Chapter 10

ANIMAL HEALTH AND WELFARE CONSIDERATIONS

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The purpose of this section of the feasibility study is to provide information on the potential health and welfare hazards that may negatively impact the success of reintroducing sea otters (*Enhydra lutris*) to the Oregon coast. The information is subdivided into two major sections, animal health (or its converse, disease) and animal welfare. For this discussion, the word "disease" includes both infectious diseases, such as parasitic infections, and noninfectious diseases, such as domoic acid (DA) intoxication. There are also circumstances in which differentiation between northern sea otters (*E. l. kenyoni*) and southern sea otters (*E. l. nereis*) is made.

This chapter's animal welfare section is more subjective and speculative. While animal welfare is becoming more science-based, it evaluates an animal's state at any one point in time, is described on a continuum from good to poor, and varies, often dramatically, within a group of animals and over time. The subject is addressed through the lens of a modified list of the Five Freedoms described by Britain's Farm Animal Welfare Council (FAWC) in 1965 and subsequently released in 1979 (FAWC 2009) and the Association of Zoos and Aquariums' (AZA's) Five Opportunities, outlined in their accreditation standards (AZA 2020). The modified list considers whether animals have the following when assessing their welfare:

1. nutritionally complete diets—in quantity, familiarity, safety, and accessibility
2. comfortable living experiences—that are appropriate for the species, provide the ability to rest, offer haul-out opportunities, and prevent anthropogenic risk
3. good physical health—humans help to mitigate known disease risk and provide live-stranding responses, carcass recovery and processing, and potential rehabilitation opportunities
4. adequate social structure—per group size, sex ratio, age range, and site fidelity
5. freedom from chronic stressors—e.g., boat traffic, ecotourism disturbances, inadequate refugia, interspecies interactions

Lastly, a discussion of health and welfare would be incomplete without including animal transportation and post-arrival conditioning. A number of federal agencies provide regulatory oversight for interstate animal transportation, and the list becomes longer albeit less specific when dealing with wildlife, especially marine mammals. Regardless of the source population, any transport will be several hours long, and the potential for transport-related stress and loss of pelage conditioning is high. Some degree of post-arrival recovery and conditioning will likely be a critical component in maintaining the otters' health and well-being.

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ANIMAL HEALTH

As previously described, animal health includes both infectious and noninfectious diseases. For this chapter, a rather stringent definition of infectious disease has been applied. *Infectious diseases* are those caused by a living organism (i.e., viruses, bacteria, fungi, protozoa, or metazoan parasites) under normal (natural) circumstances. It is important to note that the definition does not include or describe modes of transmission. Diseases transmitted directly between animals are described as transmissible, communicable, contagious, or transmitted horizontally. An exception to that definition is the diseases known to be transmitted in utero, such as toxoplasmosis, for which transplacental or vertical transmission is used. While many infectious diseases are transmitted directly between animals, not all are. Examples include both toxoplasmosis (excepting the vertical transmission between dam and fetus) and sarcocystosis. Both are caused by living organisms, specifically protozoa, but they cannot be transmitted directly to other otters (or humans) through normal mechanisms. Theoretically, they may be transmitted directly if an uninfected otter ate an infected one, but that is not a normal activity.

This document is selective in its inclusion of noninfectious diseases. An attempt was made to address those considered to potentially impact the success of a sea otter reintroduction program at a population level and are typically considered an individual animal malady. Of the 11 major groups of *noninfectious diseases* (degenerative, allergic, autoimmune, metabolic, neoplastic, nutritional, infectious, immunological, toxic, traumatic, and genetic), only four (infectious, toxic, traumatic, and genetic) are salient to this discussion. Refer to Chapter 4 for further information on genetics and disease.

Aspects of this discussion are necessarily speculative. The information provided is based upon a combination of published data, works in progress, personal communications with colleagues, and my experience in clinical sea otter medicine. In addition, inferences were drawn from other members of the otter's family, *Mustelidae*, for which a fair bit of information is known about infectious and noninfectious diseases.

INFECTIOUS DISEASE

Morbillivirus

Of the list of viral diseases affecting sea otters, morbillivirus is undoubtedly the most concerning. A member of the Paramyxoviridae family, the genus *Morbillivirus* contains two species of significant concern to sea otters: canine distemper and phocine morbillivirus. Before 2001, all sea otters tested for morbilliviruses were seronegative (Hanni et al. 2003, Thomas et al. 2020). Live otters from Washington State (henceforth, Washington) were tested in 2001–2002 following the 2000 mortality event, and 80% were seropositive (Brancato et al. 2009). A retrospective evaluation of tissue from 18 deceased otters sampled between 2000 and 2010 using immune-histochemistry and RT-PCR identified canine distemper virus as the cause of either infection (12/18) or disease (6/12; Thomas et al. 2020). Evidence collected suggests that the canine distemper virus was the cause of the 2000 mass mortality event.

Phocine morbillivirus was first associated with a mass mortality event affecting seals in the North Atlantic in 1988. Since then, a second event has occurred, and sporadic deaths have been reported. Serologic evaluation of live-captured sea otters in the eastern Aleutians and Kodiak archipelago in 2004–2005 identified 40% seropositivity to phocine morbillivirus (Goldstein et al. 2009).

The incidence of morbillivirus in southern sea otters appears to be low. A recent compilation of southern sea otter necropsies from 1998 to 2012 identified three cases of putative morbillivirus infection (3/560) as the primary cause of death (COD) and five cases (5/560) as a contributing COD (Miller et al. 2020). In nearly 1000 live strandings seen at the Monterey Bay Aquarium, no cases of morbillivirus have been identified.

Despite the fact that morbillivirus has been associated with marine mammal die-offs in the North Atlantic, Gulf of Mexico, and Mediterranean Sea, the only morbillivirus-associated mass die-off affecting sea otters was the 2000 event off the Washington coast. That said, the potential exposure of naive sea otters to canine distemper virus from terrestrial carnivores, such as canids and raccoons, and marine-foraging river otters cannot be ignored. Additionally, the ongoing loss of sea ice and the opening of the Northwest Passage may facilitate the movement of phocine morbillivirus by carrier seals. Once established in the Pacific, the potential exposure of sea otters becomes significantly greater.

Influenza Virus

Mustelids are well known for being susceptible to influenza virus infection, so much so that the domestic ferret is often used as an animal model for studying the disease. Marine mammals, particularly pinnipeds, are considered wildlife reservoirs for the virus. Northern sea otters captured in 2011 were evaluated for antibodies to influenza virus H1N1 (Li 2014). Of the 30 otters tested, 70% (21/30) were seropositive. The source of the infection was unclear; however, serologic evidence supported the notion that the sea otters' source of infection was the northern elephant seal (*Mirounga angustirostris*).

While the mortality associated with influenza virus in sea otters is uncertain, the fact that virus transmission can occur through shared haul-out areas is notable. Also, the addition of the sea otter as a wildlife reservoir for the influenza A virus may have some public health significance.

Bacterial Diseases

Morbidity and mortality associated with bacterial infections are common in the sea otter. From 1998 to 2012, bacterial infections were the primary COD in 33 out of 560 southern sea otters and the contributing COD in 35 out of 560 (Miller et al. 2020). The examined death assemblage from the 2002–2015 evaluation of Washington State otters identified 14 out of 93 cases of bacterial infection (including six cases of Leptospirosis; White et al. 2018).

Recent sea otter mortality studies have lumped bacteria-caused mortality into a single group: bacterial infection. It is unclear whether the bacterial species is considered a primary or secondary (opportunistic) pathogen. A review of the list of more than 15 species recovered at necropsy (Brownstein et al. 2011) suggests that the vast majority of bacterial species are, in fact, opportunistic. They rely on a breach of the host's intrinsic immune system (skin, mucus membranes), immunosuppression, or coinfection with a primary pathogen to gain access to the body. Notably, several pathogens identified have significant zoonotic potential and may pose a public health risk: *Brucella* spp., *Coxiella burnetii*, *Bartonella* spp., *Erysipelothrix* spp., *Leptospira* spp., and *Salmonella* spp. Most are likely opportunistic in nature.

Streptococcus phocae, one of the more commonly identified opportunistic pathogens, is frequently recovered from deceased sea otters. A true secondary pathogen, the organism requires damaged skin as a portal of entry. It has been recovered from shark-bite wounds, breeding-related wounds to the muzzle and nasal pad, and a myriad of bite wounds likely associated with intraspecific aggression. Once the organism is established, it often causes abscesses or septicemia (Bartlett et al. 2016).

Recent studies have demonstrated that several sea otter prey species—bay mussels (*Mytilus trossulus*), butter clams (*Saxidomus gigantea*), Dungeness crab (*Metacarcinus magister*), and black turban snails (*Tegula funebralis*)—are capable of bioaccumulating *S. phocae* (Rouse et al. 2021). It is unclear whether this bacterium is capable of breaching the gastrointestinal mucosa or if food-borne exposure requires a preexisting break in the gastrointestinal tract, such as ulceration or a wound associated with prey handling.

Other beta streptococcus species, *Streptococcus bovis/equinus* and *Streptococcus infantarius* ssp. *coli*, have been strongly associated with vegetative valvular endocarditis, a proliferative disease of the heart valves. While the exact pathogenesis remains unclear, some attribute the cause of the unusual mortality event declared in 2006 in Kachemak Bay, either partially or entirely, to one or both of these strep species (Carrasco et al. 2014).

Bordetella bronchiseptica is a common primary and secondary pathogen affecting domestic dogs, one of several organisms associated with what is commonly known as kennel cough. The organism was first identified as a sea otter pathogen affecting the respiratory tract (Staveley et al. 2003). In the sea otter, it is considered to be a secondary pathogen and may be associated with morbillivirus infections. This organism may become significant during post-transport holding and acclimation. The stress-mediated immunosuppression of capture, transport, abnormal social structures, and behaviorally induced inappetence may result in opportunistic infections with this contagious pathogen.

Leptospirosis has historically been an uncommon disease of sea otters. A study of otters in Washington had a seropositivity rate of one in 30 in 2001 (Brancato et al. 2009); five in 103 in California in 2003 (Hanni et al. 2003); and three in 161 in Alaska and Russia in 2004–2006 (Goldstein et al. 2011). In 2002, six beach-cast sea otter carcasses were evaluated, and COD was attributed to leptospirosis (Knowles et al. 2020). While the incidence seems to remain low, there may be some degree of concern for the transfer of infection from terrestrial wildlife. A study of peri-urban wildlife in northern California identified six species associated with significant risk factors for infection: western gray squirrel, coyote, striped skunk, raccoon, gray fox, and mountain lion (Straub and Foley 2020). Their presence in and around potential sea otter haul outs may pose some degree of interspecies transmission on the Oregon coast.

Overall, bacterial infections are unlikely to pose a significant, population-level threat to a reintroduced sea otter population along the Oregon coast. Recent mortality studies of southern and Washington sea otters identified 68 out of 560 (12%) and 14 out of 93 (15%) cases in which bacterial infections were the primary or secondary COD, respectively (White et al. 2018, Miller et al. 2020).

Fungal Diseases

There is only one fungal disease warranting discussion within this venue, coccidioidomycosis or Valley fever, a disseminated fungal infection caused by *Coccidioides immitis*. While it is an infectious disease, it is not easily transmitted from one otter to another and therefore should not be considered communicable. The infectious fungal spores have a limited range, and the primary risk to sea otters is associated with adjacency to the San Joaquin Valley (Figure 10.1). No cases were reported in northern sea otters, and nine of 560 were identified by Miller et al. (2020), all of which were found at the southern end of the sea otter range.

Interestingly, the incidence of Valley fever has increased dramatically in humans at the northern end of the southern sea otter range, from 7.3 cases per 100,000 people in 2008 to 54.7 cases per 100,000 in 2018 (Monterey Health Department 2019). Some have theorized that the sea otter cases are associated with construction and other disturbances to the topsoil in the valley associated with eastern winds.

At this point, there is no evidence of a population-level threat posed by coccidioidomycosis to a sea otter reintroduction. That said, a map of prevalence (Figure 10.1) demonstrates the proximity of the fungus to coastal and central Oregon. Given the weather and other impacts associated with climate change, it is probably unwise to assume that infection is impossible.

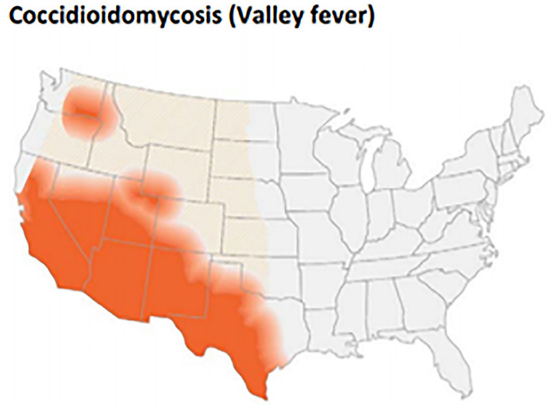
Parasitic Diseases

Unlike parasitic disease in many other wildlife species, the majority of the parasites reported in sea otters tend to be difficult to transmit horizontally. Four of the five parasitic diseases reported to be primary or contributing CODs in recent studies (White et al. 2018, Miller et al. 2020) are not communicable. In fact, the sea otter is an aberrant host for three of four infections: protozoal infection (*Sarcocystis*, *Toxoplasma*), acanthocephalan peritonitis (AP), and larva migrans (*Baylisascaris, Paragonimus*).

Sarcocystosis

Sarcocystosis is caused by a sporozoan protozoan, *Sarcocystis neurona*. It has a rather complicated life cycle, employing a number of endotherms—including dogs, cats, raccoons, and sea otters—as intermediate

Figure 10.1. Map of the distribution of Valley fever in the United States



Note. Source: Information from the U.S. Centers for Disease Control and Prevention about the estimated areas with blastomycosis, coccidioidomycosis (Valley fever), and histoplasmosis in the United States: https://www.cdc.gov/fungal/pdf/more-information-about-fungal-maps-508.pdf.

hosts, in which it forms tissue cysts. The definitive host, the species in which sexual reproduction occurs and oocysts are produced and shed, is the Virginia opossum, *Didelphis virginiana*.

In the sea otter, positive antibody titers are more common than clinical disease. It is suspected that encysted parasites may not cause significant symptoms. The 2002–2015 Washington State study found that sarcocystosis accounted for 28 of 93 primary CODs (White et al. 2018), while the California study identified protozoal infection (*Sarcocystis* and *Toxoplasma*) as the primary and contributing COD for 50 of 560 cases and 58 of 560, respectively. While numbers were not provided, sarcocystosis outnumbered toxoplasmosis as a primary COD by a factor of five (Miller et al. 2020). The 2004 mass mortality event in Morro Bay, California, was attributed to sarcocystosis as the primary COD in 15 of 16 animals (Miller et al. 2010a).

Sarcocystis infections have been identified in California, Washington, British Columbia, and Alaska, with spatial clustering most common in California and Washington. There has been a strong association of infection, as defined by positive antibody titers, with terrestrial features (wetlands, croplands, and high human-unit density), soft-sediment substrate, and the predominance of clams in the diet (Burgess et al. 2020).

A transmission pathway has been proposed in which oocysts accumulate over time and remain viable in the environment for months to years. Freshwater runoff into the nearshore system allows for concentration by the local marine habitat features, ocean physical processes, and subsequent invertebrate bioaccumulation. Benthic invertebrates, such as bivalve mollusks (e.g., razor clams), are then consumed by the sea otter, resulting in infection.

In California, there is good alignment between the dominant freshwater outflows occurring in the late winter and early fall and subsequent disease peaks in sea otters in the spring and early summer. This trend tends to confirm the land–sea transmission epidemiology of sarcocystosis (Miller et al. 2010a). In addition, disease hot spots have been identified in association with localized oceanic conditions and terrestrial features that affect runoff (Burgess et al. 2020).

Sarcocystosis is of significantly more concern than the other diseases mentioned previously in this chapter. Evidence points to *Sarcocystis* being a more virulent parasite than other apicomplexan parasites. The Virginia opossum is a very well-adapted, non-native mammal introduced in Oregon in 1910–1921; therefore, oocyst shedding is likely along the extent of the Oregon coast. Infective stages are shed into the environment and remain infective for extended periods. The method of transmission from land to sea is now well understood, as is the bioconcentration of the parasite within a normal food item without causing disease in the vector.

Toxoplasmosis

A second sporozoan (spore-producing) protozoan, *Toxoplasma gondii*, is a significant pathogen in sea otters (Thomas and Cole 1996, Miller et al. 2007). This parasite is found throughout the sea otter's range. There are several serotypes that have been identified, with Type II and Type X dominating in sea otters. Type X is the genotype most often associated with a fatal disease in sea otters. Type II, while causing seroconversion, rarely causes significant, if any, clinical disease (Miller et al. 2008b, Shapiro et al. 2019). Type X has been identified not only in sea otters but also in domestic cats, bobcats, and mountain lions. Toxoplasmosis is not an uncommon disease in humans, generally associated with undercooked meat, particularly pork. In pregnant women, serious disease in the unborn fetus is possible.

As with *Sarcocystis*, the sea otter is not the definitive host for the parasite. In the case of *Toxoplasma*, the only known definitive host is a felid, either domestic or wild. Vertical transmission of the parasite is possible, with abortion or perinatal death as likely outcomes (Miller et al. 2008a, Shapiro et al. 2016).

When evaluated at a large spatial scale, the risk of infection is greatest in areas with a higher human population density or high proportion of human-dominated land use, such as impervious surfaces and cropping land. It is thought that this effect results from an increased presence of a felid definitive host (Burgess et al. 2018).

At smaller spatial scales, the risk of infection positively correlates to increasing age, sex (male), and prey choice (Burgess et al. 2018). Diets dominated by marine snails are more commonly associated with toxoplasmosis than other feeding strategies (Johnson et al. 2009). It has been theorized that the feeding strategy of snails, like *Tegula*, is different from that of other gastropods, such as abalone. The net result is greater exposure to *Toxoplasma* oocysts in *Tegula* diets than in abalone (Krusor et al. 2015).

The epidemiology of toxoplasmosis is similar to that described for sarcocystosis. The presence of the putative definitive host (felids), which sheds large numbers of oocysts into the terrestrial watershed adjacent to sea otter habitats, ensures a durable infectious stage capable of persistence for extended time periods outside of the host, land-based surface freshwater runoff acting as the source for *Toxoplasma* in the nearshore marine environment, and the ability of benthic filter feeders, such as bivalves, to accumulate infectious stages for eventual consumption by sea otters (Miller et al. 2002). This pathway has been confirmed for the more virulent genotype, Type X (Shapiro et al. 2019).

While toxoplasmosis is not transmitted horizontally between sea otters, there may be some degree of concern for its potential impact on a recently reintroduced sea otter population. Even with the less virulent types, significant infection may impact reproductive success. Type X infections may be associated with mortality. There may also be some bio-political and public perception issues. While sea otters cannot transmit toxoplasmosis to humans under normal circumstances, it may be difficult for the public to avoid associating sea otters' well-described *Toxoplasma* relationship with any publicized human cases.

Acanthocephalan Peritonitis (AP)

AP is not an uncommon primary or contributing COD in southern sea otters (127/560), but it is rarely reported in the northern subspecies (White et al. 2018, Miller et al. 2020). The sea otter is considered an aberrant or dead-end host for AP's causative agent, *Profilicolis* spp. The normal life cycle is complex, with a free-living stage, an arthropod as an intermediate host, and a vertebrate as a definitive host. In the case of *Profilicolis*, the intermediate hosts are the sand crab, *Emerita analoga*, and the spiny mole crab, *Blepharipoda occidentalis*, and the definitive host is a scoter, gull, or sea duck (Mayer et al. 2003).

While the definitive hosts are found throughout the eastern Pacific coast, the presence of the intermediate hosts is somewhat more inconsistent in that area. *Emerita* is commonly found in sandy and mixed substrate habitats on the California coast. Sand crab populations are much more sporadically found along the Oregon coast. It has been postulated that the species is restocked by larvae drifting northward on the currents, with the highest numbers identified during El Nino years (Sorte et al. 2001).

The disease is most often diagnosed in recently weaned pups, subadults, and aged adult animals living near appropriate habitat for the intermediate host. There may also be a relationship between disease incidence and resource (food) availability (Shanebeck and Lagrue 2020, Tinker et al. 2021b). When the population is at or near carrying capacity, energy recovery rates are lower, implying that otters need to work harder to find adequate food. During these periods, the more shallowly located, easily extracted sand crabs may be an attractive food source. When food is plentiful, hunting is less demanding, and even the less physically fit otters can forage on normal prey species. This theory is obviously speculative and needs to be interpreted as such, although the positive relationship between sea otter density and the incidence of AP mortality in southern sea otters is statistically significant (Tinker et al. 2021b).

It is unclear how significant AP may be to a recently introduced sea otter population. There may be opportunities to mitigate the risk to some degree by thoughtfully selecting the release site and physically conditioning the animals pre-release. Ample food availability (at least in the early years after reintroduction) may result in otters avoiding predation upon some of the high-risk food sources, such as *Emerita* and *Blepharipoda*.

Larva Migrans

In this venue, *larva migrans* will be used as a generic term to describe the aberrant migration of helminth larvae through various tissues in a non-definitive host, the sea otter. Excluded from this definition is the previously described AP.

Larva migrans is an uncommon primary or contributing COD in the sea otter. The most commonly described parasite species are the raccoon roundworm (*Baylisascaris* sp.) and the lung fluke (*Paragonimus* sp.; White et al. 2018, Miller et al. 2020). Peripheral migration through viscera, muscle, etc. tends to be clinically insignificant. On occasion, however, the larva may enter the eye, causing blindness, or the brain, resulting in an encephalitis. Both diseases tend to be fatal in free-ranging animals due to the untoward impacts on foraging and other life-supporting activities.

Despite their uncommon occurrence, they are included within this discussion as examples of the potential health hazards associated with land–sea pathogen transmission. The presence of freshwater runoff and human-dominated land use, such as impervious surfaces, cropland, and human dwellings, seem to provide increased risks of pathogen pollution of the nearshore habitat.

NONINFECTIOUS DISEASE

Toxic Diseases

Domoic Acid (DA) Intoxication

While DA intoxication was not identified as a COD in the recent Washington death assemblage, it was a significant primary or contributing COD (probable/possible) in the California study (White et al. 2018, Miller et al. 2020). DA is a water-soluble neuronal glutamate receptor analog that is produced by certain strains and species of the diatom *Pseudo-nitzschia* (PN). It is the cause of amnesic shellfish poisoning, which was first recognized in Canada in 1987.

Harmful algal blooms (HAB) are known to occur along vast stretches of the eastern Pacific coastline, including Oregon. There are a number of factors known or suspected to enhance PN blooms, including changes in the oceanographic conditions, overfishing, eutrophication of marine waters, and global climate change (Landsberg 2002, Chavez et al. 2003, Lefebvre et al. 2016, McKibben et al. 2017). A great deal of work has been done to better understand the relationship between oceanographic conditions and HAB along the coast of Oregon.

PN blooms tend to be seen during the spring and summer months, which align with the early period to the midpoint of the oceanic upwelling of nutrient-rich water. This upwelling tends to be associated with northerly winds. As winds relax, phytoplankton blooms are moved closer to shore, where they may interact with benthic invertebrates, prey for sea otters (McKibben et al. 2015). It should be noted that not all PN blooms are associated with DA production.

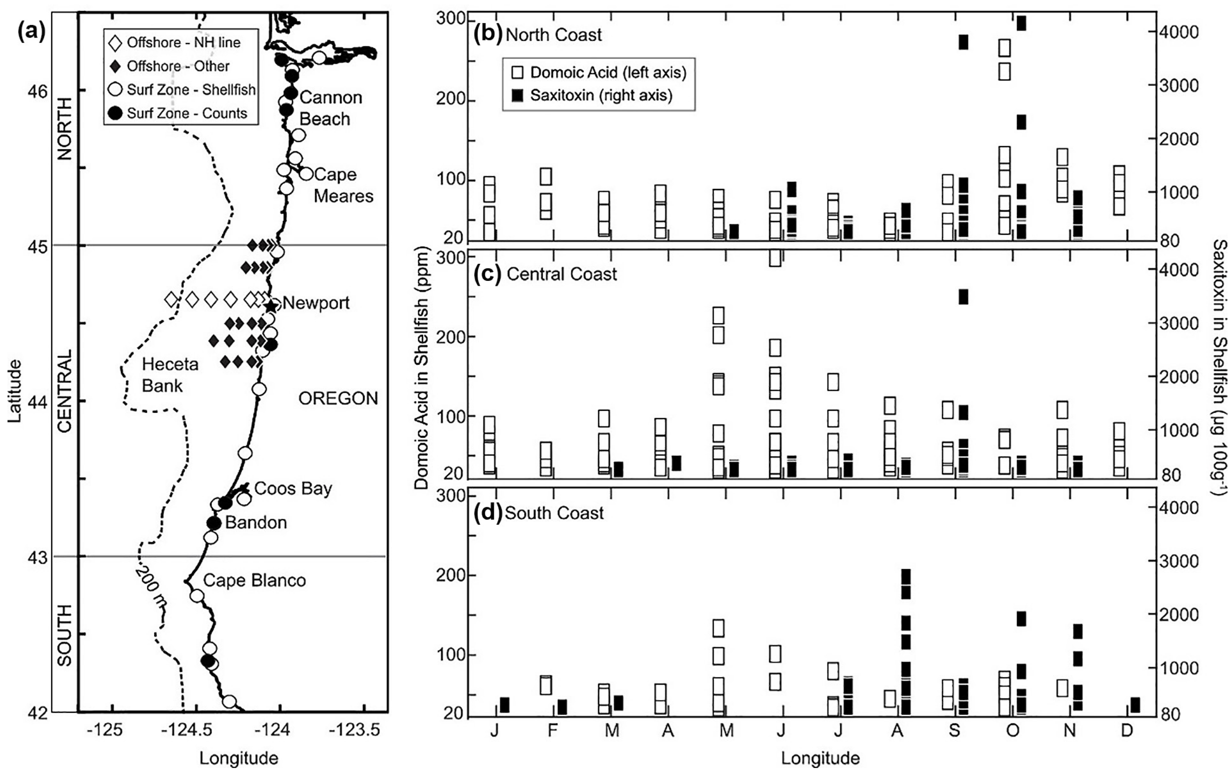
An important cautionary note is that reliance on offshore PN and DA monitoring may not reflect the degree to which benthic sea otter prey are exposed to the biotoxin. Exposure is dependent upon the movement of the algal bloom into the shallower surf zone. This movement is, in turn, affected by surf zone hydrodynamics and morphology (Shanks et al. 2018). Dissipative surf zones are often associated with rip currents, which are efficient in exchanging water and associated algal blooms with offshore water masses. More reflective surf zones limit the exchange of water, thereby reducing the entry of algal blooms into nearshore areas (Shanks et al. 2016). The net result is that the degree to which sea otter filter-feeding prey are exposed to DA may vary dramatically on small spatial scales. The use of data generated over larger scales is likely to be relatively insensitive in predicting sea otter risk to intoxication.

Because DA intoxication occurs in humans, as well as marine mammals and birds, state and local agencies carry out active monitoring programs. Several sentinel species are used, as well as an evaluation of the water column for PN. Mussels are a common bio-accumulator that is easily managed; therefore, they are commonly used as sentinel species for evaluating the presence of DA. There is some suggestion that they are less sensitive than other benthic invertebrates, such as sand crabs (Ferdin et al. 2002). Razor clams, a significant commercial and recreational fishery in Oregon, are highly effective bio-accumulators of DA. They also have a slow depuration rate relative to mussels (Blanco et al. 2002). As a result, high DA levels in razor clams may represent an acute, high-level exposure or, alternatively, a chronic, low-level exposure over time (McKibben et al. 2015). Using established monitoring systems has limited applicability to predicting sea otter exposure because (a) monitoring efforts vary from region to region, (b) bioaccumulation mechanisms differ between species, (c) the systems use human-centric toxicity thresholds, and (d) the systems emphasize human-consumed species (Figure 10.2).

Other potential sea otter prey items have been evaluated as potential DA depositories. One study looked at eight benthic invertebrate species representing four feeding groups: filter feeders (*Emerita analoga*, *Urechis caupo*), a predator (*Citharichthys sordidus*), scavengers (*Nassarius fossatus*, *Pagurus samuelis*), and deposit feeders (*Neotrypaea californiensis*, *Dendraster excentricus*, *Olivella biplicata*). While DA was identified in all eight species, it was above the human safety threshold of 20 ppm in six (*N. fossatus*, *E. analoga*, *U. caupo*, *C. sordidus*, *N. californiensis*, and *P. samuelis*; Kvitek et al. 2008).

The potential impact and pathogenesis of DA exposure are likely to be directly related to how various prey species respond to the toxin, local and regional environmental factors, and the age and size of the prey (Egmond et al. 2004). Mussels, one of the primary sentinel species for DA, accumulate it in the digestive gland. As a result, it depurates quickly but does accumulate to high levels. DA accumulates in different body tissues of the razor clam: the mantle and foot. This accumulative pathway results in a significantly slower depuration rate (Novaczek et al. 1992). As a result of the rapid accumulation and elimination in mussels, sea otters may be exposed to high DA levels in a short time; acute intoxication is the result. Prey species with slower depuration rates, such as razor clams (Blanco et al. 2002), may cause sea otters to accumulate high DA levels from either profound PN blooms or exposure to low, persistent levels of the toxin (McKibben et al. 2015).

Figure 10.2. Oregon map illustrating domoic acid (DA) and saxitoxin (STX) monitoring activities and related data.



Note. In the map of coastal Oregon (a), the area to the right of the solid black line is land. The dashed line shows the continental shelf break at the 200-m isobath. Diamond symbols show offshore locations sampled aboard research vessels. White diamonds highlight the Newport Hydrographic (NH) line at 44.658N. Wind data were collected at Newport, Oregon (star symbol). Circles on the coast represent surf zone sampling locations for shellfish DA and STX (white) or *Alexandrium* and PN cell counts (black). Surf zone data are binned into north (45–46.58N), central (43–458N), and south (42–438N) regions. Monthly STX and DA samples are shown as black squares (right axis) and white squares, respectively, for north (b), central (c), and south (d) coast locations defined in (a). Only values above the 80 mg * 100 g^{-1} and 20 ppm harvesting closure thresholds for STX and DA, respectively, are shown (i.e., Y-axes start at closure thresholds). From McKibben et al. (2015).

DA intoxication is difficult to diagnose antemortem. The toxin is readily absorbed via the gut and eliminated via the urine. Its serum half-life is short, making serological evaluation insensitive. Urine is a more sensitive test; however, it too is eliminated within a short time. There are three major postmortem presentations of DA intoxication based on the dose consumed over time. Acute intoxication is primarily a neurological disease with seizures dominating the clinical presentation. A subacute disease with doses spread out over time has both neurological changes and some degree of effect on the heart. The chronic form is a cardiac disease often associated with cardiomyopathy and other degenerative diseases of the heart (Miller et al. 2021).

Given the significance of known or suspected DA-related mortality, as well as recently published information demonstrating the relationship between DA and cardiac disease in sea otters (Moriarty et al. 2021), the potential for DA-related morbidity and mortality is high in an Oregon coast reintroduction effort. Methods for mitigation are uncertain, although likely sea otter prey items (especially razor clams) should be included in the process of identifying release sites. Additionally, local oceanographic conditions and the potential for anthropogenic eutrophication of nearshore waters warrant consideration.

Saxitoxin (STX) Intoxication

A second marine biotoxin warranting discussion is saxitoxin (STX), the causative agent of paralytic shellfish poisoning, which is produced by some species of the dinoflagellate *Alexandrium*. STX is not a single compound. Instead, it is a group of neurotoxins produced by species of dinoflagellates, including *Alexandrium* (Horner et al. 1997). Based on regional Indigenous customs and the apparent ability of some marine mammals to proactively reject toxin-bearing prey, it appears that paralytic shellfish poisoning has been present on the West Coast for centuries (Fryxell et al. 1997). For this reason, the Oregon Department of Agriculture has been monitoring shellfish for the presence of STX since 1979.

The typical pattern does not involve DA and STX events co-occurring (McKibben et al. 2015). Both are more common in warmer water and are initiated by upwelling-causing northerly winds. As winds decline, the blooms are moved toward shore, exposing nearshore invertebrates to biotoxins. Dinoflagellate blooms, including *Alexandrium*, are classically seen later than DA-associated blooms, traditionally peaking in June through November (McKibben et al. 2015).

The marine biotoxin sampling program for DA/STX and PN/*Alexandrium* is inconsistent along the Oregon coast, with the north coast most heavily monitored, followed by the central coast, and the south coast at the lowest level (Figure 10.2). Mussels are sampled more commonly than razor clams, and the sampling frequency decreases from north to south. Significant STX and *Alexandrium* have been reported. In 2010, the Oregon Department of Agriculture closed the entire Oregon coast to all harvesting of mussels, scallops, razor clams, oysters, and bay clams; all are potential sea otter prey (McKibben et al. 2015).

Despite the frequency of closures concerning commercial and recreational shellfish harvesting along the eastern Pacific coast, the incidence of STX intoxication in sea otters is low. Recent comprehensive analyses of CODs for sea otters in Washington and California did not report any cases of STX intoxication (White et al. 2018, Miller et al. 2020). Sea otters are susceptible to the effects of the neurotoxin; however, experiments involving wild-caught sea otters from Kodiak Island suggested that they seemed to detect and avoid heavily toxic loads (Kvitek et al. 1991).

In the butter clam, *Saxidomus gigantea*, approximately 60%–80% of the toxin bioaccumulates in the siphon, gills, kidneys, and pericardial glands. STX depurates slowly, and potentially toxic levels can remain in the butter clam one year following a seasonal bloom (Shumway 1990).

After consuming toxic STX levels, sea otters demonstrate a spectrum of neurological and behavioral anomalies, including vocalization, muscle tremors, and agitation. When toxic prey is removed, recovery appears to be complete (Kvitek et al. 1991). This finding may explain the absence of STX-related mortality in recent mortality reviews for sea otters (White et al. 2018, Miller et al. 2020).

It is likely that despite the prevalence of STX in Oregon shellfish, there is minimal potential for significant population-level impacts on reintroduced sea otters. Sea otters appear to be able to detect and develop an aversion to STX at levels above a certain threshold (Kvitek and Bretz 2004). It is unclear how this detection occurs and whether it occurs below the surface. The Kodiak Island study (Kvitek et al. 1991) involved wild-caught, independent otters. Therefore, it is not clear from previous work whether the STX avoidance behavior is an innate or learned one. If the latter is true, it is possible that naïve, rehabilitated juvenile and subadult otters may be at greater risk of saxitoxicosis.

Microcystin Intoxication

Microcystin intoxication is an uncommon cause of sea otter morbidity or mortality; however, its prevalence in freshwater systems is becoming a worldwide problem (De Figueiredo et al. 2004). As with several other causes of sea otter mortality, there is a freshwater link to the disease. Microcystin is an environmentally stable toxin produced by several species of Cyanobacteria, formerly known as blue-green algae. It is found in both freshwater and estuarine waters throughout North America and worldwide. In a case study published in 2010 (Miller et al. 2010b), microcystin was transported from freshwater systems into Monterey Bay via nutrient-impaired rivers. Based on experimental evidence, it is believed that the toxin biomagnified up to 107 times in the tissues of bivalves (Miller et al. 2010b). Sea otters that consumed toxic levels of microcystin-containing prey died of acute liver failure. The ability of benthic filter feeders to bioaccumulate the toxin above ambient levels and depurate the compound slowly poses a potential health threat to otters foraging adjacent to freshwater streams and rivers.

It is unlikely that microcystin is a significant, population-level health threat to a reintroduced sea otter population. It does, however, warrant some degree of consideration during the evaluation of release sites. The Oregon Health Authority's Public Health Division publishes guidelines for cyanobacterial blooms in freshwater bodies, a potential resource for this evaluation (Oregon Health Authority 2019).

Tributyltin (TBT) or Organotins

Tributyltin (TBT) was employed as an antifouling agent in marine paint for boat hulls from the 1960s until its use was regulated in 1988 (Huggett et al. 1992). As TBT ablated from its original site of application, levels increased in the water column, sediments, and local organisms. It became apparent that TBT effects extended beyond target organisms, such as barnacles and marine worms, to include oysters, snails, other mollusks, and crustaceans (Kannan et al. 1998). In fish and mammals, TBT tends to bioaccumulate primarily in the liver; however, significant levels are also found in the brain and kidney. Likely due to the sea otter's diet and high energetic demands, levels found in sea otters are more than twice that seen in cetaceans (Kannan et al. 1998).

It appears that TBT is associated with immunosuppression in birds and mammals (Snoeij et al. 1987, De Vries et al. 1991). A study of butyltin residues and COD for southern sea otters recovered from 1992 to 1996 did not demonstrate a strong association between TBT levels and immunosuppression, as evidenced by disease as COD (Kannan et al. 1998). This finding was supported by a study of organotins in sea otter carcasses from California, Washington, Alaska, and Kamchatka, Russia, from 1992 to 2002 (Murata et al. 2008). Again, the correlation between tissue levels and infectious disease was not strong, although infectious disease cases tended to have higher TBT levels in general. The immunosuppressive effect may be relatively long-term, as the half-life of the compound is estimated to be three years (Murata et al. 2008).

Since the use of organotin compounds as marine anti-biofouling agents was federally regulated in 1988, the levels seen are likely declining. Residues have historically been higher in enclosed marinas, such as Monterey Harbor and Morro Bay, and lower in open areas. There is some evidence that the compound may persist longer in larger harbors, which attract larger vessels and those from foreign fleets.

Other Contaminants

A significant amount of work has been done to look at contaminants and (to a lesser degree) their potential impact on sea otters (Kannan et al. 1998, Nakata et al. 1998, Bacon et al. 1999, Kannan et al. 2006b, Jessup et al. 2010, Reese et al. 2012). Organic compounds may be found concentrated in the water, such as methylmercury, or in sediments, such as PCBs. The mechanism for introduction into sea otter tissues is not completely understood but is most likely associated with bioaccumulation and slow depuration in benthic invertebrate prey (Rudebusch et al. 2020). Unfortunately, except for localized PCB concentrations associated with military base activity in the Aleutian Islands (Reese et al. 2012, Tinker et al. 2021a), there is little information available for linking environmental concentrations to those found in sea otters. There is also little or no information showing population-level consequences of contaminant exposure for sea otters. Therefore, it is unclear if contaminant levels previously identified in sea otters are biologically significant. Again, site selection for a translocated population will be important in the potential for exposure to anthropogenic contaminants.

Considering the degree to which a release site is polluted, compromised, or nutrient-enriched should be a part of the decision-making process. Still, its importance should not be overemphasized relative to other factors. As with many, if not most, estuarine habitats in coastal North America, Oregon's estuaries are likely to suffer negatively from anthropogenic impacts, including high levels of pollution (see Chapter 6). However, published evidence from a large California estuary, Elkhorn Slough, does not support the notion that polluted ecosystems and thriving sea otter populations are necessarily mutually exclusive. Despite having the most elevated levels of the organic contaminants DDT and DDE recorded within the southern sea otter range (Jessup et al. 2010)—pollutants that are known to have deleterious effects on sea otters (Kannan et al. 2006a)—Elkhorn Slough supports some of the highest sea otter densities in California (Tinker et al. 2021c). The Elkhorn Slough sea otter population has been found to have high survival and growth rates even in the presence of these high pollutant levels (Mayer et al. 2019). Perhaps more importantly, the net result of this thriving sea otter population has been the contribution of significant ecosystem services, such as positive effects on eelgrass and salt marsh habitats (Hughes et al. 2013, Hughes et al. 2019). It thus seems apparent that one should not consider the sea otter to be a benign occupant of an ecosystem and a passive recipient of negative effects from pollution. Rather, one should consider the sea otter to be a functioning component of a resilient ecosystem that can help mitigate problems like pollution through positive effects on habitats such as eelgrass (M. T. Tinker, pers comm).

Oil Spills

A discussion of anthropogenic contaminants would be incomplete without including oil spills. While the incidence of direct oil-associated impacts on sea otters is uncommon, the experiences surrounding the 1989 Exxon Valdez Oil Spill (EVOS) graphically illustrate the potential devastation that oil can have on sea otter populations.

The short-term, acute effects of oil exposure are dramatic and well known. Affected otters suffer from a life-threatening loss of thermoregulatory capacity due to the fouling of the fur with oil. Thermoregulatory loss causes a cascade of metabolic events associated with not only the toxicity of the petroleum compounds but also the animal's inability to meet caloric and fluid needs, either through the active loss of heat or inability to hunt. Acute toxic effects observed during the EVOS included pulmonary and mediastinal emphysema, gastric erosion and hemorrhage, hepatic necrosis, and hepatic and renal tubular lipidosis (Lipscomb et al. 1993).

Long-term effects of oil contamination can also be significant. They include the animals' exposure to sublethal amounts of oil, effects of oil on prey populations, and exposure to petroleum compounds bioaccumulated in prey species (Bodkin et al. 2011). In EVOS-affected areas of Prince William Sound, Alaska, lingering oil in intertidal sediments provided both direct and indirect exposure to foraging sea otters (Monson et al. 2000). At the population level, sea otter survival rates decreased in EVOS-impacted areas, and population growth slowed significantly due to both continued mortality and movements of new animals into the affected areas (Monson et al. 2011).

The potential for oil-related morbidity and mortality in a reintroduced sea otter population in Oregon cannot be ignored. It seems that exposure would most likely affect low numbers of otters at a time because of small spills from recreational or commercial vessels and runoff from adjacent lands. Catastrophic oil spills may also occur along the Oregon coast. While they historically have not reached the level of the EVOS, spills such as the New Carissa spill of as much as 70,000 gallons in Coos Bay in February and March 1999 [1] may be devastating to a newly introduced population, were a spill to happen at the wrong time and place.

Fortunately, most of Oregon's power comes from hydroelectric plants, renewable sources, and natural gas. The last oil refinery stopped in 2008. A small portion of the state's energy is fueled by oil refined primarily by Puget Sound refineries. It is then transported to Oregon via the Olympic Pipeline or by barge. The oil shipped from Puget Sound is refined and not the problematic "Bunker C" oil that causes the worst contamination of wildlife and habitats; nonetheless, opportunities for oil spills in Oregon do exist.

The Oregon Department of Environmental Quality's Emergency Response Program is responsible for working together with the industry and other agencies to prevent and respond to oil spills. While facilities and training for oil spill response in Oregon likely exist, there is probably not much consideration of sea otters and oil spill response. As a reintroduction program becomes more likely, a proactive, sea-otter-based response plan and training program should be considered. Fortunately, California, Alaska, and Washington are good resources for such a program.

TRAUMA-CAUSED DISEASE

Shark Bite

Shark bite trauma is the most common primary COD described for the southern sea otter from 1998 to 2012 (Miller et al. 2020), with dramatic increases recorded since 2003 (Tinker et al. 2016). A recent analysis indicated that shark-bite mortality has a greater impact on overall population recovery in California than any other COD (Tinker et al. 2021b). The reported incidence in Washington State otters is not nearly as common, with only two of 93 reported between 2002–2015 (White et al. 2018). Predation, although not specifically attributable to sharks, is also thought to be an important limiting factor on sea otter populations in Southwest Alaska (Estes et al. 1998).

Shark-related mortality of southern sea otters has been attributed to bites from the white shark (*Carcharodon carcharias*) based on recovered tooth fragments and parallel scratches on sea otter bones (Tinker et al. 2016). Unlike other marine mammal bites, sea otter attacks are nonconsumptive, probably exploratory bites. The nature of the resulting wound occurs later because of blood loss, tissue trauma, or the loss of thermal integrity and subsequent metabolic collapse.

The nature of shark-bite-related mortalities involving northern sea otters has not been provided; however, the pathogenesis of the ultimate death was likely similar to that observed in southern sea otters (White et al. 2018). There is an increasing body of anecdotal evidence to suggest that shark-related sea otter mortality may be important in coastal Oregon. Reports involving beach-cast sea otter carcasses for the first 11 months of 2021 (USFWS [U.S. Fish and Wildlife Service], unpublished data; T. Waterstrat, pers comm.) suggest that seven of eight had evidence of shark bites, although the timing of the shark bites, ante- or postmortem, could not be reliably determined.

The potential threat posed by shark predation to a reintroduced sea otter population in Oregon is unclear. It is likely to depend on several factors, including prey availability, kelp canopy cover, numbers and species of predatory sharks, and water temperatures (Tinker et al. 2016, Nicholson et al. 2018, Moxley et al. 2019). Tagging data (T. Chapple, unpublished data) and anecdotal evidence indicate a presence of white sharks in Oregon. However, recent personal communication with shark biologists from California State University, Long Beach (C. Lowe) and Oregon State University (T. Chapple) has suggested that there is not currently a good sense of the abundance or distribution of white sharks off the Oregon coast. Recent evidence does suggest that white shark distribution in California may be moving northward (Tanaka et al. 2021) with warming conditions. While these size classes do not feed on marine mammals, it is possible that the larger size class of white sharks, which does feed on marine mammals, may be experiencing a similar northward distribution shift. This trend would mirror a hypothesized northward shift in white shark distribution along the U.S. East Coast (Bastien et al. 2020).

1 Read more about the New Carissa spill here: https://www.cerc.usgs.gov/orda_docs/CaseDetails?ID=992.

A second shark species with the potential for sea otter predation is the broadnose sevengill shark (*Notorynchus cepedianus*). Broadnose sevengill sharks are circumglobally distributed, ectothermic predators. On the west coast of North America, they range from Baja Mexico to Southeast Alaska, typically occupying shelf waters (< 200 m), including bays and estuaries. Except for the white sharks, broadnose sevengills are thought to be the dominant shark predator in coastal marine ecosystems where they reside, foraging individually or cooperatively and transitioning from a fish-based feeding structure to a diet focused on other elasmobranchs and marine mammals as they grow (Ebert 2002). While not considered a significant threat to sea otters in California, their potential impact in Oregon is less certain given their high trophic level and abundance in estuarine and coastal systems. A well-described and documented migration pattern of this shark species exists between the continental shelf and the shallow nearshore and estuarine habitats (Williams et al. 2012).

Sevengill sharks feed on a broad spectrum of animals, including other sharks, batoids, teleost fishes, and marine mammals (Ebert 1991, Lucifora et al. 2005). The sevengill shark employs multiple hunting strategies, including stealth, similar to the white shark. It also uses social facilitation, in which a pack of sharks surrounds its victim to prevent escape before subduing it—a strategy employed at depth (Ebert 1991).

Unfortunately, the risk posed by shark attacks on sea otters in a reintroduction program is unknown and unlikely to be known before embarking on such a program. Similarly, it is purely speculative to predict the broadnose sevengill's potential impact on the population. Their known presence in both nearshore and estuaries is of some concern. While the white shark population of Oregon is uncertain, the effects of ocean warming due to climate change on white shark distribution may place Oregon-resident sea otters in harm's way. An example of the northward shift of white shark populations is exemplified by the recent documentation of a nursery area in Monterey Bay (Tanaka et al. 2021).

Anthropogenic Trauma

There are several direct human-caused health risks warranting discussion during an evaluation of a potential reintroduction of sea otters to the Oregon coast. While coastal Oregon has not been closely evaluated to date, a recent evaluation of anthropogenic risks for sea otters in San Francisco Bay was published and may serve as a road map for an Oregon introduction (Rudebusch et al. 2020). In this study, anthropogenic risks were subdivided into four groups: vessel traffic, contaminants, commercial fishing, and major oil spills. These categories cover the majority of direct human-caused primary and contributing CODs reported for northern and southern sea otters (White et al. 2018, Miller et al. 2020), the exceptions being blunt trauma to the skull and gunshot.

These two forms of direct anthropogenic trauma—gunshot and blunt trauma to the skull—are most assuredly malicious in nature (trauma from boat strikes is discussed in the next section; White et al. 2018, Miller et al. 2020). These incidents seem to be uncommon. Published reports do not identify locations, either specifically or generically, nor do they postulate the "justification" for the use of deadly force. Rather than speculating without an adequate basis, it suffices to say that public reaction to a sea otter reintroduction program is unlikely to be universally embraced. It is incumbent upon project managers to recognize the potential for this type of trauma and take necessary steps to mitigate its occurrence, if possible. Public outreach and education may be the most effective mitigation strategies.

Vessel Traffic

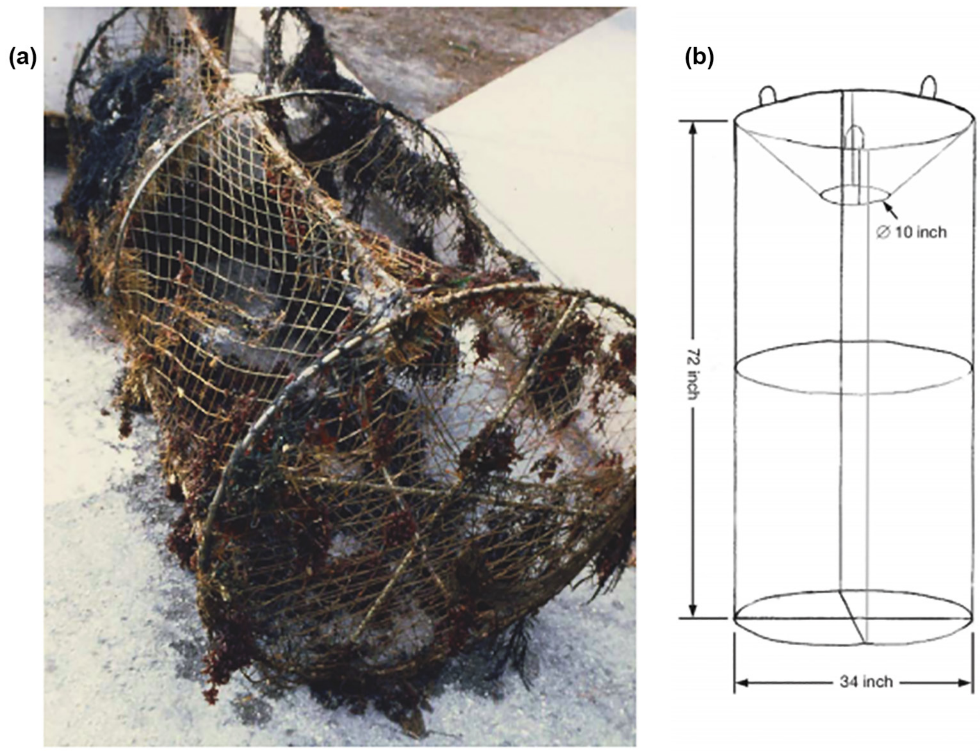
The incidence of boat-strike-related mortality was low in both the California and Washington State studies: 25 out of 560 and one out of 93, respectively (White et al. 2018, Miller et al. 2020). The negative effects of vessel traffic are not limited to boat strikes. Any disturbance of resting or grooming otters, normal social structure, and foraging efforts may have significant impacts both directly and indirectly through stress (the immunosuppression caused by chronic adrenocortical hormone release), as well as the energetic expense of responding to the disturbance (Barrett 2019). A consideration of anthropogenic disturbance should include not only commercial boating and fisheries traffic but also recreational fishing, watersports such as kayaking, and boat-based nature-watching tours. The risk associated with vessel traffic will likely be site-specific and, as human numbers continue to grow, can be expected to increase.

Trauma Involving Fishing Gear

Trauma in sea otters associated with commercial and recreational fisheries is most frequently attributable to net entanglement, fishhook injuries or consumption, or entrapment in fish or invertebrate traps (Figure 10.3). Since fishing regulations in California were changed to move gillnet fisheries into deeper water, the incidence of net entanglement has decreased significantly (Wendell et al. 1986). However, it still occurs occasionally, either due to illicit fishing practices or entanglements in lost, abandoned, or damaged nets. By mandating gillnets be set at depths deeper than sea otter dives (40 m), the hazard seems avoidable.

Rigid traps, especially those used for Dungeness crabs, have been recognized as a potential entrapment threat, especially for younger sea otters that may be capable of entering the trap. Following extensive testing using rehabilitated otters at the Monterey Bay Aquarium, a solution to the mortality in fish and shellfish traps was identified. By reducing the fyke size from a 10 in. (25.4 cm) circle to a 3 in. by 9 in. (7.6 cm by 22.9 cm) rectangle, most independent sea otters were excluded from the traps, and yet, crab capture rates were not significantly impacted (Hatfield et al. 2011).

Figure 10.3. A derelict fish trap that drifted into Monterey Harbor in 1987.



Note. (a) A photograph of the derelict fish trap containing two drowned sea otters (one adult female and one large male pup). (b) A line drawing of the same trap. Note the 10 in.-diameter (25.4 cm) fyke opening. The figure is from Hatfield et al. (2011).

ANIMAL WELFARE

Animal welfare and its application to free-ranging wildlife is a challenging subject. Welfare assessments tend to focus on individual animals, while conservation goals tend to focus on populations. These two underlying goals are not always consistent (Estes and Tinker 2017). While aspects of animal welfare have gained increasing degrees of scientific grounding, they remain predominantly subjective, and by the nature of welfare, they are not static. In fact, they change frequently.

Original concepts of animal welfare were based on the FAWC's Five Freedoms (FAWC 2009). The AZA subsequently modified these freedoms, renaming them the Five Opportunities for its animal welfare and accreditation standards (AZA 2020). The modification was made to better align the concept of animal welfare with wildlife, particularly wildlife under human care.

Within the context of this chapter, a paraphrased version of the Five Opportunities provide the structure upon which welfare considerations are outlined. By their nature, they are subjective, and attempts have been made to apply them to a reintroduced population whenever possible. At times, however, it is necessary to consider the individual animal within the context of the opportunities:

» Nutritionally complete diets
» Comfortable living experiences
» Good physical health
» Adequate social groupings
» Freedom from chronic stress

Animal welfare is a hot-button topic in the public's eyes, especially as it applies to marine mammals. Including animal welfare in this feasibility study may be of benefit if and when a reintroduction project in Oregon is formally proposed. Considering not only the scientific and model-based aspects of a reintroduction but also the humane and welfare issues could help the Elakha Alliance gain public support with any future project it pursues.

Nutritionally Complete Diets

Several aspects of nutrition and diet need to be included in release site selection to help protect sea otters' welfare. Prey availability is important, to be sure, but so too is the spectrum of species and the otters' recognition of them as food. The availability of a variety of prey may provide some degree of insulation from naturally occurring recruitment cycles. Prey also needs to be present in sufficient quantities at depths attainable by reintroduced otters.

The wholesomeness (or health risks) of food items also warrants consideration. Areas with large aggregations of *Emerita* and *Blepharipoda,* the intermediate hosts of the cause of AP, may be problematic. Similarly, food-based risk factors associated with toxoplasmosis and those known to bioaccumulate DA effectively are noteworthy.

Comfortable Living Experiences

A great deal of effort has been made in identifying appropriate habitat suitable for the release of sea otters, particularly animals that will be unfamiliar with the release site(s). It is important to factor into the decision-making process the ability of animals to rest comfortably without undue disturbance from boat traffic and other noxious stimuli. In addition, while the potential for shark attack is unknown, risk factors that have been identified in California warrant consideration in the release site evaluation process (Moxley et al. 2019).

Moreover, the release site is not the only living experience that is a factor. As plans for pre-release holding and conditioning are developed, animal welfare will be an important consideration. The federal Animal Welfare Act and Animal Welfare Regulations (APHIS [Animal and Plant Health Inspection Service] 2020) have established minimum standards for marine mammal enclosures for exhibition and research animals based on animal size (sec. 3.104(f)), but their applicability to animals in a reintroduction program is doubtful. Regardless, there must be some consideration for the size of animal enclosures. Tanks used for surrogate-reared, pre-release juveniles at the Monterey Bay Aquarium are approximately 20 ft (6.10 m) in diameter and 3 ft (0.91 m) deep. Animal comfort appears to decrease significantly with group sizes exceeding six animals. Population density within holding facilities will be an important consideration.

Good Physical Health

Much of the discussion about health-related welfare considerations is found in the first section of this chapter. Still, several additional considerations are not disease-specific. First, there should be a protocol developed to describe the frequency (i.e., pre-transport, pre-release, and post-release) with which individual animal health assessments are made. It is readily apparent that starting with healthy animals before reintroducing them to a new site is essential.

After otters have been released, program managers must be prepared to answer this question: What is the response to animals in distress? There will undoubtedly be a public expectation that attempts will be made to capture and rehabilitate sick or injured sea otters associated with the reintroduction program. Some preexisting coastal marine mammal rehabilitation centers may be able to provide some support for developing and implementing a stranding response program. However, facilities, protocols, and even regulatory agencies will be different for sea otters.

One of the confounding knowledge gaps in reviews of the previous Oregon reintroduction program has been the lack of information about why it failed. To better understand the outcome of any future program, plans for post-release monitoring and carcass recovery and analysis should be made. The development and implementation of these post-release efforts warrant further discussion and investigation.

Adequate Social Groupings

Sea otters tend to be social animals, aggregating in cohorts of varying sizes up to hundreds of otters. These rafts are typically segregated by sex, and females tend to demonstrate the greatest site fidelity, with individuals spending nearly their entire lives in a relatively small area. Males tend to more loosely aggregate with the formation of bachelor rafts, and some become solitary, dominant territorial males. Males have been known to travel long distances and typically occupy otter-less areas well before females and pups arrive. Successfully reintroducing sea otters into sea-otter-free habitats may be difficult because the area has no existing otters with which the newly released individuals can socialize and bond. The critical mass for reintroduction is unknown, but data from the previous sea otter translocations may be informative. The number of otters available for the project will depend upon the source populations (see Chapter 3 and Chapter 9).

Success will be further complicated by the potential need to hold otters at the release site for a time to allow acclimation and recovery of the pelage after transportation. Maintaining natural social groupings is confounded by the males' tendencies toward aggression if held in the same tank or net pen. Necessarily, only one male is held per tank/pen. Holding times will be directly proportional to the distance traveled.

The Monterey Bay Aquarium has occasionally released pairs of juvenile animals that spent enough time together to develop a bond while under human care. Despite this pre-release relationship, the otters commonly split up immediately upon release. On occasion, they might have re-encountered one another, but no evidence suggests that the bond was retained. In some cases, there was a loose re-association at common rafting or feeding areas, or they might have remained separated but within the same general location (M. Staedler, K. Mayer, S. Hazan, pers comm). It is important, however, to recognize that these observations were made in release sites already occupied by sea otters, possibly serving as anchors for recently released individuals.

While not causally related to social groupings, some consideration should be made to animal age and experience. First, younger animals are less likely to have strong site fidelity and the desire to swim back to their original territory. Second, young animals may not be as athletic or physically conditioned to swim back, and rehabilitated sea otters may not be as athletic or physically conditioned as wild otters of similar age. In addition, rehabilitated otters have not experienced the realities of the open sea or estuary. Their lives have been confined to tanks of varying sizes and depths. A future reintroduction program can help ensure the welfare of the subject otters by considering their varying needs based on age and proficiency in living in the wild.

The animal welfare aspects of social groupings may be the most problematic of the five opportunities. The questions are relatively straightforward, the answers less so. The options available are limited and involve a series of trade-offs.

Freedom From Chronic Stress

This animal welfare consideration is a bit oxymoronic in this study's context. There is no way to avoid stress during a reintroduction, and some of it may be prolonged. Every aspect of any project will be associated with some degree of stress for the otters. A more realistic goal is to minimize stress whenever possible during the process. Minimizing both direct and indirect human contact, managing isolation, and segregating sexes are examples of actions that can reduce stress. Other stressors are likely to be mitigated by paying attention to the other four welfare opportunities. A reintroduction program should be designed to maximize opportunities for success. Minimizing sea otter stress and discomfort will be a natural outcome of the plans to succeed.

SUMMARY

A chapter on the animal welfare concerns associated with reintroducing sea otters to the Oregon coast would be incomplete without some discussion of the potential for failure. While population-level metrics determine the success or failure of the project, both outcomes are based on the sum of individual otters, which is where animal welfare is relevant. The concept of failure will need to be evaluated and defined on different levels, which may impact decisions to continue reintroductions, reevaluate release sites, and modify methods for animal capture, transportation, and release.

The preceding sections have attempted to identify, summarize, and extrapolate information regarding sea otter health and welfare from known circumstances to an anticipated reintroduction site. It is impossible to predict all the potential health threats that may exist in the future or that occur cryptically along a coastline free from sea otters for several centuries. That said, a good faith effort has been made to identify those of greatest concern, either known or suspected. A summary table (Table 10.1) ranks the population-level risks and likelihoods of the diseases described within this chapter.

Based on a review of all the risk factors in Table 10.1, it appears the most substantial threat to sea otters living along the Oregon coast is likely to be DA intoxication. Its presence in shellfish has been recognized as a potential human health threat for well over a decade—a concern mostly directed toward the acute intoxication of shellfish consumers. Monitoring activities and associated toxicity thresholds have been designed to protect the public; therefore, it is likely that chronic, low levels, which have been shown to be a driver of cardiac disease in sea otters, may go undetected (Moriarty et al. 2021).

A second disease of deep concern, though uncertain potential, is shark bite trauma. Shark bites are a significant cause of mortality for southern sea otters, and the white shark has been accepted as the primary source of injury. White sharks have been found off the Oregon coast; however, their population numbers and locations are unknown. A second potential sea otter predator, the broadnose sevengill shark, is present in high numbers in coastal, offshore, and estuarine systems. A known marine mammal predator, its proclivity to interact with sea otters is unclear.

While it is unlikely that infectious diseases will have population-level impacts on the reintroduction program, they may have significant impacts in specific areas and may increase over time as sea otter numbers increase in the case of density-dependent diseases (Tinker et al. 2021b). Contagious diseases, such as one of the morbillivirus infections, have been associated with epizootics in a spectrum of marine and terrestrial mammals. They tend to be density-dependent due to the mode of transmission; a population spread out over a relatively lengthy stretch of coastline may be advantageous, especially for a disease like canine distemper. The same consideration may not apply to other morbilliviruses, such as phocine or cetacean morbillivirus, which may be carried by animals with large home ranges or a few animals making longer-distance movements (Jameson 1989, Ralls et al. 1996).

Noncontagious infectious diseases, such as sarcocystosis and toxoplasmosis, are not density-dependent in terms of their transmission processes, but in some cases, their impacts on population health can be greater at higher population densities because individual animals are in poorer health and/or selecting suboptimal prey species (Johnson et al. 2009, Burgess et al. 2018, Tinker et al. 2021b). Such diseases may also significantly impact small populations in localized areas, especially those associated with freshwater runoff. A significant first-flush runoff may flush a large pathogen load into the nearshore system, and bioaccumulation by sea otter prey may result. This scenario would be unlikely to have a significant impact on an established population but may be devastating to a recently introduced one.

Table 10.1. Summary of health threats for sea otters in the case of a reintroduction to Oregon, by a subjective ranking of potential population impact.

Health concern	Category	Contagious	Population impact	Likelihood	Source	Site specificity
Domoic acid (DA)	Noninfectious, toxic	No	High	High	Prey, HAB	Possible
Shark bite	Trauma	No	Medium-high (med-high)	Med-high	White shark, sevengill shark	No
Morbillivirus, phocine	Infectious, viral	Yes	Med-high	Medium (med)	Phocid seals	No
Morbillivirus, canine distemper	Infectious, viral	Yes	Med-high	Med	Terrestrial carnivores	No
Sarcocystis	Infectious, parasitic	No	Med-high	High	Land–sea, runoff, prey	Freshwater runoff
Toxoplasma	Infectious, parasitic	No	Med-high	High	Land–sea, runoff, prey	Freshwater runoff
Oil spill	Noninfectious, toxic	No	Med-high	Medium-low (med-low)	Vessels, land-based runoff	Site-specific increase
Streptococcus phocae	Infectious, bacterial	Possible	Med	Med-high	Bite wounds, prey	No
Acanthocephalan peritonitis (AP)	Infectious, parasitic	No	Med	Med	Prey, sandy substrate	Sandy seafloor
Microcystin	Noninfectious, toxic	No	Med	Med	Freshwater runoff	Freshwater runoff
Saxitoxin (STX)	Noninfectious, toxic	No	Low	Med-high	Prey, HAB	Widespread
Tributyltin (TBT)	Noninfectious, toxic	No	Low	Low	Prey, sediment association	Marinas, large harbors
Influenza	Infectious, viral	Yes	Low	Low	Pinnipeds	No
Leptospirosis	Infectious, bacterial	Yes	Low	Med-low	Pinnipeds	Possible pinniped haul outs, rookery
Bordetella bronchiseptica	Infectious, bacterial	Yes	Low	Low	Open	No
Coccidioidomycosis	Infectious, fungal	No	Low	Low	Environment	Possible
Fishing gear	Anthropogenic	No	Low	Low	Nets, crab pots	Possible
Larva migrans	Infectious, parasitic	No	Low	Low	Land–sea, runoff, prey	Freshwater runoff
Vessel traffic	Anthropogenic, trauma	No	Low	Low	Commercial, recreational	Heavily traveled, populated areas
Contaminants	Anthropogenic	No	Low	Low	Sediments, water column	Yes
Streptococcus bovis/equinus	Infectious, bacterial	Possible	Uncertain	Med	Probable prey	No
Bacterial infections, not specified	Infectious, bacterial	Possible	Uncertain	High	Multiple	No

Note. This table includes a subjective ranking of each health concern's potential population impact and the relative likelihood of each threat occurring, as well as other attributes. The rows are listed in descending order from a high to low potential population impact, with uncertain likelihoods listed at the end.

The animal welfare issues associated with reintroduction are important for the effect they may have on the population, albeit one otter at a time, and for their role in maintaining public confidence and support. Their importance will be most notable during the otters' time under human care, including the capture (if that is needed as an animal source), transportation, acclimation, and release of sea otters in Oregon. During these activities, it would be best to consider the animals individually. Each of the five opportunities concerning animal welfare—nutritionally complete diets, comfortable living experiences, good physical health, adequate social groupings, and freedom from chronic stress—will need to be addressed. Many of the considerations and recommendations are not well defined, as they depend on animal numbers, sources, and release plans. Once these parameters have been set, it will be important to address them.

An additional health and welfare consideration that does not fit well into the previously described categories is humans' post-release activities. Tracking after release may provide important insight into the otters' acclimation and adjustments. It will also be important to identify otters in distress, retrieve carcasses, and perhaps follow those who emigrate from the release site. Tracking questions are naturally associated with the consideration of tagging technologies and the myriad associated decisions (refer to Chapter 9).

Although not necessarily a population-level health consideration, plans for managing live otters in distress (i.e., sick or injured) must be made. Will they go to a rehabilitation center? If so, which one? A plan for retrieving beach-cast otter carcasses is important. A component of the carcass program will be the postmortem examination of dead animals. The development of a standardized necropsy protocol is recommended. Again, the questions of who, where, and what need to be answered before a reintroduction begins.

No glaring concerns suggest that reintroducing sea otters to the Oregon coast would likely face insurmountable health and welfare issues. There are known diseases and conditions that may be somewhat problematic, but such is the case for every extant sea otter population. Also, several unknowns should be recognized. The effects of climate change through direct impacts on weather patterns, oceanographic parameters, and sea level rise will affect otters' welfare at some point in time. Indirect effects, such as changes in prey species, pathogen distribution, and animal movements, also exist. Lastly, if the COVID-19 pandemic of the early 2020s has taught us anything, it may be that there are things out there that can have devastating effects on animal (and human animal) populations—things not yet known that are difficult to predict. While there are no fail-proof insurance policies for such unknowns, the most prudent strategy for reducing the potential for failure is likely to consist of frequent, close monitoring of individuals in a newly established population, with the flexibility to respond quickly should unanticipated risks emerge.

FINAL CONCLUSIONS

The discussion above is not intended to be an all-inclusive list of the potential diseases, infectious and noninfectious, that may impact sea otters or of animal welfare considerations. It is an attempt to present information on those shown to have the potential for population-level effects on a reintroduced sea otter population. Much of the information provided was interpreted via data extrapolation concerning California's southern sea otter and the Washington northern sea otter populations. Alaskan otters also warrant consideration; however, that region's mortality investigations are problematic due to the nature of the Alaskan coast; subsequent access to otters, especially distressed or dead otters; and the incidence of scavenging upon dead and moribund beach-cast otters.

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