Appendix A – Answers to Frequently Asked Questions (FAQs)

1. Historically, what did the population of sea otters look like on the Oregon and northern California coast? Can we make any inferences about it based on historical harvest records?

Sea otters were once present along the Oregon and northern California coastline, as evidenced by their remains in the middens of indigenous peoples throughout these areas (Lyman, 2011; Curran et al., 2019). However, abundances prior to the maritime fur trade are difficult to determine. Fur trade records indicate that fewer sea otters were taken by hunters along the Oregon and northern California coasts than from Washington and other areas of California, but Ogden (1941) notes that the local indigenous people's resistance to trade and the lack of good harbors may have been contributing factors to having fewer records in those areas. Habitat modeling indicates that at carrying capacity the Oregon coast could support an estimated 4,538 (1,742−8,976; 95% CI) sea otters (Kone et al., 2021), whereas the northern California coast (excluding San Francisco Bay) and San Francisco Bay could support an estimated 3,513 (1,297–7,767; 95% CrI) and 4,036 (716–11,328; 95% CrI) sea otters, respectively (Tinker et al., 2021).

Even if reintroduction occurred and succeeded in establishing one or more small populations, there is no guarantee that the population(s) would ever grow to these maximum numbers or recolonize all available habitat. Instead, the increase in sea otter number and range would likely occur gradually over the course of many decades, similarly to the sea otter's population trajectory in California, which required more than a century to grow from a remnant population of a few dozen animals in 1915 (Bryant 1915) to about 3,000 in 2019 and still remains largely restricted to central California (Hatfield et al. 2019).

2. Why did the first attempt at reintroduction in Oregon fail?

The Oregon reintroduction was attempted in 1970 and 1971 through the translocation of 93 sea otters from Amchitka Island, Alaska, to Cape Arago and Port Orford in southern Oregon. The failure of the population to persist does not appear to be a simple matter of the number of sea otters, as fewer sea otters were released in Washington (59 total), and the Washington population eventually became established whereas the Oregon population did not. Some of the sea otters released remained in southern Oregon for 10 years following reintroduction (with a high count of 23 individuals observed in any one year) and successfully produced at least 17 pups over the years subsequent to the releases (Jameson et al., 1982). However, by 1981 only a single sea otter was observed and was the last animal documented from this release (Jameson et al., 1982). For an in-depth evaluation of the failed attempt to reintroduce sea otters to

Oregon in 1970–71, see (Jameson, 1974). In short, there is no clearcut explanation for why the Oregon reintroduction failed while others succeeded, and it may have just been a matter of chance.

The majority of sea otters released at the Oregon sites disappeared relatively quickly, and there were no documented large mortality events (Jameson, 1974), although Riedman & Estes (1990) suggest that possible unobserved post-release mortality may nonetheless have been high. Homing behavior and emigration of sea otters away from the release sites resulting in an unsustainably small population is believed to have been the most likely cause for failure of the Oregon reintroduction (Jameson, 1974; Jameson et al., 1982; Riedman & Estes, 1990). It is notable that sea otters appear to have abandoned the Oregon release sites despite the apparent availability of sufficient prey and high-quality habitat, a phenomenon similarly observed in the subsequent reintroductions to San Nicolas Island in California. Also notable is that there appears to be a tipping point of founding population size in the establishment phase, at which populations of fewer than 20 animals or so appear to have a roughly equal chance of either declining to extinction (as in Oregon) or managing to persist at a low level for a long period of time before gradually commencing a phase of population growth and becoming established (as in Washington and at San Nicolas Island). Chance factors such as the age and sex of the few individuals remaining in the founding population may have determined whether these reintroductions succeeded or failed. For example, if by chance the remaining population is dominated by males, the probability of population establishment is reduced.

3. If the habitat in Oregon and northern California is good for sea otters, why haven't they recolonized naturally?

After the maritime fur trade, the nearest sea otters to the remnant population that survived off central California were in Prince William Sound, Alaska, about 2,000 miles (mi) (more than 3,000 kilometers (km)) away as sea otters would swim along the coastline. Reintroduction efforts in the 1960s and 1970s resulted in the re-establishment of sea otter populations along parts of this coastline, with the nearest restored population in Washington (also see FAQ #2 on the unsuccessful Oregon translocation). Although these efforts lessened the distance between extant populations of southern sea otters in California (a distinct subspecies, *Enhydra lutris nereis*) and northern sea otters (*Enhydra lutris kenyoni*), the gap remains large, about 930 mi (1500 km), and is the largest gap in the global sea otter historical range (Davis et al., 2019).

Sea otters do not migrate seasonally, and long-distance movements are relatively rare. Adult female sea otters, who are the most important for population growth, are the least likely to make long-distance movements. Their home range size is very small, on the order of tens of linear mi/km of coastline. Because of these biological constraints, range expansion generally occurs slowly outward from a core population. If that population is located on a linear (as opposed to convoluted or complex) coastline, population growth will be even slower. This is because areas with relatively simple, linear configurations of shallow habitat suitable for sea otters—such as the narrow strip of coastline in California, which is bounded by the offshore continental shelf—restrict range expansion to just north or south. Most of the population quickly becomes resource limited (reaches local carrying capacity), and growth is constrained to only the small portion of the population near the range ends (also see FAQ #10).

The population of northern sea otters in Washington State, founded with the translocation of 59 sea otters from Alaska in 1969–1970 (Jameson et al., 1982), has become well established, with a minimum count of 2,785 animals in 2019 and a positive annual growth rate of 9.81% between 1989 and 2019 (Jeffries et al., 2019). Most of these sea otters are located between Cape Flattery (Clallam County) in the north and Point Grenville (Grays Harbor County) in the south. Occasional single sea otters, presumed to be from the Washington population, are observed or strand in Oregon from time to time (Rice 2024), indicating that individuals are capable of moving over this distance but only rarely do so. Despite the passage of more than half a century since the Washington translocations occurred, the established range remains limited to the northern half of the Washington coastline.

The population of southern sea otters in California, which originated from about 50 animals who survived the fur trade, ranges from Pigeon Point (San Mateo County) in the north to approximately Gaviota State Beach (Santa Barbara County) in the south (Hatfield et al., 2019). Natural range expansion was occurring, albeit slowly, in California until about 20 years ago. There has been no net range expansion since. The primary reason for the lack of range expansion is mortality caused by white shark bites. The probability of shark-related mortality in sea otters has tripled range-wide in recent decades and increased eightfold in the southern portion of the mainland range (Tinker et al., 2015; Nicholson et al., 2018). White sharks do not appear to target sea otters as prey, and all available evidence suggests they do not consume the sea otters they bite (Tinker et al., 2015; Moxley et al., 2019). However, the resulting injuries due to mistaken attacks or investigatory bites are usually fatal to a sea otter.

The reasons for the increase in shark-related mortality of sea otters are unknown and remain the subject of investigation. Potential explanations include an increase in white shark numbers as a result of increases in their preferred marine mammal prey, including elephant seals (*Mirounga angustirostris*) and California sea lions (*Zalophus californianus*); increased encounters between immature white sharks and sea otters as a result of a ban on fishing for white sharks in 1990 and gill-net restrictions put in place in southern California in 1994, which resulted in an increased number of young white sharks; and changes in the encounter rate between immature white sharks and sea otters due to episodes of ocean warming, which allow immature white sharks to venture further north for greater portions of the year (Tinker et al., 2015; Moxley et al., 2019).

4. Where would sea otters be reintroduced?

No decisions have been made about sea otter reintroduction, and the locations where sea otters might be reintroduced have not yet been determined. Once sites have been identified that are biologically and logistically suited for reintroduction, these sites will be fully evaluated for possible socioeconomic effects as well. If reintroduction is formally proposed, the proposal will receive full analysis and there will be opportunities for public comment under the National Environmental Policy Act (NEPA).

5. What is the current state of kelp along the Oregon and northern California coast?

Beginning in 2014, an epidemic of sea star wasting disease associated with anomalously warm waters affected more than 20 sea star species along the coast of North America and was especially lethal to the sunflower star (*Pycnopodia helianthoides*), whose abundance declined by 80–100% (Harvell et al., 2019). Because sunflower stars are an important predator of purple sea urchins[1] (*Strongylocentrotus purpuratus*), the resulting release of sea urchins from sea star predation, in combination with thermal and nutrient stress associated with the North Pacific marine heat wave that occurred from 2014–2016, has led to substantial losses of kelp—both bull kelp (*Nereocystis luetkeana*) and giant kelp (*Macrocystis pyrifera*)—along the coast of North America.

Different areas along the coast have experienced different outcomes. The presence of other important sea urchin predators (predator redundancy) appears to have been partly responsible for these differences. Kelp losses in Alaska, British Columbia and central California have been buffered by the presence of sea otters, also a key predator of sea urchins (Burt et al., 2018; Smith et al., 2021; Gorra et al., 2022), whereas those in southern California have been buffered by the presence of sheephead fish (*Semicossyphus pulcher*) and spiny lobsters (*Panulirus interruptus*) (Eisaguirre et al., 2020). However, northern California kelp forests, now lacking any effective predators of sea urchins, have declined by 95% (McPherson et al., 2021). Kelp forests have also deteriorated in southern and central Oregon, which similarly lack any effective sea urchin predators. A study is underway to document the extent of kelp losses in Oregon (https://coastalscience.noaa.gov/project/oregon-kelp-forest-survey/).

6. Sea otters won't eat empty, non-gravid purple sea urchins in urchin barrens, so how would they help restore the kelp ecosystem?

Only one study, to our knowledge, has assessed the gonad contents of sea urchins in patches where sea otters preferentially fed. (Smith et al., 2021) found that sea otters were more likely than not to consume sea urchins in a patch once the average gonad index (gonad weight/total body weight) was greater than 12%. This study took place in central California following the marine heatwave and the loss of sea stars, an important predator of the smaller size classes of sea urchins, beginning in 2014 (see also FAQ #5). Sea otters responded to the increase in sea urchin abundance by consuming three times as many sea urchins as they had before 2014. Their preference for energy-rich individuals (those with a higher gonad index) within or at the margins of patches of kelp led to a mosaic of kelp patches and urchin barrens (Smith et al.,

[1] Purple sea urchins normally subsist on drift kelp, but in the absence of predators will actively forage on growing kelp. An overabundance of purple sea urchins can result in the elimination of stands of kelp, resulting in a condition commonly referred to as an "urchin barren."

2021). By preferentially feeding on healthy sea urchins, sea otters defended and maintained these patches of kelp, allowing them to persist and produce spores to facilitate kelp recovery elsewhere.

Despite the lack of precise information on the gonad contents of sea urchins eaten by sea otters in other studies, research conducted throughout the sea otter's range has repeatedly demonstrated that sea otters greatly reduce sea urchin populations, including those in urchin barrens, with resulting large-scale increases in the abundance of macroalgae like kelp (e.g., McLean, 1962; Estes & Palmisano, 1974; Estes et al., 1978; Simenstad et al., 1978; Duggins, 1980; Breen et al., 1982; Laur et al., 1988; Duggins et al., 1989; Watson, 1993; Estes & Duggins, 1995; Estes et al., 2010a; Watson & Estes, 2011; Burt et al., 2018; Gorra et al., 2022). The change in macroalgal abundance can take the form of a distinct switch between an urchin barrens state and a heavily forested state, as has been observed in Alaska (e.g., Estes & Palmisano, 1974; Estes & Duggins, 1995; Estes et al., 2010b; Gorra et al., 2022), or it can be more gradual, as in central and southern California, because it is mediated by additional species (Foster & Schiel, 1988; Kenner & Tinker, 2018).

Watson & Estes (2011) documented the transition from an urchin barrens state to an algal-dominated state in British Columbia with the return of sea otters. Whereas the transition occurred rapidly at some sites, a temporary transitional state composed of algal/urchin mosaics occurred at other sites. They demonstrated experimentally that the mosaic formed when sea urchins fled from the damaged remains of sea urchins discarded by foraging sea otters. Kelp then began to grow in the urchin-free patches. Burt et al. (2018) similarly documented a large-scale expansion in the area and density of canopy kelp cover following the arrival of a large raft of sea otters at northwest Calvert Island, British Columbia, in 2013. Kelp canopy cover was 2.9 times higher the year after sea otters arrived, and the density of kelp beds also increased. However, sea star wasting disease demonstrated the importance of the complementary effects of predation by sea stars. With the loss of sea stars from the area in 2015, sites occupied by sea otters had higher and more variable urchin densities and lower and more variable kelp densities. Nevertheless, kelp densities remained higher in all sites where sea otters were present than where they were absent (Burt et al., 2018).

Positive effects of sea otters on kelp abundance are also evident at much larger spatial and temporal scales. In Alaska, the recovery of sea otters from the maritime fur trade was associated with large-scale increases in kelp over the last century (Hollarsmith et al., 2024). In central California, the presence of sea otters has led to dramatic increases in kelp over the last century, while kelp forests along the northern and southern California mainland, where sea otters remain extirpated, have dramatically declined (Nicholson et al., 2024).

7. Would sea otters prevent the recovery of abalone populations?

Abalone populations along the coast of northern California and Oregon have been devastated by the widespread loss of kelp and other macroalgae, which abalone depend on for food. If a sea otter population became established on the rocky outer coast, it would likely improve food availability for abalone populations by controlling sea urchins, thereby enhancing the abundance of kelp. Although sea otters also eat abalone, they cannot reach abalone that are in deep, narrow crevices. When sea otters are present in an area, nearly all abalone are found in these crevices, where they capture and eat drift kelp. Because sea urchins and abalone compete for space as well as food (Lowry & Pearse, 1973), sea otter predation on sea urchins can also help to ensure that abalone have adequate space. One study in California (Micheli et al., 2008) found that red abalone densities in the Hopkins Marine Life Reserve (a no-take reserve) remained stable in the presence of sea otters for more than three decades. Another study in California (Raimondi et al., 2015) found that densities of endangered black abalone were highest in the areas where sea otter densities were highest, though nearly all abalone were in inaccessible crevices. Although sea otters would be expected to promote the recovery of abalone populations through indirect positive effects on their kelp food source, they would not be expected to restore the abalone fishery.

8. How would reintroducing sea otters impact salmon fisheries?

Although sea otters have been observed eating salmon in Russia and Alaska on rare occasions, sea otters do not generally eat salmon or other fast-moving fish. Therefore, they would have no direct negative effects on salmon populations. Instead, sea otters would be expected to benefit salmon recovery and salmon fisheries through their beneficial effects on kelp and seagrass. Kelp forests are crucial habitat for juvenile salmon and many of the forage fishes they prey on (Shaffer et al., 2023). Eelgrass beds are similarly important, with one study finding that 93% of the diet of juvenile Chum salmon and 83% of the diet of juvenile Chinook salmon was made up of eelgrass-associated invertebrate species (Kennedy et al., 2018). The Pacific Fishery Management Council has identified submerged aquatic vegetation, including kelp and seagrasses, as Habitat Areas of Particular Concern for Pacific Coast salmon (https://www.pcouncil.org/documents/2019/08/salmon-efh-appendix-a.pdf/).

9. How would reintroducing sea otters affect the crab fishery?

Sea otters are a shallow-water species and cannot survive in areas where they are unable to dive to the bottom to retrieve food. Thus, they have limited overlap with the depth range used by Dungeness crabs. Sea otters typically forage in water depths from the intertidal zone to 131 ft (40 m), although deeper dives occur. Males tend to dive deeper on average than females, who care for pups and must remain in close proximity to them. In California, the highest densities of sea otters occur at depths of 10–66 ft (3–20 m), with peak abundance at 16 feet (5 m) (Tinker et al., 2021). In contrast, Dungeness crabs can occur in much deeper waters, with greatest abundance occurring in water depths from the intertidal zone to 300 ft (91 m), though they can occur as deep as 750 ft (229 m) (https://www.psmfc.org/crab/2014-2015%20files/DUNGENESS_CRAB_REPORT_2012.pdf). Although a substantial portion of the Dungeness crab population occurs in waters far deeper than sea otters can dive, sea otter foraging depths may overlap with the shallower depths in which some crab fishermen operate.

If sea otters were reintroduced, the areas where incipient groups of sea otters became established could see a localized decline in crab abundance. However, based on the results of past sea otter translocations, we would expect any reintroduced sea otter population to start small and grow slowly over the ensuing decades; thus, any potential impacts would likewise remain highly localized for a long period of time (see FAQ #10 and Figure 1, below).

Two independent teams of researchers found that sea otters have had no negative effects on the Dungeness crab fishery in California. Grimes et al. (2020) found that sea otters had localized negative effects on juvenile crab size in the unvegetated portions of estuaries but no effects on Dungeness crab landings. Boustany et al. (2021) found, based on 83,000 foraging dives, that Dungeness crabs constituted less than 2% of the southern sea otter diet and that there was in fact a positive (not negative) correlation between Dungeness crab fishing success and sea otter abundance, likely due to oceanographic factors. In Washington, there appears to be a negative correlation between areas where sea otters have become re-established and Dungeness crab landings, but statewide Dungeness crab landings have increased over time since sea otter reintroduction there (USFWS, 2022, pp. 73-75).

Because seagrass meadows are important habitat for juvenile Dungeness crabs (Armstrong et al., 2003; Sherman & DeBruyckere, 2018), it is likely that sea otters in estuarine habitat would provide indirect benefits to Dungeness crab populations through their beneficial effects on seagrass (Hughes et al., 2013).

10. Why would reintroduction here result in different outcomes from SE Alaska?

The Southeast Alaska sea otter population was anomalous, in that it grew rapidly from about 400 translocated animals in the 1960s to more than 22,000 sea otters in 2022 (Schuette et al., 2023). Other translocated populations have grown much more slowly, as has the remnant population along the central California coast, which originated from a few dozen animals who survived the maritime fur trade (Figure 1). Two primary factors explain this difference: sea otter home range size and habitat configuration (Tinker, 2015). Female sea otters, the main drivers of population growth, have small home ranges and high site fidelity wherever they occur. Habitats with highly convoluted coastlines and shallow waters that extend a great distance in every direction provide them with the option of successful dispersal and abundant resources in nearly any direction and hence high levels of population growth. Southeast Alaska has ideal habitat in this respect: the shoreline consists of inlets, bays, glacial fjords, and more than 2,000 islands, with abundant shallow waters. Additionally, it is vast, about 560 mi (900 km) long and 140 mi (230 km) wide, with about 15,550 linear mi (25,000 km) of shoreline, allowing it to support large numbers of sea otters (Tinker et al., 2019). In contrast, areas with relatively simple, linear configurations of shallow habitat—such as the narrow, linear strip of coastline in California, which is bounded by the offshore continental shelf—restrict range expansion to just north or south, such that most of the population quickly becomes resource limited and growth is constrained to only the small portion of the population near the range ends.

Any sea otter populations reintroduced to the northern California or Oregon outer coast (with relatively one-dimensional nearshore habitats similar to the central California coast) would be more likely to exhibit relatively slow population growth, on the order of that observed in California, as opposed to the more rapid rates of population growth and wide range expansion demonstrated by sea otters in the highly complex habitat of Southeast Alaska.

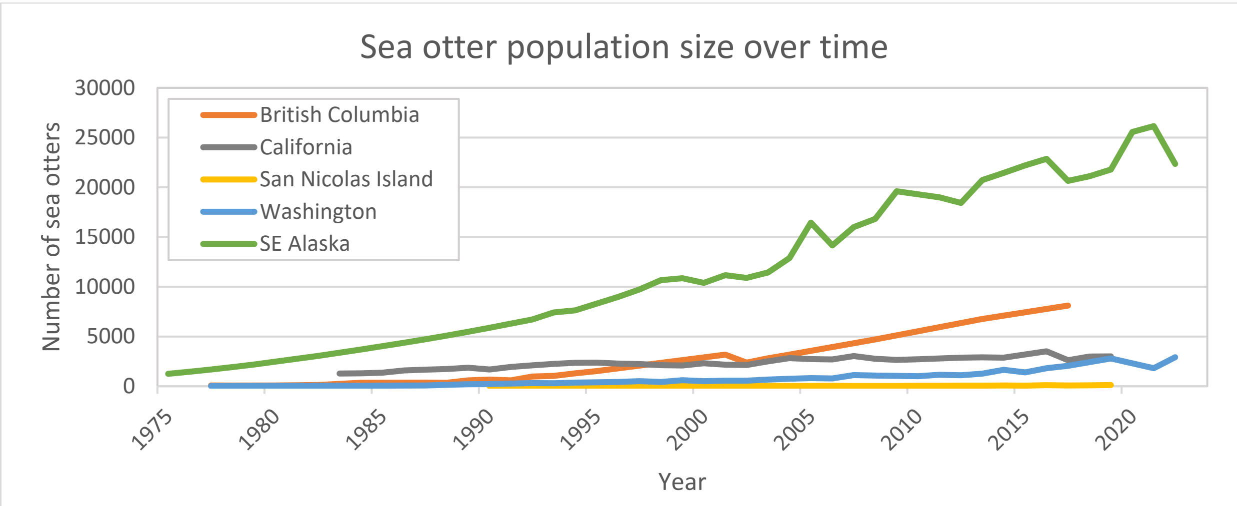

Figure 1. Sea otter population estimates over time (Hatfield et al., 2019; Nichol et al., 2020; Clark et al., 2022; Schuette et al., 2023).

11. How would you control numbers of sea otters once they were reintroduced?

Sea otters are subject to natural controls imposed by their environment. As predators, sea otters in established populations are most often limited by prey availability, but their population sizes may also be strongly limited by other predators. In the Aleutian Islands, predation by killer whales has greatly reduced sea otter abundance (Estes et al., 2009; Tinker et al., 2021). In some areas along the outer coast of California, white sharks exert strong controls on sea otter numbers (Tinker et al., 2015; Moxley et al., 2019), preventing natural range expansion.

Habitat characteristics strongly influence the availability of sea otter prey, the risk of attacks by predators, and whether sea otters can find shelter during rough weather. As a result, the maximum number of sea otters per unit area can be predicted by depth and distance from shore, substrate type, the presence of kelp canopy, net primary productivity, and whether the area is inside an estuary (Tinker, et al., 2021). Estuaries and shallow rocky-bottom habitats tend to support the highest densities of sea otters, whereas mixed-bottom and sandy areas support lower densities. A sea otter population reintroduced to an estuary, where waters are generally too shallow for white sharks, would likely be prevented from spreading if there are high levels of white shark activity along the adjacent outer coast.

We advise against any consideration of lethal control or zonal management via capture and relocation (USFWS 2022, p. 138). These methods of controlling sea otters are not allowable under the Marine Mammal Protection Act and are contrary to the purposes of reintroduction, which would be to enhance the resilience of kelp forest and seagrass habitats (for fisheries, recreation, and climate change mitigation) and to improve the conservation status of sea otters, particularly the federally threatened southern sea otter. Additionally, zonal management via capture and relocation, which was attempted as part of the San Nicolas Island translocation program, turned out to be inefficient, ineffective, and harmful to the animals moved.

Instead, we recommend the development of an adaptive impact management plan, which would address any potential impacts of sea otter reintroduction economically or by other means. The details of such a plan, including the appropriate time horizon, would be developed in collaboration with Tribes and stakeholders. Although any impacts of reintroduction are expected to remain highly localized for a long time because reintroduced populations typically start small and grow slowly over the ensuing decades, the plan would provide a means of addressing these localized impacts and also provide adaptive measures if impacts exceeded predictions.

Over the longer term, many other ecosystem changes would occur, most notably those brought about by climate change. Human uses of the marine environment are expected to change over this time scale in response to ecosystem changes, market forces, and other factors.

12. What is the evidence for the claim that coastal communities could see a net economic benefit from the presence of sea otters?

Several peer-reviewed, published studies have specifically evaluated the economic benefits of sea otters for coastal communities or society at large via their contribution to tourism revenue and/or existence value (Loomis, 2006; Martone et al., 2020; Gregr et al., 2020; Fujii et al., 2023) or carbon sequestration (Wilmers et al., 2012; Gregr et al., 2020). Markel & Shurin (2015) documented the beneficial effects of sea otters on rockfish but did not quantify these benefits in economic terms. Loomis (2006) calculated the economic benefits of tourism and existence values expected from the return of sea otters to a portion of southern California and noted that these gains exceeded the costs to commercial fishing calculated by USFWS. Gregr et al. (2020) quantified the net economic impact of the return of sea otters to British Columbia by evaluating costs to shellfish fishing losses and benefits to finfish fishing, carbon sequestration, and tourism. They found that economic benefits were 7 times greater than costs, due largely to sea otters' beneficial effects on tourism.

13. Would sea otters be affected by offshore wind development?

Offshore wind development is planned for, or occurring in, areas that are much deeper than sea otters can dive. Therefore, sea otters will not be affected directly by wind installations. However, depending on which ports are selected for building or servicing offshore wind installations, sea otters could be affected indirectly by increased vessel traffic or other associated activities taking place closer to shore.

Citations

Armstrong, D. A., Rooper, C., & Gunderson, D. (2003). Estuarine Production of Juvenile Dungeness Crab (Cancer magister) and Contribution to the Oregon-Washington Coastal Fishery. *Estuaries*, *26*(4), 1174–1188.

Boustany, A. M., Hernandez, D. A., Miller, E. A., Fujii, J. A., Nicholson, T. E., Tomoleoni, J. A., & Van Houtan, K. S. (2021). Examining the potential conflict between sea otter recovery and Dungeness crab fisheries in California. *Biological Conservation*, *253*, 108830. https://doi.org/10.1016/j.biocon.2020.108830

Breen, P. A., Carson, T. A., Foster, J. B., & Stewart, E. A. (1982). Changes in Subtidal Community Structure Associated with British Columbia Sea Otter Transplants. *Marine Ecology Progress Series*, *7*(1), 13–20.

Bryant, H. C. (1915). Sea otters near Point Sur. California Department of Fish and Game Bulletin. 1:134–135

Burt, J. M., Tinker, M. T., Okamoto, D. K., Demes, K. W., Holmes, K., & Salomon, A. K. (2018). Sudden collapse of a mesopredator reveals its complementary role in mediating rocky reef regime shifts. *Proceedings of the Royal Society B: Biological Sciences*, *285*(1883), 20180553. https://doi.org/10.1098/rspb.2018.0553

Clark, C., Pasi, C., Waterstrat, T., Heron, A., & Ament, S. (2022). *Results of the 2022 Survey of the Sea Otter Population in Washington State*. Washington Dept. of Fish and Wildlife.

Curran, L. S., Kone, D. V., & Wickizer, B. J. (2019). Assessing the feasibility of a sea otter reintroduction to Oregon through a coupled natural-human lens. *Corvallis: Oregon State University*. https://ir.library.oregonstate.edu/ concern/technical_reports/c821gs71d

Davis, R. W., Bodkin, J. L., Coletti, H. A., Monson, D. H., Larson, S. E., Carswell, L. P., & Nichol, L. M. (2019). Future Directions in Sea Otter Research and Management. *Frontiers in Marine Science*, *5*, 510. https://doi.org/10.3389/fmars.2018.00510

Duggins, D. O. (1980). Kelp Beds and Sea Otters: An Experimental Approach. *Ecology*, *61*(3), 447–453. https://doi.org/10.2307/1937405

Duggins, D. O., Simenstad, C. A., & Estes, J. A. (1989). Magnification of Secondary Production by Kelp Detritus in Coastal Marine Ecosystems. *Science*, *245*(4914), 170–173.

Eisaguirre, J. H., Eisaguirre, J. M., Davis, K., Carlson, P. M., Gaines, S. D., & Caselle, J. E. (2020). Trophic redundancy and predator size class structure drive differences in kelp forest ecosystem dynamics. *Ecology*, *101*(5), e02993. https://doi.org/10.1002/ecy.2993

Estes, J. A., Doak, D. F., Springer, A. M., & Williams, T. M. (2009). Causes and Consequences of Marine Mammal Population Declines in Southwest Alaska: A Food- Web Perspective. *Philosophical Transactions: Biological Sciences*, *364*(1524,), 1647–1658.

Estes, J. A., & Duggins, D. O. (1995). Sea Otters and Kelp Forests in Alaska: Generality and Variation in a Community Ecological Paradigm. *Ecological Monographs*, *65*(1), 75–100. https://doi.org/10.2307/2937159

Estes, J. A., & Palmisano, J. F. (1974). Sea otters: Their role in structuring nearshore communities. *Science (New York, N.Y.)*, *185*(4156), 1058–1060. https://doi.org/10.1126/science.185.4156.1058

Estes, J. A., Tinker, M. T., & Bodkin, J. L. (2010a). Using ecological function to develop recovery criteria for depleted species: Sea otters and kelp forests in the Aleutian archipelago. *Conservation Biology: The Journal of the Society for Conservation Biology*, *24*(3), 852–860. https://doi.org/10.1111/j.1523-1739.2009.01428.x

Estes, J. A., Tinker, M. T., & Bodkin, J. L. (2010b). Using Ecological Function to Develop Recovery Criteria for Depleted Species: Sea Otters and Kelp Forests in the Aleutian Archipelago. *Conservation Biology*, *24*(3), 852–860. https://doi.org/10.1111/j.1523-1739.2009.01428.x

Estes, J. E., Smith, N. S., & Palmisano, J. F. (1978). Sea Otter Predation and Community Organization in the Western Aleutian Islands, Alaska. *Ecology*, *59*(4), 822–833. https://doi.org/10.2307/1938786

Foster, M. S., & Schiel, D. R. (1988). Kelp Communities and Sea Otters: Keystone Species or Just Another Brick in the Wall? In G. R. VanBlaricom & J. A. Estes (Eds.), *The Community Ecology of Sea Otters* (pp. 92–115). Springer. https://doi.org/10.1007/978-3-642-72845-7_5

Fujii, J., Colgan, C., Castelletto, A., Staedler, M., Wolfrum, A., & Van Houtan, K. (2023). The Economic Value of Sea Otters and Recreational Tourism in a California Estuary. *Journal of Ocean and Coastal Economics*, *10*. https://doi.org/10.15351/2373-8456.1160

Gorra, T. R., Garcia, S. C. R., Langhans, M. R., Hoshijima, U., Estes, J. A., Raimondi, P. T., Tinker, M. T., Kenner, M. C., & Kroeker, K. J. (2022). Southeast Alaskan kelp forests: Inferences of process from large-scale patterns of variation in space and time. *Proceedings of the Royal Society B: Biological Sciences*, *289*(1967), 20211697. https://doi.org/10.1098/rspb.2021.1697

Gregr, E. J., Christensen, V., Nichol, L., Martone, R. G., Markel, R. W., Watson, J. C., Harley, C. D. G., Pakhomov, E. A., Shurin, J. B., & Chan, K. M. A. (2020). Cascading social-ecological costs and benefits triggered by a recovering keystone predator. *Science*, *368*(6496), 1243–1247. https://doi.org/10.1126/science.aay5342

Grimes, T., Tinker, M., Hughes, B., Boyer, K., Needles, L., Beheshti, K., & Lewison, R. (2020). Characterizing the impact of recovering sea otters on commercially important crabs in California estuaries. *Marine Ecology Progress Series*, *655*, 123–137. https://doi.org/10.3354/meps13530

Harvell, C. D., Montecino-Latorre, D., Caldwell, J. M., Burt, J. M., Bosley, K., Keller, A., Heron, S. F., Salomon, A. K., Lee, L., Pontier, O., Pattengill-Semmens, C., & Gaydos, J. K. (2019). Disease epidemic and a marine heat wave are associated with the continental-scale collapse of a pivotal predator (Pycnopodia helianthoides). *Science Advances*, *5*(1), eaau7042. https://doi.org/10.1126/sciadv.aau7042

Hatfield, B. B., Yee, J. L., Kenner, M. C., & Tomoleoni, J. A. (2019). *California sea otter (Enhydra lutris nereis) census results, spring 2019* (Report 1118; Data Series). USGS Publications Warehouse. https://doi.org/10.3133/ds1118

Hollarsmith, J. A., Cornett, J. C., Evenson, E., & Tugaw, A. (2024). A century of canopy kelp persistence and recovery in the Gulf of Alaska. *Annals of Botany*, *133*(1), 105–116. https://doi.org/10.1093/aob/mcad149

Hughes, B. B., Eby, R., Van Dyke, E., Tinker, M. T., Marks, C. I., Johnson, K. S., & Wasson, K. (2013). Recovery of a top predator mediates negative eutrophic effects on seagrass. *Proceedings of the National Academy of Sciences*, *110*(38), 15313–15318. https://doi.org/10.1073/pnas.1302805110

Jameson, R. J. (1974). *An evaluation of attempts to reestablish the sea otter in Oregon*. Oregon State University.

Jameson, R. J., Kenyon, K. W., Johnson, A. M., & Wight, H. M. (1982). History and Status of Translocated Sea Otter Populations in North America. *Wildlife Society Bulletin (1973-2006)*, *10*(2), 100–107.

Jeffries, S., Lynch, D., Waddell, J., Ament, S., & Pasi, C. (2019). Results of the 2019 Survey of the Reintroduced Sea Otter Population in Washington State. *Unpublished Report*, *Report provided to U.S. Fish and Wildlife Service*, 12.

Kennedy, L. A., Juanes, F., & El-Sabaawi, R. (2018). Eelgrass as Valuable Nearshore Foraging Habitat for Juvenile Pacific Salmon in the Early Marine Period. *Marine and Coastal Fisheries*, *10*(2), 190–203. https://doi.org/10.1002/mcf2.10018

Kenner, M. C., & Tinker, M. T. (2018). Stability and Change in Kelp Forest Habitats at San Nicolas Island. *Western North American Naturalist*, *78*(4), 633–643. https://doi.org/10.3398/064.078.0407

Kone, D., Tinker, M., & Torres, L. (2021). Informing sea otter reintroduction through habitat and human interaction assessment. *Endangered Species Research*, *44*, 159–176. https://doi.org/10.3354/esr01101

Laur, D. R., Ebeling, A. W., & Coon, D. A. (1988). Effects of Sea Otter Foraging on Subtidal Reef Communities off Central California. In G. R. VanBlaricom & J. A. Estes (Eds.), *The Community Ecology of Sea Otters* (pp. 151–168). Springer. https://doi.org/10.1007/978-3-642-72845-7_7

Loomis, J. (2006). Estimating Recreation and Existence Values of Sea Otter Expansion in California Using Benefit Transfer. *Coastal Management - COAST MANAGE*, *34*, 387–404. https://doi.org/10.1080/08920750600860282

Lowry, L. F., & Pearse, J. S. (1973). Abalones and sea urchins in an area inhabited by sea otters. *Marine Biology*, *23*(3), 213–219. https://doi.org/10.1007/BF00389487

Lyman, R. L. (2011). 1819A History of Paleoecological Research on Sea Otters and Pinnipeds of the Eastern Pacific Rim. In T. Braje (Ed.), *Human Impacts on Seals, Sea Lions, and Sea Otters: Integrating Archaeology and Ecology in the Northeast Pacific* (p. 0). University of California Press. https://doi.org/10.1525/california/9780520267268.003.0002

Markel, R. W., & Shurin, J. B. (2015). Indirect effects of sea otters on rockfish (Sebastes spp.) in giant kelp forests. *Ecology*, *96*(11), 2877–2890. https://doi.org/10.1890/14-0492.1

Martone, R. G., Naidoo, R., Coyle, T., Stelzer, B., & Chan, K. M. A. (2020). Characterizing tourism benefits associated with top-predator conservation in coastal British Columbia. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *30*(6), 1208–1219. https://doi.org/10.1002/aqc.3320

McLean, J. H. (1962). Sublittoral ecology of kelp beds of the open coast area near carmel, california. *The Biological Bulletin*, *122*(1), 95–114. https://doi.org/10.2307/1539325

McPherson, M. L., Finger, D. J. I., Houskeeper, H. F., Bell, T. W., Carr, M. H., Rogers-Bennett, L., & Kudela, R. M. (2021). Large-scale shift in the structure of a kelp forest ecosystem co-occurs with an epizootic and marine heatwave. *Communications Biology*, *4*(1), 298. https://doi.org/10.1038/s42003-021-01827-6

Micheli, F., Shelton, A. O., Bushinsky, S. M., Chiu, A. L., Haupt, A. J., Heiman, K. W., Kappel, C. V., Lynch, M. C., Martone, R. G., Dunbar, R. B., & Watanabe, J. (2008). Persistence of depleted abalones in marine reserves of central California. *Biological Conservation*, *141*(4), 1078–1090. https://doi.org/10.1016/j.biocon.2008.01.014

Moxley, J. H., Nicholson, T. E., Van Houtan, K. S., & Jorgensen, S. J. (2019). Non-trophic impacts from white sharks complicate population recovery for sea otters. *Ecology and Evolution*, *9*(11), 6378–6388. https://doi.org/10.1002/ece3.5209

Nichol, L. M., Doniol-Valcroze, T., Watson, J. C., & Foster, E. U. (2020). Trends in growth of the sea otter (Enhydra lutris) population in British Columbia 1977 to 2017. *DFO Can. Sci. Advis. Sec. Res. Doc. 2020/039.*, 29 pp.

Nicholson, T. E., Mayer, K. A., Staedler, M. M., Fujii, J. A., Murray, M. J., Johnson, A. B., Tinker, M. T., & Van Houtan, K. S. (2018). Gaps in kelp cover may threaten the recovery of California sea otters. *Ecography*, *41*(11), 1751–1762. https://doi.org/10.1111/ecog.03561

Nicholson, T. E., McClenachan, L., Tanaka, K. R., & Houtan, K. S. V. (2024). Sea otter recovery buffers century-scale declines in California kelp forests. *PLOS Climate*, *3*(1), e0000290. https://doi.org/10.1371/journal.pclm.0000290

Ogden, A. (1941). *The California sea otter trade, 1784-1848*. Berkeley : University of California Press. http://archive.org/details/californiaseaott0000ogde

Raimondi, P., Jurgens, L. J., & Tinker, M. T. (2015). Evaluating potential conservation conflicts between two listed species: Sea otters and black abalone. *Ecology*, *96*(11), 3102–3108. https://doi.org/10.1890/15-0158.1

Riedman, M. L., & Estes, J. A. (1990). *The sea otter (Enhydra lutris): Behavior, ecology, and natural history* (Vol. 90, pp. 126-) [Report]. USGS Publications Warehouse. https://pubs.usgs.gov/publication/96682

Schuette, P., Eisaguirre, J., Weitzman, B., Power, C., Wetherington, E., Cate, J., Womble, J., Pearson, L., Melody, D., Merriman, C., Hanks, K., & Esslinger, G. (2023). *Northern Sea Otter (Enhydra lutris kenyoni) Population Abundance and Distribution across the Southeast Alaska Stock*. *USFWS Region 7 Technical Report MMM 2023-01*.

Shaffer, A., Gross, J., Black, M., Kalagher, A., & Juanes, F. (2023). Dynamics of juvenile salmon and forage fishes in nearshore kelp forests. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *33*(8), 822–832. https://doi.org/10.1002/aqc.3957

Sherman, K., & DeBruyckere, L. A. (2018). EELGRASS HABITATS ON THE U.S. WEST COAST: *A Publication Prepared by the Pacific Marine and Estuarine Fish Habitat Partnership for The Nature Conservancy. 67pp.*

Simenstad, C. A., Estes, J. A., & Kenyon, K. W. (1978). Aleuts, sea otters, and alternate stable-state communities. *Science (New York, N.Y.)*, *200*(4340), 403–411. https://doi.org/10.1126/science.200.4340.403

Smith, J. G., Tomoleoni, J., Staedler, M., Lyon, S., Fujii, J., & Tinker, M. T. (2021). Behavioral responses across a mosaic of ecosystem states restructure a sea otter–urchin trophic cascade. *Proceedings of the National Academy of Sciences*, *118*(11), e2012493118. https://doi.org/10.1073/pnas.2012493118

Tinker, M., Hatfield, B., Harris, M., & Ames, J. (2015). Dramatic increase in sea otter mortality from white sharks in California. *Marine Mammal Science*, *32*. https://doi.org/10.1111/mms.12261

Tinker, M. T. (2015). Chapter 10—The Use of Quantitative Models in Sea Otter Conservation. In S. E. Larson, J. L. Bodkin, & G. R. VanBlaricom (Eds.), *Sea Otter Conservation* (pp. 257–300). Academic Press. https://doi.org/10.1016/B978-0-12-801402-8.00010-X

Tinker, M. T., Bodkin, J. L., Bowen, L., Ballachey, B., Bentall, G., Burdin, A., Coletti, H., Esslinger, G., Hatfield, B. B., Kenner, M. C., Kloecker, K., Konar, B., Miles, A. K., Monson, D. H., Murray, M. J., Weitzman, B. P., & Estes, J. A. (2021). Sea otter population collapse in southwest Alaska: Assessing ecological covariates, consequences, and causal factors. *Ecological Monographs*, *91*(4), e01472. https://doi.org/10.1002/ecm.1472

Tinker, M. T., Gill, V. A., Esslinger, G. G., Bodkin, J., Monk, M., Mangel, M., Monson, D. H., Raymond, W. W., & Kissling, M. L. (2019). Trends and Carrying Capacity of Sea Otters in Southeast Alaska. *The Journal of Wildlife Management*, *83*(5), 1073–1089. https://doi.org/10.1002/jwmg.21685

Tinker, M. T., Yee, J. L., Laidre, K. L., Hatfield, B. B., Harris, M. D., Tomoleoni, J. A., Bell, T. W., Saarman, E., Carswell, L. P., & Miles, A. K. (2021). Habitat Features Predict Carrying Capacity of a Recovering Marine Carnivore. *The Journal of Wildlife Management*, *85*(2), 303–323. https://doi.org/10.1002/jwmg.21985

U.S. Fish and Wildlife Service (USFWS). (2022). *Feasibility Assessment: Sea Otter Reintroduction to the Pacific Coast*. *Report to Congress prepared by the U.S. Fish and Wildlife Service, Region 9, Portland, Oregon; and Region 10, Sacramento, California*.

Watson, J. C. (1993). *The effects of sea otter (Enhydra lutris) foraging on shallow rocky communities off northwestern Vancouver Island, British Columbia*. University of California, Santa Cruz.

Watson, J., & Estes, J. A. (2011). Stability, resilience, and phase shifts in rocky subtidal communities along the west coast of Vancouver Island, Canada. *Ecological Monographs*, *81*(2), 215–239. https://doi.org/10.1890/10-0262.1

Wilmers, C. C., Estes, J. A., Edwards, M., Laidre, K. L., & Konar, B. (2012). Do trophic cascades affect the storage and flux of atmospheric carbon? An analysis of sea otters and kelp forests. *Frontiers in Ecology and the Environment*, *10*(8), 409–415. https://doi.org/10.1890/110176