jeff Foott

In addition to these exceptions, the moratorium does not apply to nonwasteful takes by Alaskan Natives for subsistence or handicraft purposes (Id. § 1371(b)). This exception is limited to any Indian, Aleut, or Eskimo who resides in Alaska and dwells on the coast of the North Pacific Ocean or the Arctic Ocean. In the 1994 Amendments, Congress gave greater recognition to the need to promote a cooperative approach with Alaska Natives by authorizing the federal agencies to enter into "co-management agreements" with Alaska Native organizations for the purpose of undertaking research, management and conservation efforts on a joint basis (Id. § 1388).

Addressing Native take outside of Alaska under the 1994 MMPA amendments, Congress clarified that nothing in those amendments was intended to impinge on pre-existing Indian treaty rights (Pub. Law No. 103-238, § 14). In those amendments, however, Congress did not extend this nonabrogation clause to the pre-existing provisions of the MMPA. Thus, the take prohibition would override any pre-existing treaty rights that might exist to hunt sea otters.

An especially important aspect of the MMPA protections applying to sea otters is the take prohibition as it applies to commercial fishing. During the early 1980s, it was discovered that southern sea otters were dying in high numbers in California set net fisheries. This incidental take was causing the population, which had only recently begun to recover, to once again decline. Under the MMPA as it existed at that time, all incidental take of depleted marine mammals (including the southern sea otter) was prohibited and could not be authorized. Because of this prohibition, the state of California imposed a series of fishery closures throughout the sea otter range (discussed below). These closures were essential to eliminating this take and putting the southern sea otter back on the track of recovery.

Optimum sustainable population

Linked to the application of the moratorium are the concepts of OSP and depletion. The MMPA defines OSP to mean:

> *[W]ith respect to any population stock, the number of animals which will result in the maximum productivity of the population or the species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element* (Id. § 1362(8)).

Any species or population stock that has been listed as endangered or threatened under the ESA or determined to be below its OSP level is defined as "depleted" (Id. § 1362(1)). If a species or stock is below OSP and thus, by definition depleted, it is effectively precluded from being made subject to a waiver of the moratorium, cannot be taken under a state management program, and cannot be taken under permit except for scientific research, species enhancement, or photographic purposes. Limitations also apply to incidental take of depleted species, although after the 1994 MMPA amendments such take under most commercial fishing is no longer prohibited and exemptions also exist for some non-fisheries' incidental take.

For purposes of implementing the OSP concept, in 1976 NMFS promulgated the following "interpretative" definition:

> "*Optimum sustainable population" is a population size which falls within a range from the population of a given species or stock which is the largest supportable within the ecosystem to the population level that results in maximum net productivity. Maximum net productivity is the greatest annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth less losses due to natural mortality* (50 C.F.R. § 216.3).

Because the maximum net productivity level (MNPL) is the lower end of the OSP range, it has been the focal point of conservation efforts under the MMPA. MNPL is defined as "the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth less losses due to natural mortality" (16 U.S.C. § 1362(9)). As applied in numerous rulemaking proceedings, MNPL has been generally accepted to mean a population size that represents 60 percent of the species' or stock's carrying capacity (e.g., 42 Federal Register 64,548 (1977); 45 Federal Register 72,178 (1980)).

To date, there has been no formal determination of OSP for sea otters. The FWS 1995 stock assessment for sea otters in Alaska asserts that the population is believed to be within its OSP range, but this conclusion is based on the highly questionable assumption that there is a single population stock in Alaska (U.S. Fish and Wildlife Service 1995). No OSP finding has been made for the southern sea otter. Although the depleted status of the southern sea otter is formally derived from its ESA classification (50 C.F.R. § 17.11(h)), there is no question that the southern sea otter also is well below its MNPL. Determination of the MNPL for the southern sea otter is likely to be particularly difficult based upon present knowledge due to the uncertainty of the pre-exploitation population size, the fact that the sea otter is recovering from harvests that took place before reliable records were kept, the lack of a clear understanding of the relationship between sea otters and the near-shore marine community, and the fact that at least portions of the formerly occupied range are no longer suitable as sea otter habitat.

In 1988 and 1994, Congress amended the MMPA to provide more flexibility in authorizing incidental take of marine mammals in commercial fisheries. Congress passed this amendment in reaction to the decision in Kokechik Fishermen's Association v. Secretary of Commerce (839 F.2d 795, 802, D.C. Cir. 1988), which held that no permit could be issued under the MMPA to take a depleted species and that if a proposed fishery would take depleted as well as nondepleted species, the fishery itself could not be authorized. Fearing that this rule would shut down many fisheries in the United States, Congress established a new regime for authorizing incidental take that allowed depleted species to be taken.

Congress recognized, however, that the southern sea otter was a special case. Because the sea otter is especially vulnerable to incidental take, in recognition of the link between the MMPA absolute ban on taking depleted species and the state's closures, and in an effort to maintain the status quo under the sea otter translocation law (discussed below), which established two stringent "no take" zones for sea otters, Congress exempted southern sea otters from these new provisions that allowed for incidental take of depleted species (16 U.S.C. § 1387(a)(4)). Thus, of all the species subject to the MMPA, only the southern sea otter still has the benefit of the strong legal protections enacted by Congress in 1972 prohibiting incidental take of depleted marine mammals.

Marine ecosystem protection

In enacting the MMPA, Congress made maintenance of the health and stability of the marine ecosystem the primary objective (16 U.S.C. § 1361(6)). OSP is to be achieved when consistent with this goal. Because sea otters are often recognized as a "keystone species" which indicates ecosystem health, it is clear that promoting population and range expansion of this species advances this underlying goal of the MMPA.

Without referring specifically to habitat protection or other measures, section 112 authorizes the Secretary to "prescribe such regulations as are necessary and appropriate to carry out the purposes of the MMPA" (Id. § 1382(a)). This authority can be used to promulgate regulations to protect habitat areas. In the legislative history of the 1994 Amendments, Congress made it clear that section 112 includes such authority. As stated by the House Merchant Marine and Fisheries Committee in its legislative history for amendments to section 2(2), by adding the phrase "essential habitats," "[t]he Committee believes that the Secretary currently has the authority to protect marine mammals and their habitats under the general rulemaking authority of section 112 of the MMPA" (H.R. Rep. No. 439, 103d Cong., 2d Sess. 29 (1994)). The Committee expressly noted, as an example, that this authority would apply "to protect polar bear denning, feeding, and migration routes . . . ." (Id.). Thus, this authority also could be used to protect sea otter habitat by, for example, prohibiting or restricting human activities that pose threats to sea otters (Baur 1996).

The second important federal law governing sea otter conservation is the ESA. The provisions of the ESA are discussed in detail elsewhere in this issue (see Clark, this issue). By way of summary, several aspects of the ESA are of special significance to the sea otter. Section 4 defines the criteria and procedures for listing species under the ESA (16 U.S.C. § 1373). Distinct populations are subject to listing (61 Federal Register 4722, 1996). Under section 4, the southern sea otter is designated as a threatened species. The small population in Washington (about 350 animals) might also qualify for listing.

Once listed, a species is subject to the ESA's take prohibition (16 U.S.C. § 1358 (a)(1); 50 C.F.R. § 17.21). This prohibition is broader than that under the MMPA because it also prohibits "harm" to a species, which includes habitat degradation (50 C.F.R. § 17.3; Babbitt v. Sweet Home Chapter of Communities for a Great Oregon, 115 S. Ct. 2407, 1995). The ESA also prohibits the federal government from taking any action that is likely to jeopardize the continued existence of the species in the wild (Id § 1536 (a)(2)). The goal of the ESA is to achieve recovery of listed species (Id. §§ 1531, 1532 (3)). To accomplish this goal, section 4(f) of the ESA requires that recovery plans be issued by FWS for most listed species (Id. § 1533 (f)).

The FWS issued its original recovery plan for the southern sea otter on February 2, 1982. The Recovery Plan addresses necessary actions to achieve both delisting under the ESA and attainment of OSP under the MMPA. With regard to prospects for species recovery under the ESA, the Recovery Plan states that "delisting should be considered when the southern sea otter population is stable or increasing at sustainable rates in a large enough area of their original habitat that only a small proportion would be decimated by any single natural or man-caused catastrophe" (U.S. Fish and Wildlife Service 1982). For purposes of achieving this objective, the Recovery Plan indicates that it is necessary to accomplish all of the following:

(1) minimize the risk of oil spills;
(2) minimize the possible effects of oil spills;
(3) minimize vandalism, harassment, and incidental take of sea otters;
(4) monitor recovery progress of the existing population and any new colonies; and
(5) integrate the recovery plan into development and management plans of local coastal governments (Id. at 40).

The establishment of one or more colonies has been identified as the most important task to be accomplished for bringing about recovery of the subspecies (Id. at 34).

The 1982 southern sea otter recovery plan remains in effect. It is currently being revised through a process which has now been underway for several years (see Benz, Recovery Plan, this issue). This revision process began in 1989, in part as a result of the *Exxon Valdez* oil spill in Alaska. The size of this spill and its impact on sea otters demonstrated that the entire southern sea otter population would be at risk from such an event. This information called into question some of the key assumptions in the 1982 Recovery Plan.

Upon publication of this article, the revised recovery plan was undergoing its second public review period. The draft revised recovery plan focuses almost exclusively on oil spill risk and does not address other threats, including new threats that did not exist in 1977. It also does not address OSP under the MMPA (U.S. Fish and Wildlife Service 1996). These and other aspects of the draft revised recovery plan have been the subject of debate and controversy (see Faurot-Daniels and Baur, this issue).

The translocation law

The 1982 recovery plan identified the establishment of a new colony of sea otters, apart from the mainland population, as the most important step in ensuring that a single oil spill or similar catastrophe could not endanger the entire population (Id. at 34). The recovery plan adopted the idea of zonal management earlier put forward by the Marine Mammal Commission to deal with conflicts between range expansion of the sea otter and human activities, especially commercial and recreational fisheries (U.S. Fish and Wildlife Service 1982; Marine Mammal Commission 1996; see Wendell, this issue). Early planning for a relocation effort was, however, hampered by the opposition of commercial interests and questions about whether the FWS could relocate sea otters in the face of MMPA "no-take" prohibitions.

The matter was settled in 1986 with enactment of Pub. Law No. 99-625, 100 Stat. 3500 (1986), in which Congress adopted the zonal management concept and specifically authorized the FWS to carry out one or more relocations outside the southern sea otters' mainland range (see Benz, Attempts to Reintroduce, this issue). Subsequently, the FWS decided on San Nicolas Island, and established a translocation zone around San Nicolas, and, outside of that, a management zone including all waters south of Point Conception (see Wendell, this issue). Sea otters found in either zone are presumed by the law to be members of the translocated population. Inside the translocation zone, sea otters are accorded full ESA protections, with one partial exception: section 7 federal agency consultations are required only for non-defense related actions occurring inside the translocation zone, rather than for all federal actions that may affect the population (Pub. Law No. 99-625, § 1(c)). In the management zone, on the other hand, sea otters are accorded only the status of species proposed to be listed under the Act (requiring only the informal conference procedure). Incidental taking of sea otters in the management zone may not be treated as violations of the ESA or the MMPA (Pub. Law 99-625, § 1(c)).

The FWS released 139 sea otters between 1987 and 1990. Counts between 1993 and 1995 have shown a stable population of 12 to 15 adults and continued pupping (six pups were known to have been born on the island in 1995; Marine Mammal Commission 1996). According to the plan, the population can be considered "established" when the population (1) numbers 150 sea otters, with little or no migration to management zone and (2) recruits (i.e., successfully pups) 20 sea otters a year for a three to five year period or maintains a population close to the island's carrying capacity. At present, the San Nicolas population has no legal signifi-

Photograph by Jeff Foott

cance with regard to the status of southern sea otters as a whole under the ESA and MMPA. However, if the population becomes established it will be taken into account for future consideration of delisting the sea otter under the ESA or removing its designation as "depleted" under the MMPA (50 C.F.R. § 17.84(d)). The FWS regulations also define criteria for determining the translocation a failure, which would require the sea otters at San Nicolas to be captured and returned to the range of the parent population and termination of the management zone (Id. § 17.84(d)(8)). Even if any one of these criteria are met, the FWS has discretion to continue the translocation if reasonable measures can be implemented to address the identified problems (Id. § 17.84(d)(8)(v)).

Protected areas

Sea otters and sea otter habitat also benefit as a result of protective federal land and water area designation. National parks, such as the Channel Islands in California and Olympic in Washington, national wildlife refuges, such as Alaska Maritime, and marine sanctuaries, such as Monterey Bay and Olympic Coast, provide such protection by prohibiting habitat modifications and activities that could harm sea otters (Baur 1991). In the Monterey Bay Sanctuary, regulations promulgated by the National Marine Fisheries Service to restrict jet skis, which were placing sea otters and other protected species at risk, were upheld against a legal challenge by an industry trade association (Personal Watercraft Industry Association v. Department of Commerce, 48 F.3d 540, 545, D.C. Cir. 1995; see Saunders, this issue).

State Laws

In addition to the federal statutes described above, various state laws are significant to the recovery and management of sea otters. Although laws directly governing sea otters are preempted by the MMPA, a number of state laws intended to protect a variety of species provide benefits to sea otters.

Most significant are California restrictions that have been imposed on trammel and gill net fisheries since the early- and mid-1980s, when the State Legislature recognized that these net fisheries were causing significant incidental take of sea otters as well as other marine mammals and sea birds (California Fish & Game Code § 8609). In 1982, legislation was passed prohibiting use of these nets in certain shallow (10 to 15 fathoms deep or less) coastal waters (Id. at § 8664.5). Subsequently, these fishing prohibitions were extended to cover deeper and deeper waters, and the Director of the California Department of Fish and Game was authorized to close any area to all net-setting upon a finding that such fishing is causing an "adverse impact on any population of any species of sea bird, marine mammal, or fish" (Id. at §§ 8664.5, 8664.8). In 1990, a popular referendum, the California "Marine Resources Protection Act of 1990," further extended the gill and trammel net prohibitions (Id. §§ 8610.1-15). Trammel and gill nets are now prohibited for at least 30 to 40 fathoms off of most coastal areas inhabited by sea otters (Id. §§ 8610.1-15, 8618.0-8618.2, 8664).

California has also listed the southern sea otter as a "fully protected mammal" under state law, meaning that it "may not be taken or possessed at any time" except pursuant to permits issued for scientific research (Id. at § 4700). (Consistent with the translocation law, however, incidental take of sea otters south of Point Conception but outside of the San Nicolas translocation zone is not to be considered a violation of the California law (Id. at § 8664.2; see Wendell, this issue)).

Finally, in 1990, California enacted legislation requiring that a network of rescue and rehabilitation centers be established to deal with sea birds, sea otters, and other marine mammals in the event of oil spills (California Government Code § 8670.37.5; see Jessup et al., this issue).

Conservation issues

In California, the principal conservation issues arise from the effort to direct the sea otter recovery program in a manner that will truly result in recovery of the species. There are several complex issues presented by this question.

(1) Can sea otter recovery be defined simply in terms of attaining a given population level, without reference to other standards, such as range expansion, distribution, measures to avoid oil spill, analysis of infectious disease and other threats, etc.?

(2) Is the proposed number for delisting (2,650 maintained over three years) sufficient considering unresolved threats to the species and when the historic population size for this species is 14,000 or greater?

(3) Can delisting be predicated upon merely a current assessment of the threats posed in 1977, or must new threats also be considered?

(4) Should zonal management be abandoned? If so, how will the requirements for maintenance of the translocation and management zones of the translocation law be addressed?

(5) Should the translocation be declared a failure? If so, will this result in new resource management conflicts for the species? If not, does the maintenance of a management zone conflict with current species recovery goals?

(6) What degree of public involvement and consensus should be achieved in developing the prescription for sea otter recovery?

(7) What is the OSP level for this population? What is the geographic boundary of the population for determining carrying capacity and OSP? If this population is delisted under the ESA, should it be formally designated as depleted under the MMPA, and if so what is the significance of this classification for future conservation efforts?

(8) If the population continues to grow in numbers and expand in size, what should be done to reduce conflicts with shellfish fisheries and other resource users?

(9) Do sea otters promote a healthy marine ecosystem? If so, should sea otters be reestablished to promote this MMPA goal regardless of whatever population level may be required to achieve ESA delisting or OSP?

In the opinion of these authors, the southern sea otter remains at considerable risk of endangerment, if not extinction. Not enough has been done to reduce the oil spill risk, and other threats underlying the original listing remain. The new threat of a high rate of infectious disease (40% of retrieved dead sea otters) has emerged (see Thomas and Cole, this issue). The current population size is just a fraction of historic size, and it is far from a level that would support recovery. The species range has expanded very little in recent years, and it is clear that oil spill threats remain significant and require much greater distribution of the species, as well as a larger population size.

Under both the MMPA and the ESA, legal protection is given to population stocks. Because the southern sea otter has been determined to be a distinct subspecies, the meaning of the discrete population standard as applied to this species has not yet been tested. The discrete population standard issue will become increasingly important, however, as the sea otter populations in California, Washington, and Alaska continue to grow.

The question of what constitutes a separate sea otter population is most likely to be confronted first in Alaska, where groups of sea otters are currently found in several different locations. The MMPA defines a "population stock" as "a group of marine mammals of the same species or smaller taxa in a common spatial arrangement, that interbreed when mature" (16 U.S.C. § 1362(11)). The FWS has suggested that sea otters in Alaska are a single population stock (U.S. Fish and Wildlife Service 1995).

Data collected on the movements of radio-instrumented sea otters in several parts of the range in Alaska provide no support for the idea that sea otters captured at locations distant from one another tend to inhabit a common space at any time during their lives. For example, of hundreds of wild-caught radio-instrumented sea otters monitored in Prince William Sound between 1984 and 1992, none moved to adjacent habitat in the Kenai Peninsula (e.g., Monnett and Rotterman 1992). Since such data do not demonstrate movements of sea otters between very distant localities throughout the Alaska range, they also provide no indication that sea otters from such distant localities are interbreeding.

Data from genetic studies also provide no support for the idea that sea otters from at least certain distant parts of Alaska intermingle spatially (Cronin et al. 1996; Rotterman 1992). Further, genetic data indicate that sea otters captured from at least three localities in Alaska do not interbreed when mature (Rotterman 1992).

In previous MMPA proceedings for the issuance of incidental take permits where the population stock definition has been applied, it has been found that populations of other marine mammals in which there is interspersing of animals and even some interbreeding do not constitute a common stock because there is an insufficient "common spatial arrangement" (e.g., 52 Federal Register 7912, 1987, Dall's porpoise permit). Under this test, there appears to be no valid basis upon which to support the legal finding of a single Alaska sea otter stock. This then raises the question of how many separate stocks exist, whether any of them are depleted and, if so, what regulatory measures are necessary. The answers to these questions will have application to other sea otter populations, with resulting management consequences.

Conclusion

The effort to recover sea otters from the brink of extinction has made notable progress. Nevertheless, important conservation issues are yet to be resolved. If the FWS and other involved parties make this necessary commitment of resources to carry forward past conservation initiatives, the sea otter recovery program can stand as one of the crowning achievements of the ESA and MMPA. The challenge that lies ahead is to ensure that the conservation ethic underlying the MMPA and ESA, not political expediency or the desire to avoid controversy, is the guiding principle for sea otter management.

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Estimating the Historical Abundance of Sea Otters in California

Douglas P. DeMaster, Catherine Marzin, and Ron J. Jameson

Prior to commercial exploitation, the estimated abundance of sea otters (*Enhydra lutris*) in the North Pacific Ocean was between 150,000 (Kenyon 1969) and 300,000 (Johnson 1982). Sea otters historically ranged from Baja California along the Pacific coast northward to Prince William Sound, Alaska; southwestward along the Alaska Peninsula, throughout the Aleutian Islands, Pribilof Islands, and Commander Islands to Kamchatka; and then southward through the Kuril Islands to Sakhalin and Hokkaido (Kenyon 1969; see Anderson, this issue). Prior to commercial exploitation in California, sea otters occupied the waters off the entire coast of California. The population was estimated to have included between 16,000 to 18,000 animals (California Department of Fish and Game (CDFG) 1976a). Due to a lack of suitable alternatives, this estimate has become the best available estimate of the current carrying capacity (K) of sea otters in California. Further, because the range of sea otters is currently discontinuous between California and Washington, evidence that sea otters in California should be afforded sub-specific status (U.S. Fish and Wildlife Service 1996; see Anderson et al., this issue), and a lack of alternative historical estimates of abundance for sea otters along the west coast of the United States, the 16,000 to 18,000 abundance estimate has also been used as the best available estimate of K for the population of sea otters referred to as southern (or California) sea otters.

The objective of this paper is to refine the 1976 estimate of K for sea otters in California. To some, estimating K for a population that currently occupies less than 250 miles of coastline in central California and includes approximately 2,400 animals (U.S. Fish and Wildlife Service 1996) may seem pointless; however, having a reliable estimate of K is important for the following reason. Under the provisions of the Marine Mammal Protection Act, a population is considered depleted if its current abundance level is below a range of population sizes referred to as the optimum sustainable population (OSP) level (Gerrodette and DeMaster 1990; see Baur et al., this issue). As Congress intentionally left the definition of OSP vague, an operational definition has evolved where the lower end of the OSP range is assumed to occur at approximately 60% of the maximum population size the environment will support (i.e., K). Therefore, from a management perspective, it is important to have a reliable estimate of K.

Unfortunately, estimating K is very difficult. As noted by Gerrodette and DeMaster (1990), there are only a handful of methods that can be applied to this problem: (1) back-calculating historical abundance levels, based on a current estimate of abundance, a history of human-related annual removals, and information regarding the relationship between abundance and net productivity; (2) using historical estimates of abundance that were made prior to the onset of commercial exploitation; or (3) directly estimating the current carrying capacity, based on information about factors which limit population growth. All of these require information that is typically not available. For sea otters in California, techniques Numbers 1 and 2 are easily dismissed as there are no reliable abundance estimates from the 1700s, and there is no reliable information on the catch history of sea otters from the late 1700s until the early 1900s.

At first blush, one might also abandon the approach of estimating current K based on knowledge regarding factors that limit or regulate population growth. Fortunately, the recovery of sea otters has occurred primarily as a result of range expansions initiated by peripheral groups of males (Riedman and Estes 1990), where the core density of adult males and females, juvenile females, and dependent pups has remained relatively constant in the center of the range. Therefore, it should be possible to estimate K by having an estimate of the equilibrium density of sea otters per linear mile of coastline or square mile of available habitat from the central portion of their current range and knowing the amount of available habitat in the state (Gerrodette and DeMaster 1990).

Methods

The maximum number of sea otters that the marine environment in California will support (K) was estimated by first determining the equilibrium density of sea otters in each of three habitat types, and then determining the amount of each habitat type that exists in California.

The following values for equilibrium density were made using survey data as of 1992 (Marzin and DeMaster 1992): (1) 13.21 otters per square nautical mile (nm^2; nm=1,852 m) for rocky habitat; (2) 6.95 otters per nm^2 for mixed habitat; and (3) 1.19 otters per nm^2 for sandy habitat. The equilibrium density of otters for sandy habitats was based on the density of sea otters in Monterey and Morro Bays. The equilibrium density of sea otters in mixed habitat was based on the density between Año Nuevo and the Santa Maria River, while for rocky habitat the estimate was based on the number of sea otters between Cayucos Point and Monterey Bay.

The amount of area available to sea otters in California by habitat type was estimated based on the assumption that sea otters cannot effectively forage in water depths greater than 130 ft (40 m). This threshold was selected based on Ralls et al. 1995, where they reported that juveniles, which usually forage in water deeper than adults, typically do not feed in water deeper than 160 ft (49 m). In a preliminary exercise to estimate K, it

	Geographical Location	Habitat	Area (nm^2)	number otters
1	Mexican border - Pt. Loma	sandy	46	55
2	Pt. Loma - Bird Rock	sandy	10	12
3	Bird Rock- Pt. La Jolla	rocky	7	92
4	Pt. La Jolla - Corona Del Mar	rocky	64	845
5	Corona Del Mar - Pt. Fermin	sandy	118	140
6	Pt. Fermin - Palos Verdes Pt.	mixed	6	42
7	Palos Verdes Pt. - Pt. Dume	mixed	80	556
8	Pt. Dume - Pt. Mugu	rocky	12	159
9	Pt. Mugu - Ventura	sandy	83	99
10	Ventura - Pt. Conception	mixed	62	431
11	Pt. Conception - Rocky Pt.	mixed	19	132
12	Rocky Pt. - N. Pt. Pedernales	mixed	8	56
13	N. Pt. Pedernales - Santa Ynez River	mixed	10	70
14	Santa Ynez River - Purissima Pt.	rocky	2	26
15	Purissima Pt. - Lions Head	sandy	35	42
16	Lions Head - Pt. Sal	mixed	16	111
17	Pt. Sal - Shell Beach	sandy	48	57
18	Shell Beach - Pt. San Luis	rocky	4	53
19	Pt. San Luis - Hazard Canyon	rocky	22	291
20	Hazard Canyon - Cayucos Pt.	sandy	33	39
21	Cayucos Pt. - Monterey	rocky	117	1546
22	Monterey - Capitola	sandy	75	89
23	Capitola - Sandhill Bluff	mixed	7	49
24	Sandhill Bluff - Ano Nuevo Pt.	rocky	7	92
25	Ano Nuevo - Pt. San Pedro	mixed	93	646
26	Pt. San Pedro - Pt. Lobos	sandy	93	111
27	Pt. Lobos - Bodega Head	mixed	102	709
28	Bodega Head - Fort Bragg	rocky	97	1281
29	Fort Bragg - Cape Vizcaino	rocky	35	462
30	Cape Vizcaino - Pt. Delgado	mixed	54	375
31	Pt. Delgado - Punta Gorda	sandy	30	36
32	Punta Gorda - Cape Mendocino	mixed	23	160
33	Cape Mendocino - Trinidad Head	sandy	124	148
34	Trinidad Head - Patricks Pt.	rocky	21	277
35	Patricks Pt. - Klamath River	sandy	63	75
36	Klamath River - Pt. St. George	rocky	71	938
37	Pt. St. George - Oregon Border	sandy	47	56
38	Channel Islands	rocky	210	2774
39	San Francisco Bay	sandy	321	382

Table 1. Summary of geographical areas in California suitable for sea otters, where each area has been assigned a habitat type (and associated equilibrium density- D_i). The surface area (nm^2) for a particular geographical area was calculated, assuming a maximum feeding depth of 130 ft (40 m). The number of otters per area was calculated as the product of D_i and area.

was determined that the estimate was relatively insensitive to the choice of the depth contour between 30 ft (9 m) and 160 ft. For example, if the 160 ft contour had been selected as the offshore boundary, the resulting density would be lower than if the 130 ft contour had been selected, but the available habitat for the former would be increased relative to the latter, and the resulting estimate of available habitat would have been similar. The estimate of surface area out to a depth of 130 ft and along the entire California coastline, including the Channel Islands and San Francisco Bay (SFB), was estimated using the FORTRAN subroutine SPHAREA (Forney 1988).

Thirty-nine discrete areas were identified off the coast of California, ranging in size from 2 nm^2 to 321 nm^2, and a habitat type was assigned to each area (see Table 1). The specific characterization of an area as being sandy, mixed or rocky was done by one of the authors (RJJ) based on information provided in nautical charts and personal experience.

Following the procedure described above, the total area available to sea otters was estimated to equal 2,275 nm^2. By habitat type, the following areas were calculated: rocky (669 nm^2), mixed (480 nm^2), and sandy (1,126 nm^2). Based on these results, almost 50% of the available habitat for sea otters in California is low quality, while less than 30% of the available habitat is high quality.

Results and discussion

The estimated number of sea otters that could be supported by the marine environment in California was 13,513 (see Table 2). The weighted average density of sea otters in California was approximately 5.9 sea otters per nm^2, based on an estimate of a total area of 2,275 nm^2. The estimate of K was based on the assumption that the habitat quality of SFB is the lowest density of the three habitat types (i.e., sandy habitat). If it were assumed that the habitat quality was intermediate between the sandy and rocky habitat types (i.e., mixed), the resulting estimate of sea otters that could be supported within SFB is 2,231 sea otters (321 nm^2 multiplied by 6.95 otters per nm^2). Incorporating this assumption into the estimate of K would increase the estimate to 15,362 sea otters. For a variety of reasons, it is difficult to predict the equilibrium density of sea otters in SFB, including uncertainty regarding the number of sea otters commercially harvested in SFB, the unknown impact of pollutants on the environment, and the unknown influence of fisheries on the benthos in SFB.

If we had assumed the equilibrium density of sea otters in California was equal to the existing density between Cayucos Point and Monterey Bay (i.e., 13.21 otters per nm^2), the resulting estimate of K would have been over 30,000 otters. This estimate is likely to be positively biased because the average quality of the habitat used to estimate the equilibrium density in "typical"

Habitat Type	Density (/nm^2) (D_i)	Area (nm^2) (A_i)	Number of otters ($A_i * D_i$)
1. Rocky	13.21	669	8837
2. Mixed	6.95	480	3336
3. Sandy	1.19	1126	1340
Total		2275	13,513

Table 2. Estimated number of sea otters that could be supported by habitat type.

rocky habitat is considerably better than the average quality of habitat throughout the state (Marzin 1996). In fact, based on our analysis, the average quality of habitat in waters off the coast of California is marginally less than the classification that we referred to as "mixed." It should also be noted that in the original estimate of K for sea otters in California by CDFG (1976a), it was assumed that: (1) the equilibrium density of sea otters was approximately 12 sea otters per nm^2, and (2) the amount of available habitat was approximately 1,300 to 1,500 nm^2. The 12 sea otters per nm^2 figure was derived by dividing the number of sea otters known to occur between Seaside and Morro Bay by the area between Seaside and Morro Bay out to a depth of 120 ft (California Department of Fish and Game 1976b). It was assumed in using the 12 sea otters per nm^2 that it accounted for all habitat types, including rocky, sandy, and mud bottoms (California Department of Fish and Game 1976b). Given that the average quality of habitat reported in this study was 5.9 sea otters per nm^2, the estimate of 12 sea otters per nm^2 should also be considered positively biased. Finally, while estimates of equilibrium densities of 10 to 15 sea otters per nm^2 (based on a maximum feeding depth of 180 ft (55 m)) have been reported in Alaska (Kenyon 1969), with short-term (i.e., non-equilibrium) density estimates reaching in excess of 50 animals per nm^2 (Palmisano and Estes 1977), it seems unreasonable in the face of the available information on the distribution and density of sea otters in California to use information on Alaska otters in estimating K for sea otters in California (California Department of Fish and Game 1976a, b).

Conclusions and recommendations

Under the existing Marine Mammal Protection Act, the southern sea otter population should be considered depleted as long as its abundance is less than 60% of K. At present, therefore, the best estimate of the lower bound for being depleted is 60% of 13,513, or approximately 8,100 animals.

We believe our preliminary estimate of between 13,500 and 15,400 animals is the best available estimate of K for sea otters in California at this time for the following reasons: (1) the current information on the existing density of sea otters was used; (2) equilibrium density estimates were stratified by habitat types and based on recent information regarding the distribution of sea otters in California; (3) estimates of maximum foraging depth were based on current information on foraging behavior, as determined from radio-telemetry; and (4) estimates of total habitat available were based on all of the available habitat types in California. Additional studies are needed to test the statistical validity of the assumed equilibrium density for each of the three habitat types and the reliability of the characterization of the coastal marine habitat. For example, it would be useful to have more recent estimates of the density for each habitat type, as well as estimates of the associated variance.

Finally, the technique described in this paper could be used to provide guidance as to the number of sea otters that might be expected to exist within a specified area. For example, the equilibrium number of sea otters that could occupy the area surrounding the Channel Islands or areas 11 through 25 (Pt. Conception to Pt. San Pedro) was estimated to equal 2,774 animals and 3,300 animals (see Table 1), respectively. An extensive application of this technique is reported in Marzin (1996).

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The State of California's Role in the Conservation of Sea Otters and Other Aquatic Resources

Fred Wendell

The State of California plays an important role in the protection and management of California's sea otter population. However, that role has changed substantially over the years, from primary responsibility for protection and management of sea otters to a role secondary to the federal government. Within California State government, responsibility for wildlife resources, including sea otters, rests with the California Department of Fish and Game (CDFG). The CDFG is part of the Resources Agency which oversees the management of California's natural resources. Overseeing and regulating policies that guide the CDFG in fulfilling its public trust responsibility are provided by the State Legislature and the California Fish and Game Commission. Thus, the state's public trust responsibilities are expressed through the CDFG.

CDFG management policies

The CDFG's mission is to serve the public by conserving the state's living natural resources for their ecological values and for their use and enjoyment by the public today and in the future. The foundation for this mission is contained in policies established by the State Legislature over the last several decades. When considering the conservation of aquatic resources, the Legislature declared it to be state policy to encourage the conservation, maintenance, and utilization of the living resources of the ocean for the benefit of all the citizens of the state, and to promote the development of local fisheries in harmony with the conservation of the ocean's living resources (California Fish and Game Code, Section 1700).

Six objectives were delineated to give guidance in carrying out the policy for conserving aquatic resources. These objectives provide the foundation for the CDFG's ongoing evaluations of alternative sea otter management strategies. The objectives are abbreviated below and appear in the order in which they have been prioritized.

(1) Maintain sufficient populations of all species of aquatic organisms to insure their continued existence.

(2) Recognize the importance of the aesthetic, educational, scientific, and nonextractive recreational uses of aquatic resources.

(3) Maintain sufficient resources to support a reasonable sport use.

(4) Encourage the growth of local commercial fisheries, consistent with aesthetic, educational, scientific, and recreational uses of such living resources, and to foster the use of unused resources.

(5) Manage fisheries under the state's jurisdiction on a basis of adequate scientific information promptly promulgated for public scrutiny with the objective of maximizing a sustained harvest.

(6) Encourage the development of commercial aquaculture.

Broadly translated, these objectives espouse a conservation-oriented perspective. How that perspective has been expressed in action has changed appreciably through the course of the sea otter's recovery in California.

History of California's role in sea otter protection

Early in the population's recovery from over-exploitation (see Anderson et al., this issue), just after the turn of the century, the sea otter population was provided complete protection under state law (California Fish and Game Code, Section 4700). Complete protection was deemed to be commensurate with the population's precarious status. The emphasis was placed on achieving the first objective mentioned above, in this case to establish and maintain a sufficient number of sea otters to insure the population's continued existence in state waters. That emphasis remains unchanged. With protection provided at the turn of the century by state law and international treaty, the population grew and expanded its range at a fairly consistent rate. The State augmented its protection by establishing the Sea Otter Game Refuge in 1941 (see Figure 1). The refuge boundaries were expanded to include virtually the entire sea otter range in 1959. However, with continued growth came controversy and eventually the recognition that achieving all of the objectives for the conservation of aquatic resources might require a modification of the CDFG's protective posture.

Otter-fisheries conflict

In the early 1960s, views differed within the CDFG about the relative influence of sea otter predation and human consumptive uses on the loss of red abalone (*Haliotis rufescens*) fisheries. The prevailing view was that human overexploitation was responsible for the loss of abalone fisheries within areas reoccupied by sea otters. However, the ongoing controversy and legislative action (described below) prompted a reevaluation of that subjective appraisal and the status of the sea otter population.

In 1967, the State Senate passed a resolution directing the CDFG to determine the feasibility of containing the sea otter population in an effort to protect the existing recreational and commercial abalone fisheries while maintaining the sea otter population (Bissel and Hubbard 1968). In compliance, the CDFG initiated studies to evaluate the status of the population and to obtain the background biological information necessary for safe management of the sea otter population. Studies were also conducted to assess the effects of sea otter foraging on shellfish resources, with an emphasis on abalone fisheries (Ebert 1968; Wild and Ames 1974; Wendell et al. 1986).

Sea otter range expansion, between 1967 and 1972, into the state's most productive red abalone fishing grounds near Point Estero afforded an opportunity to assess the status of the red abalone resource before, during, and after reoccupation of the area by sea otters.

This research yielded compelling evidence that sea otters were responsible for the loss of recreational and commercial abalone fisheries within the sea otter's range (Wendell 1994). The progression in the precipitous decline in abalone densities closely corresponded to the southward progression of sea otter foraging activity in the area.

Zonal management

Clarifying the factual basis for the resource-use conflict underscored the problem in achieving the state's policy objectives if sea otter range expansion continued. The only management strategy that appeared to have potential for insuring the continued existence of a sea otter population in state waters (objective Number 1) and sufficient shellfish resource for human use (objectives Numbers 3 and 4) was to establish geographically separate zones for these apparently incompatible uses of the state's shellfish resources. This concept, suggested in the 1967 State Senate resolution, has come to be known as zonal management.

In 1968, the CDFG began conducting research to evaluate capture, tagging, and transport techniques for sea otters (Odemar and Wilson 1969). The effort was designed to assess the utility of translocating otters from the area of conflict at the range periphery back into the well-established range. The effort established basic translocation protocols but did little to test the technical feasibility of zonal management before the concern over the loss of commercial and recreational shellfish fisheries became a secondary issue.

Shift to federal control

The passage of the federal Marine Mammal Protection Act (MMPA) in 1972 placed responsibility for sea otters under federal control and imposed a legislative mandate that focused on increasing the numbers of sea otters within state waters (see Baur et al., this issue). This dramatically changed the CDFG's role. Addressing the state's other policy objectives is not easily achieved under the MMPA mandate. The single-species emphasis effectively delayed the implementation of any form of zonal management designed to achieve a balance that recognized both the objectives of protecting the sea otter population and providing for human uses of shellfish resources. As a consequence, the CDFG's role shifted to one that emphasized advocacy of zonal management as well as sea otter protection.

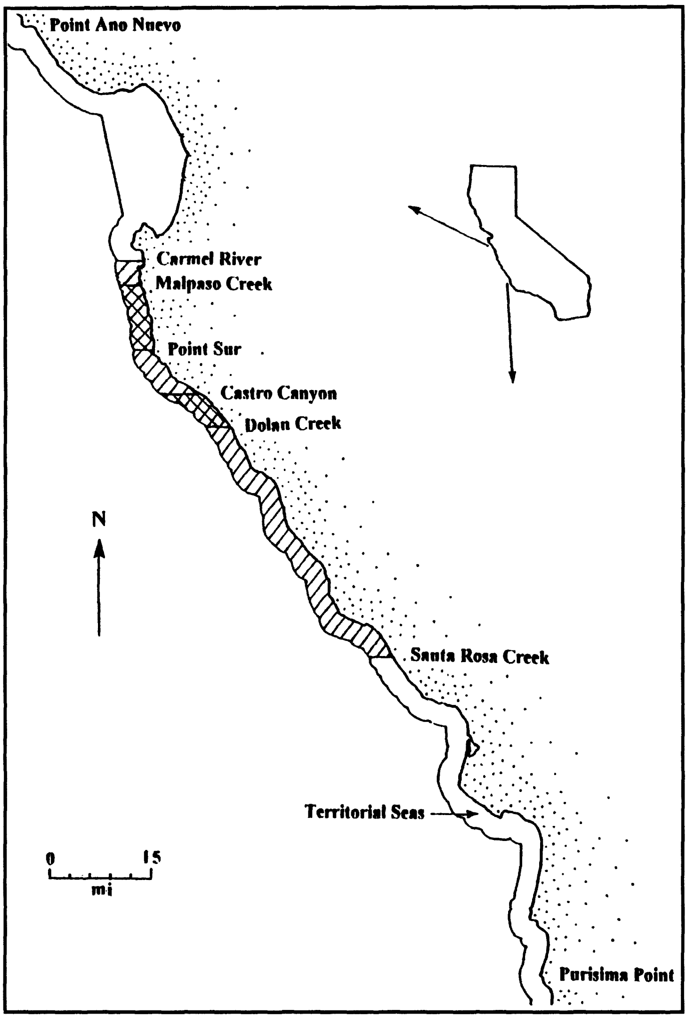

Figure 1. Location of California's sea otter game refuge as originally established in 1941 (cross hatch) and expanded in 1959 (diagonal hatch).

Southern sea otters and the Endangered Species Act

This historical perspective is relevant because it gives the background for the CDFG's recommendations concerning the population's possible listing under the Endangered Species Act (ESA). While the CDFG did not establish what measures would be necessary to protect the sea otter population from the threat of a large-scale oil spill within a zonal management context, it concluded that a sufficient number of sea otters existed to insure the population's continued existence (California Department of Fish and Game 1976). As a consequence, the CDFG recommended against the listing of this population under the ESA. The U.S. Fish and Wildlife Service nevertheless listed the population in California as threatened.

While the CDFG questioned the assessment that the population's status was precarious, the response to the listing proposal did not signal a change in the CDFG's policy on protection of sea otters. When protection was warranted, action was taken. A case in point is the legislation to limit the accidental drowning of sea otters in large-mesh set nets (California Fish and Game Code, Section 8664.5). The accidental drowning of sea otters in gill and trammel nets, used to catch California halibut (*Paralichthys californicus*), was identified as a source of mortality that had probably increased as the sea otter population expanded into areas of intense fishing. The estimated number of otters drowned annually during a two year study period in the early 1980s (80 otters) was of a magnitude sufficient to contribute significantly to the lack of sea otter population growth during that time period. Legislative action created a spatial separation between the fishing activity and sea otters by closing waters less than 30 fathom depth to that fishery. The level of accidental drowning declined to virtually zero; however, the fishery was not sustainable with the depth restriction and essentially collapsed within a few years. The balance between competing objectives cannot favor human uses of the state's resources if those uses conflict with insuring the existence of a viable sea otter population. Rather, the CDFG's opposition to the listing reflected concern over the institution of yet another single-species mandate that had significant ramifications on the state's ability to manage its wildlife resources.

Safeguarding the population of sea otters in California is a common goal for all of the regulating agencies involved. However, the CDFG also recognizes that determining what constitutes a safe population level has been and will likely continue to be a contentious process. The CDFG is also concerned that the management strategy proposed in the second recovery plan moves away from a recovery strategy that considered impacts to human uses of shellfish resources. In that regard, the second recovery plan rejects a broadly supported compromise developed to implement the original recovery plan that addressed the CDFG's desire for balance between competing and conflicting uses of the state's shellfish resources. In fact, the second recovery plan questions the validity of the view that sea otter predation has directly caused the loss of shellfish fisheries. Thus, where consideration of human uses of affected resources will balance against additional sea otter population growth remains to be seen. This raises the question of whether the recreational and commercial shellfish fisheries that are an important part of California's colorful heritage will survive.

The ESA's inability to consider the socioeconomic impacts of recovery actions has contributed significantly to the polarized positions taken by groups concerned with the sea otter-shellfish fishery conflict. Pub. Law 99-625 and the translocation plan (see Baur et al., this issue) were supported by the CDFG because they recognized socioeconomic impacts. In effect, Pub. Law 99-625 acted as an interim long-term management plan by providing the sea otter population with an additional safeguard while recognizing the need to limit sea otter distribution because of the conflict with human uses of shellfish. It created a workable compromise that generated the legal authority necessary to attempt to maintain the beneficial uses of both the state's sea otter population and shellfish resources.

Conclusion and recommendations

The implementation of Pub. Law 99-625's containment management provisions afforded the first opportunity to evaluate the technical feasibility of zonal management. The effort achieved limited success while demonstrating that ongoing efforts would likely prove to be costly and labor intensive. However, the effort raised more questions about the technical feasibility, efficacy and safety of zonal management than it answered.

Subsequent CDFG actions related to sea otter management will continue to emphasize protection for sea otters and advocacy for conservation approaches that consider human uses of aquatic resources. The CDFG's protective efforts will likely focus on oil spill contingency planning and reducing the risk associated with oil spills. Whether a balance is possible between sea otter protection and providing a continuing resource that will support existing shellfish fisheries will now likely depend on how the MMPA is administered with regard to socioeconomic issues. The MMPA seems to have the flexibility, however its expression will require broad public support.

In the CDFG's view, a balance that considers all of the state's policy objectives would provide for more diverse and, potentially, better uses of resources by considering both human and other species' needs. The CDFG realizes that successful implementation will require partnerships among a variety of interests. One crucial component in creating those partnerships is to achieve a common view, or at least a workable compromise, on *reasonable* human uses (aesthetic, educational, scientific, nonextractive, and consumptive) of natural resources in the marine environment.

It is likely that sea otter conservation efforts under state and federal law will be successful in securing a future for sea otters within California waters. However, our conservation efforts will not end with achieving that goal. Recognizing that, we should ensure that a long-term perspective is built into our conservation planning process. It is from that perspective that I offer the following specific recommendations.

(1) Initiate a dialogue on long-term management of aquatic resources that provides opportunity for involvement by all interested parties to fully discuss the merits of zonal management.

(2) Develop funding mechanisms to support the testing and, if subsequently found to be appropriate, the implementation of zonal management.

(3) Initiate studies that focus on the efficacy and safety of limiting sea otter population growth potential through contraception.

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Saving the Sea Otter Population in California: Contemporary Problems and Future Pitfalls

Glenn R. VanBlaricom

California sea otters first entered the biopolitical arena in the 1960s when the conflict developed between the red abalone *(Haliotis rufescens)* fishery and the growing sea otter population. Since that time the central issues of concern for sea otter conservation have been conflicts with shellfisheries and, later, the perception of risk associated with marine oil development and transport. Concern about possible oil spills eventually placed California sea otters on the list of threatened species pursuant to the Endangered Species Act (ESA) of 1973 as amended. The listing provided an early example of the conundrum that has bedeviled conservation efforts since passage of the ESA: Here was a population viewed simultaneously as desperately in need of protection by some, and as a socioeconomic menace by others. Although other issues have since emerged, discussions of the conservation of California sea otters have to date invariably focused primarily on shellfisheries or oil spills. Now we approach a transition, from which the range of issues broadens and their complexity deepens.

I have two purposes here. The first is to provide a synopsis of key issues identified in the other papers of this publication and briefly discuss their significance. The second purpose is to look beyond current controversies and anticipate issues emerging in the conservation politics of sea otters as we enter the new millennium. The central assumption throughout this paper is that sea otters will be taken off the endangered species list and will be declared at an optimum sustainable population (OSP) level, pursuant to the Marine Mammal Protection Act (MMPA) of 1972 as amended, within the next few decades. As a consequence new problems will move to the forefront. In my opinion these problems will be vexing, possibly even intractable. Thus, it is not too soon to begin considering approaches to their resolution.

Problems emerging from other articles

Reducing the risk of oil spills in California waters

Preceding papers include accounts of considerable effort devoted to mitigating the consequences of a drastic reduction in sea otter numbers. Such efforts follow largely from the perception that a major oil spill is possible in California sea otter habitat and could affect a significant portion of the population (VanBlaricom and Jameson 1982; Bonnell et al., this issue), and the recognition that oil spills cause significant mortality in sea otter populations (Garrott et al. 1993; DeGange et al. 1994; Loughlin 1994; Brody et al. 1996).

Three specific types of mitigation effort are discussed: techniques and facilities for rescue, treatment, and rehabilitation of sea otters (see Jessup et al.; Williams and Williams, this issue); strategies for captive breeding (see Brennan and Houck; Duffield et al., this issue); and development of a genome resource bank (see Long et al., this issue). Each approach promises a significant contribution toward enhancement of a population that has been precipitously reduced by an oil spill.

The efficacy and efficiency of post-spill mitigation measures for sea otter conservation have been hotly debated (e.g., VanBlaricom and Gornall 1989; Ames 1990; VanBlaricom 1990; Estes 1991). Even among antagonists there is broad agreement, however, that measures preventing oil spills from occurring likely are much more effective tools than any measures designed to restore sea otter populations from spill-related reductions. There is a clear need for involved agencies, researchers, and non-governmental organizations (NGO) to develop a joint plan for reduction of oil spill risk, and to enter negotiations with the large vessel industry to implement new standards from which sea otter conservation will benefit. The new standards must focus on moving vessel traffic farther offshore (e.g., Bonnell et al., this issue). An obvious advantage of this process is that reduced spill risks are of benefit to *everyone* involved in coastal zone management: oil companies and related industries, tourism interests, marine sanctuary programs, commercial and recreational fisheries, local governments, transportation regulatory agencies, conservation-oriented NGOs, university researchers, and resource agencies. There are few negatives other than increases in operational costs for large vessels, and possibly increased enforcement costs. The megaliabilities of damage assessment, restoration, and litigation falling to parties responsible for oil spills (witness the case of the *Exxon Valdez*) argue that increased operational and enforcement costs should be the preferred alternative.

At least one objection to the risk reduction approach can be imagined. The oil industry and the related large-vessel transportation industry are expansive and multi-faceted, thus, "negotiating with the industry" will in fact be a daunting logistical challenge. However, the translocation of sea otters to San Nicolas Island faced comparably intimidating obstacles. Despite substantial administrative and technical challenges, political complexities, and the vocal disapproval by some interest groups, management authority was able to build a plan that led to project approval (see Benz, Attempts to Reintroduce, this issue).

What should the optimum sustainable population level be?

The ESA and MMPA provide key legislative guidelines for conservation of marine mammal populations such as California sea otters. The presence of listed populations can result in far-reaching habitat protection policies and can limit many kinds of economic activity within preferred habitat (e.g., Clark, this issue). Thus it is desirable to "recover" listed populations in order to facilitate conservation and perhaps to reduce impediments to various options for management and economic enterprise.

For the ESA, definition of listing criteria typically has fallen to Recovery Teams appointed on a case-by-case basis. For California sea otters the appointed Recovery Team has proposed that endangered status is appropriate for a population size less than 1,850 animals, and threatened status for a population size between 1,850 and 2,650 animals. The MMPA mandates that populations of marine mammals smaller than the OSP level are to be listed as depleted, subject to a petition process (see below). Again, specific listing criteria are not a part of the legislation, but the customary management practice has been to set a minimum OSP size at 60% of carrying capacity (K; see DeMaster et al., this issue).

Marine mammal populations listed either as endangered or threatened under ESA are by default categorized as depleted under MMPA. Removal from lists defined by ESA also automatically removes the depleted designation as defined by MMPA, even if the population size is less than 60% of K. An approved petition is required for populations delisted under ESA to be listed as depleted under MMPA (see Baur et al., this issue).

For my purposes here I assume that such a petition will follow immediately after the delisting of the sea otter population. This circumstance would make the delisting meaningless in a management context, because depleted status under the MMPA carries many of the same restrictions as the ESA, and could limit management options designed to balance conservation goals and socioeconomic needs. Thus, in my view, the central recovery issue relates to MMPA, not ESA, and specifically is: What is OSP level for California sea otters?

There is a range of views regarding the appropriate criteria for determination of the OSP size. DeMaster et al. (this issue) present a largely ecologically-based argument for a minimum value of 8,100 animals. Wendell (this issue) argues for consideration of socioeconomic as well as ecological issues in setting a minimum OSP level, implying that a value closer to ESA thresholds would be preferred in order to accommodate diverse human concerns along with sea otter conservation goals. Given the gap between these estimates I see an obvious potential for discord.

The MMPA is ambiguous in defining minimum OSP levels, implying substantial flexibility in approaching the problem. Thus the opportunity is available for setting OSP levels that accommodate diverse interests and concerns. I urge management authority and affected parties to begin, now, the process of negotiating toward a consensus OSP range.

Jurisdictional strife: template for polarization

Since 1972 there has been a consistent pattern of dissension between California Department of Fish and Game (CDFG) and U. S. Fish and Wildlife Service (FWS; note that the research division of FWS, formerly known as the National Biological Service, became part of the U.S. Geological Survey (USGS) in 1996) with regard to the conservation of sea otters. The preemption of state management of sea otters by MMPA in 1972 greatly complicated the efforts of CDFG to find a solution for sea otter-shellfishery conflicts. The listing of California sea otters as threatened in 1977 was, in the view of CDFG, an unjustifiable exaggeration of oil spill risk relative to the population size and distribution of sea otters (see Wendell, this issue). These events fostered an understandable resentment of federal management authority, injecting distrust and bitterness to interactions of state and federal managers and researchers. Efforts by federal agencies to introduce new research hypotheses and management concepts only engendered further skepticism and division, with the result that federal staff also became suspicious and distrustful of state positions on key issues. Because there has been relatively little turnover in staffing of federal and state sea otter management and research since the late 1970s, there have been few stimuli for embittered individuals on either side to seek a more positive approach to resolution of mutually significant issues. Thus, federal-state interactions regarding California sea otter conservation often have shown all the sophistication of a rugby match on the mudflats of Elkhorn Slough.

The real tragedy of the dysfunctional state-federal relationship is that it has created a template for polarization of public interest in sea otter conservation and management. Given the strongly dichotomous, apparently irreconcilable positions of CDFG and FWS/USGS on many sea otter conservation issues, non-governmental interest groups and stakeholders have gravitated to one side or the other. Rather than developing a unified front necessary to influence decision-makers and move forward on the implementation of consensus conservation policy, each side instead has invested substantial energy in attempts to discredit the views and goals of the other side, with the result that decision-makers have done nothing on many significant issues.

It is disturbing to find new evidence of the destructive polarization process. For example, Jessup et al. (this issue) summarize the recent progress in the development of facilities and procedures for care of oiled marine wildlife in California. The Oiled Wildlife Care Network (OWCN), managed by CDFG, is a good model of cooperative effort among potentially disparate agencies, NGOs, and other interests, and reflects the lesson of the *Exxon Valdez* disaster: rescue and rehabilitation facilities and procedures cannot possibly succeed if they are assembled post-spill. Unfortunately, the 1996 draft revised Southern Sea Otter Recovery Plan (Recovery Plan), prepared at the behest of FWS, makes a strongly negative editorial categorization of the type of approach represented by OWCN. The draft Recovery Plan offers no analytical justification for the stated position. Thus the Recovery Team, and by extension FWS, appear to be arbitrarily categorizing as worthless the most prominent element of the CDFG strategy for dealing with oil spills in California sea otter habitat.

A consensus agreement on OSP level probably is not attainable if the dysfunctional relationship of CDFG and FWS/USGS persists. Public polarization and decision-making stagnation will follow inevitably from continued failure of state and federal authorities to place high value on effective cooperation. Third-party mediation may be a desirable approach in moving CDFG-FWS/USGS interactions to a more constructive realm.

Photograph by Jeff Foott

Omissions of note

There are two important problems receiving only minimal discussion in this issue. The first is the method currently used for assessing the size and dispersion of the California sea otter population (see Bodkin and Ballachey, this issue). This method was developed by FWS and CDFG in the early 1980s, primarily through the initiative of R. J. Jameson, and includes two components. Most of the current sea otter range can be censused by ground observers because of the availability of State Highway 1 and the precipitous nature of the coastline. Less accessible portions of the range, such as those off Santa Cruz County and south of Pismo Beach, are surveyed by aircraft. Detection probabilities for ground counts are known (Estes and Jameson 1988), but to my knowledge detection probabilities for the aerial surveys have not been estimated for California sea otters. Thus, the total number of sea otters counted underestimates the total number present, but the magnitude of error is unknown. The unknown error has not been regarded as a significant problem because the range of the sea otter population has changed relatively little since the early 1980s, and surveys have been consistent with regard to technique, timing, weather and sea conditions, and personnel.

Monitoring of population size and distribution of sea otters in California will continue to be a crucially important activity, forming the basis for decisions regarding attainment of conservation and management goals. As the population continues to grow, it may be necessary to modify survey methods for at least two reasons. First, an expanding range will increase the difficulty in completing a count in a short period, which is important to ensure that survey results are not biased by significant movements of animals during the survey period (R. Jameson, personal communication). Second, increases in range likely will change the proportion of the population that can be surveyed by each of the two component methods. Such changes will alter the correlation between total number counted and actual population size in an unknown manner. In turn, these changes affect the accuracy of calculated trends in population size and alter the error in numbers used to measure attainment of management goals (see Bodkin and Ballachey, this issue). I recommend that research staffs of FWS/USGS and CDFG undertake the tasks necessary to resolve these problems, keeping in mind the need to determine the relationship of new methods with those currently in use, such that a long-term measure of population trend can be maintained without artificial discontinuities.

The second problem not receiving extensive coverage in this issue involves the relationship of sea otters with the biological structure of kelp forest communities in California. Sea otter foraging is known to limit numbers of benthic herbivorous invertebrates, particularly sea urchins, with the result that kelp forests are larger, more productive, more diverse biologically and structurally, and provide more benefits in terms of secondary availability of fixed carbon (e.g., Estes and Duggins 1995). This model has become dogma for much of the coastal Pacific Rim, especially in Alaska, but it remains in dispute in California (McLean 1962; VanBlaricom 1984; Foster and Schiel 1988; Estes and Duggins 1995). The alternative view, articulated by Foster and Schiel (1988), is that sea otters are only one of a number of factors that influence kelp forest structure at any particular location. Foster and Schiel argue that our capability for predicting the otter-urchin-kelp relationship is weak and that the model is overgeneralized, and possibly not applicable, for California coastal habitats.

Resolution of the dispute is important for two reasons. First, both ESA and MMPA mandate an understanding of the ecological connections between sea otters and their ecosystems. Because kelp have profound effects on habitat for other coastal organisms (e.g., Duggins 1988; Duggins et al. 1989), appropriate management of sea otters demands that the dispute be resolved. Second, kelp is harvested and supports a significant economic enterprise in California (e.g., Tarpley and Glantz 1992). Wendell (this issue) argues that human recreational and commercial enterprises in coastal marine waters should be significant factors in the determination of OSP level for California sea otters. For such determinations kelp harvesting interests should be considered (VanBlaricom 1984).

The best opportunity for additional study of the sea otter-kelp relationship in California is at San Nicolas Island (SNI). Coastal habitats at SNI include a diverse array of ecological patch types on shallow rocky substrata, with patches of well-developed kelp forests and areas that have been largely deforested by grazing sea urchins (e.g., Harrold and Reed 1985). The FWS/USGS ecosystem database for SNI dates to 1980 and represents systematic monitoring since that time. The future of the sea otter population at SNI is uncertain given the small number of animals present (Benz, Attempts to Reintroduce, this issue), but should the population grow and the FWS/USGS monitoring program be continued, many aspects of the current dispute may be resolved. Because of the potential management significance of data from SNI, continued monitoring of the translocation is imperative.

Problems for the new millennium

In this section I offer predictions of three problem areas that may develop over the next few decades as California sea otters emerge from the protection of ESA and reach a consensus OSP level: (1) sustainability of shellfisheries as zonal management of sea otters becomes broadly implemented and accepted; (2) changes in marine oil activity, and the associated consequences for oil spill risk; and (3) the emergence of interest in harvest of sea otters and shellfish by Native Americans. These issues will be direct and logical consequences of the removal of California sea otters from the list of threatened species, and the attainment of OSP levels. They will be as challenging as any issues currently under consideration.

Sustainability of shellfisheries

CDFG and FWS have for some years endorsed the concept of zonal management of California sea otters. Zonal management involves restriction of the range of the sea otter population to certain agreed areas, with the premise that areas without sea otters will be better suited for productive shellfisheries (see Wendell, this issue). Zonal management likely will become firmly implemented at some point after the population is delisted and attains the OSP level.

The concept of zonal management includes three assumptions: (1) sea otter range can be effectively constrained by an economically reasonable and politically palatable management program; (2) shellfisheries cannot be sustained in the presence of an unmanaged sea otter population; and (3) shellfisheries are sustainable and productive in the absence of sea otters. All three assumptions are controversial (Estes and VanBlaricom 1985; Wendell et al. 1986; Wendell 1994; see Benz, Attempts to Reintroduce; Wendell, this issue). Here I limit my comments to the third assumption. I focus primarily on California's abalone fisheries to illustrate my arguments, although with some caution my views can be generalized to other shellfisheries.

Photograph by Jeff Foott

The chronology of harvest data for California's commercial abalone fisheries suggests that, for a given species, high-yield areas are fished at a rate that typically exceeds the actual local rate of biomass production. Once a given location is depleted, fishing effort is moved elsewhere. Ultimately the fishery must refocus effort to a less desirable species (because high-yield areas are not able to recover from depletion before all high-yield areas for a given species are depleted). This pattern is apparent in harvest data records that indicate chronologically progressive depletion of abalone stocks (*Haliotis* spp.) over a period of several decades (Estes and VanBlaricom 1985). The problem has been exacerbated by sea otter predation in central California (Wendell 1994) and disease outbreaks in southern California (Haaker et al. 1992; Davis 1993; Lafferty and Kuris 1993; Richards and Davis 1993; VanBlaricom et al. 1993; Gardner et al. 1995), but the general model of over-utilization seems clear for areas and species that have not been affected by sea otters or disease (Estes and VanBlaricom 1985).

As a consequence of excessive harvest the present status of southern California's abalone stocks is dismal. White abalone are nearly extinct (Davis et al. 1996) and should be a candidate for immediate listing under the ESA. Fisheries for pink, green, and black abalones presently are closed because of depleted stocks or, in the case of blacks, disease (P. Haaker, personal communication).

Among California's harvested abalone species only red abalones have significant populations north of the present sea otter range. Commercial fishing for red abalones has been closed north of San Francisco since 1945, and recreational fishers are not allowed to use scuba gear, as they are in southern California. Stock sizes of red abalones are much larger in northern California than elsewhere, probably as a direct consequence of reduced total fishing mortality and the prolonged absence of sea otters (e.g., Pollard 1992). However, northern California stocks also face problems. Good recruitments are rare and growth rates of post-metamorphic individuals are low (Tegner 1989; Tegner et al. 1992). Large-scale illegal harvest is a burgeoning problem, and there is interest in opening northern California to commercial harvest.

Shellfishery management will be further complicated should the Native American communities of California successfully reassert access to traditional shellfishing grounds and resources. The coastal Native tribes of California relied heavily on shellfish gathered from ocean shore habitats for subsistence in pre-Columbian times (e.g., Vedder and Norris 1963; Bryan 1970; Douros 1993) and there can be little doubt that any legally binding affirmation of fishing rights for coastal California's Native Americans would extend to shellfish. Two federal court cases, the Boldt Decision and the Rafeedie Decision, both involving issues in Washington State, appear to provide legal precedents that could stimulate entry of Native tribes as significant users in

California shellfisheries. These decisions also stated that it is within the right of tribal fishers to use modern techniques such as scuba diving, to seek newly available species such as those introduced from other regions (Katzen 1996), and to pursue commercial as well as subsistence harvests of shellfish.

The imposition of zonal management as the long-term foundation of sea otter management carries an assignment of responsibility to fishery management authority and the shellfishing industry. If sustainable shellfisheries are to be a part of coastal California's future, shellfishery management may need to assert more conservative harvest guidelines, and the appearance of Native fishers as significant participants in California shellfisheries would require a further reduction in the harvest share taken by non-tribal fishers. Ludwig et al. (1993) review the discouraging status of the world's marine fisheries, describe several insidious mechanisms that can lead to unforeseen and damaging overharvest, and argue for "distrust" of claims of sustainability in fisheries management. Such patterns certainly are of concern for species with the life history characteristics typical of abalones and many other shellfish species harvested in California. The failure to sustain shellfisheries will mean a failure of zonal management, destabilizing a crucial element in long-term conservation planning for sea otters.

Changes in marine oil activity

The California sea otter population has been viewed as vulnerable to the effects of spilled oil for at least two decades, on the basis of laboratory studies (e.g., Costa and Kooyman 1982; Williams et al. 1988), examination of surrogates for oil spills (VanBlaricom and Jameson 1982), oil spill risk modelling (e.g., Bonnell et al., this issue), and actual oil spills in sea otter habitats. As a consequence, marine oil development plans routinely have been modified or cancelled since the listing of the sea otter population as threatened in 1977. Since the *Exxon Valdez* oil spill of 1989, sea otters have been the very symbol of resistance to marine oil activity for purposes of environmental protection (e.g., Batten 1990). Nevertheless, the fundamental socioeconomic, cultural, and demographic factors that drive global consumer demand for petroleum products have not changed appreciably in recent decades and likely will not change in the foreseeable future, necessitating additional development and transportation of new oil reserves.

Removal of California sea otters from the list of threatened species, and subsequent attainment of OSP levels, likely will lead to new plans for increased development of California's marine oil reserves, and new consequent transportation scenarios. Having lost the status of a listed or depleted population, California sea otters also will lose some of their "poster-child" clout as the oppressed victims of Big Oil. Any pre-OSP negotiated changes in oil shipment patterns off California could become obsolete as the demand for inexpensive oil supersedes public concern for a "recovered" sea otter population.

As development plans are implemented, risks of oil spills in sea otter habitat will increase, perhaps precipitously. The magnitude of the change is difficult to predict for several reasons. First, tanker traffic carrying crude oil southward from the trans-Alaska pipeline system (TAPS) has been declining for several years, and recent changes in TAPS-associated tanker traffic patterns off California will reduce spill risks by an unknown degree (see Jessup et al.; Saunders, this issue). Second, the choice of offshore tracts targeted for development will depend largely on economic and political factors well beyond the scope of this discourse. Third, a significant portion of petroleum transport through or near the California sea otter range is done by tankers moving refined products between San Francisco Bay and Los Angeles County, and these transport rates are affected by a complex of economic and demographic factors. Thus, although rates and associated spill risks likely will increase over the long term, the magnitudes of trends in the rates are difficult to predict.

Most available risk analyses consider current scenarios for transportation and development. The possibility of a significant change of risk levels associated with removal of sea otters from protected status has not been evaluated quantitatively to my knowledge. Changing oil spill risks after the year 2000 certainly represent a potential pitfall in sea otter conservation, and zonal management may have a regressive long-term impact on sea otter conservation if sea otter population size and range are constrained to constant values while oil spill risks increase.

Harvest by Native Americans

The MMPA includes provisions allowing Alaskan Native peoples to harvest marine mammals. The provisions are in recognition that harvest of marine mammals is a matter of enormous cultural significance to Alaskan Native communities, and that many marine mammal populations in Alaska are large enough to sustain Native hunting activity. The original MMPA was ambiguous about methods for regulation of Native harvest. Subsequent amendments and decisions have formalized co-management of marine mammal stocks between federal agencies and tribal governments.

The MMPA provisions for Native harvest laid groundwork for significant take of sea otters by Natives in Alaskan coastal waters. For most of the 1970s and 1980s few sea otters were taken as various legal issues were sorted out. Between 1988 and 1996 Native hunters took about 500 sea otters per year from Alaskan coastal waters (C. Gorbics, personal communication).

The MMPA makes no provision for harvests of marine mammals by Native peoples outside of Alaska. In 1995, after gray whales were taken off the endangered species list, the Makah Native people of coastal Washington State announced an interest in a limited harvest of gray whales off tribal lands of the Olympic Peninsula. The tribe cited rights specified in 19th century treaties with the U.S. government including provisions for continued pursuit of hunting practices in a manner consistent with tribal tradition. The Makah people are also known to have hunted sea otters in previous generations, and may be considering an assertion of treaty-based rights to renew the take of sea otters, whose population has been growing rapidly in the vicinity of tribal lands (R. Jameson, personal communication).

Many Native tribes in the western United States signed treaties with the U.S.

government in the 19th century. Often these agreements involved retention of hunting and fishing rights and other traditions in return for land exchanges and other concessions. Such agreements often seem ambiguously worded by contemporary standards. To date, portions of the language of five treaties involving Native tribes in western Washington have been tested in the U.S. Supreme Court on seven different occasions. Two important conclusions emerge from Court rulings, as summarized by Katzen (1996). First, the right of tribes to fish and hunt in usual and accustomed places is an inherent right pre-dating the appearance of European colonists, and this right remained with tribes unless explicitly relinquished. Second, the burden of proof for ambiguity in treaty language lies with challengers of treaty rights and obligations, not with the tribes. The courts interpret treaty language as it is thought to have been understood by tribes at the time the treaties were signed (Katzen 1996).

I suggest the possibility that attainment of OSP levels by the California sea otter population may open the door to proposals for Native harvest in California. California Native peoples are known to have taken marine mammals, including sea otters, either for food or to generate pelts for trade (e.g., Kroeber 1925; Bennyhoff 1950; Kroeber and Barrett 1962; Bleitz 1993). Coastal tribes without legally binding forfeitures of hunting rights likely will have a case for the legal development of sea otter harvests.

It is both difficult and highly presumptuous to predict the actions of Native tribes with regard to the harvest of sea otters. Given the potential establishment of a precedent by a non-Alaskan tribe such as the Makah, and the stimulus provided by removal of California sea otters from protected status, a move toward Native hunting of sea otters in California is a reasonable expectation. Such a move likely would provide politically contentious pitfalls and technical challenges for those charged with shepherding the conservation of sea otters after the year 2000. Should Native harvest plans materialize in California, I predict a difficult, high-profile public debate with no obvious pathway for resolution.

Conclusion and recommendations

Sea otters are attractive to scientists because they are accessible, easy to observe and count, have easily quantifiable diets with readily recognized prey, and are part of ecological interactions that are interesting, sometimes astonishing, and always relevant to a number of significant management issues. It is no coincidence that we have a better technical understanding of many aspects of sea otter biology than for most other carnivorous marine and terrestrial mammals. It should follow, then, that the available repository of data and models is a powerful resource for resolution of questions bearing on conservation of sea otters in California. In short, if science can't save the California sea otter population, science probably can't save anything.

Science cannot function as a tool for conservation planning without broad public support. Diminishing support for the scientific method as a pathway for answers is a widespread and growing problem in our culture (e.g., Sagan 1995; Ehrlich and Ehrlich 1996). The loss of faith in science results from the consistent failure of society to understand the process of science, and from the progressive replacement of secular logic with traditional values and mythologies as the basis for making decisions. Here emerges a dilemma, wherein public support for science may be tied to lay participation, but lay participation may be at best inappropriate, and at worst a detriment to objective knowledge.

The making of public policy in the 1990s is a pluralistic process in which user groups and interest groups sit at a round table with scientists and managers. For complex issues involving social, economic, and technical components, pluralism and egalitarianism are appropriate. Determination of the OSP level is perhaps a good example. For scientific questions that underlie many management issues, the involvement of interests outside the realm of science may interfere with the search for truth. In evaluating hypotheses, scientists cannot be swayed by association with advocacy, nor can they mix the roles of scientist and advocate, without compromising the process. The involvement of advocacy may lead to settlement of scientific questions by popular consensus rather than rigorous elimination of incorrect explanations and the development of accurate syntheses.

If sea otters are to be saved in California, scientists must do good science and avoid advocacy. Advocates must defend their interests but not meddle in the dialectic of research. Managers must determine whose data are objectively represented, and whose models represent good science. The interested public must demand the highest standards of all. The reward for commitment to the scientific process and assumption of appropriate roles is the survival of the California sea otter population for another millennium.

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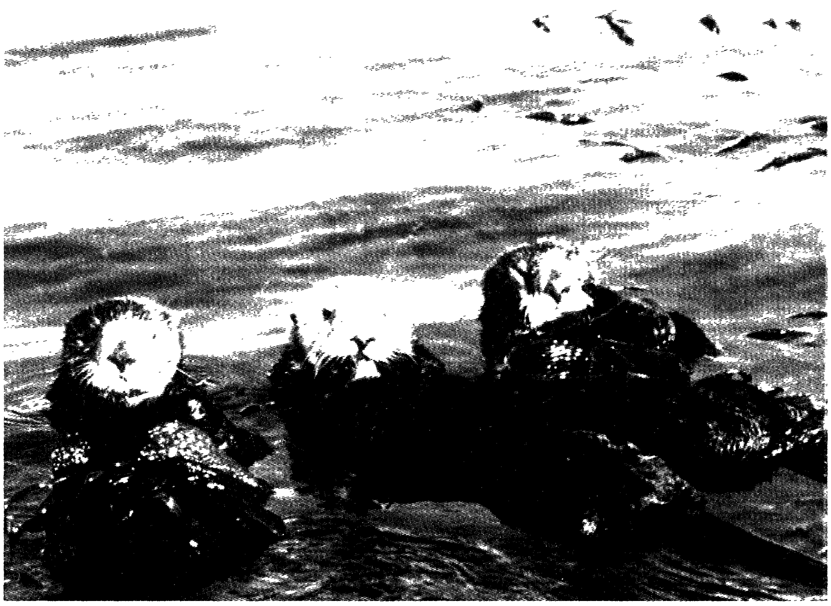

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