THE EFFICACY OF REINTRODUCING *ENHYDRA LUTRIS* TO THE OREGON COAST

by

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From the 1700s to the early 1910s the Sea Otter, *Enhydra lutris*, was hunted to extinction off the Oregon Coast. The absence of this keystone species has caused significant disruption to nearshore kelp forests due to the lack of top-down pressure on organisms like the kelp-grazing Pacific purple sea urchin, *Strongylocentrotus purpuratus*. From 1970 to 1971, a concerted effort to reintroduce the otters back to Oregon and unite northern and southern otter populations along the West Coast took place but ultimately failed to establish a long-term population in the area. Recently, renewed discussions amongst organizations on the local, state, and federal levels have sparked interest in a potential new attempt at reintroduction. This study aims to provide advisory information for this latest effort by identifying patterns in past reintroduction methodologies and their levels of relative success. Through a comprehensive literature review of academic and governmental reports on the reintroductions and translocations of sea otters and other comparable species, this research will highlight previously effective strategies and ineffective strategies to avoid. Learning from past reintroduction efforts could increase the chances of success of the latest attempt to return sea otters to the Oregon Coast, enhancing the stability of nearshore ecosystems and supporting global sea otter populations.

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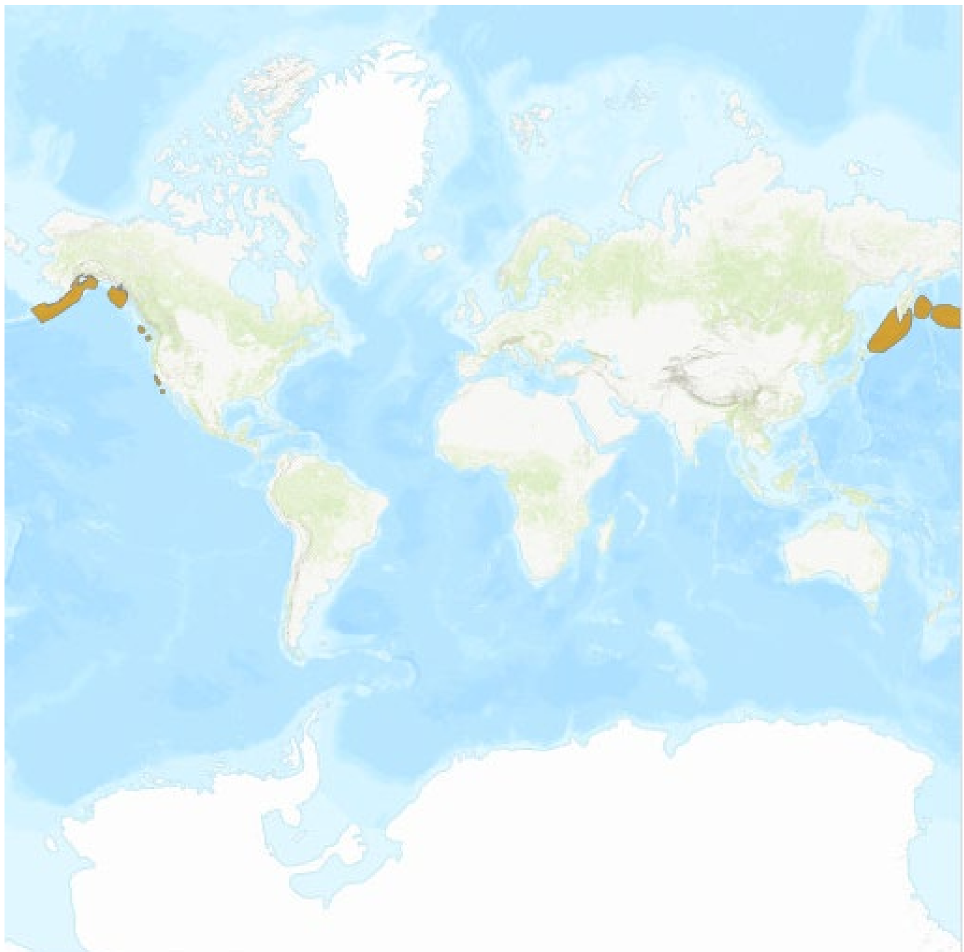

Sea Otter Range map according to the latest IUCN assessment made in 2020. Orange highlights depict current range (Larson, S., Doroff, A., & Burdin, A. (2020). IUCN Red List of Threatened Species: Enhydra lutris. IUCN Red List of Threatened Species. https://www.iucnredlist.org/en).

Introduction

In our current age, it is widely accepted that anthropogenic forces have had incredibly adverse and wide-ranging impacts on ecosystems on a global scale. The Global Assessment Report on Biodiversity and Ecosystem Services published by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) in 2019 claims that an average of 25% of all assessed plant and animal species are currently threatened, resulting in about 11 million species actively facing threat of extinction. The rate at which species are going extinct "is already at least tens to hundreds of times higher than it has averaged over the past 10 million years".[1] In the last 50 years in particular, the species with whom we cohabitate on this planet are facing unprecedented rates of habitat loss, poaching, exploitation, pollution, and invasion of relocated species.[2]

The organizations and initiatives focused on the conservation of threatened species have a substantial toolbox, and the methodologies practiced in the field vary dramatically depending on the species, location, nearby communities, and available resources. However, as the conditions for endangered species worsen, new and more extreme avenues of conservation are being considered. Reintroduction is one such method, defined as "the deliberate movement of organisms from one site for release in another. It must be intended to yield a measurable conservation benefit at the levels of a population, species or ecosystem, and not only provide benefit to translocated individuals."[3]

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1 IPBES. Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-policy Platform on Biodiversity and Ecosystem Services. Zenodo, May 4, 2019. https://doi.org/10.5281/zenodo.6417333.
2 Ibid.
[3] Robert, A., Colas, B., Guigon, I., Kerbiriou, C., Mihoub, J.-B., Saint-Jalme, M., & Sarrazin, F. (2015). Defining reintroduction success using IUCN criteria for threatened species: A demographic assessment. Animal Conservation, 18(5), 397–406. https://doi.org/10.1111/acv.12188

Reintroductions represent a unique approach to conservation biology, stepping beyond the typical practices of holding the line against anthropogenic threats and enforcing protections for remaining wild spaces and species, and instead aiming to restore disrupted landscapes to their previous states through the return of extirpated species. The ambition inherent in this approach can yield significant results that could not be replicated with other methods, but reintroduction also carries a plethora of risks. Any failed conservation effort means a waste of time and resources, but reintroductions carry the added cost of the potential loss of life of members of the source population, which is further compounded by the relative increase in value of every reproductively viable member of an endangered population. Furthermore, while typical conservation practices aim to prevent or minimize significant disturbances to an environment, reintroduction holds the antithetical goal of introducing a rapid change by returning an organism to an environment that may have been without that species for an extended period of time. This can have rippling effects throughout the entire food web, changing both interspecific and intraspecific interactions.

Due to the nature of reintroductions being an unpredictable practice, and the fact that we are dealing with animals and ecosystems that are currently unstable and at risk, it is of the utmost importance that we use due caution and consideration, and that every step is taken to avoid previous failures and achieve new success. To that end, this thesis will evaluate reintroductions on several different levels, in order to achieve a cohesive picture of the possible reintroduction, its sources of either failure or success, and a handful of the possible impacts.

Sea Otter Basics

In 1974, James A. Estes published his revolutionary article *Sea Otters: Their Role in Structuring Nearshore Communities*. It was his research in the Amchitka Islands that examined how the presence of *Enhydra lutris* impacts the abundance of sea urchins and macroalgae, demonstrating that despite their relatively low biomass, they can have far-reaching impacts, shaping the ecosystem around them.[4] It was the belief of Estes that "the sea otter is an evolutionary component essential to the integrity and stability of the ecosystem".[5]

The sea otter, *Enhydra lutris*, is the second largest of the 13 otter species in the world, falling behind only the South American giant river otter (*Pteronura brasiliensis*) in size.[6] It is the second smallest marine mammal, larger only than its South American counterpart, the marine otter (*Lontra felina*).[7] The genus *Enhydra* has only one species, but there are 3 known subspecies of sea otter. The Asian sea otter (*E. lutris lutris*) is found in Russia, around the Kuril Islands, the Kamchatka Peninsula and the Commander Islands.[8] The northern sea otter (*E. lutris kenyoni*) is found along the West Coast of North America ranging from the Aleutian Islands in Alaska to Southern Washington.[9] Lastly, the southern sea otter (*E. lutris nereis*) can be found from Northern California to about Baja, California (Figure 1).[10]

There is moderate sexual dimorphism amongst sea otters, with males measuring on average 29.0kg and 129.1cm, and females measuring 19.8kg and 119.8cm, constituting a 34% higher weight and 8% longer length for males.[11] Their fur is the densest of any mammal on the planet, with more than 100,000 hairs per cm^2.[12] This thick fur replaces the need for blubber, acting as an effective layer of insulation by trapping a layer of air, and accounts for an estimated

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[4] Estes, J. A., & Palmisano, J. F. (1974). Sea Otters: Their Role in Structuring Nearshore Communities. Science, 185(4156), 1058–1060.
[5] Ibid.
[6] Riedman, M., & Estes, J. A. (1991). The Sea Otter (Enhydra Lutris): Behavior, Ecology, and Natural History. U.S. Department of the Interior, Fish and Wildlife Service.
[7] Ibid
[8] Ibid.
[9] Ibid.
[10] Ibid.
[11] Ibid.
[12] Jefferson, T. A., Leatherwood, S., & Webber, M. A. (1993). Marine mammals of the World.

70% of their total thermal regulation.[13] The air trapped by their pelts also contributes substantially to their overall positive buoyancy on the surface of the water, allowing them to rest and sleep without expending energy to remain above the water's surface.[14] However, this pelage comes with its own downsides, one of the most significant of which is that the fur must be carefully maintained. Sea otters spend about 19% of their daily activity self-grooming.[15] If their pelt is disturbed by things such as anthropogenic oil spills, dirt, or debris it can have drastic impacts on the integrity of their insulative layer, creating significant mortality events.[16]

Their incredibly dense and meticulously managed pelage provides a means for maintaining internal body temperatures that circumvents their small size and lack of blubber and is complemented by an unrivaled metabolism. Marine mammals on average possess a basal metabolic rate (BMR) that is 2 times higher than the allometric prediction would be for terrestrial carnivorans, with the upper range belonging to the sea otter with a 2.6-fold higher BMR than any terrestrial carnivoran counterpart. The sea otter holds the highest BMR in relation to mass of any marine mammal.[17] This in turn means that the sea otter is capable of generating a substantial amount of body heat, maintaining an internal temperature of 100.6 ± 0.61° F, which is 2.4-3.2 times higher than expected for a terrestrial mammal of similar size.[18] This production of heat

[13] Zellmer, N. T., Timm-Davis, L. L., & Davis, R. W. (2021). Sea Otter Behavior: Morphologic, Physiologic, and Sensory Adaptations. In R. W. Davis & A. M. Pagano (Eds.), Ethology and Behavioral Ecology of Sea Otters and Polar Bears (pp. 23–55). Springer International Publishing. https://doi.org/10.1007/978-3-030-66796-2_3
14 Ibid.
15 Ibid.
16 Riedman, M., & Estes, J. A. (1991). The Sea Otter (Enhydra Lutris): Behavior, Ecology, and Natural History. U.S. Department of the Interior, Fish and Wildlife Service.
[17] Riedman, M., & Estes, J. A. (1991). The Sea Otter (Enhydra Lutris): Behavior, Ecology, and Natural History. U.S. Department of the Interior, Fish and Wildlife Service.
[18] Riedman, M., & Estes, J. A. (1991). The Sea Otter (Enhydra Lutris): Behavior, Ecology, and Natural History. U.S. Department of the Interior, Fish and Wildlife Service.

requires a high caloric intake to maintain, and indeed the adult sea otter requires 189-253 kcal/kg body weight, which is equivalent to 20-25% of their body weight in food every day.[19]

These high caloric needs are met with a generalist diet, spending the greatest amount of foraging time in subtidal zones at depths varying from <25m and up to >40m depending on geographical location.[20] There is a wide variety in the range of prey they feed upon. An observational study conducted by Jameson and Laidre in Washington in 2006 found that in 7,888 successful foraging dives, at least 19 species were represented, including bivalves, crustaceans, echinoderms, and annelids.[21] The most dominant prey species consumed were littleneck clams (*Protothaca staminea*), red urchins (*Strongylocentrotus franciscanus*), and turban snails (*Tegula* spp.).[22] There is variation in diet according to geographic location, with otters on the coast of California shifting towards a diet focused more on abalones (*Haliotis* spp.) and the red sea urchin, whereas around Amchitka Island, fish constitute a significant portion of the otter diet.[23] In contrast, around islands with recently reintroduced populations like the Aleutian Islands, benthic invertebrates remain the largest source of food for local otters. The majority of the diet of Aleutian Islands otters consists of sea urchins and crustaceans.[24] This is likely due to the impact otters can have on the number of benthic invertebrates in an ecosystem. It is believed that the presence of otters around Amchitka reduced the number of benthic invertebrates, and as they became scarce the more energetically taxing prey, nearshore fish, became a more significant part

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[19] Ibid
[20] Ibid
[21] Laidre, K. L., & Jameson, R. J. (2006). Foraging Patterns and Prey Selection in an Increasing and Expanding Sea Otter Population. Journal of Mammalogy, 87(4), 799–807. https://doi.org/10.1644/05-MAMM-A-244R2.1
[22] Ibid.
[23] Riedman, M., & Estes, J. A. (1991). The Sea Otter (Enhydra Lutris): Behavior, Ecology, and Natural History. U.S. Department of the Interior, Fish and Wildlife Service.
[24] Riedman, M., & Estes, J. A. (1991). The Sea Otter (Enhydra Lutris): Behavior, Ecology, and Natural History. U.S. Department of the Interior, Fish and Wildlife Service.

of the otter diet.[25] This could be further impacted by the reduction in benthic invertebrates allowing for the growth of kelp forests, which in turn provide more habitat for nearshore fish.

Enhydra lutris displays some variation in typical group size with the majority of their foraging time spent alone (or with pups), occasionally reaching groups of 2 or 3, though when resting group size tends to vary more, reaching groups (called rafts) of up to 12.[26] Once again demonstrating regional variation, group sizes in Alaska tend to be significantly larger than those in California, with female groups tending to be much smaller than male groups, which can reach upwards of 300-400 individuals.[27] There is a high level of sexual segregation; males and females have not been observed foraging together and the only times they seem to rest together are solitary, adult males who maintain territory that overlaps with "females areas".[28] Both males and females tend to show preference for both resting and foraging sites that they have frequented before.[29] Males on average live for about 15 years, whereas females can live for about 22, though one has reached 27 in captivity.[30]

Rather than following the pattern of all other mustelids and having litters with multiple young, the sea otter instead follows the trends of other marine mammals and produces only one offspring at a time. Twinning events have been observed in the wild, but due to the high cost of rearing otter pups, a successful rearing of both offspring is yet to be documented.[31] Females typically reach sexual maturity at between 3 and 5 years old, though the rate at which they

[25] Riedman, M., & Estes, J. A. (1991). The Sea Otter (Enhydra Lutris): Behavior, Ecology, and Natural History. U.S. Department of the Interior, Fish and Wildlife Service.
[26] Estes, J. A., & Jameson, R. J. (1988). A Double-Survey Estimate for Sighting Probability of Sea Otters in California. The Journal of Wildlife Management, 52(1), 70–76. https://doi.org/10.2307/3801061
[27] Riedman, M., & Estes, J. A. (1991). The Sea Otter (Enhydra Lutris): Behavior, Ecology, and Natural History. U.S. Department of the Interior, Fish and Wildlife Service.
[28] Ibid.
[29] Ibid.
[30] Ibid.
[31] Larson, S., Bodkin, J. L., & VanBlaricom, G. R. (2015). Sea Otter Conservation. Elsevier Science & Technology. http://ebookcentral.proquest.com/lib/uoregon/detail.action?docID=1910195

produce offspring varies depending on location and population density. In areas like Amchitka and the Aleutian Islands, females are documented to give birth once every 2 years, while in California that cycle is shortened to once every 12.4 months on average.[32] Studies have found evidence suggesting that population growth is more dependent on pup survival than it is reproductive rate, which can range from 0.22 overall population growth at Amchitka Islands where the population is near equilibrium density to about 0.85 at Kodiak Islands where the population is far below carrying threshold and food availability is higher.[33] Once pups surpass the first year of life, survival rates rise dramatically. Their first year of life is made riskier due to post-parturition decisions made by females. Most marine mammals can rely on strategies involving the storage of large amounts of energy in blubber, making them "investment strategists", where the decision to reproduce can be made based on the amount of energy stored.[34] *Enhydra lutris* lacks the ability to store energy in those capacities, and is instead an "income strategist", where the decision to reproduce is instead made based on resource availability at the time of copulation.[35] This has culminated in a reproductive strategy referred to as "bet-hedging", in which females become pregnant again immediately after giving birth, and then make a decision based on resource availability whether or not to abandon their pups, rather than making decisions on whether or not to reproduce.[36]

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[32] Riedman, M., & Estes, J. A. (1991). The Sea Otter (Enhydra Lutris): Behavior, Ecology, and Natural History. U.S. Department of the Interior, Fish and Wildlife Service.
[33] Larson, S., Bodkin, J. L., & VanBlaricom, G. R. (2015). Sea Otter Conservation. Elsevier Science & Technology. http://ebookcentral.proquest.com/lib/uoregon/detail.action?docID=1910195
[34] Ibid
[35] Ibid.
[36] Monson, D. H., Estes, J. A., Bodkin, J. L., & Siniff, D. B. (2000). Life history plasticity and population regulation in sea otters. Oikos, 90(3), 457–468. https://doi.org/10.1034/j.1600-0706.2000.900304.x

Chapter 1: Past Reintroductions

Oregon Otter Reintroductions

The reintroduction of *Enhydra lutris* to Oregon has been attempted on two chronologically separate occasions, though both efforts were orchestrated and performed by the same team of scientists and used the same source population of individuals. Amchitka Island of the Aleutian Islands, Alaska, was the home of Amchitka Air Force Base constructed during World War II. The base went largely unused until the Cold War when the US Atomic Energy Commission (USAEC) began to use it as a site for nuclear device testing. Public concern over the detonation of a 5-megaton bomb planned for 1971 prompted the USAEC to carry out an environmental impact assessment, the results of which indicated significant harm could come to the local sea otter population.[37] The Alaska Department of Fish and Game, along with other organizations like the Oregon State Game Commission, with funding and resources from the USAEC, began the laborious process of catching wild otters to be translocated to Oregon, Washington, and British Columbia.[38]

There was a total of 93 otters released along the Oregon Coast as a result of the translocation from Amchitka Island. Port Orford was chosen as the first release site, due in part to its rocky coast and flourishing kelp forests, an essential aspect of sea otter habitat. The initial release in 1970 consisted of 29 otters, with another 24 being released to the same location in 1971[39]. In that same year another 40 otters were released at Cape Arago, about 40 miles North of Port Orford.

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37 Elakha Alliance. (2023). Oregon’s 1970’s Sea Otter Translocation - What Happened? Youtube.com. July 25, 2023. https://www.youtube.com/watch?v=tyKTCzdBdCQt=623s
38 Ibid.
[39] Ibid.

The 1970-1971 otter releases were plagued with misfortune from the very start. Translocation is never an easy undertaking, but the practice was relatively new and hardly tested at the time. It wasn't until 2013 that the International Union for Conservation of Nature (IUCN) published guidelines that established a centralized methodology for the practice of translocations.[40] Additionally, a series of coastal storms disrupted the releases, causing stress to the otters and even requiring a premature release in both cases, resulting in the otters being released in locations several miles away from their predetermined sites.[41] The less than ideal circumstances around these reintroductions were further compounded by the lack of subsequent monitoring. What monitoring there was, was conducted by Ronald James Jameson, a master's student at Oregon State who conducted regular visual surveys and collected community reports regarding the otters from 1971 to 1974 and continued to carry out annual summer surveys until 1981.

Jameson documented significant dispersal for the otters, finding that in the course of the study, there were reports of otters ranging from Tillamook Head to Brookings, Oregon, a total range of about 276 miles.[42] The majority of the otters observed seemed to follow seasonal patterns, appearing most often in Simpson Reef in the Winter, and Blanco Reef 35 miles south of that during the rest of the year.[43] The first pup sighting occurred in February of 1972, 19 months after the first release in Port Orford, and between then and 1974 there were 13 other pups

[40] Robert, A., Colas, B., Guigon, I., Kerbiriou, C., Mihoub, J.-B., Saint-Jalme, M., & Sarrazin, F. (2015). Defining reintroduction success using IUCN criteria for threatened species: A demographic assessment. Animal Conservation, 18(5), 397–406. https://doi.org/10.1111/acv.12188
[41] Elakha Alliance. (2023). Oregon's 1970's Sea Otter Translocation - What Happened? Youtube.com. July 25, 2023. https://www.youtube.com/watch?v=tyKTCzdBdCQt=623s
[42] Jameson, R. J. (1974). An evaluation of attempts to reestablish the sea otter in Oregon. Oregon State University.
[43] Ibid.

observed. However, from 1975 to 1980, only 3 pups were spotted.[44] The final survey in 1981 found only a single otter, and none have been seen since.[45]

While the Oregon reintroductions failed to establish a stable population, aspects of their outcomes provide substantial opportunities to better prepare for further attempts. The first significant outcome was that of demonstrating that otters released on the Oregon coast can and will produce pups. Surveys spotted 14 pups in the period from 1972 to 1974; which was comparable to the number of pups spotted from the 1969-1972 releases in British Columbia, in which 89 total otters were released, and by 1975 15 pups had been spotted.[46] However, the British Columbia effort was a success, and has since established a population of about 7,000 otters.[47] Thus, it is unlikely that the Oregon failure was a result of an unsustainable rate of reproduction. The second teachable outcome is that dispersal is one of the most significant challenges to reintroduction. The range that the translocated otters were found across was significantly larger than initially predicted, and during the observation period there was only an estimated <10% mortality rate (which is significantly lower than the mortality rates of other post-release observations), implying that many of the otters left rather than died in the area.[48] Furthermore, as the number of otters observed by Jameson decreased over the years, anecdotal reports of otters north of the release site both increased in number and distance away.[49] In fact, it's been discussed as a possibility that the success of the otter reintroduction in Washington in

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[44] Jameson, R. J. (1974). An evaluation of attempts to reestablish the sea otter in Oregon. Oregon State University
[45] Tinker, M. T., Estes, J. A., Bodkin, J. L., Larson, S., Murray, M. J., & Hodder, J. (2023). Restoring Sea Otters to the Oregon Coast (2nd ed.). Elakha Alliance.
[46] 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.
[47] Tinker, M. T., Estes, J. A., Bodkin, J. L., Larson, S., Murray, M. J., & Hodder, J. (2023). Restoring Sea Otters to the Oregon Coast (2nd ed.). Elakha Alliance.
[48] 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.
[49] Ibid.

1981 was in part due to the emigration of the otters released in Oregon as they traveled north in search of their source locations and settled in Washington amongst the recently released individuals, supplementing their numbers.[50] Dispersal rates have also been documented amongst other reintroduction efforts as a significant factor in the reduction of possible founding populations. The release at San Nicolas Island, California, used source otters captured from central California, and nearly half of them (36 of 75) returned to their source locations soon after release.[51]

While the sites chosen for release were by all accounts suitable for sustaining sea otters, and the numbers released and rates of reproduction were comparable to other releases that have succeeded in establishing stable populations, the reintroduction in Oregon did not succeed for reasons that are still not entirely clear. However, for future reintroduction efforts in Oregon to succeed, it's clear that there are several things that we must learn from, and goals we must strive towards. Firstly, dispersal rates must be reduced below what they were for the first release. The fact that mortality and reproductive rates were similar to or even better than other attempts that have been successful implies that some other factor must be the driving force behind the dwindling of otter numbers. This information, coupled with reports of otters moving north following the release indicates that the high dispersal could be mostly at fault. Secondly, while Jameson's work in observing the otters post-release provided invaluable insights into the immediate outcomes of the translocations, it remains an unfortunate truth that not much is known about the fates of most of the 93 released otters. A more in-depth system of post-release tracking

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[50] Tinker, M. T., Estes, J. A., Bodkin, J. L., Larson, S., Murray, M. J., & Hodder, J. (2023). Restoring Sea Otters to the Oregon Coast (2nd ed.). Elakha Alliance.
[51] Rathbun, G. B., Hatfield, B. B., & Murphey, T. G. (2000). Status of Translocated Sea Otters at San Nicolas Island, California. The Southwestern Naturalist, 45(3), 322–328. https://doi.org/10.2307/3672835

could have provided information that would have been a significant tool to be used for this possible next attempt.

Otter Reintroductions Around the World

While the first known translocation of sea otters was accomplished in Russia in 1937, this particular attempt was meant to establish another population from which fur traders could hunt and was not done in pursuit of any conservation goal.[52] Translocations for the sake of conservation didn't begin until 1951, when otters sourced from the Amchitka Islands were released in the Pribilof Islands.[53] The attempts made to translocate otters from Amchitka to the Pribilofs were replicated in 1955, 1957, 1958 and 1959, and each of them was unsuccessful.[54] These early attempts encountered significant difficulties even before the actual release. In the attempts made between 1951 and 1959, 53 otters died in captivity after capture, before the transportation began.[55] Lack of understanding regarding otter physiology was likely partly at fault for the mortality events in captivity, as well as inadequate facilities, untested husbandry practices, and long transport times.[56]

While early mortality events set an initial negative tone for the practice of sea otter translocation and reintroduction, these early attempts provided an invaluable knowledge base with which to move forward. For instance, each of the attempts from 1951 to 1959 used different

[52] 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.
[53] Ibid.
[54] Tinker, M. T., Estes, J. A., Bodkin, J. L., Larson, S., Murray, M. J., & Hodder, J. (2023). Restoring Sea Otters to the Oregon Coast (2nd ed.). Elakha Alliance.; 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.
[55] Tinker, M. T., Estes, J. A., Bodkin, J. L., Larson, S., Murray, M. J., & Hodder, J. (2023). Restoring Sea Otters to the Oregon Coast (2nd ed.). Elakha Alliance.
[56] Ibid.

methods for keeping the otters in captivity after capturing them from shores, ranging from keeping the otters in dry, indoor locations with straw, to placing them in nearby freshwater lakes surrounded by fences.[57] While each of these methods varied in the amount of time that the held otters survived, unfortunately, every one of them ended in the deaths of every captured otter.[58] It was these attempts, however, that led to the increased understanding of otter physiology, particularly, the critical importance of maintaining the pelage of the otters while in captivity. Hindsight revealed that previous methods afforded too many opportunities for the otters to get dirt and debris mixed into their coats, with too little water or space to clean them. The dirtying of their coats reduced their ability to trap heat, effectively removing the otters' ability to maintain internal body temperature and causing the mortality events.[59] The early Russian translocation was successful in part due to a series of experiments from 1932 to 1937 in which otters were kept in cages built right along the tide, allowing for seawater to flow through the cages and clean both them and the otters. Unfortunately, the results of these experiments were not openly known until 1966.[60] Early translocations also vastly underestimated the caloric needs of sea otters, who maintain a basal metabolic rate higher than any other mammal relative to their body size and were providing inadequate quantities of food.[61]

Following this streak of unsuccessful translocations from Amchitka to the Pribilof Islands was a period of repeated successes. The lessons in husbandry learned from early failures provided a significant advantage, and fatalities of otters in captivity decreased dramatically.[62]

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57 Kenyon, K. W. (1969). The Sea Otter in the Eastern Pacific Ocean. U.S. Bureau of Sport Fisheries and Wildlife.
58 Ibid.
59 Ibid.
60 Ibid.
61 Riedman, M., & Estes, J. A. (1991). The Sea Otter (Enhydra Lutris): Behavior, Ecology, and Natural History. U.S. Department of the Interior, Fish and Wildlife Service.
62 Larson, S., Bodkin, J. L., & VanBlaricom, G. R. (2015). Sea Otter Conservation. Elsevier Science & Technology. http://ebookcentral.proquest.com/lib/uoregon/detail.action?docID=1910195

The first successful reintroduction occurred from 1965 to 1969, in which a total of 297 otters once again sourced from Amchitka Island were translocated to the coast of St. George Island, one of the 4 Pribilof Islands.[63] In this case the determined efforts of continuous releases worked, and estimates of 2021 put the otter population around the Pribilof Islands to be about 11,600 total otters.[64] This success was shortly followed by further reintroductions to Southeast Alaska, British Columbia, Washington and Oregon, with a total of 708 otters captured from Amchitka Island and Prince William Sound. [65] The Oregon reintroduction was the only one amongst those attempts that failed to establish a long-term stable population. The two most recent translocation attempts both took place in California, first to San Nicolas Island from 1987 to 1990, and later to Elkhorn Slough from 2002 to 2016.[66]

Black-footed Ferret Reintroductions

While past reintroductions of *Enhydra lutris* around the globe provide much needed insight and valuable background research, there are still relatively few examples from which to draw a clear picture of possible failures or unintended consequences. To better meet that goal, it may be prudent to consider other reintroduction efforts, of either similar species, ecological niche, or geographical location. Reintroduction efforts in North America of *Mustela nigripes*, provide one such case.

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[63] Larson, S., Bodkin, J. L., & VanBlaricom, G. R. (2015). Sea Otter Conservation. Elsevier Science & Technology. http://ebookcentral.proquest.com/lib/uoregon/detail.action?docID=1910195
[64] Tinker, M. T., Estes, J. A., Bodkin, J. L., Larson, S., Murray, M. J., & Hodder, J. (2023). Restoring Sea Otters to the Oregon Coast (2nd ed.). Elakha Alliance.
[65] Larson, S., Bodkin, J. L., & VanBlaricom, G. R. (2015). Sea Otter Conservation. Elsevier Science & Technology. http://ebookcentral.proquest.com/lib/uoregon/detail.action?docID=1910195
[66] Rathbun, G. B., Hatfield, B. B., & Murphey, T. G. (2000). Status of Translocated Sea Otters at San Nicolas Island, California. The Southwestern Naturalist, 45(3), 322–328. https://doi.org/10.2307/3672835; Tinker, M. T., Estes, J. A., Bodkin, J. L., Larson, S., Murray, M. J., & Hodder, J. (2023). Restoring Sea Otters to the Oregon Coast (2nd ed.). Elakha Alliance.

Mustela nigripes, the black-footed ferret, with a historical range of distribution throughout the Great Plains from Canada to Mexico, were officially declared extinct in 1980.[67] It is believed that their rapid decline was due to the systematic hunting of white-tailed prairie dogs (*Cynomys leucurus*) by American farmers. Prairie dogs make up 90% of the black-footed ferret diet, and their rapid reduction led to a ferret population crash that was further compounded by widespread poisoning, habitat loss and exotic disease.[68] A remnant population of only 18 ferrets discovered in 1981 prompted the creation of a captive-breeding program, which has resulted in more than 7,000 ferrets produced in captivity, and since 1991, 3,500 of those ferrets have been released into 19 different locations in the United States, Mexico and Canada.[69] However, only 4 of those sites currently have populations that are considered viable and self-sustaining with annual population counts numbering over 100 individuals.[70] Captive-reared ferrets are released annually at viable sites unless they have been labeled as "self-sustaining".

Choosing an initial site for release is the responsibility of the United States Fish and Wildlife Service (USFWS) and is decided by a matrix of multiple different criteria. The most impactful criteria, the primary factors, are the presence and abundance of prairie dogs (*Cynomys* spp.), as they are the primary source of prey and shelter for *Mustela nigripes*, the current status of sylvatic plague in the area, and the documented rates of offspring production and adult survivorship.[71] Secondary factors, considered with half the value of primary factors, include the

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[67]Black-footed Ferret: Rebounding in the Badlands (U.S. National Park Service). (n.d.). Retrieved February 3, 2024, from https://www.nps.gov/articles/000/black-footed-ferret-badl.htm.
[68] Soorae, P. S. (ed.) (2011). Global Re-introduction Perspectives: 2011. More case studies from around the globe. Gland, Switzerland: IUCN/SSC Re-introduction Specialist Group and Abu Dhabi, UAE: Environment Agency-Abu Dhabi. xiv + 250 pp.
[69] Livieri, T. (2011). Black-footed ferret recovery in North America. In Global Re-introduction Perspectives: 2011. IUCN/SSC Re-introduction Specialist Group & Environment Agency-ABU DHABI.
[70] Ibid.
[71] Jachowski, D. S., & Lockhart, J. M. (2009). Reintroducing the Black-footed Ferret Mustela nigripes to the Great Plains of North America. 41.

long-term conservation potential of the site, ease of habitat monitoring, and opportunities for research.[72]

One site in particular, the Shirley Basin site in Wyoming, currently has the largest estimated population with 239 ferrets, after 11 years of repeated annual reintroduction attempts, and a total of 518 ferrets released in that time.[73] While at first this may seem like an argument for sheer numbers, implying that once you supply enough reproductively viable individuals you're bound to reach a threshold at which the population can sustain itself, possible evidence exists for the contrary. The Aubrey Valley site in Arizona is also currently labeled as "self-sustaining", and also went through a period of 10 years of annual releases before reaching a stable population but had barely more than half the number (306) of ferrets released in that period that the Shirley Basin site had.[74] This could indicate that rather than stability of the population being dependent upon the number of individuals released, it is in fact a result of sustained releases over time that adequately supplement the population or surpass any annual variations in site suitability. This is further supported by the self-sufficient populations at the Conata Basin and the Cheyenne River Indian Reservation in South Dakota, both of which have significant differences in total number of ferrets released but had 13 and 9 respective years of repeated releases.[75] One other potential explanation for the success of some sites over others comes from the Aubrey Vally site. Releases in Aubrey Valley proved far more effective when coordinated to align with the natural life cycles of prairie dogs. Releases in Aubrey Valley that occurred in Spring, when prairie dogs are

[72] Ibid.
[73] Ibid.
[74] Ibid.
[75] Jachowski, D. S., & Lockhart, J. M. (2009). Reintroducing the Black-footed Ferret Mustela nigripes to the Great Plains of North America. 41.

emerging from hibernation and have young pups, resulted in greater population increases when counts were done the following year.[76]

Another factor that had a significant impact on the chances of success regarding reintroduction attempts was "preconditioning". Preconditioning is the practice of exposing captive-born individuals to outdoor environments meant to simulate the conditions of the natural environment in which they will be released. In the case of *Mustela nigripes*, this consisted of placing the cage-reared ferrets in large outdoor pens with established prairie dog burrow systems, with live prairie dogs inhabiting them.[77] The direct effects of preconditioning on black-footed ferrets were examined in a study comparing dispersal and survival rates between 18 preconditioned ferrets, and 72 ferrets raised in standard cages, 32 of which were given experience killing prairie dogs in cages.[78]

While it's unclear which factors of a preconditioned release play the most significant role in increasing survival rates of released individuals, there are numerous possible explanations. Ferrets exposed to outdoor conditions may be better acclimated to variations in climatic conditions or may have associated burrows with refuge. It's also possible that the shock of exposure to microorganisms in the soil, or parasites like fleas and ticks was more than they could handle. While the exact mechanism is unknown, ferrets that have received preconditioning have at least a threefold increase in survival over ferrets who did not receive preconditioning.[79]

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[76] Roelle, James. E., Miller, B. J., Godbey, J. L., & Biggins, D. E. (2006). Recovery of the black-footed ferret: Progress and continuing challenges- Proceedings of the Symposium on the Status of the Black-footed Ferret and Its Habitat, Fort Collins, Colorado, January 28-29, 2004. In Scientific Investigations Report (2005–5293). Symposium on the Status of the Black-footed Ferret and Its Habitat. U.S. Geological Survey. https://doi.org/10.3133/sir20055293

[77] Ibid.

[78] Biggins, D. E., Vargas, A., Godbey, J. L., & Anderson, S. H. (1999). Influence of prerelease experience on reintroduced black-footed ferrets (Mustela nigripes). Biological Conservation, 89(2), 121–129. https://doi.org/10.1016/S0006-3207(98)00158-X

[79] Jachowski, D. S., & Lockhart, J. M. (2009). Reintroducing the Black-footed Ferret Mustela nigripes to the Great Plains of North America. 41.

Hawaiian Monk Seal Translocations

While closely related species like the black-footed ferret provide substantial opportunities to learn from the reintroduction efforts of the past, there lies a significant discrepancy between sea otters and ferrets due to the vastly different nature of marine and terrestrial mammal ecology. While there have been no other documented reintroductions of marine mammals into the historical range to date, there have been translocation efforts for the sake of conservation that can be examined to furnish a comparative perspective different from that of the black-footed ferret. The Hawaiian monk seal (*Monachus schauinslandi*) offers one such opportunity for comparison.

Hawaiian monk seal populations are unfortunately in circumstances similar to those of sea otters following the ravages of the fur trade. They live almost entirely within the Hawaiian archipelago and are the only pinniped with a range that falls exclusively within the bounds of the United States.[80] While they are occasionally found throughout the main Hawaiian Islands (MHI) they are most frequently located around the Northwestern Hawaiian Islands (NWHI).[81] It is believed that their range around the islands was drastically decreased by anthropogenic influences, as they were hunted for their meat, pelts and oil throughout the 19th century.[82] The continued overexploitation eventually led to the near extinction of the 6 primary subpopulations of Hawaiian monk seals in the NWHI.[83] While anecdotal evidence suggested a slight increase in the population from about 1900 to 1950, from 1983 to 2011 the Hawaiian monk seal population

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[80] Lowry, L., Laist, D., Gilmartin, W., & Antonelis, G. (2011). Recovery of the Hawaiian Monk Seal (Monachus schauinslandi): A Review of Conservation Efforts, 1972 to 2010, and Thoughts for the Future. Aquatic Mammals, 37(3), 397–419. https://doi.org/10.1578/AM.37.3.2011.397

[81] Ibid.

[82] Schultz, J. K., Baker, J. D., Toonen, R. J., Harting, A. L., & Bowen, B. W. (2011). Range-Wide Genetic Connectivity of the Hawaiian Monk Seal and Implications for Translocation. Conservation Biology, 25(1), 124–132. https://doi.org/10.1111/j.1523-1739.2010.01615.x

[83] Schultz, J. K., Baker, J. D., Toonen, R. J., & Bowen, B. W. (2009). Extremely Low Genetic Diversity in the Endangered Hawaiian Monk Seal (Monachus schauinslandi). Journal of Heredity, 100(1), 25–33. https://doi.org/10.1093/jhered/esn077

decreased from 1,520 to 1,209 total individuals, and from 795 mature individuals to 632, constituting a 20.4% reduction in mature individuals.[84] It's estimated that predation from sharks, haul out site disruptions, entanglement, food limitations and the activities of nearby military installations have contributed to an approximate 4.5% annual decrease in the total population.[85]

This extended bottlenecking has had significant impacts on the genetic diversity of the species as a whole. A 2009 study analyzing 154 microsatellite loci for 2409 Hawaiian monk seals found an extremely low level of genetic diversity, lower than that of any pinniped.[86] In fact, the allelic diversity and heterozygosity of the Hawaiian monk seal are lower than both the Mediterranean monk seal, the most threatened pinniped species, and the Northern elephant seal, which previously held the record for the most depleted genetic diversity among animals.[87] While some of the low genetic diversity may be an aspect of the species, evidence suggests that the prolonged bottlenecking of the species has played a significant role[88]

Hawaiian monk seals are mostly separated into different subpopulations, 6 of which occur in the NWHI while a smaller, but growing, single subpopulation resides around the MHI.[89] These subpopulations exhibit significant variability in demographic trends, enough so that even while the total population of Hawaiian monk seals declines at an annual rate of about 4%, some

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[84] Littnan, C., Baker, J., & Harting, A. (2014). IUCN Red List of Threatened Species: Neomonachus schauinslandi. IUCN Red List of Threatened Species. https://www.iucnredlist.org/en

[85] Baker, J. D., Becker, B. L., Wurth, T. A., Johanos, T. C., Littnan, C. L., & Henderson, J. R. (2011). Translocation as a tool for conservation of the Hawaiian monk seal. Biological Conservation, 144(11), 2692–2701. https://doi.org/10.1016/j.biocon.2011.07.030

[86] Schultz, J. K., Baker, J. D., Toonen, R. J., & Bowen, B. W. (2009). Extremely Low Genetic Diversity in the Endangered Hawaiian Monk Seal (Monachus schauinslandi). Journal of Heredity, 100(1), 25–33. https://doi.org/10.1093/jhered/esn077

[87] Ibid.

[88] Schultz, J. K., Baker, J. D., Toonen, R. J., & Bowen, B. W. (2009). Extremely Low Genetic Diversity in the Endangered Hawaiian Monk Seal (Monachus schauinslandi). Journal of Heredity, 100(1), 25–33. https://doi.org/10.1093/jhered/esn077

[89] Baker, J. D., Becker, B. L., Wurth, T. A., Johanos, T. C., Littnan, C. L., & Henderson, J. R. (2011). Translocation as a tool for conservation of the Hawaiian monk seal. Biological Conservation, 144(11), 2692–2701. https://doi.org/10.1016/j.biocon.2011.07.030

sites have exhibited documented annual growth of up to 7%.[90] Variability in the survival rates of juveniles amongst different subpopulations creates a substantial opportunity for translocations as a viable measure to conserve Hawaiian monk seals. If pups born and weaned in a subpopulation that inhabits an area with a lower survival rate can be moved to a location with a statistically higher rate of survival, it may increase the amount of reproductively viable adults, which could have significant impacts on the seals ongoing recovery. This thought process was a driving factor in the translocations of a total of 247 monk seals from 1984 to 2009, 209 of which were conducted with either recently weaned or nursing pups.[91]

One of the possibly applicable lessons learned through monk seal translocations is that younger translocated seals were less likely to disperse from release sites or return to their source locations than older seals were.[92] This is thought to be a result of the increased confidence in travel and foraging in older seals, as opposed to young seals who may find it difficult to make the journey across previously unencountered waters to return to their natal locations. While older males tended to disperse further away from release sites than any other group, the only times males went far enough to fully return to their source sites was when they were released in locations with no seals already present.[93] There was no significant difference between survival rates of translocated individuals and those who were native to the release locations, however, there was a significant difference between the survival rates of juveniles translocated away from

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[90] Schultz, J. K., Baker, J. D., Toonen, R. J., Harting, A. L., & Bowen, B. W. (2011). Range-Wide Genetic Connectivity of the Hawaiian Monk Seal and Implications for Translocation. Conservation Biology, 25(1), 124–132.
[91] Baker, J. D., Becker, B. L., Wurth, T. A., Johanos, T. C., Littnan, C. L., & Henderson, J. R. (2011). Translocation as a tool for conservation of the Hawaiian monk seal. Biological Conservation, 144(11), 2692–2701. https://doi.org/10.1016/j.biocon.2011.07.030
92 Ibid.
[93] Baker, J. D., Becker, B. L., Wurth, T. A., Johanos, T. C., Littnan, C. L., & Henderson, J. R. (2011). Translocation as a tool for conservation of the Hawaiian monk seal. Biological Conservation, 144(11), 2692–2701. https://doi.org/10.1016/j.biocon.2011.07.030

areas with low juvenile survival rates and those who were not translocated.[94] In terms of increasing juvenile survival rates through translocation, the majority of attempts observed were successful.

While translocating recently weaned individuals may prompt concerns over their ability to adapt to hunting on their own in a new environment, findings suggest that translocated seals were able to adjust to their new environment and engage in foraging activities just as effectively as pups in their locations who did not experience translocations.[95] A factor that did, however, have significant impact on the rates of survival for translocated individuals was the girth of the pups at the time that they were collected. It's been observed that pups below axillary girth of 90cm have significantly lower probabilities of survival across all of the NWHI, regardless of natal location, but particularly for those who were recently translocated.[96]

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[94] Ibid.

[95] Ibid

[96] Norris, T., Littnan, C., Gulland, F., Baker, J., & Harvey, J. (2017). An integrated approach for assessing translocation as an effective conservation tool for Hawaiian monk seals. Endangered Species Research, 32, 103–115. https://doi.org/10.3354/esr00788

Chapter 2: Potential Impacts

Species Impacts

The southern subspecies of sea otter, *Enhydra lutris nereis*, stands to benefit greatly from the re-establishment of an Oregon population and the existence of a "genetic highway". A 2022 study found that the southern population of otters in California had the lowest genetic diversity among the 13 populations spread across the West Coast of North America. There was also no evidence of gene flow into the California population, and their genetic diversity has not significantly changed at all over a 15-year period.[97] Comparisons between the genetic data isolated from pre-extirpation otter bones and samples collected from modern otters revealed a loss in heterozygosity of about 30%-40%.[98] The exact cause of this is unclear, but there are likely several factors contributing to the lack of diversity. The southern population experienced intense genetic bottlenecking from the fur trade, which left a remnant population of only about 50 otters in the area. This bottlenecking is likely exacerbated by the geographic location of this population. The population of southern sea otters in California, along with the population of northern otters in the Bering Sea, constitute the full extent of the geographical range of *Enhydra lutris*. According to the "center-periphery hypothesis", genetic diversity in a species decreases as distance from the center of their geographical range increases. While the southern sea otter population has reached an estimated size of 3,000 individuals, due to their lack of genetic diversity, they "may be the most vulnerable to any further reduction of diversity through predation, oil spills, or other means and may have reduced adaptive potential to respond to novel

[97] Larson, S., Gagne, R. B., Bodkin, J., Murray, M. J., Ralls, K., Bowen, L., Leblois, R., Piry, S., Penedo, M. C., Tinker, M. T., & Ernest, H. B. (2021). Translocations maintain genetic diversity and increase connectivity in sea otters, enhydra lutris. Marine Mammal Science, 37(4), 1475–1497. https://doi.org/10.1111/mms.12841
[98] Tinker, M. T., Estes, J. A., Bodkin, J. L., Larson, S., Murray, M. J., & Hodder, J. (2023). Restoring Sea Otters to the Oregon Coast (2nd ed.). Elakha Alliance.

diseases or environmental changes associated with climate change."[99] The existence of an Oregon sea otter population could allow for genetic exchange between the two subspecies, reducing the genetic bottlenecking that has afflicted the southern sea otter.

Another reintroduction could also have significant impacts on the overall number of the species on a global scale. It's estimated that past translocations are responsible for roughly one-third of all sea otters that exist on the planet today. [100] The roughly 582km stretch that is the Oregon Coast could provide a substantial amount of habitat for a species that according to the most recent 2020 IUCN assessment, is still endangered with an overall trend of decreasing in population.[101] The argument could be made that with populations both north and south of the Oregon coast where otters could migrate from, it should only be a matter of time before the otters naturally move into the open habitat and expand into their historical range. Indeed, there have even been occasional rare otter sightings along the Oregon coast, with the most recent being a sighting of a single otter in the Yaquina Bay in 2021.[102] However, these sightings are very rare, and are almost always lone adult males who have wandered South from Washington and are not in the area for any extended period.[103] And while it is possible that *Enhydra lutris* could naturally expand back into its natural territory along the Oregon coast, it's worth mentioning that in more than 100 years that otters have been absent from Oregon, they have not established a population on their own, not even in the 50 years since otters were reintroduced to Washington.

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[99] Ibid; Hoffmann, A. A., & Parsons, P. A. (1997). Extreme Environmental Change and Evolution. Cambridge University Press.
[100] 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.
[101] Larson, S., Doroff, A., & Burdin, A. (2020). IUCN Red List of Threatened Species: Enhydra lutris. IUCN Red List of Threatened Species. https://www.iucnredlist.org/en
[102] Urness, Z. (n.d.). Sea otters take 'important step' toward reintroduction on Oregon Coast with study. Statesman Journal. Retrieved May 12, 2024, from https://www.statesmanjournal.com/story/news/2022/07/31/sea-otters-take-important-step-toward-reintroduction-on-oregon-coast/65386593007/
[103] Ibid.

Natural range expansion for sea otters is a very slow process, and it's unclear just how long it could take for them to establish themselves in Oregon once more.[104] A successful reintroduction could drastically speed up the process, creating another population of otters and boosting their numbers, positively contributing to the overall resiliency of the species.

Lastly, while it is an unfortunate circumstance to consider, even if the Oregon reintroduction attempt were to be carried out and ultimately fail, it still offers an opportunity from which we could learn and draw new conclusions about how best to reintroduce otters elsewhere. Every past attempt that was unsuccessful improved upon the methodologies used, and a more recent attempt would be no different. In fact, it's worth noting that with improvements made to monitoring technology, and a newly realized understanding of the importance of post-release monitoring, it's likely that any attempt made could provide substantial data on the outcomes of otter translocations to Oregon, filling in some of the gaps in knowledge regarding the true reasons for the failure of the 1970s attempts.

Environmental Impacts

The relationships between *Enhydra lutris, Strongylocentrotus purpuratus* and macroalgae such as *Macrocystis pyrifera* have become one of the most well-known paradigms in ecology ever since James A. Estes and John F. Palmisano first published their work examining the distribution of otters, urchin, and kelp around island groups in SE Alaska in 1974.[105] Estes and Palmisano found that Pacific purple sea urchins, which are voracious algal grazers, were capable of consuming and destroying large quantities of kelp unless they were kept in check by the

[104] Tinker, M. T., Estes, J. A., Bodkin, J. L., Larson, S., Murray, M. J., & Hodder, J. (2023). Restoring Sea Otters to the Oregon Coast (2nd ed.). Elakha Alliance.
[105] Dean, T., Bodkin, J., Jewett, S., Monson, D., & Jung, D. (2000). Changes in sea urchins and kelp following a reduction in sea otter density as a result of the Exxon Valdez oil spill. Marine Ecology Progress Series, 199, 281–291. https://doi.org/10.3354/meps199281

presence of sea otters, which are capable of reducing urchin populations by a significant margin through size-selective predation.[106] Groups of islands that were devoid of sea otters were almost entirely lacking macroalgae, and instead had wide swaths of urchins carpeting the sea floor, referred to as "urchin barrens," whereas island groups with sea otters had thriving kelp forests and the motile herbivorous invertebrates in the area were scarce and small.[107] It was the belief of Estes and Palmisano that the reintroduction of sea otters along the west coast of North America would have "profound ecological effects".[108] These findings were more recently reaffirmed after the Exxon Valdez oil spill in Prince William Sound, Alaska, in 1989. The oil spill had drastic effects on sea otter density in the surrounding areas. For instance, the western Aleutian Islands saw a 90% reduction in sea otter density, and subsequently, a 9-fold increase in sea urchin biomass, and nearly a 90% reduction in kelp.[109]

Oregon could be in dire need of top-down pressure on Pacific purple sea urchin populations. Recent counts have found that sea urchin populations on the Oregon Coast are rising at unprecedented rates. One Oregon reef in particular was home to an estimated 350 million urchins, which is more than a 10,000% increase since counts were last done in 2014.[110] This is a result of more than just the missing otter populations, however. In 2014, a disease known as sea star wasting disease (SSWD) began sweeping through the populations of 20 different sea star species in North America, disproportionately affecting the sunflower sea star

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[106] Estes, J. A., & Palmisano, J. F. (1974). Sea Otters: Their Role in Structuring Nearshore Communities. Science, 185(4156), 1058–1060.
[107] Ibid.
[108] Ibid.
[109] Dean, T., Bodkin, J., Jewett, S., Monson, D., & Jung, D. (2000). Changes in sea urchins and kelp following a reduction in sea otter density as a result of the Exxon Valdez oil spill. Marine Ecology Progress Series, 199, 281–291. https://doi.org/10.3354/meps199281
[110] Flaccus, G., & Chea, T. (2019, October 24). Swarm of sea urchins wreaks destruction on US West Coast. AP News. https://apnews.com/article/ap-top-news-wa-state-wire-ca-state-wire-oregon-us-news-8fed34f1418d4e60a4afeb1c79da9158

(*Pycnopodia helianthoides*).[111] It has been claimed as the largest epizootic marine disease outbreak in any noncommercial species.[112] Prior to the outbreak of SSWD, sunflower sea stars were one of the most prevalent species along the western coast of North America, but it's estimated that *Pycnopodia* populations have declined by over 97% since 2013 and show no signs of recovery.[113] The sunflower sea star is one of the largest and fastest sea stars in the world, and exerts substantial predatory pressure on a wide variety of bivalves, gastropods and echinoderms in subtidal and intertidal zones, including *Strongylocentrotus purpuratus*.[114] Recent studies have found that sunflower sea stars are capable of consuming 0.68±0.33 purple sea urchins every day, meaning that their abrupt disappearance from nearshore ecosystems would have resulted in a significant decrease in top-down pressure on the kelp grazing urchins.[115]

However, these ecological relationships can be quite complex, and the resurgence of *Enhydra lutris* along the Oregon Coast could put the sunflower sea star at further risk. Jameson and Laidre documented cases of otters consuming sunflower sea stars along the coast of Washington, and while this was in 2006 and they constituted less than 1% of the observed otter diet, even a slight increase in the rate of decline for this critically endangered species could drastically affect the future of their existence along the West Coast of the United States.[116] While sunflower sea stars are estimated to be maintaining a presence in deeper waters in the southern

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[111] Stephens, T. (2021, March 8). Sea otters maintain remnants of healthy kelp forest amid sea urchin barrens. UC Santa Cruz News. https://news.ucsc.edu/2021/03/kelp-forests-monterey.html

[112] Jessup, D. A., & Radcliffe, R. W. (2023). Wildlife Disease and Health in Conservation. JHU Press.

[113] Galloway, A. W. E., Gravem, S. A., Kobelt, J. N., Heady, W. N., Okamoto, D. K., Sivitilli, D. M., Saccomanno, V. R., Hodin, J., & Whippo, R. (2023). Sunflower sea star predation on urchins can facilitate kelp forest recovery. Proceedings of the Royal Society B: Biological Sciences, 290(1993), 20221897. https://doi.org/10.1098/rspb.2022.1897

[114] Ibid.

[115] Galloway, A. W. E., Gravem, S. A., Kobelt, J. N., Heady, W. N., Okamoto, D. K., Sivitilli, D. M., Saccomanno, V. R., Hodin, J., & Whippo, R. (2023). Sunflower sea star predation on urchins can facilitate kelp forest recovery. Proceedings of the Royal Society B: Biological Sciences, 290(1993), 20221897. https://doi.org/10.1098/rspb.2022.1897

[116] Laidre, K. L., & Jameson, R. J. (2006). Foraging Patterns and Prey Selection in an Increasing and Expanding Sea Otter Population. Journal of Mammalogy, 87(4), 799–807. https://doi.org/10.1644/05-MAMM-A-244R2.1

part of their range, they have seen an estimated 80-100% decline along the west coast from California to Washington.[117] Reintroducing one of the few predators of vulnerable species could hinder their potential future recovery along the Oregon coast. There could be further implications for the interactions between otters and *Pycnopodia* regarding the aforementioned circumstances with *Strongylocentrotus purpuratus* as well.

It has been observed that while sea otters are typically voracious predators of purple sea urchins, they maintain a level of selectivity that comes into play when encountering sea urchin barrens. Sea urchins that have actively consumed all of the macroalgae in an area will transition to a more passive form of foraging, remaining stationary to catch pieces of drift algae.[118] In this stationary modality, decreased food abundance leads to declining gonad condition for the urchins, and subsequently a decrease in their energetic profitability for potential predators.[119] Studies have placed the energetic density of a purple sea urchin in a kelp forest at roughly 1.5 times higher than those present in urchin barrens.[120] While the overall increased density of urchins in urchin barrens represents a hoard of potential calories, it has been observed that otters typically will avoid urchins in barrens in favor of urchins living in remaining kelp forest fragments.[121] This means that while the presence of *Enhydra lutris* can increase the resiliency of kelp forests ecosystems by maintaining top-down pressure on *Strongylocentrotus purpuratus*,

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[117] 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

[118] 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

[119] Ibid.

[120] Stewart, N. L., & Konar, B. (2012). Kelp Forests versus Urchin Barrens: Alternate Stable States and Their Effect on Sea Otter Prey Quality in the Aleutian Islands. Journal of Marine Sciences, 2012, e492308. https://doi.org/10.1155/2012/492308

[121] 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

they are less effective at prompting the recovery of kelp forests that have already been decreased by urchin over-grazing.[122] This recovery role can, however, be filled by *Pycnopodia helianthoides*. A study conducted with sunflower sea stars kept in captivity in Washington found that they showed no significant preference for fed or starved urchins in y-maze trials.[123] In fact, the sea stars on average consumed 21% more starved urchins in a day than they did when offered fed urchins, possibly to make up for the reduction in energy density offered by the gonad-depleted urchins.[124] These findings indicate that *Pycnopodia helianthoides* could act as a significant contributor to top-down pressure on the Pacific purple sea urchin, much like the sea otter, but without the added concerns about selectivity for non-depleted urchins. While the presence of otters could reduce overgrazing in surviving fragments of kelp forests, thus preserving the macroalgae, their propensity to avoid starved urchins lowers their potential for reducing urchins in barrens and allowing for kelp forests to gain some of their lost area. *Pycnopodia* could fulfill this gap, which makes the possibility of sea otter predation further reducing their numbers that much more serious. Without sunflower sea stars, the regeneration of depleted kelp forests becomes ever more difficult. The relationship between sea otters, sunflower sea stars, purple urchins and kelp is one that makes the possible reintroduction of otters that much more important, but also much riskier.

[122] Ibid.

[123] Galloway, A. W. E., Gravem, S. A., Kobelt, J. N., Heady, W. N., Okamoto, D. K., Sivitilli, D. M., Saccomanno, V. R., Hodin, J., & Whippo, R. (2023). Sunflower sea star predation on urchins can facilitate kelp forest recovery. Proceedings of the Royal Society B: Biological Sciences, 290(1993), 20221897. https://doi.org/10.1098/rspb.2022.1897

[124] Galloway, A. W. E., Gravem, S. A., Kobelt, J. N., Heady, W. N., Okamoto, D. K., Sivitilli, D. M., Saccomanno, V. R., Hodin, J., & Whippo, R. (2023). Sunflower sea star predation on urchins can facilitate kelp forest recovery. Proceedings of the Royal Society B: Biological Sciences, 290(1993), 20221897. https://doi.org/10.1098/rspb.2022.1897

Societal & Economic Impacts

Many residents are skeptical about Oregon otter reintroductions because they worry about the potentially adverse impacts they may have on the Oregon crabbing industry. According to the Oregon Seafood Commodity Commission, Dungeness crab is the most valuable single-species fishing industry in Oregon, having brought in 17 million pounds of crab and about $91.5 million in revenue in the 2021-2022 season.[125] It is impossible to determine exactly how the presence of otters will impact Oregon crabbing, an industry that is already facing challenges like delayed seasons to avoid harmful algal blooms. Tim Novotny, the executive director of the Oregon Dungeness Crab Commission, has been an advocate for approaching otter reintroductions with caution, stating that "sea otters, in any true number, have never co-existed with the commercial Oregon Dungeness crab industry. And, in other areas of the Pacific Northwest where reintroduction has taken place, notably southeast Alaska, the results have been devastating for the fisherman and the industry."[126]

Novotny's concerns may be merited. A study published in 1996 surveying Dungeness crab abundance in Glacier Bay National Park in Southeast Alaska found that in survey sites occupied by sea otters, crab densities were significantly lower than their otter-free counterparts.[127] Continued observation of sea otter feeding habits found that Dungeness crab constituted roughly 15% of the average sea otter diet.[128] However, there was a significant difference in crab density between the two survey depths of 25m and 95m, with the 95m depth

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[125] Ligori, C. (2023, January 17). After a six-week delay, Oregon's commercial Dungeness crabbing season is now open. opb. https://www.opb.org/article/2023/01/17/oregon-commercial-dungeness-crabbing-season-opens-after-delay/
[126] Urness, Z. (2023, February 3). Challenges remain as interest grows for returning sea otters to oregon coast. Statesman Journal. https://www.statesmanjournal.com/story/travel/outdoors/explore/2023/02/03/oregon-sea-otter-diet-sea-urchins-predator-sunflower-sea-star/69854692007/
[127] Shirley, T. C., Bishop, G. H., O'Clair, C. E., Taggart, J. S., & Bodkin, J. L. (1996). Sea otter predation on Dungeness crabs in Glacier Bay, Alaska. Alaska Sea Grant College Program , 96–02, 563–576.
[128] Ibid.

surveys finding crab densities in areas with otters that were higher and more similar to densities of crabs at 25m with no otters.[129] This could indicate that in the presence of sea otters, crabs move to greater depths, where the energetic cost of diving becomes too high for the otters to justify foraging for crabs, seeing as how their maximum observed dive depth is about 100m.[130]

Crustaceans are not the only economically valuable invertebrates that have been impacted by sea otter populations. The depletion of sea otters in California resulted in decades of abundance of their prey species, including abalone (*Haliotis* spp.), which led to the rapid growth of the abalone industry.[131] However, as the otters naturally expanded beyond their limited population left after the fur trade they came into direct conflict with abalone fishermen, prompting a California Senate hearing in 1963, and marking the first major conflict in North American between sea otters and a fishing industry.[132] Abalone fishermen made claims that the intrusion of sea otters had entirely disrupted the industry, and that the reduction in annual take was the result of otters, and conveniently ignored that there had been a 400-fold increase in the number of licensed commercial abalone fisherman in the 35 years prior to the hearing.[133] The requests of abalone fisherman to have the otters moved beyond their fishery areas would over time transform into the basis for the California translocations, which moved the otters beyond central California and increase the resiliency of the southern sea otter by establishing multiple populations.[134] Meanwhile, the commercial abalone fisheries would be closed by 1997, not just

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[129] Ibid.
[130] Bodkin, J. L., Esslinger, G. G., & Monson, D. H. (2004). Foraging Depths of Sea Otters and Implications to Coastal Marine Communities. Marine Mammal Science, 20(2), 305–321. https://doi.org/10.1111/j.1748-7692.2004.tb01159.x
[131] Larson, S., Bodkin, J. L., & VanBlaricom, G. R. (2015). Sea Otter Conservation. Elsevier Science & Technology. http://ebookcentral.proquest.com/lib/uoregon/detail.action?docID=1910195
[132] Ibid.
[133] Ibid.
[134] Ibid.

in otter territory but throughout all California, as abalone colonies collapsed due to overharvesting and disease.[135]

Local residents who rely on fishing for income have also voiced concerns. The West Coast Seafood Processors Association, a coalition backed by communities from the ports of Ilwaco, Astoria, Newport, Coos Bay and Brookings submitted a letter to the USFWS in 2021 calling for extreme caution regarding their feasibility report of Oregon sea otter reintroductions that was in the works during that time.[136] Their concerns lie most heavily in the possible impacts that the otters could have on fish populations and the fishing industry. While the results of reintroducing sea otters are difficult to predict accurately, it’s likely that the fishing industry will be safe from otter interruptions. It’s worth recalling that between groups of islands in Alaska with adjacent otter populations, the only times that fish were a significant part of the otter diet were when benthic invertebrate densities were low from extended sea otter foraging and a high population density of resident otters.[137] And while it’s possible that over a prolonged period after a successful reintroduction that otter density rises and benthic invertebrate density decreases, decreasing benthic invertebrate density could lead to increased kelp forest area, which provides habitat for nearshore fish. Furthermore, estimates for sea otter carrying capacity claim that the “core habitat” most likely habitable for otters on the Oregon Coast will support around 4,500 otters, which is significantly lower than the current estimated population of about 25,000 otters

[135] Larson, S., Bodkin, J. L., & VanBlaricom, G. R. (2015). Sea Otter Conservation. Elsevier Science & Technology. http://ebookcentral.proquest.com/lib/uoregon/detail.action?docID=1910195
[136] Banse, T. (2021, August 13). Skeptics Of Sea Otter Reintroduction Getting Organized On Pacific Coast. Northwest Public Broadcasting. https://www.nwpb.org/2021/08/13/skeptics-of-sea-otter-reintroduction-getting-organized-on-pacific-coast/
[137] Riedman, M., & Estes, J. A. (1991). The Sea Otter (Enhydra Lutris): Behavior, Ecology, and Natural History. U.S. Department of the Interior, Fish and Wildlife Service.

in SE Alaska.[138] Other long-term studies conducted on otter populations in California have found that predation on crabs, kelp crabs in this case, did not occur until after urchin populations had been diminished, and after an initial spike, decreased as the otters switched to consuming primarily clams.[139]

The reintroduction of sea otters does not have only the potential for economic damage but benefit as well. A study examining the economic output of Elkhorn Slough post-translocation using an analysis of average visitor spending and surveys, found that tourism to the area yielded an annual potential value of between $1.29 million and $1.35 million.[140] Interest surveys found that visitors rated otters as both their most significant reason to visit the slough, and the part they most enjoyed on their way out.[141] Furthermore, there was a dramatic increase in the number of businesses catering to recreational visitors to the slough between 2010 and 2019, as well as an increase in otter, eelgrass, fish, bird and invertebrate abundance in the slough in that time.[142] Outcomes like this suggest that increasing the health of ecosystems can still be economically beneficial, without relying on the exploitation of natural resources. While the resurgence of sea otters along the Oregon Coast presents the possibility of conflict with local fisherman, the high benthic invertebrate density and potential for the increase in charismatic-megafauna-fueled tourism could be significant contributors to the offset of an impact that is likely to be minimal due to the estimated current low sea otter carrying capacity of the coast.

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[138] Tinker, M. T., Gill, V. A., Esslinger, G. G., Bodkin, J. L., Monk, M., Mangel, M., Monson, D., Raymond, W. W., & Kissling, M. (2019). Trends and carrying capacity of sea otters in Southeast Alaska. Journal of Wildlife Management, 83(5), 1073–1089. https://doi.org/10.1002/jwmg.21685

[139] Ostfeld, R. S. (1982). Foraging Strategies and Prey Switching in the California Sea Otter. Oecologia, 53(2), 170–178.

[140] Fujii, J., Colgan, C., Castelletto, A., Staedler, M., Wolfrum, A., & Houtan, K. V. (2023). The Economic Value of Sea Otters and Recreational Tourism in a California Estuary. Journal of Ocean and Coastal Economics, 10(1). https://doi.org/10.15351/2373-8456.1160

[141] Ibid.

[142] Ibid.

Chapter 3: Reintroductions Moving Forward

One of the most significant questions remaining for the proposed reintroduction of sea otters to the Oregon coast is what source population the reintroduced otters will be translocated from. This question can be broken down into two smaller questions. Firstly, will wild or captive otters be used for the source population? Secondly, if a wild population is chosen as the source, which population will the otters be taken from?

A meta-analysis examining the past 20 years of published results of animal relocations of all species found that of the 97 published reintroduction efforts that listed source populations, 52 of them (53.6%) used captive populations as the source, while the other 45 (46.4%) used wild populations.[143] However, the success rate for reintroductions from wild source populations was more than double that of those using captive populations, with wild-sourced reintroductions succeeding 31% of the time and captive-sourced succeeding only 13% of the time.[144] While this particular study did not provide a hypothesis to explain the discrepancy between the outcomes of these two approaches, it's likely that captive-bred individuals just do not have as high of odds of survival as their wild-bred counterparts, due to their relative lack of experience in essential skills like hunting or finding shelter.

As for where the wild otters would be sourced from, the two major distinctions would be either the northern sea otter, *Enhydra lutris kenyoni* from along the coast of Alaska, British Columbia, and Washington, or the southern sea otter *Enhydra lutris nereis* from California. As mentioned during the discussion of the history of otter reintroduction, nearly all reintroductions conducted in the past have involved northern otters sourced from Amchitka Island. The only

[143] Fischer, J., & Lindenmayer, D. B. (2000). An assessment of the published results of animal relocations. Biological Conservation, 96(1), 1–11. https://doi.org/10.1016/S0006-3207(00)00048-3
[144] Ibid.

reintroductions using southern otters have been translocations within California to expand their range into regions they formerly inhabited but had not naturally spread to on their own. There exist several arguments for either side, the first of which comes from the perspective of genetics.

A recent study conducted an in-depth analysis of the mitogenomes of pre-extirpation otters from Oregon (collected using teeth from archaeological sites) and compared them to the published mitogenomes of otters along the Pacific coast, including those both of California and Amchitka.[145] It was assumed that since the otters in Washington and British Columbia were recently established there from the otters of Amchitka, they would be sufficiently genetically similar. Interestingly, the results of the study found that archaeological samples collected from Southern Oregon presented genetic haplotypes closer in similarity to those of Southern California otters, while those found in Northern Oregon were more genetically similar to the Alaskan otters.[146] These results support previously suggested hypotheses that Oregon served as a genetic mixing ground between the northern and southern subspecies of otters, allowing for extended gene flow between the two. These findings are further supported through the phenotypic comparisons between the skeletal systems of ancient Oregon otters (primarily teeth) and those of Alaskan and Californian otters. Comparisons of tooth width and long bone length along the geographical distribution of the west coast of North America found that while stored ancient Oregon sea otter teeth were on average more similar in width to otters in southern California, their average femur bone was "overwhelmingly larger" than those of modern California sea otters, and far more similar to those of modern Alaskan otters.[147] Both genotypic

[145] Wellman, H. P., Austin, R. M., Dagtas, N. D., Moss, M. L., Rick, T. C., & Hofman, C. A. (2020). Archaeological mitogenomes illuminate the historical ecology of sea otters (Enhydra lutris) and the viability of reintroduction. Proceedings of the Royal Society B: Biological Sciences, 287(1940), 20202343. https://doi.org/10.1098/rspb.2020.2343
[146] Ibid.
[147] Wellman, H. P. (2018). Applied zooarchaeology and Oregon Coast sea otters (Enhydra lutris). Marine Mammal Science, 34(3), 806–822. https://doi.org/10.1111/mms.12484

and phenotypic evidence seem to suggest that the population of sea otters along the Oregon coast acted as a transitional zone between the northern and southern subspecies, and it's likely that if they were reintroduced, they could continue to operate in that function. It has been suggested by Wellman et al. that in order to reflect the genetic history of Oregon sea otters, future reintroduction attempts should incorporate a mix of both northern and southern sea otters in the founding population.[148] In doing so, the Oregon population may sooner reach a semblance of their past role as a genetic mixing ground, rather than shifting the balance of the otter genetic landscape in either particular direction. Establishing a population along the Oregon coast could provide an opportunity for enhanced connectivity between northern and southern sea otter populations, increasing genetic diversity between both populations and lending the entire North American otter population greater resilience in the face of continued anthropogenic threats.

The mixing of northern and southern otters as a founding population may bring about new, separate challenges, however. While SE Alaska and Washington both have stable reintroduced populations, the population of otters in California is relatively less established due to their more recent reintroduction. Taking a significant number of otters from California populations may be more disruptive than it would be from the northern populations.[149] The solution to this, however, is conveniently offered through the reproductive habits of otters. As discussed, the "bet-hedging" strategies practiced by otter females often result in a high number of abandoned pups whenever females don't predict that resource availability will be conducive to the rearing process. These pups are often discovered on the California beaches by the public, and

[148] Wellman, H. P., Austin, R. M., Dagtas, N. D., Moss, M. L., Rick, T. C., & Hofman, C. A. (2020). Archaeological mitogenomes illuminate the historical ecology of sea otters (Enhydra lutris) and the viability of reintroduction. Proceedings of the Royal Society B: Biological Sciences, 287(1940), 20202343.

[149] Tinker, M. T., Estes, J. A., Bodkin, J. L., Larson, S., Murray, M. J., & Hodder, J. (2023). Restoring Sea Otters to the Oregon Coast (2nd ed.). Elakha Alliance.

are raised in captivity, often with the goal of release in mind from the very start.[150] This means that California has a somewhat steady reserve of sea otter pups that are raised in captivity for release. However, current studies have found that survival for these pups is less than ideal. While 87% of the southern otter pups recovered survive their transition to captivity, only 27% of the juveniles released survive in the wild compared to the 80%-88% of juveniles raised entirely in the wild.[151] These survival rates are likely to drop even further if the stressors of translocation are included, and the potential genetic benefits of mixing both northern and southern otters in an Oregon founding population would be irrelevant if the southern otters do not survive the attempt.

Recently, the otter pups raised in captivity at the Monterey Bay Aquarium's Sea Otter Research and Conservation (SORAC) program transitioned to keeping found pups with surrogate, non-releasable adult females during their time in captivity. For the otters raised with surrogacy, juvenile survival rate has increased to about 71%.[152] It's possible that examining the practices of reintroductions with comparable species could provide methods to increase that number even further. The process of preconditioning, keeping individuals soon to be released in outdoor conditions that simulate the environment in which they will be released, provided substantial positive results with the reintroductions of black-footed ferrets. Ferrets that were released after experience preconditioning were 3 times more likely to survive in the wild than their entirely captive-raised counterparts.[153] While the logistics of providing sea otters with a preconditioning space are daunting, the potential benefits are substantial. Sourcing otters from

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[150] Larson, S., Bodkin, J. L., & VanBlaricom, G. R. (2015). Sea Otter Conservation. Elsevier Science & Technology. http://ebookcentral.proquest.com/lib/uoregon/detail.action?docID=1910195

[151] Nicholson, T. E., Mayer, K. A., Staedler, M. M., & Johnson, A. B. (2007). Effects of rearing methods on survival of released free-ranging juvenile southern sea otters. Biological Conservation, 138(3), 313–320. https://doi.org/10.1016/j.biocon.2007.04.026

[152] Ibid.

[153] Biggins, D. E., Vargas, A., Godbey, J. L., & Anderson, S. H. (1999). Influence of prerelease experience on reintroduced black-footed ferrets (Mustela nigripes). Biological Conservation, 89(2), 121–129. https://doi.org/10.1016/S0006-3207(98)00158-X

the wild Californian population is considered a risky strategy, and there is already a reliable source of pups to be rescued and raised in captivity. If these pups can be raised with surrogate females, and go through a preconditioning process, it's possible they could be just as likely to survive in the wild as their wild-raised northern otter counterparts in a mixed-subspecies reintroduction model.

It's worth mentioning that one other practice implemented by the black-footed ferret reintroductions is already being considered as a strategy to be used for otter reintroductions as well. The feasibility report released by the Elakha Alliance voices the opinion that subsequent releases after the first initial release could improve the odds of success and is an effective method of improving the viability of a population during the establishment period.[154] This theory has been supported by the results of the California reintroduction to Elkhorn Slough, in which between 1 and 4 otters were released annually after an initial release of 37 otters.[155] It is believed that the presence of conspecifics at the time that supplemental releases were done decreased the odds of dispersal. The black-footed ferret reintroductions also employed a supplemental translocation approach, providing sites with more captive-bred individuals on an annual basis.[156] While supplemental translocation of northern sea otters could prove costly and logistically challenging due to the need for repeated captures, it is possible that the pups sourced from California and raised in captivity could act as the supplemental population source. If an initial translocation of northern otters could be completed, the annual supplementary translocations

[154] Tinker, M. T., Estes, J. A., Bodkin, J. L., Larson, S., Murray, M. J., & Hodder, J. (2023). Restoring Sea Otters to the Oregon Coast (2nd ed.). Elakha Alliance.
[155] Biggins, D. E., Vargas, A., Godbey, J. L., & Anderson, S. H. (1999). Influence of prerelease experience on reintroduced black-footed ferrets (Mustela nigripes). Biological Conservation, 89(2), 121–129. https://doi.org/10.1016/S0006-3207(98)00158-X
[156] Holmes, B. E. & United States. (2008). A review of black-footed ferret reintroduction in northwest Colorado, 2001-2006. U.S. Department of the Interior, Bureau of Land Management, White River Field Office ; https://doi.org/10.5962/bhl.title.152955

could consist of the California surrogate raised and preconditioned pups. This approach could allow for supplemental releases to occur without the labor and financial strains associated with repeat captures of wild northern otters, while still creating a genetic mixing ground of northern and southern subspecies to mimic pre-extirpation Oregon sea otters.

One of the most prevalent remaining issues concerning another Oregon reintroduction attempt is lowering the emigration of the released individuals. While there have been numerous examples thus far of successful otter reintroductions, data collected by Tinker et al., suggests that "in all translocations for which there are data, the numbers of sea otters reintroduced appeared to have declined rapidly following their release and, in most cases, appeared to stabilize at 10%-50% of the original number released."[157] Larson et al. have settled on an even more conservative estimate, claiming that populations tend to stabilize at only around the 10% of released individuals mark.[158] Reducing the odds of emigration is a multifaceted problem, and represents one of the most significant challenges to a successful Oregon reintroduction. The 1970s reintroduction is believed to have failed largely due to the attempts made by the released otters to return to their source locations, which makes sense given the context that otters typically prefer to forage and rest repeatedly in the same locations. While there are obvious parts of the solution to this problem, such as ensuring that the release sites offer adequate habitat and resource availability, it could be argued that the sites at Port Orford and Cape Arago offered as close to ideal habitat as possible, hence their initial selection. And prolonged human activity at and around these sites likely hasn't made them any more favorable in the 50 years since those releases. Thus, it may be prudent to cast a wider net when looking for solutions. Despite the

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[157] Tinker, M. T., Estes, J. A., Bodkin, J. L., Larson, S. E., Murray, M., & Hodder, J. (2023). Restoring sea otters to the Oregon Coast: A feasibility study. Elakha Alliance.
[158] Larson, S., Bodkin, J. L., & VanBlaricom, G. R. (2015). Sea Otter Conservation. Elsevier Science & Technology. http://ebookcentral.proquest.com/lib/uoregon/detail.action?docID=1910195

physiological and taxonomic differences between the Hawaiian monk seal and the sea otter, the results of monk seal translocations may offer a potential avenue for decreasing emigration rates of released otters. Translocated monk seals that were younger were less likely to attempt to return to their source locations, and it could be inferred that a similar outcome could be present for sea otters. The research conducted for this thesis did not yield any information regarding the exact ages of any of the translocated otters and given the urgency with which those relocations happened due to the military base operations, it's possible that the data was not collected/recorded. If future reintroductions were to rely on young or freshly weaned otters, it's possible that the lack of confidence to traverse swathes of unencountered waters could limit the number of otters who would attempt to leave and return to their source locations. This is supported by movement and spatial use data collected from 40 Californian translocated otters, which found that juvenile males moved a greater distance in a short span of time while eventually returning to the release site, while the adult released males ended up dispersing a greater distance in the long term.[159] Furthermore, during the 1980 translocation to San Nicolas Island, nearly 90% of the released adult and juvenile otters dispersed and traveled over 100km South to return to their original habitat.[160] However, during the Elkhorn Slough reintroduction which used only "ecologically-naïve" rescued juveniles, 80% of males and 88% of females released remained in the Slough, despite it being considered less ideal otter habitat than the San Nicolas coast.[161]

[159] Ralls, K., Eagle, T. C., & Siniff, D. B. (1996). Movement and spatial use patterns of California sea otters. Canadian Journal of Zoology, 74(10), 1841–1849. https://doi.org/10.1139/z96-207
[160] Ibid.
[161] Ralls, K., Eagle, T. C., & Siniff, D. B. (1996). Movement and spatial use patterns of California sea otters. Canadian Journal of Zoology, 74(10), 1841–1849. https://doi.org/10.1139/z96-207

Conclusion

Reintroduction is a costly undertaking, and it's nearly impossible to accurately predict its outcomes. In the roughly 110 years since sea otters were extirpated from the Oregon Coast, nearshore ecosystems have changed. Benthic invertebrates such as the Pacific purple sea urchin have exploded in numbers and decimated nearshore kelp communities, which in turn has reduced habitat for other species, productivity, and carbon sequestration of coastal marine ecosystems. These issues are the result of a complex series of events beyond just the absence of sea otters. However, it is the belief of some that the reintroduction of sea otters to the Oregon Coast will have substantial benefits and combat some of the afflictions Oregon nearshore ecosystems currently face. For this reintroduction to work, there are several challenges and hurdles that must be addressed. The dispersal of released individuals must be reduced, translocation mortality must be minimized, a source population must be chosen, and the concerns of locals must be considered and alleviated. The histories of the reintroductions of otters in Oregon and of otters around the world provide examples from which we may learn and create new strategies to avoid past pitfalls. However, due to the delicate nature and historical failure of reintroducing otters to Oregon, the more information we can have to inform future decisions, the better. The reintroduction of black-footed ferrets to the midwestern United States, and the translocations of Hawaiian monk seals around the Hawaiian Islands both provide substantial data from which we can glean potential strategies to improve the odds of success of an Oregon otter reintroduction. These strategies include using a younger founding population, using repeated annual releases, and engaging in preconditioning.

While no singular strategy is going to guarantee a successful next reintroduction attempt, if efforts can be made to incorporate many possible applicable facets of successful reintroductions and translocations, otters may indeed be returned to Oregon in the future.

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