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Special Section: Marine Sentinel Species

Southern Sea Otter as a Sentinel of Marine Ecosystem Health

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Abstract The southern sea otter (*Enhydra lutris nereis*) is listed as "threatened" under the Endangered Species Act (ESA) and is a "keystone species," strongly influencing the abundance and diversity of the other species within its kelp forest ecosystem. This is accomplished primarily by preying upon urchins that eat the kelp stipe and holdfast, which can reduce a kelp forest to an urchin barren. Sea otters are very susceptible to marine pollutants such as petroleum, which may be directly toxic and/or alter their fur's insulating properties. Sea otters are an excellent sentinel species. They eat approximately 25% of their body weight per day in shellfish and other invertebrates, and can concentrate and integrate chemical contaminants. In addition, they appear to be susceptible to a number of diseases and parasites that may have anthropogenic origins, and shellfish may serve as an intermediary for some of these infections. Many of the shellfish the otters eat are also harvested for human food. In their role as sentinels, sea otter health has implications for human health, economic sustainability of shellfisheries, as well as overall marine ecosystem health. The recent southern sea otter decline has been viewed with some alarm by conservationists and, indeed, recovery seems a long way off. High mortality rather than depressed recruitment appears to underlie the decline. A good deal of debate has centered on the role of infectious diseases and parasites, exposure to contaminants, nutrition and prey availability, net and pot fishery interactions, and other sources of mortality. Current research is being done related to major classes of mortality, various types of pollutants and some specific organisms causing southern sea otter mortality, and their implications for marine ecosystem health and sustainability.

Keywords ecosystem health - *Enhydra lutris nereis* - petroleum - pollutants - sea otter - sentinel species - toxoplasmosis

INTRODUCTION

The southern sea otter (*Enhydra lutris nereis*) is listed as "threatened" under the Endangered Species Act. Once thought to be extinct, the remnant Big Sur populations of this subspecies grew steadily during the early half of the 20th century and expanded their range to both the north and south (Fig. 1). The recovery appeared to falter during the late 1970s, presumably due to bycatch in the gill net fishery (*Wendell et al., 1996*). But in the early 1980s, after government restrictions moved net fisheries away from most sea otter habitats, the recovery continued. Recovery faltered again in 1995 with an approximately 12% decline in the ensuing 4 years [Hatfield, unpublished report]. Data from Spring 2000 demonstrate an increase in the population; however, during the following spring, the count was back down. The overall trend of the sea otter population since 1995 has been a decline, and as of today there are 9% fewer otters than there were in 1995 (Fig. 2).

1985

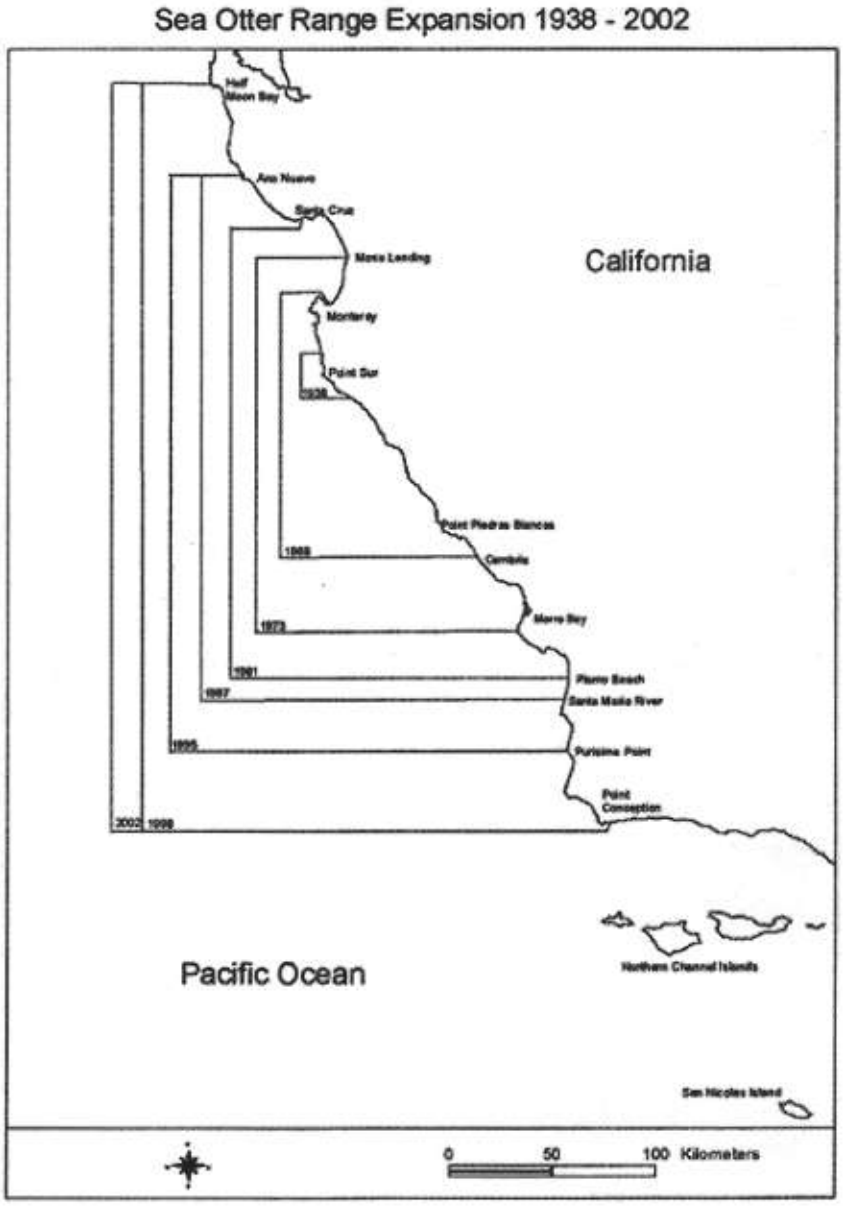

Figure 1 Sea otter range map with expanding ranges, 1938–2002.

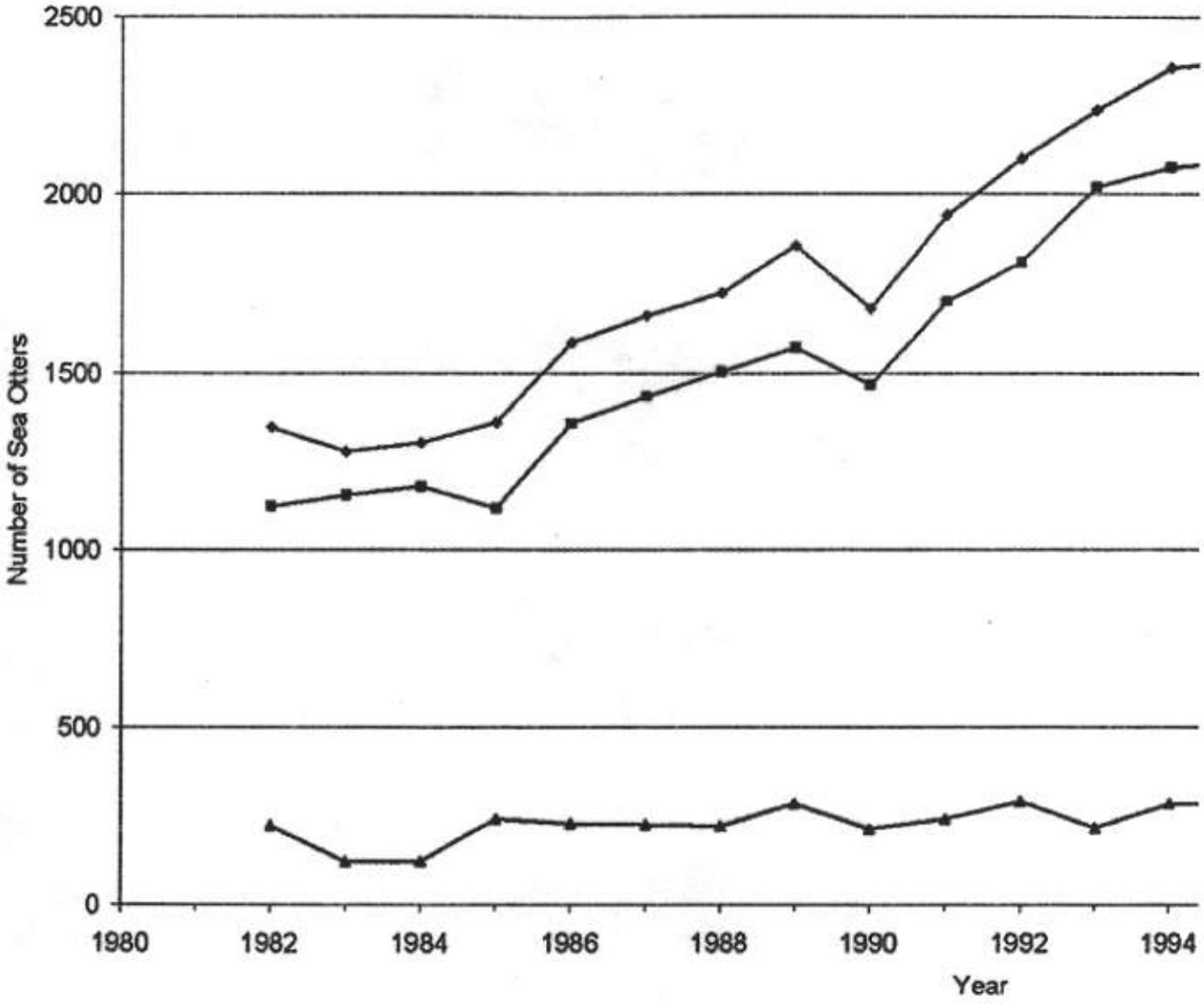

Figure 2 Chart of rangewide sea otter counts, 1975–2001.

The sea otter is a "keystone species," one that strongly influences the abundance and diversity of the other species within its kelp forest ecosystem, primarily by its effect on sea urchins that eat the kelp stipe and holdfast. An imbalance in the sea otter-to-urchin ratio can reduce a kelp forest to an urchin barren. In the presence of sea otters and a more abundant kelp canopy, many species of fin fish and other kelp-dependent species tend to be more numerous, and most shellfish tend to be fewer in number and smaller in size. Sea otters are also a very charismatic species; their antics and feeding and maternal behaviors are very attractive to people. Protection of sea otters may have the classic "umbrella species" effect, with a popular species providing protection and habitat for less noticeable, but nonetheless biologically important species. Many small businesses catering to various facets of the tourist industry profit from the presence of sea otters. Thus, the significant negative impacts of sea otters on some commercial and recreational shell fisheries may be partly offset by more general benefits to tourism.

The recent southern sea otter decline has been of concern to conservationists and, indeed, recovery is not likely in the foreseeable future. Higher adult mortality rather than depressed recruitment appears to be a component of the decline. A good deal of debate has centered on the role of infectious diseases and parasites, exposure to contaminants, nutrition and prey availability, net and pot fishery interactions, and other sources of mortality. Adult sea otter mortality, the contribution of emerging diseases, and population decline and/or failure of recovery are important conservation issues. Beneath these lay the issues of the general health of California's near shore marine ecosystems and the potential role of sea otters as sentinels of marine ecosystem health.

SEA OTTERS AS SENTINELS

The unique biology of sea otters potentially makes them an excellent sentinel species. They are relatively local, foraging in the near shore ecosystem, usually at depths less than 125 meters, unlike seals and small whales that range widely (*Riedman and Estes, 1990*). Although male otters may range over larger areas, females generally show significant site fidelity, typically ranging along 20 km or so of coastline. Thus, the pathogens and contaminants they accumulate are more representative of those present locally rather than regionally. Other cetaceans and pinnipeds range more widely and it is quite difficult to determine what the source or sources might be for their contaminants or pathogens.

Sea otters eat approximately 25% of their body weight per day in shellfish and other benthic invertebrates (*Riedman and Estes, 1990*). These invertebrates and shellfish can concentrate and integrate a variety of chemical and biological contaminants. In addition, sea otters appear to be susceptible to a number of infectious pathogens and parasites that may have anthropogenic origins, and shellfish may serve as an intermediary for some of these infections. Many of the shellfish otters eat are also harvested for human food, some of the pathogens that we are finding in shellfish, which also cause disease and death of sea otters, are potentially serious or opportunistic human pathogens. Shellfish are only valuable to both commercial and recreational fisheries if they are fit for consumption. Thus, in its role as a sentinel, the sea otter health may have implications for human health, economic sustainability of shell fisheries, and overall health of the near shore marine ecosystem.

MARINE ECOSYSTEM HEALTH

Marine ecosystem health is a relatively new and poorly defined concept. It is generally agreed, however, that healthy ecosystems (marine or terrestrial) are those that do not have obvious environmental degradation, frequent pollution events, or serious anthropogenic effects due to over harvest; do not have a high frequency of new or emerging diseases/intoxications with negative implications for human and wildlife health; have stable, or at least not declining, species abundance and diversity; and do not have frequent dieoffs or similar stochastic events, particularly those involving "indicator" or "keystone" species (*Rapport, 1989*).

THE PERSISTENT ORGANIC POLLUTANTS CHLOROPHENOTHANE (DDT) AND POLYCHLORINATED BIPHENOLS (PCB's)

Previous work suggests that contaminants such as ~~DDT, PCBs,~~ PLEASE DEFINE DDT AND PCB AT FIRST USE IN TEXT. and tributyl tin (an organometallic compound, with impressive biocidal activity, which has been used extensively in marine paint formulations to prevent the accumulation of barnacles and slime on boat hulls) may predispose southern sea otters to dying from infectious diseases (*Kannan et al., 1998*; *Nakata et al., 1998*), although these initial studies were quite limited in sample size and have serious spatial, temporal, and age biases. Currently, we are expanding on this work and investigating the potential relationships between contaminant burdens and cause of death in a much larger group of animals.

It has also been observed that higher mortality rates appear to follow years of higher than normal runoff and subsequent release of a variety of contaminants into the near shore environment [Parades and Worchester, unpublished data]. Mercury and organochlorine pesticides in sea otter food items and the potential for synergistic and/or endocrine disruptor effects are of concern Jessup D, unpublished data]. *Kannan et al. (2003)* PLEASE CONFIRM IF KANNEN ET AL. IS THE BEGINNING OF A NEW SENTENCE, OR CLARIFY AS NEEDED have shown that sea otters concentrate organic pollutants from their prey 60 to 240 times in their tissues and appear to be capable of metabolizing PCBs with lower numbers of halogen substitutions. We are now examining the potential connections between contaminant exposure, immune function, and health of live free-ranging southern sea otters in several study areas across the length of their range.

California receives over 200 million gallons of crude oil a day and the threat of a major oil spill continues to loom over the sea otter. Incidental drowning of sea otters in nets and, potentially, in fish traps have been a cause for renewed concern and have resulted in observer programs and mandated changes in fishing regulations.

Several newly recognized diseases and intoxications have been identified. These include harmful algal blooms that cause amnesic shellfish poisoning and neurotoxic shellfish poisoning. These may be relatively new phenomena or simply increasing in frequency and/or severity. Coccidioidomycosis (San Joaquin Valley Fever), a soil-borne fungal disease, is affecting sea otters, and cases are clustered in the southern end of their range (San Luis Obispo County) near the Santa Maria River mouth. Soil disturbance due to agriculture and development may be the ultimate source of these fungi (*Jessup, 2003*). Recent investigations suggest sea otter infections with pathogenic protozoa *Toxoplasma gondii* and *Sarcocystis neurona* (*Miller et al., 2001a,b*) may be related to terrestrial runoff or human/domestic animal pollution. Several bacterial septicemias (*E. coli*, *Clostridium perfringens*, *Salmonella*, *Listeria*, *Eyrsipelas*, *Bortdetella*, *Archanobacter*) that have been implicated in sea otter deaths could have originally come from terrestrial habitats.

Numerous hypotheses have been developed to explain the apparent increase in mortalities caused by thorny headed worms (Acanthocephala of the genus *Profilicolis* and *Corynosoma*) in the 1990s. These include emergence or host shifts of the more pathogenic species and changes in foraging habitat or prey species selection by sea otters. The *Profilicolis* spp. of thorny headed worms appears to be much more poorly host adapted than the *Corynosoma* spp. and, thus, they are more pathogenic. The sand crab hosts of *Profilicolis* vary in abundance and in consumption by sea otters depending on weather cycles and possibly alternative prey availability (*Mayer et al., 2003*). In recent years, the percentage of sea otters dying from thorny headed worm infestations has declined and, suffice it to say, the complexity, importance, and connection to anthropogenic activity of these infestations are poorly understood. From both ecological and

regulatory perspectives, if anthropogenic activities including traditional chemical or pathogen pollution from point sources, non-point sources, or other ecological changes are definitely shown to cause significant morbidity and mortality of sea otters at the population level, regulatory and management actions must be considered.

Abundance of many of California's fish and shellfish stocks are depressed or fluctuate widely. Regulatory agencies have recently reduced or eliminated the harvest of a number of once plentiful species. Several preferred sea otter prey species, including red, black, green, pink, and white abalone (*Haliotis rufescens, H. cracherodii, H. fulgens, H. corrugata, H. sorenseni*), are in serious decline or on the brink of extinction, due at least in part to introduction of pathogens and parasites. Emaciation is a relatively common finding in sea otters, although it is unclear whether it is primary or secondary to disease. If sea otter numbers decline further, the structure of some kelp forests may be altered via reduction in their "keystone species" role, with resulting further reduction in the abundance and diversity of species dependent on the kelp canopy.

Notable, and still unexplained, focal sea otter mortality events occurred in 1995 and 1998, and, between 1995 and 2001, the southern sea otter counts declined by 9%, apparently due in part to increased adult mortality. This decline preceded and has spanned both the El Niño and La Niña oceanic cycles. When one compares the above cited findings, facts, and events with the criteria for ecosystem health, it seems reasonable to conclude that the marine ecosystems supporting sea otters, as well as the otters themselves, are showing signs of ill health.

CAUSES OF MORTALITY

Current evidence suggests that no one single activity or organism is responsible for the decline of sea otters. It is not "a shot to the heart" that is killing them, but rather "the death of a thousand cuts." Several lines of evidence suggest that there are many obvious and subtler connections to human activities. In a recent study, approximately 40% of mortalities of fresh necropsied otters were attributed to infectious diseases and parasites (*Thomas and Cole, 1996*). Protozoal encephalitis, caused by *Toxoplasma gondii* and *Sarcocystis neurona*, may prove to be an emerging disease of marine mammals. The most recent reviews suggest that mortality due to these two organisms may be occurring at levels sufficient to be the cause of the current population decline (*Kreuder et al., 2003*; *Jessup, 2003*). The first recognized cases in free-living marine mammals in California were reported in both harbor seals (*Phoca vitulina*) and sea otters in the early 1990s (*Thomas and Cole, 1996*; *Lapointe et al., 1998*). The only common definitive host for *T. gondii* is the domestic cat. The opossum (*Didelphis virginiana*), an introduced species in California, is the definitive host for *S. neurona*. Thus, sea otters and harbor seals may act as sentinels for potentially pathogenic protozoa in the near shore ecosystems of central California whose presence may be related to introduced and invasive terrestrial species associated with disturbed habitats.

Data from detailed necropsies of freshly dead southern sea otters are currently being analyzed for geographical, temporal, and demographic patterns, as well as possible risk factors for certain categories of mortality. Interestingly, this has revealed that otters bitten by white sharks (*Carcharodon carcharias*) commonly have preexisting disease that may have impaired their