Reviving Sea Otters (*Enhydra lutris*) Populations Post Fur-Trade in the Aleutian Archipelago of Alaska

Donovan Hughes

May 5th, 2019

Source: U.S. Department of the Interior

A paper submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Fisheries and Wildlife Sciences, Wildlife Concentration, at Paul Smith's College

AKNOWLEDGEMENTS:

I'd like to thank my peers for helping me improve my management plan throughout the semester, especially Gavin Shwala and Iris Li (Bip Bop Bip). Thank you to Autumn Florence for your continued love and encouragement, I really couldn't have done it without you. I'd also like to give a special thanks to Dr. Ross Conover for guiding me throughout my time here at Paul Smith's College and inspiring me to pursue a career in wildlife conservation.

TABLE OF CONTENTS

EXECUTIVE SUMMARY:

Northern sea otters (*Enhydra lutris*) are a very important predator to the Aleutian Archipelago of Alaska. They are a keystone species that helps maintain a balanced relationship between sea urchins and kelp. Sea otters were nearly extinct in the early 20th century, but most populations have since recovered. However, otters of the Aleutian Islands are facing large declines due to increased killer whale (*Orcinus orca*) predation. Due to small, extant populations that are isolated from one another, it is difficult for otters to disperse from their birthplace, thus creating genetic bottle necking. This management plan's goal is to stabilize sea otter populations, at islands that were not operating at equilibrium in 1965, to approximately 300 total individuals by 2026. Population models show adult survivability is the most influential on the population. The objective measures that will be taken to achieve this goal would be to (1) Stop the hunting of sea otters from 2019-2026, (2) decrease killer whale predation by 50% by 2026, and (3) increase the number of adults by at least 30% in areas that provide protection from killer whales by 2026. This plan expects a positive outcome with the goal being achieved within the given time frame, ± 1 year.

INTRODUCTION:

Sea otters (*Enhydra lutris*) are large marine mammals that lives in the Pacific coasts of North America and some parts of Asia (Ogden 1941). Global populations were nearly driven to extirpation in the early 20th century due to the fur-trade. Populations in the Aleutian Islands have never fully recovered and have been on a steady decline since the 1960s (Estes 1990, Estes et al. 1998, Doroff et al. 2003). Sea otters are important to the Aleutian Islands because they control red sea urchin (*Mesocentrotus franciscanus*) populations and allow kelp forests to grow abundantly (Laidre and Jameson 2006). This management plan describes a six-year plan to restore and stabilize sea otter populations in the Aleutian Islands of Alaska.

NATURAL HISTORY

Identification:

Sea otters are the largest member of family *Mustelidae* with males being as large as 148 cm (58 in) long and weighing 45 kg (100 lbs; Kenyon 1969). The sea otter's general physical form can be described as a robust head, elongated body, short forelimbs, and webbed, paddle-like hindlimbs (Fig. 1). Fur color are a shade of brown ranging from dark brown to a brown with red hues; other types of hairs sea otters possess are thick facial vibrissae (Lekh 1907).

Males can be sexed by the presence of penial bulge and females can be sexed by the presence of mammary glands on the abdomen (Barabash-Nikiforov 1947, Kenyon 1969). As individuals age the fur around their face and neck becomes faded and gray (Lekh 1907).

Figure 1: Image of a sea otter. Photo sourced from the U.S. Department of the Interior

Distribution:

Sea otter distribution was first described in 1740, and ranged from northern Japan, along the Pacific coast of Russia, and the west coast of North America down to Baja California (Ogden 1941). As of 1979 much of their original range is still occupied, with only small areas east of Prince William Sound and the northwestern United States uninhabited (Fig 2).

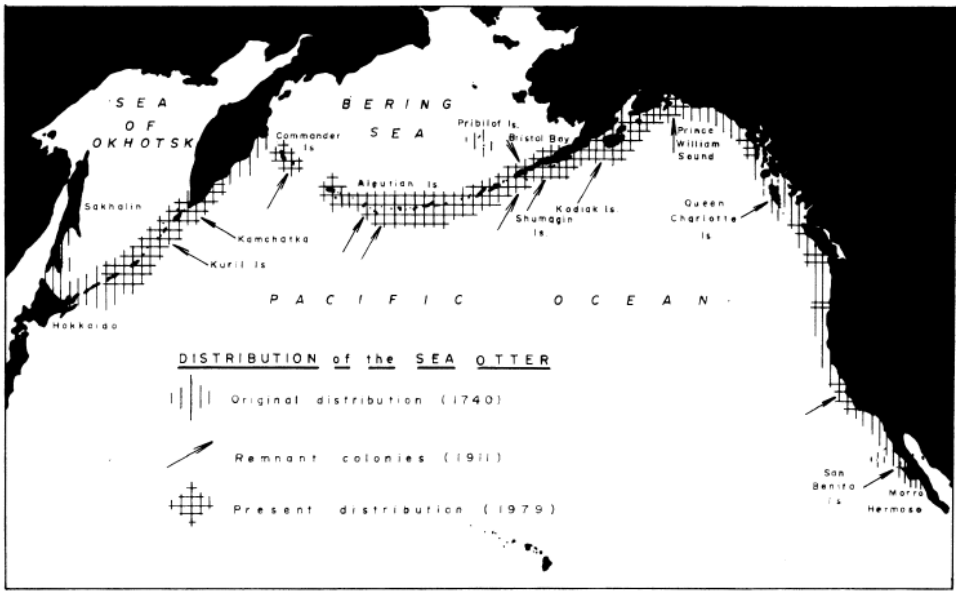

Figure 2: Distribution map for the years 1740, 1911, and 1979. Source, Kenyon 1969.

Food and Cover:

The daily nutritional need for sea otters can be up to 30% of their individual body weight and will feed either as individuals or in small cohorts (Costa 1978, Kvitek et al. 1992). In the Aleutian Archipelago red sea urchins are the primary prey source; red sea urchins have been shown to make up approximately 22% of sea otters' diets (Laidre and Jameson 2006). Since sea otters require a high number of daily calories, which plays a significant role in prey selection, the amount of surface time (metabolic energy being spent compared to dive time) is significantly correlated to prey densities, availability of preferred prey, and size (Laidre and Jameson 2006).

Sea otters prefer to forage for prey items in shallower water and will move to deeper waters if prey have been depleted or if it's more metabolically efficient (Kvitek et al 1992*a*). Sea otters feed primarily on sea urchins, but if other prey species are more abundant, they will feed primarily on those prey items (Calkins 1978, Kvitek and Oliver 1992*b*, Kvitek et al. 1993). Sea otters inhabiting areas with a softer substrate composition are more inclined to feed on bivalves such as butter clams (*Saxidomus giganteus*) (Calkins 1978). In more southern extents of sea otter

habitat, individuals have been shown to have drastically different prey selection than other individuals in their population (Estes et al. 2003).

Dive times are highly correlated to how deep prey are within the substrate; otters will spend on average 55 seconds diving for sea urchins (Laidre and Jameson 2006). Also, otters are systematic foragers and are able to find the exact location of buried bivalves and, in some cases, are able to decipher which contain toxic dinoflagellate (Kvitek and Beitler 1991, Kvitek et al. 1993, Kvitek and Oliver 1992*b*).

Since sea otters are generalist predators in their ecosystem the have a significant impact on community assemblages (Kvitek et al. 1992*a*). Red sea urchins are the most metabolically cost-efficient prey species for sea otters of the islands because of their abundance and ability to be consumed easily. Areas with large, rocky pinnacles are ideal habit for sea urchins and, subsequently, good habitat for sea otters in the Aleutian Islands (Kvitek and Oliver 1992*b*).

Studies have shown that sea otters prioritize habitat that is abundant in prey items that provide the greatest energetic return with the least amount of expenditure; however, they will choose different habitat if there is an increased risk of predation. It's been shown that animals will avoid areas with high food availability if the same areas are also associated with increased risk of predation (Gilliam and Fraser 1987). Throughout the decline of sea otters on the islands in the 1990s, otters started to become selective of the near shore habitat that they utilized. (Estes et al. 2010). Research has since come to find that the increased killer whale (*Orcinus orca*) predation caused this shift in habitat selectivity (Stewart et al. 2015).

In the past sea otters were known to be associated with large coasts that slope gradually in to the ocean; now, we see more individuals inhabiting large outcrops of exposed rock (Stewart et al 2015). It appears that otters now prefer habitat that consists of a least 28 outcrops of

exposed rock per 20,000 m2, with 13-28% of these rocks perpetually exposed, and that are located in areas with complex ocean floor topography (Stewart et al. 2015). The factor of increased predation causes a trade-off between sustenance and refuge (Sih 1980).

Disease:

The most lethal diseases that affect sea otters are acanthocephalan infection, encephalitis caused by *Toxoplasma gondii*, and cardiac disease (Kreuder et al. 2003). Encephalitis is seen to be one of the leading causes in death of sea otters in California; it causes the brain and surrounding tissue to develop lesions that become inflamed then necrotize and is most commonly found in male, adults (Miller et al. 2002, Kreuder et al. 2003). Felines and rodents are the only known vector of this specific encephalitis causing protist, however they can pass *T. gondii* to sea otters through contaminated coastal freshwater ways (Miller et al. 2002, Elmore et al. 2010). Currently there are many cases of beach-cast carcasses of southern sea otters *(E. lutris nereis*) infected with *T. gondii* that have been found at various beaches in California, and one study observing the protist in northern sea otters (*E. lutris kenyoni*) in Washington (Lindsay et al. 2001, Miller et al. 2002, Kreuder et al. 2003). There are also several strains of *T. gondii* which makes it possible for sea otters in the Aleutian Islands to contract the protist if individuals aren't infected already (Lindsay et al. 2001). Infection is highest in males that are of either adult or senior age and it has been reported that 59% of males and 61% of adults in 20 km area were positively diagnosed as dying from encephalitis caused by *T. gondii*; it should also be noted that in areas where there is heavy freshwater outflow 76% of sea otters were infected with *T. gondii* (Miller et al. 2002). Since this disease has a significant impact on older males in a population it should not have an impact on fecundity, unless the number of males decreases to the point where a viable population can no longer be sustained. Contaminated waterways can often be traced back to urban areas, therefore it is suggested that an investment into infrastructure that stores excess

stormwater be built, so that it may be treated and reverted back into the soil at a later date (Weniger et al. 1983, Gaffield et al. 2003). Humans are susceptible to infection (usually through contact with feline feces), but adults are at minimal risk of possessing fatal symptoms. Women that are pregnant and are infected can transmit *T. gondii* to the fetus which can result in deformities upon delivery or death (Elmore et al. 2010).

Reproduction and Population:

Sexual maturity for sea otters is usually obtained once individuals reach 5 years of age. Female sea otters only reproduce every other year, but breeding can occur during any time of year (Kenyon 1969). Breeding is most frequent in the months of October and November and the most births occur in late May or June (Schneider 1972). Females produce one pup every breeding period, but a captive female was observed giving birth to twins on one occasion (Snow 1910). Mating and birthing are both suggested to take place in water.

Sea otter populations consist of three stages classes; pup (< 1 yr), juvenile (1-2 yrs), subadult (2-4 yrs), and adult (> 5 yrs) (Fig. 3). Populations have been in significant decline since the mid-1960s and this is largely due to increased killer whale predation (Fig 4; Estes et al. 1998, Doroff et al. 2003). Sensitivity and elasticity matrices were conducted to observe which stage class would have the most significant effect on population dynamics (Table 1).

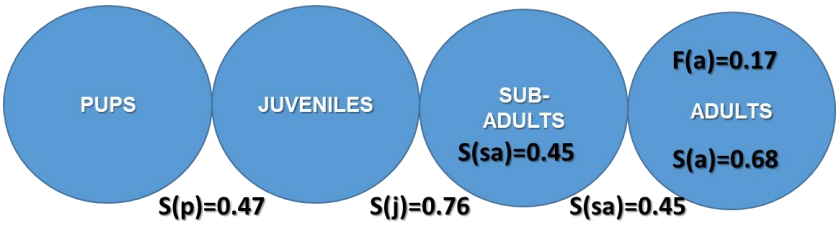

Figure 2: Life cycle diagram; where, S = survivability and F = fecundity per female. Survival rates outside the blue bubbles indicates probability of survival into the next year, survival rates inside the blue bubbles indicates probability of survival within the same stage.

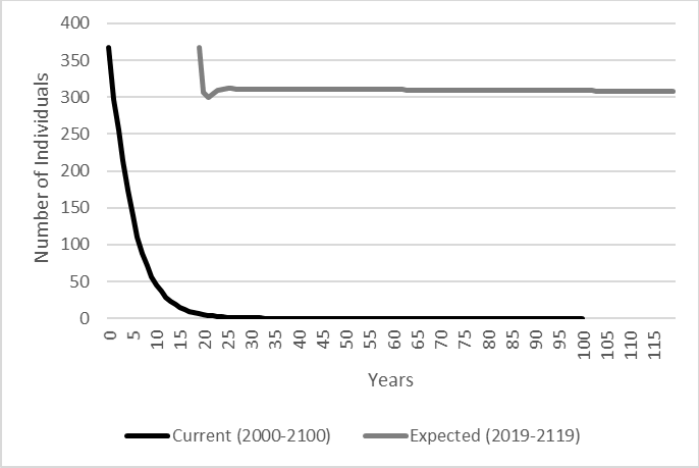

Figure 4: A population model that shows the current population trend and what the expected population trend would be if adult survival was increased to 93%

Table 1: Sensitivity (A.) and elasticity (B.) matrices for the current population trend. These matrices show the importance of each life stage and its relationship to survivability.

	Sensitivity Matrix			
(A.)	*F*(p)	*F*(j)	*F*(sa)	*F*(a)
Pup	0.2459	0.0533	0.1136	0.4265
Juvenile	0.1549	0.0908	0.1937	0.7272
Subadult	0.1633	0.0958	0.2043	0.7667
Adult	0.1308	0.0767	0.1636	0.6140

(B.)	Elasticity Matrix			
	F(p)	*F*(j)	*F*(sa)	*F*(a)
Pup	0	0	0	0.090843903
Juvenile	0.090843903	0	0	0
Subadults	0	0.090843903	0.113436095	0
Adult	0	0	0.090843903	0.523188295

NEED STATEMENT:

History and Factors:

Sea otters (*Enhydra lutris*) inhabit the islands of the Aleutian Archipelago and are considered a globally endangered species (International Union for Conservation of Nature 2018). Paleo-ecological records have shown the ancient Aleuts of the western islands once used the sea

otter as a food source and consequently altered the fish and invertebrate nearshore communities (Simenstead et al. 1978). At the turn of the 20th century sea otter populations were near extinction until international legislation was established to protect the species (Estes 1990, Doroff et al. 2003, IUCN 2018). Today, populations have been declining since the 1960s and it is most likely due to increased predation from killer whales (*Orcinus orca*, Estes et al. 1998). Sea otters are important to their ecosystem because they are a keystone species that effect the interactions between sea urchins (*Strongylocentrotus* spp.), kelp (*Nereocystis luetkeana*), and other near shore communities (Estes et al. 1998, Doroff et al. 2003). There are currently management plans for the species commissioned by Canada and an outdated plan commissioned by the state of Alaska (DeGange 1994, Fisheries and Oceans Canada 2014).

Ecology:

Sea otters have played an important role in the recovery of native kelp beds because they feed primarily on sea urchins (Duggins 1980). A study conducted by Lairde and Jameson (2006) in Washington found that in areas where otters have been reintroduced, *Laminaria groenlandica* (a species of sea kelp) increased with the increased predation of sea urchins. Although sea otters show a preference for feeding on echinoderms, they have been known to feed on crustaceans, bivalves, snails, and other benthic invertebrates.

Pinnipeds have also been in severe decline and to compensate for this, killer whales have been feeding almost exclusively on sea otters. This new shift in feeding ecology has consequently caused sea otter populations to take a sharp decline in the past 50 years (Estes et al. 1998, Doroff et al. 2003). Since 1965 to 2001 sea otter populations in the Aleutian Islands have decline ~90% with an annual decline of 17%; compared to a 17-20% projected annual rate of increase estimated in 1990 (Estes 1990, Doroff et al. 2003).

Overexploitation has caused a bottle neck effect in the gene pools of these populations across the western coast of North America. A study conducted by Larson et al. (2002) compared four loci between pre-fur trade populations and current populations. The pre-fur trade populations had significantly more alleles (n = 32) at the four loci compared to that of the current populations (mean 12.8 ± 0.735 SE, $P = 0.004$). It is predicted that bottlenecking will continue to decrease genetic diversity by inbreeding, decrease in individual fitness, and ultimately go extinct due to effects of natural events (Wildt et al. 1987, Lacy 1997).

The current decline in sea otter populations will have significant long-term effect on nearshore/benthic communities. Historical evidence shows that the decline in sea otters will result in a trophic cascade of primary producers such as kelp and macroalgae, causing pelagic species of fish to dominate the nearshore (Simenstad et al. 1978, Duggins 1980, Laidre and Jameson 2006).

Economic:

Since the end of the fur trade in the early 20th century, sea otters are no longer hunted. The coasts of many of the islands are classified as marine protected areas by the National Oceanic and Atmospheric Administration, these areas contribute to a lot of ecotourism in Alaska (NOAA; National Oceanic and Atmospheric Administration 2018). Wildlife ecotourism contributes to about $550 million, from nearly 646,000 visitors, annually (Alaska Department of Commerce and Economic Development. 1984). The Exxon Valdez oil spill of 1989 killed many marine wildlife species, including sea otters, and still has a negative effect on ecotourism (Dorsett 2010). In addition to revenue generated from ecotourism, conservation of wildlife and natural resources provides jobs for locals and non-residences; major conservation projects can sometimes generate upwards of tens-of-millions of USD (Tallis et al. 2008).

Sociocultural:

Alaska's sea otters have been used by native people for an estimate of roughly 12,000 years and have been a valuable food source for native Aleuts (Drucker 1951). Today hunting of sea otters have been reserved for the native people of Alaska while commercial harvest is prohibited (U.S. Fish and Wildlife Service 2014). The Alaskan government has worked diligently with native tribes to conserve their valuable resource but are worried that new legislation will be passed that won't consider the Aleuts traditional needs and concerns in regard to sea otter hunting (Nuu-chah-nulth Tribal Council 2012).

In more southern extents of their range, sea otters are considered a nuisance to red abalone fisheries (Fanshawe et al. 2003).

Legalities and Regulations:

The Endangered Species Act gives the most general protection for sea otters in the United States; all federal entities that are responsible for environmental protection are required to take any action in preventing the extinction of sea otters (16 U.S.C. § 1531). This act is general an does not provide adequate consideration for allocation of financial resources. The marine mammal protection act (16 U.S.C. §§1361-1383b) is focused specifically on the protection of marine mammals and has been responsible for sea otter protection over the past 20 years. The fur seal act of 1966 (16 U.S.C. 1165) provides protection against the consumptive use of sea otters in order to prevent extinction caused by the fur trade.

MANAGEMENT PLAN:

Goal: Stabilize population on islands that were not at equilibrium in 1965 at approximately 300 individuals by 2026.

Objective 1: Stop hunting of sea otters by natives from 2019-2026.

Action 1.1: Send out surveys to gain an understanding of how many people hunt sea otters, for what purposes, and how important sea otters are for them. Historically Aleuts hunted sea otters as a food resource for almost 8,500 years, but there is no data explaining why natives are still hunting sea otters (Laughlin 1972, Lichtenstein 2013).

Action 1.2: Brochures can be effective in give the public information and interest in wildlife conservation issues. A study conducted on tourist satisfaction showed that people had an increase interest in the city that they were touring because of the brochures that they received (Zhou 1997). Therefore, action 1.2 suggests handing out brochures to the public in order to raise awareness on the management goal and processes in hopes that natives will be more inclined to stop hunting sea otters for the duration of the management plan.

Action 1.3: Indigenous groups of people around the world have not always had steady relationships with government agencies. That is why this study suggests working with Alaskan tribes that still consumptively use sea otters and create a temporary ban on hunting sea otters (Sasaoka and Laumonier 2012). This ban will be compliant with "The Appropriate Standards Requirement" from the Office for State, Tribal, Local and Territorial Support, as to not infringe upon any rights of the native people (Menon 2019).

Action 1.4: If no actions were taken sea otter populations could potential rebound by themselves, but it's highly unlikely due to isolated conditions, increased predation, and low recruitment (Estes et al. 1998, Larson et al. 2002).

Final Courses of Action (1.1-1.3): *The combined efforts stated in actions 1.1 and 1.2 allow for the management plan to get an adequate understanding of the demographic hunting sea otters and the importance of their consumptive use (Zhou 1997, Lichtenstein 2013). What would then follow is a collaborative effort, stated in action 1.3, between the native tribes, and state and*

federal agencies to form an appropriate temporary ban that is compliant with Native Alaskan rights and the goal of the management plan (Sasaoka and Laumonier 2012, Menon 2019).

Assessment Protocol: *The implementation of a survey will begin in 2019, and data from these surveys will be collected until one year after the initial distribution (Appendix 1). Surveys will be sent to all tribes recognized as Alaska Natives or Native Americans in the State of Alaska. Within each tribe 15 random households will be selected to receive a survey. This survey will provide the management team with adequate data if at least 56% (± 3%) of the households that received surveys return them (Koval and Mertig 2004). The next step would be to handout brochures to the tribes in the Aleutian Islands to inform them on the management plan that we are proposing.*

If the study finds that the data are adequate and there is a majority favor for stopping sea otter hunting then the plan will proceed with forming a committee from various federal and state environmental agencies, and Alaska Natives that hold positions in the tribes' councils. Members representing the Native Alaskan tribes will be asked to join the committee if data from the survey show that their tribes prioritize sea otter hunting over other tribes. The goal of the committee is to form "cease hunt" on sea otters that is able to meet the management plan's objective while also respecting the rights of the indigenous peoples in Alaska (Castro and Nielsen 2001).

If indigenous people have no interest in stopping sea otter hunting, this plan might abandon this objective to focus attention and resources to the other two objectives described. This objective will be considered a success if we can get the hunting of sea otters to stop for the duration of the plan while satisfying the needs of the indigenous Alaskans that consumptively utilize the sea otter.

Objective 2: Decrease predation from killer whales by 50% by 2026.

Action 2.1: Survey the general population will allow for this plan to understand people's perception on recreational whaling to decrease predation on sea otters. According to the IUCN (2017), there is little information to classify killer whales as endangered, but predation rates show that they are not lacking in abundance (Estes et al. 1998).

Action 2.2: Opening a season for whaling killer whales has the potential to control their populations similar to deer hunting and the take of other large mammals (Brown et al. 2000, Packer et al. 2009). Killer whale hunting is feasible, but this plan would need to gain more information about population sizes around the Aleutian Islands which is currently lacking (IUCN 2017). In addition, human participation is key to the success of this action (Treves 2009).

Action 2.3: Since killer whale predation is the leading cause of sea otters in the Aleutian Islands, it is possible that sea otter populations will continue to decline, and then become extinct (Estes et al. 1998, Doroff et al. 2003). This would happen if there was no action taken to stop killer whale predation.

Final Courses of Action (2.1 & 2.3): *Opening a harvest season for killer whales doesn't appear to have any detrimental effects on killer whale populations (IUCN 2017). Therefore, this study suggests opening a season for killer whale hunting within the coastal boundaries of all Aleutian Islands once enough data is collected on how many people would actually hunt killer whales.*

Assessment Protocol: *The first step would be to construct a survey to distribute to cities in Alaska that have a population greater than 30,000 residence and/or are located less than 50 miles from the shore. The survey will consist of questions that give the study an idea of what attitudes and knowledge the public has about killer whales (Appendix 2). We will then mail surveys to 15,000 people from the total population of the cites that meet the criteria stated above.*

This representatives' information can be gained through an organization such as Survey Sampling, Inc. (Shelton, CT.). The survey will be considered a success if at least 56% (± 3%) of people return the surveys. This objective will proceed further in the plan if between 15-40% of the respondants have a positive opinion on killer whale hunting (Koval and Mertig 2004). These surveys will have 6 months from the time of release to get a response, and then the data will be analyzed.

Once the surveys are submitted back this plan will proceed in establishing the appropriate harvest regulations and have a season opened before the end of 2020. This objective would be considered a success if by 2026 we saw a decrease in killer whale predation of 50%. Alternative actions would include increasing or decreasing harvest limits and/or hiring state employees to hunt killer whales.

Objective 3: Increase the number of adults by at least 30% in areas that provide protection from killer whales by 2026.

Action 3.1: Since the predation by killer whales is the reason for the recent decline in sea otters, it is important to provide adequate habitat for individuals to seek refuge (Kenyon 1969, Estes et al. 1998). Therefore, increasing the amount of exposed rocky surfaces has the potential to increase the number of breeding females on the islands. This type of shoreline habitat is not easily created, but suitability analysis can be performed, and thus we can move breeding adults to areas that provide protection from killer whales (Brooks 1997, Stewart et. al 2015).

Action 3.2: Increase protection of coasts with prime protection habitat by stopping human expansion. operations and archeological operations until 2026. The Aleutians have been the sites for many archeological excavations and these digs take place near the coasts causing disturbances to ecological processes (Erlandson and Rick 2008). Also, this plan aims to extend

marine protected areas guidelines so that very minimal human traffic occurs during the implementation of the plan (National Oceanic and Atmospheric Administration 2018)

Action 3.3: Since it is difficult for individuals to disperse to different islands, and even different areas on islands they already inhabit, this study suggests transplanting females and males at a two to one ratio, respectively, from populations in southeast Alaska. There should be a density of seven females per square kilometer (Bigg and MacAskie 1978).

If transplants are successful there should be a 10-12% annual increase in sea otters due to increased fecundity (Kenyon 1969). By 2026 there is expected to be a total of 310 individuals at islands that were not at equilibrium in 1965 (Fig. 3). Taking individuals from the Kodiak islands rather than stable Aleutian populations will introduce new genetic material and increase fitness of the populations (Larson et al. 2002).

Action 3.4: If no actions were implemented, it is most likely that the population will rapidly decline until there are no otters by the year 2032; because adults are the most influential component in the survival of these populations (Fig. 3, Table 1).

Final courses of action (3.1-3.3): *Actions 3.1 and 3.2 will allow managers to assess the areas that provide adequate protection from predators, and then increase the amount of protection from human impacts (Brooks 1997, Stewart et. al 2015, NOAA 2018). Action 3.3 allows the plan to use the knowledge it has gain, to influence the survivability of adult sea otters.*

Assessment Protocol: *This this objective will be considered complete if this plan can successfully identify areas provide adequate protection from killer whales and successfully transplant breeding individuals of both sexes. These areas should consist of large rocky outcrops that are continually exposed above the surface of the water. The objective as a whole will be considered successful if the breeding pairs that are transplanted continue mating in the*

established areas after 2026. If the objective is not met through these actions a last resort would be to improve areas already established by sea otters.

CONCLUSION:

This management plan aims to increase the sea otter populations in the Aleutian Islands and sustain a minimum population of approximately 300 individuals. The main agencies that will be employed to conduct this management plan are the Federal Department of Fish and Wildlife and the Alaska Department of Fish and Game. If the goal is achieved in the described time frame, a monitoring plan will then be implemented to ensure that the populations are stable. Sea otter management plans have been successful in other parts of Alaska; therefore, there is a good chance this plan will be successful for the Aleutian Islands.

LITERATURE CITED:

Alaska Department of Commerce and Economic Development. 1984. Alaska economic and statistical review. Juneau, Alaska, USA.

Barabash-Nikiforov, I. I. 1947. Kalan (The sea otter). Soviet Ministrov RSFSR. (Transl. from Russian by Israel Program for Sci. Transl., Jerusalem, Israel, 1962, 227 pp.)

Bigg, M. A. and I. B. MacAskie. 1978. Sea otters reestablished in British Columbia. Journal of Mammalogy 59:874-876.

Brooks, R. P. 1997. Improving habitat suitability index models. Wildlife Society Bulletin 25:163-167.

Brown, T. L., D. J. Decker, S. J. Riley, J. W. Enck, T. B. Lauber, P. D. Curtis, and G. F. Mattfeld. 2000. The future of hunting as a mechanism to control white-tailed deer populations. Wildlife Society Bulletin, 28:797-807.

Calkins, D. G. 1978. Feeding behavior and major prey species of the sea otter, *Enhydra lutris*, in Montaque Strait, Prince William Sound, Alaska. Fisheries Bulletin 76:125-131.

Castro, A. P., and E. Nielsen. 2001. Indigenous people and co-management: implications for conflict management. Environmental Science & Policy 4:229-239.

Costa, D. P. 1978. The ecological energetics, water, and electrolyte balance of the California sea otter (*Enhydra lutris*). Ph.D. dissertation, University of California, Santa Cruz, Santa Cruz.

DeGange, A. R. 1994. Conservation plan for the sea otter in Alaska. U.S. Fish and Wildlife Service, Marine Mammals Management, Anchorage, Alaska, USA.

Doroff, A. M., J. A. Estes, M. T. Tinker, D. M. Burn, and T. J. Evans. 2003. Sea otter population declines in the Aleutian archipelago. Journal of Mammalogy 84:55-64.

Dorsett, M. 2010. Exxon Valdez oil spill continued effects on the alaskan economy. Colonial Academic Alliance Undergraduate Research Journal 1:7.

Drucker, P., 1951. The Northern and Central Nootkan Tribes. Smithsonian Institution. Bureau of American Ethnology, Washington, DC.

Duggins, D. O. 1980. Kelp beds and sea otters: an experimental approach. Ecology 61:447-453.

Elmore, S. A., J. L. Jones, P. A. Conrad, S. Patton, D. S. Lindsay & J. P. Dubey. 2010. *Toxoplasma gondii*: epidemiology, feline clinical aspects, and prevention. Trends in parasitology 26:190-196.

Erlandson, J. M., and T. C. Rick. 2008. Archaeology, marine ecology, and human impacts on marine environments. Human Impacts on Ancient Marine Ecosystems: A Global Perspective 1:1-20.

Estes, J. A. 1990. Grow and equilibrium in sea otter populations. The Journal of Animal Ecology 1:385-401.

Estes, J. A., M. T. Tinker, T. M. Williams, and D.F. Doak. 1998. Killer whale predation on sea otters linking oceanic and nearshore ecosystems. Science 282:473-476.

Estes, J. A., M. L. Riedman, M. M. Staedler, M. T. Tinker, & B. E. Lyon. 2003. Individual variation in prey selection by sea otters: patterns, causes and implications. Journal of Animal Ecology 72:144-155.

Estes, J. A., J. L. Bodkin, and M. T. Tinker. 2010. Threatened southwest Alaska sea otter stock: delineating the causes and constraints to recovery of a keystone predator in the North Pacific Ocean. North Pacific Research Board Final Report 717:117.

Fanshawe, S., G. R. Vanblaricom, and A. A. Shelly. 2003. Restored top carnivores as detriments to the performance of marine protected areas intended for fishery sustainability: a case study with red abalones and sea otters. Conservation Biology 17:273-283.

Fisheries and Oceans Canada. 2014. Management plan for the sea otter (*Enhydra lutris*) in Canada. Species at Risk Act Management Plan Series. Fisheries and Oceans, Ottawa, Toronto, Canada.

Gaffield, S. J., R. L. Goo, L. A. Richards, & R. J. Jackson. 2003. Public health effects of inadequately managed stormwater runoff. American Journal of Public Health 93:1527-1533.

Gilliam, J. F., and D. F. Fraser. 1987. Habitat selection under predation hazard: test of a model with foraging minnows. Ecology 68:1856-1862.

International Union for the Conservation of Nature [IUCN]. 2017. IUCN Red List of Threatened Species search. Killer whale, *Orcinus orca*. <http://www.iucnredlist.org/details/22780/0>. Accessed 17 April 2019.

International Union for the Conservation of Nature [IUCN]. 2018. IUCN Red List of Threatened Species search. Sea otter, *Enhydra lutris*. <http://www.iucnredlist.org/details/22780/0>. Accessed 10 Feb 2019.

Kenyon, K. W. (1969). The sea otter in the eastern Pacific Ocean.Volume 68. US Government Printing Office, Washington (DC), USA.

Koval, M. H., and A. G. Mertig. 2004. Attitudes of the Michigan public and wildlife agency personnel toward lethal wildlife management. Wildlife Society Bulletin 32:232-243.

Kreuder, C., M. A. Miller, D. A. Jessup, L. J. Lowenstine, M. D. Harris, J. A. Ames, ... & J. A. K. Mazet. 2003. Patterns of mortality in southern sea otters (*Enhydra lutris nereis*) from 1998–2001. Journal of Wildlife Diseases 39:495-509.

Kvitek, R. G., and M. K. Beitler. 1991 Relative insensitivity of butter clam neurons to saxitoxin: a pre-adaptation for sequestering paralytic shellfish poisoning toxins as a chemical defense. Marine Ecology Progress Series 69:47-54.

Kvitek, R. G., J. S. Oliver, A. R. DeGange, and B. S. Anderson. 1992*a*. Changes in Alaskan soft-bottom prey communities along a gradient in sea otter predation. Ecology 73:413-428.

Kvitek, R. G., and J. S. Oliver. 1992*b*. The influence of sea otters on prey communities in southeast Alaska. Marine Ecology Progress Series 82:103-113.

Kvitek, R. G., C. E. Bowlby & M. Staedler. 1993. Diet and foraging behavior of sea otters in southeast Alaska. Marine Mammal Science 9:168-181.

Lacy, R. C. 1997. Importance of genetic variation to the viability of mammalian populations. Journal of Mammalogy 78:320-335.

Laidre, K. L. and R. J. Jameson. 2006. Foraging patterns and prey selection in an increasing and expanding sea otter population. Journal of Mammalogy 87:799-807.

Larson, S., R. Jameson, M. Etnier, M. Fleming, and P. Bentzen. 2002. Loss of genetic diversity in sea otters (*Enhydra lutris*) associated with the fur trade of the 18th and 19th centuries. Molecular ecology 11:1899-1903.

Laughlin, W. S. 1972. Ecology and population structure in the Arctic. The structure of human populations, Oxford University Press, Oxford, England.

Lekh, S. 1907. Some observations on the sea otters inhabiting Medny Island in the Commander Islands. Zap 10:1-37.

Lichtenstein, M. 2013. Sea Otter numbers and harvests on the rise. <http://www.adfg.alaska.gov/index.cfm?adfg=wildlifenews.view_article&articles_id=637>. Accessed 15 April 2019.

Lindsay, D. S., N. J. Thomas, A. C. Rosypal, & J. P. Dubey. 2001. Dual *Sarcocystis neurona* and *Toxoplasma gondii* infection in a Northern sea otter from Washington state, USA. Veterinary Parasitology 97:319-327.

Menon, A. 2019. American Indian and Alaska Native Hunting and Fishing Rights. Centers for Disease Control and Prevention, Atlanta, Georgia, USA.

Miller, M. A., I. A. Gardner, C. Kreuder, D. M. Paradies, K. R. Worcester, D. A. Jessup, ... & P. A. Conrad. 2002. Coastal freshwater runoff is a risk factor for *Toxoplasma gondii* infection of southern sea otters (*Enhydra lutris nereis*). International journal for parasitology 32:997-1006.

National Oceanic and Atmospheric Administration [NOAA]. 2018. What is a marine protected area? <https://oceanservice.noaa.gov/facts/mpa.html>. Accessed 11 April 2019.

Nuu-chah-nulth Tribal Council. 2012. DRAFT—A management plan for kw akw atl (sea otter) in the Nuu-chah-nulth Ha' houlthee, West Coast Vancouver Island. Nuu-chah-nulth Fisheries Program, Port Alberni, BC, p. 28.

Ogden, A. 1941. The California sea otter trade, 1784-1848. Univ. California Press, Berkeley, 251 pp.

Packer, C., M. Kosmala, H. S. Cooley, H. Brink, L. Pintea, D. Garshelis, and L. Hunter. 2009. Sport hunting, predator control and conservation of large carnivores. PloS one 4:1-9.

Sasaoka, M., and Y. Laumonier. 2012. Suitability of local resource management practices based on supernatural enforcement mechanisms in the local social-cultural context. Ecology and Society 17:1-10.

Schneider, K. B. 1972. Reproduction in the female sea otter. Alaska Department of Fish and Game.

Sih, A. 1980. Optimal behavior: can foragers balance two conflicting demands? Science 210:1041-1043.

Simenstad, C. A., J. A. Estes, and K. W. Kenyon. 1978. Aleuts, sea otters, and alternate stable-state communities. Science 200:403-411.

Snow, H. J. 1910. In Forbidden Seas. Recollections of sea-otter hunting in the Kurils... Illustrated. Edward Arnold.

Stewart, N. L., B. Konar, and M. T. Tinker. 2015. Testing the nutritional-limitation, predator-avoidance, and storm-avoidance hypotheses for restricted sea otter habitat use in the Aleutian Islands, Alaska. Oecologia, 177:645-655.

Tallis, H., P. Kareiva, M. Marvier, and A. Chang. 2008. An ecosystem services framework to support both practical conservation and economic development. Proceedings of the National Academy of Sciences 105:9457-9464.

Treves, A. 2009. Hunting for large carnivore conservation. Journal of Applied Ecology 46:1350-1356.

U.S. Fish and Wildlife Service. 2014. Marine Mammal Management. <https://www.fws.gov/alaska/fisheries/mmm/seaotters/otters.htm>. Accessed 12 Feb 2019.

Weniger, B. G., M. J. Blaser, J. Gedrose, E. C. Lippy, & D. D. Juranek 1983. An outbreak of waterborne giardiasis associated with heavy water runoff due to warm weather and volcanic ashfall. American journal of public health 73:868-872.

Wildt, D. E., M. Bush, K. Goodrowe, C. Packer, A. E. Pusey, J. L. Brown, ... and° S. J. O'Brien. 1987. Reproductive and genetic consequences of founding isolated lion populations. Nature 329:328.

Zhou, Z. 1997. Destination marketing: Measuring the effectiveness of brochures. Journal of Travel & Tourism Marketing 6:143-158.

APPENDIX 1

A sample survey for the management plan to gain an understanding of how many Native Alaskans are hunting sea otters and how they would feel about banning hunting for the duration of the management plan.

1. Please state what Native Alaskan tribe you reside in.

2. Do you hunt sea otters?
    a. Yes
    b. No (Please disregard the following questions but do send the survey back to the return address)

3. How often do you leave your residence with the intention hunt sea otters?
    a. Once during the season
    b. 2-5 times during the season
    c. More than 5 times during the sea

4. How long have you been hunting sea otters?
    a. Less than 1 year
    b. 1-5 years
    c. 6-10 years
    d. 11-15 years
    e. More than 15 years

5. What is the main reason why you hunt sea otters? (please select only one answer)
    a. Food
    b. Pelt
    c. Bones
    d. Other_____

6. How severe would an 8-year ban on sea otter hunting impede your way of life?
    a. Severely impede
    b. Slightly impede
    c. Not impede
7. On a scale from 1-5 how likely would you allow a ban on hunting sea otters if it was for better management of the species? (1 being not highly unlikely and 5 being highly likely)
    a. 1
    b. 2
    c. 3
    d. 4
    e. 5
8. Please select your age bracket.
    a. Younger than 18 years
    b. 18-35 years old
    c. 36-55 years old
    d. 56-75 years old
    e. Older than 75 years
    f. Prefer not to answer

*** Thank you for completing this survey. Your participation is highly valued and extremely important to wildlife management.***

APPENDIX 2

Sample survey to gain an understanding if people would be receptive to opening a season on hunting killer whales in Alaska.

1. Please state the current city you reside in Alaska.

2. How often do you live in Alaska?
    a. Year-round
    b. Seasonal
3. How long have you lived in Alaska?
    a. Less than a year
    b. 1-5 years
    c. 6-10 years
    d. 11-15 years
    e. More than 15 years
4. Do you participate in any of the following recreational activities in Alaska? (Select all that apply)
    a. Fishing
    b. Clamming
    c. Hunting
    d. Boating
5. If selected hunting for the previous question, which of the following to you predominantly hunt? (Please select only one answer)
    a. Cervids (Deer, Elk, Caribou, Moose, etc.)
    b. Bears
    c. Canids (Wolves or Coyotes)
    d. Small game (Rabbits, Squirrels, etc.)
    e. Gallinaceous Birds (Grouse, Ptarmigan, etc.)
    f. Waterfowl (Ducks, Geese, etc.)
6. Have you ever thought about hunting killer whale?
    a. Yes
    b. No

7. How likely would you be to consider hunting killer whale if it were for the management of another wildlife species?
    a. Highly likely
    b. Likely
    c. Somewhat likely
    d. Unlikely
    e. Highly Unlikely

8. Please select your gender
    a. Male
    b. Female
    c. Non-binary
    d. Prefer not to answer

9. Please select your age bracket
    a. Younger than 18 years
    b. 18-35 years old
    c. 36-55 years old
    d. 56-75 years old
    e. Older than 75 years
    f. Prefer not to answer

*** Thank you for completing this survey. Your participation is highly valued and extremely important to wildlife management.***