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

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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 Woodland 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.

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).

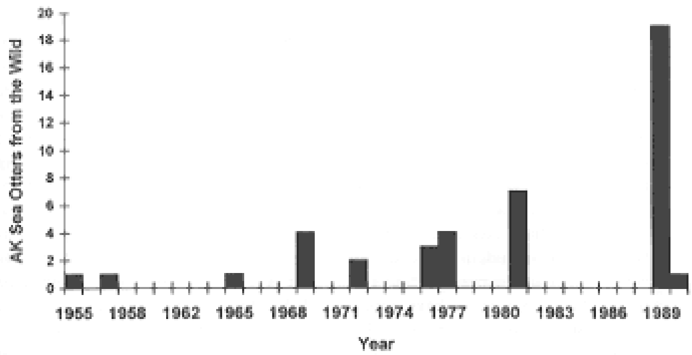

Figure 1. Chronological history showing the number and year wild Alaska sea otters joined the North America captive sea otter population. Figure does not include animals that died within the first month after capture.

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).

Table 1. Life history rates of sea otters in captivity

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

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 between 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.

Table 2. Assigned values used in Vortex© model

Number of simulations	1,000
Number of years	24
Breeding system	Polygymous
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 capabity non-limiting	Yes
Population supplementations	As specified
Initial population size	Current

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.

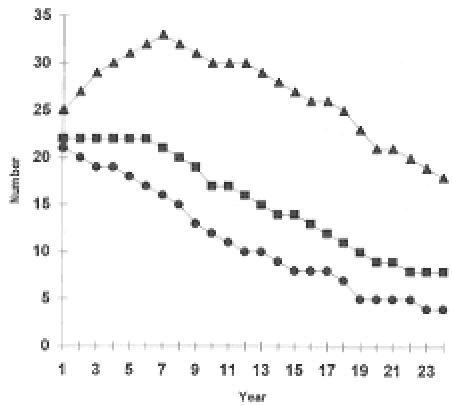

Figure 2. Most probable outcome based on computer simulations of the captive Alaska sea otters in North America under three different management strategies: [circle] continue to limit female reproduction and transfer half of the offspring out of the breeding population; [square] continue to limit female 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.

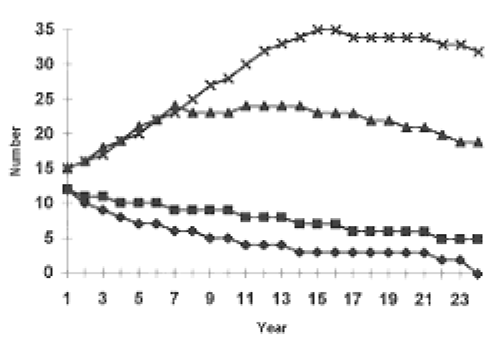

Figure 3. Most probable outcome of computer simulations of the captive California sea otters in North America under four different management strategies: [diamond] continue to manage as a non-reproductive population; [square] female reproductive rate equal to that observed in the Alaska subpopulation; [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.

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.

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

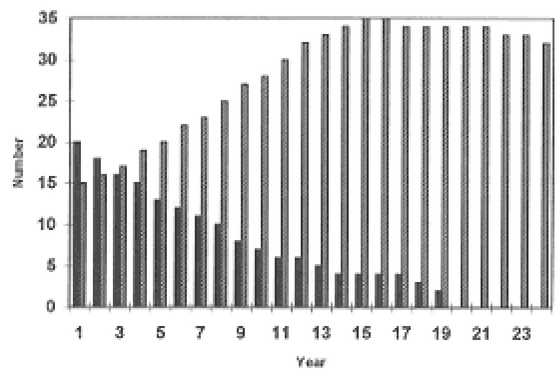

Figure 4. Graphic illustration of a management strategy to exhibit both Alaska and California sea otters in North America while gradually replacing Alaska sea otters with California sea otters.

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 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.

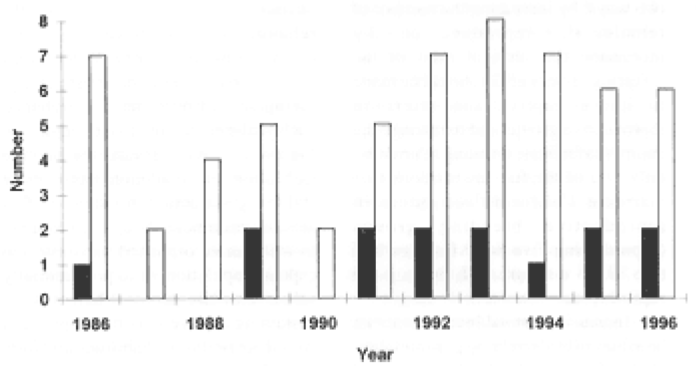

Figure 5. Chronological history of stranded California sea otter pups: [white] number that stranded; [black] number of non-releasable pups that were added to the captive population.

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.

Literature Cited

Antonelis, G.A., Jr., S. Leatherwood, L.H. Cornell, and J.G. Antrim. 1981. Activity cycle and food selection of captive sea otters. The Murrelet 62:6-9.

Antrim, J.E., and L.H. Cornell. 1980. Reproduction of the sea otter (Enhydra lutris) in captivity. International Zoo Yearbook 20:76-80.

Barabash-Nikiforov, I.I. 1947. Kalan. Pages 1-174 in Soviet Ministrov RSFSR. Glavnoe upravlenie po zapovednikam. [The sea otter. Translated from Russian by A. Birron and Z.S. Cole for the National Science Foundation by the Israel Program for Scientific Translations, Jerusalem, Israel. 1962. 227 pp.].

Brosseau, C., M. L. Johnson, and K. W. Kenyon. 1975. Breeding the sea otter (Enhydra lutris) at the Tacoma Aquarium. International Zoo Yearbook 15:144-147.

Brown, S.R., M. Glenn, and S.R. Libra. 1994. Case report: perivular uroliths in the Alaska sea otter. Proceedings 25th IAAAM Conference, Vallejo, California. Pages 16-20.

Casson, C.J. 1990. Administering oral medications to captive sea otters (Enhydra lutris). Proceedings 18th International Marine Animal Trainers Association Conference, Chicago, Illinois. Pages 12-19.

Casson. C.J., B. Anderson, and J.W. Nightingale. 1987. A descriptive analysis of nursing in captive born Alaskan sea otters. Proceedings American Association of Zoological Parks and Aquariums Conference, Portland, Oregon. Pages 490-500.

Crandall, L.S. 1964. Sea otters. Pages 345-348 in L. S. Crandall. Management of wild mammals in captivity. University of Chicago Press, Chicago, Illinois. 761 pp.

Fausett, L.L. 1976. Assimilation efficiency of captive sea otters. M.S. thesis, University of California, Long Beach, California. 39 pp.

Foose, T.J. 1980. Demographic management of endangered species in captivity. International Zoo Yearbook 20:154-166.

Giddens, W.E., M. Ryland, T.A. Gornall, and C. J. Casson. 1984. Idiopatic scoliosis in a newborn sea otter, (Enhydra lutris). Journal of Wildlife Diseases 20(3):248-250.

Glazier, R. J. 1984. Sea otters: delight or dilemma. Proceedings American Association of Zoological Parks and Aquariums Conference, Miami, Florida. Pages 237-241.

Graham, M. and K. G. Hewlett. 1988. The biology of the Northern sea otters at the Vancouver Aquarium. Proceedings American Association of Zoological Parks and Aquariums Regional Conference, Monterey, California. Pages 218-222.

Hanson, M. B., L. J. Bledsoe, B. C. Kirkvold, C. J. Casson, and J. W. Nightingale. 1993. Behavioral budgets of captive sea otter mother-pup pairs during pup development. Zoo Biology 12:459-477.

Harrold, C., E. J. Brennan, T. Williams, M. Staedler, and J. Hymer. 1996. The California sea otter: changing needs and challenges. Proceedings 4th International Aquarium Congress, Tokyo, Japan (in press).

Hewlett, S. 1983. A decade of sea otters (Enhydra lutris). Proceedings American Association of Zoological Parks and Aquariums Conference, Vancouver, British Columbia. Pages 224-228.

Hoffer, S.A. 1973. Sea otters in captivity. Sea Frontiers, (May-June). Pages 141-147.

Jameson, R.J., A.M. Johnson, and K.W. Kenyon. 1975. Maternal behavior and pup ontogeny of captive sea otters. Proceedings 1st Biennial Conference on Marine Mammals. Santa Cruz, California. Page 41.

Johnson, M.L. 1972. The sea otter in captivity. Pages 17-24 in A. Seed, editor. Sea otter in eastern North Pacific waters. Pacific Search. 37 pp.

Johnson, M. L., K. W. Kenyon, and C. Brosseau. 1967. Notes on a captive sea otter, (Enhydra lutris). International Zoo Yearbook 7:208-209.

Joseph, B.E. and T.R. Spraker. 1989. Acute fatal pharyngitis in a California sea otter (Enhydra lutris). Proceedings 20th IAAAM Conference, San Antonio, Texas. Pages 90-92.

Kenyon, K.W. 1969. The sea otter in the eastern Pacific Ocean. North American Fauna, Number 68. 352 pp.

Kenyon, K.W., C.E. Yunker, and I.M. Newell. 1965. Nasal mites (Halarachnidae) in the sea otter. Journal of Parasitology 51(6):960.

Kirkpatrick, C.M., D.E. Stulken, and R.D. Jones, Jr. 1955. Notes on captive sea otters. Journal of Arctic Institute of North America 8(1):46-59.

Lacy, R.C. Vortex: a computer simulation model for population viability analysis. Wildlife Research. (in press).

Lacey, R.C. and T. Kreeger. 1992. Vortex users manual: a stochastic simulation of the extinction process. Chicago Zoological Society, Brookfield, Illinois. 57 pp.

Mattison, J.A., Jr. and R.C. Hubbard. 1969. Autopsy findings on thirteen sea otters (Enhydra lutris nereis) with correlations with captive animal feeding and behavior. Proceedings 6th Annual Conference of Biological Sonar and Diving Mammals, Stanford Research Institute. Palo Alto, California. Pages 99-101.

Nakajima, M., A. Furuta, Y. Fujimaki, and J. Yamada. 1988. Breeding of the northern sea otter, Enhydra lutris lutris, at Izu Mito Sea Paradise. Japanese Association of Zoological Gardens and Aquariums 39(2).

Nightingale, J. W. 1981. Essential elements of a successful breeding program with captive sea otters. Proceedings American Zoo Vet Association Conference, Seattle, Washington. Pages 84-86.

Nightingale, J. W., H. D. Kemper, and J. P. Styers. 1978. A computer-ready record system for storage and correlation of nutritional and other husbandry data. Proceedings American Association of Zoological Parks and Aquariums Conference, Denver, Colorado. Pages 197-202.

Nightingale, J. W., C. Timmis, and J. Styers. 1979. Food preference studies with captive sea otters (Enhydra lutris) using a comparison matrix. 3rd Biennial Conference of the Biology of Marine Mammals, Seattle, Washington. Page 64.

Pollard, R. J. 1969. Notes on the husbandry and behavior of the sea otter in captivity. Proceedings 6th Annual Conference on Biological Sonar and Diving Mammals, Stanford Research Institute. Palo Alto, California. Pages 95-98.

Powell, D. 1994. A multispecies exhibit for the southern sea otter (Enhydra lutris). Proceedings of Annual American Zoo and Aquarium Association Conference, Atlanta, Georgia. Pages 229-231.

Ralls, K., K. Brugger, and J. Ballou. 1979. Inbreeding and juvenile mortality in small populations of ungulates. Science 206:1101-1103.

Ralls, K., K. Brugger, and A. Glick. 1980. Deleterious effects of inbreeding in a herd of captive Dorcas gazelle. International Zoo Yearbook 20:137-146.

Ramirez, K., M. Hudson, and L. Takaki. 1996. Initiation of a sea otter training program. Marine Mammal: Public Display and Research 2(1):43-49.

Riedman, M.L., and J.A. Estes. 1990. The sea otter (Enhydra lutris): behavior, ecology, and natural history. U.S. Department of Interior, Fish and Wildlife Service. Biological Report 90(14). 126 pp.

Soulé, M.E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-169 in M.E. Soulé and B.A. Wilcox, editors. Conservation biology: an ecological-evolutionary perspective. Sinaur, Sunderland, Massachusetts. 395 pp.

Stetzer, E., T. D. Williams, and J. W. Nightingale. 1981. Cholangiocellular adenocarcinoma, leiomyoma, and pheochromocytoma in a sea otter. Journal of the American Veterinary Medical Association 179:1283.

U.S. Fish and Wildlife Service. 1996. Southern sea otter recovery plan, 1996 draft. Ventura, California. 41 pp.

Vincenzi, F. 1962. The sea otter (Enhydra lutris) at Woodland Park Zoo. International Zoo Yearbook 3:27-29.

Whitt, A.P. 1971. The behavior of the sea otter in captivity. M.S. thesis, Pacific Lutheran University, Tacoma, Washington. 170 pp.

Wildt, D.E., U.S. Seal, and W.F. Rall. 1991. Genetic resource banks and reproductive technology for wild species conservation: an overview, a strategy, a draft policy statement and background documentation. (Singapore). IUCN/SSC Conservation Breeding Specialist Group Publication. Apple Valley, Minnesota.

Williams, T. D. 1986. Mustelidae (sea otter). Pages 820-822 in M. E. Fowler, editor. Zoo and wild animal medicine, 2nd edition. Philadelphia, Pennsylvania. 1127 pp.

Williams, T. D. 1990. Sea otter biology and medicine. Pages 625-648 in L. A. Dietrauf, editor. Handbook of marine mammal medicine: Health disease and rehabilitation. CRC Press, Boca Raton, Florida. 735 pp.

Williams, T.D., D.M. Baylis, S.H. Downey, and R.O. Clark. 1990. A physical restraint device for sea otters. Journal of Zoo and Wildlife Medicine 21(1):105-107.

Williams, T. D., L. Henderson, P. Harr, J. Hymer, and G. Issvoran. 1991. Nutritional requirements of the sea otter (Enhydra lutris). Proceedings 22nd IAAAM Conference, Marine Land, Florida. Page 61.

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back to index