The Importance of Keystone Species: Sea Otters in Alaska

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Abstract

Sea otters are an important keystone species in the marine system. Keystone species are species in an ecosystem that are not necessarily abundant, but those that other species greatly depend on. Without these keystone species, ecosystems could fail or drastically change. Sea otters are especially important in maintaining sea urchin populations which directly increases the health of kelp forests. It was not until the last few decades, however, that sea otter population numbers have begun to stabilize and increase to a more sustainable level, however, in some places they are still declining. Understanding whether there is a direct link between sea otters and sea health is important in understanding and determining the necessary conservation that needs to be implemented to help this endangered species. Although research has been done on the scale of impact that sea otters have on ecosystems, more research can be done to determine how sea otters affect sea urchins and kelp forests over an extended period of time. This study determined the importance of the sea otter as a keystone species of the Alaskan Islands by comparing and analyzing sea otter populations, sea urchin density, and kelp forest density over multiple decades. This comparison further confirmed the validity of the sea otter/urchin/kelp paradigm. Results have confirmed that sea urchin biomass and kelp density have an inverse relationship. Generally, my results have also shown that as the number of sea otters on an island increase, the sea urchin biomass on the island will decrease. Future studies should focus on how to apply this knowledge to the conservation of other keystone species.

Keywords: sea otters, keystone species, conservation

Introduction

Sea otters are an important keystone species in the marine system. It isn't until the last few decades that their population numbers have stabilized, however, sea otter populations overall are still in a state of decline (Jessup et al. 2004). Prior to the 21st century their population numbers dropped to a dangerously low level due to the fur trade and other negative human activities (Konar 2000). The maintenance of a healthy sea otter population is extremely important for both the sea otters and the environment. The conservation of sea otters sets off a chain reaction of positive effects on the ecosystem (Estes et al 2010). This is because sea otters feed on the sea urchins which would otherwise completely destroy kelp forests. These kelp forests are used as habitats for thousands of species of marine organisms as well as regulators of anthropogenic climate change.

The understanding of the importance of keystone species is essential because without keystone species the likelihood that entire ecosystems would fail drastically increases. The sea otter is a perfect example of a marine keystone species that both indirectly and directly benefits many trophic systems within the ecosystem (Estes et al. 2010). This research focuses on the importance of sea otters as a keystone species. This includes benefits to the ecosystem, recovery and conservation of the species, and decline in population size. By understanding the indirect and direct effects that the lack of sea otters has on an ecosystem or some location, better and more efficient efforts may be put in to the conservation of these sea creatures.

Key Terms and Concepts

A keystone species is a species that is not necessarily abundant in numbers but is of great importance to an ecosystem (Power et al. 1996). It is similar to the keystone in an arch; if the keystone falls, the arch does as well. In this case if the sea otter population declined to an extremely low level or went away completely, the marine ecosystem would suffer drastically due to the failing of this one mammal. A keystone species often keeps a specific species of animal or other living organism in check which, in turn, keeps the ecosystem healthy. Damage to a keystone species population could set off a chain reaction of negative effects towards the ecosystem which could eventually impact human quality of life in one way or another.

When referring to the food web, which sea otters greatly impact, the term "trophic" will be used.

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"Trophic" refers to nutrition, and in this case a trophic cascade is the ripple effect that is felt when a keystone species is removed completely or greatly diminished from an existing ecosystem (Estes et al. 2016). This trophic cascade is important in understanding the impact of a keystone species.

In understanding how the trophic system works, it is important to note that sea otters are secondary consumers. Secondary consumers are either carnivores or omnivores which primarily prey on primary consumers, also known as herbivores. In this case the sea otter is considered an omnivore as it feasts on animals such as sea urchins and plants such as kelp.

Background

Sea otters, or *Enhydra lutris*, cause both direct and indirect positive effects on kelp forests and marine systems. As a keystone species, sea otters do more than just keep the sea urchin population in check. They are important in keeping kelp forests alive and intact which provides habitats for many other marine species. They also mitigate negative anthropogenic effects. Conservation of the sea otter should be of utmost importance; however, this way of thinking became popular only in the latter half of the 20th century. Identifying and negating threats to the sea otter population is important as the species population as a whole is not entirely stable. By understanding how greatly the sea otters impact the marine ecosystem, more efforts may be put in to their conservation as a whole.

Aleutian Islands. Although sea otters can be found in various locations along the west coast, particular attention should be paid to the Aleutian Islands in Alaska. These islands span westward from the mainland of Alaska through the Bering Sea (Tollit et al. 2017). This Aleutian archipelago consists of 6 island groups called Andreanof, Near, Fox, Rat, Delarof, and the Islands of Four Mountains. Sea otter populations living on these islands were among the first to recover following their near extinction in the early 20th century (Doroff et al. 2003). Although many populations recovered on these islands between 1965 and 1992, there is now an alarming trend of population decline from 1992 to 2000 (Doroff et al. 2003). Although data from subsequent aerial surveys of these populations has yet to be published from the last couple of years, previous trends indicate that sea otter populations have and will continue to decline.

Sea Otters and Their Environment. In marine biology there is a sea otter/urchin/algae paradigm (Kvitek et al. 1998). Because kelps are brown algae seaweeds, this paradigm can be referred to as the former or as the sea otter/urchin/kelp paradigm. In the presence of sea otters, kelp forests are typically left intact and healthy which is useful as these are absorbers of carbon dioxide, a greenhouse gas. Of course, this doesn't take into consideration the many other ways that kelp forests could be damaged, such as by human activity, but the presence of sea otters seems to be a constant in areas with healthy kelp forests and other algae deposits.

Sea otters keep kelp forests in tact by feasting on sea urchins (Kvitek et al. 1998). A major part of a sea urchin's diet consists of kelp. Without sea otters keeping the sea urchin population in check, the urchins increase in size and become uncontrollable. This often results in massive sections of kelp forests being destroyed. This is important because sea otters help to decrease herbivory of kelp forests in order to turn areas that are generally sea urchin dominated into communities that are kelp forest dominated. Kelp forest dominated sections of the ocean usually have more diverse wildlife as they provide healthy marine habitats for many other aquatic species.

Kelp forests also indirectly reduce coastal erosion by reducing the harsh impact of waves (Jackson 1984). When kelp beds have been depleted because of predation by sea urchins, coastal health declines. Sea otters, however, have always been a good indicator of marine health. Because they often stay relatively close to the coastline, diseases and parasites that they acquire give scientists a good indication of which pathogens are local and dangerous (Jessup et al. 2004). This helps determine how healthy the coastal marine life actually is.

Sea otters also set off a trophic cascade if removed from an ecosystem as they are secondary consumers which control organisms from the top-down of the food web. Top-down control of a trophic system is when consumers depress the trophic level that contains the type of organisms they feed on which increases lower trophic levels (Estes et al. 2016). In other words, because sea otters consume large amounts of sea urchins, the kelp which the urchins feed on increase in population size and density. Because of this, sea otter predation has resulted in positive top-down effects. In the Elkhorn Slough, for example, the presence of sea otters has caused eelgrass beds to prosper. This increase in abundance to eelgrass has slowly mitigated the negative effects of nutrient loading in the slough (Hughes et al. 2013). This shows the importance of sea otter predation in consumer controls.

Conservation. It is not enough, however, to just acknowledge the importance of sea otters as a keystone species. Extensive effort also needs to be put in to the conservation of the sea otter. Humans fail to realize that the exploitation and decline in sea otter populations often is a result of anthropogenic reasons such as trapping, poaching, climate change, or just

carelessness. The aftermath of the Exxon Valdez oil spill is a good example of why more attention needs to be given to this important keystone species. Following this catastrophic oil spill in 1989, 878 sea otter carcasses were found floating on the surface of the water alone (Estes 1991). The exact number of sea otter deaths are not known because the sea otter population was only counted after the oil spill. If the importance of the sea otter was completely understood prior to this oil spill then more information could have been known about how detrimental this event was to the population.

Aside from catastrophes such as the Exxon Valdez oil spill, sea otters were also hunted to near extinction just over a century ago in the early 20th century, leading to overexploitation (Doroff et al. 2003). In the Aleutian Islands in Alaska, these sea otter populations were among the first to recover, however, they are now at an extreme low. It has been estimated that approximately three quarters of the sea otter population died in a span of 35 years (Doroff et al. 2003). This eradication of the sea otter occurred between 1965 and 2000. Previous information regarding the abundance of sea otters in Alaska are unknown as 1965 was one of the first years that surveys were taken and published. The main cause of mortality at this particular site was determined to be from killer whales although parasites are also a cause of death at other locations (Doroff et al. 2003). This decline in sea otter population is an alarming trend. Scientists aren't sure why their population has begun decreasing again in some locations, however, increased predation by whales is certainly one option (Slee 2009). Sea otters are also prone to infections caused by various water-borne parasites (Jessup et al. 2004). This unexpected decrease in sea otter population brings the health of kelp forests back into question.

Because of oil spills, predation, disease, and pollution, the population of sea otters has fluctuated greatly in the last decade. The loss of sea otter lives has landed the Northern Sea Otter on to the Endangered Species Act where it still remains today (Slee 2009). The state of the sea otter population is in question which leaves the general health of the entire marine ecosystem unknown.

Methods

Overview. In recent years much research has been done to determine the importance of keystone species. The importance of sea otters as a keystone species is just a small portion of that. This research consists of an extensive analysis of studies which discuss the effects that sea otters have on an ecosystem. This includes sea urchin biomass as well as kelp density. This meta-study used both published and unpublished data from official sources to compare sea urchin density and kelp forest health and density in areas with little to no sea otters to areas with a high sea otter population in the Aleutian Islands. Graphs were generated using the collected data to determine if any trends or patterns could be seen. Percent change was also calculated in order to determine which islands experienced the greatest amount of sea otter loss, kelp density loss, and sea urchin biomass increase.

Results

The number of sea otters counted on the Adak, Attu, Kiska, and Amchitka Islands were graphed against the sea urchin biomass recorded in the year 2000 (Fig. 1). Generally, the islands with upwards of 200 sea otters had low sea urchin biomass compared to those with fewer sea otters.

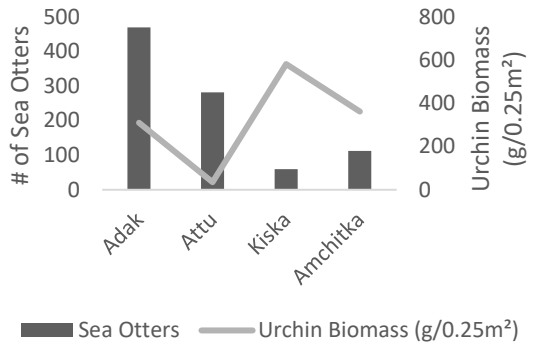

Figure 1. Sea otter abundance compared to sea urchin biomass across the Adak, Attu, Kiska, and Amchitka Islands of the Aleutian Islands of Alaska in the year 2000.

Kelp density on various islands was analyzed before and after sea otter decline over a period of 10 years (Fig. 2). All islands had a negative percent change in kelp density which suggested a decrease in kelp forests. Amchitka Island had the greatest percent change at 95% followed by Kiska at 91%. Adak Island had the lowest percent change at 82%. The average percent change between all 5 islands was 65%. Kelp density was also analyzed at Adak, Alaid, Amchitka, and Kiska Islands before and after an increase in sea urchin biomass (Fig. 3). Again, all islands had a negative percent change in kelp density. Amichitka Island had the highest percent change at 95% followed by Kiska at 91%. Adak Island had a percent change of 84% and Alaid Island had the lowest percent change at 81%. The average percent change between the 4 islands was 88%.

Kelp density was also analyzed against sea urchin biomass across the Aleutian Islands (Fig. 4).

This included data from 1987, 1990, 1993, 1994, 1997, 1999, and 2000. There was a negative correlation between kelp density and sea urchin biomass.

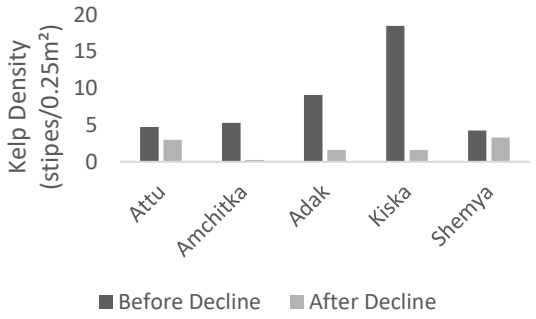

Figure 2. Kelp density on 5 islands within the Aleutian Islands before and after sea otter decline from 1990-2000.

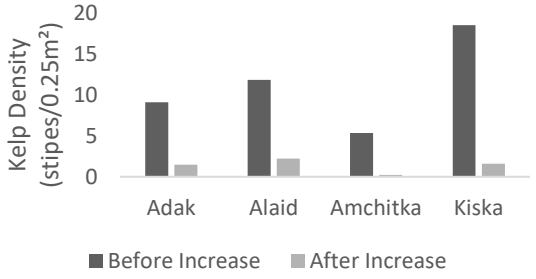

Figure 3. Kelp density on 4 islands within the Aleutian Islands before and after an increase in sea urchin biomass.

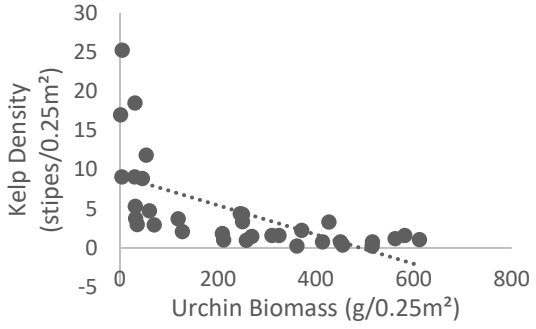

Figure 4. Plot of kelp density and sea urchin biomass trends across the Aleutian Islands of Alaska from 1987 to 2000.

Sea otter abundance on the six major island groups of the Aleutian Islands showed that all six experienced declines in population between 1992 and 2000 (Fig. 5). The number of sea otters also declined on various islands along the Alaska Peninsula from 1989 to 2001 (Fig. 6).

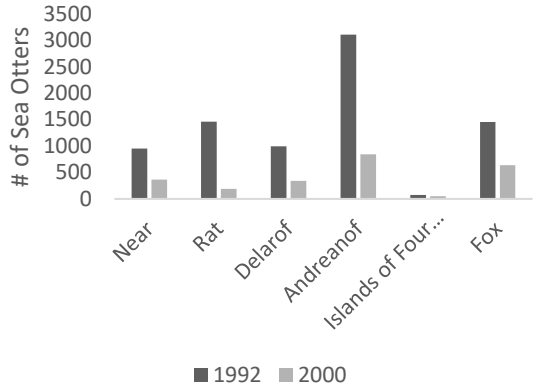

Figure 5. Sea otter abundance on the six major island groups of the Aleutian Islands in 1992 and 2000.

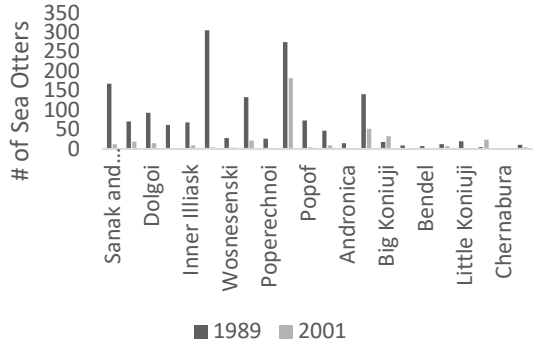

Figure 6. Sea otter abundance on various islands along the Alaska Peninsula in 1989 and 2001.

The adjusted estimate of sea otters in the Southwest, East, and Central Alaskan stock showed that the Southwest stock held the greatest amount of Northern Sea Otters while the Southcentral stock held the least (Fig. 7). This estimate is using data collected between the years of 2000 and 2008.

Figure 7. The number of recorded sea otters in the Southwest, Southeast, and Southcentral Alaskan stock.

Discussion

Based on the collected data, it is shown that kelp density and sea urchin biomass have a negative

correlation (Fig. 4). As sea urchin biomass increases, kelp density decreases. This trend remained constant from 1987 to 2000 in the Aleutian Islands. In figure 1, the abundance of sea otters on the Adak, Attu, Kiska, and Amchitka Islands was analyzed against the sea urchin biomass on each island in 2000. Adak and Attu had twice as many sea otter inhabitants as the Kiska and Amchitka Islands. The latter two islands also had much higher sea urchin biomasses than the Adak and Attu Islands. This is further evidence that the sea otter/ urchin/kelp paradigm is true. Islands with a decreasing number of sea otters had high sea urchin biomasses and, as a result, lower kelp density.

Further confirming this idea of the sea otter/urchin/kelp paradigm were figures 2 and 3. Comparing the kelp density on the Adak, Attu, Kiska, Amchitka, and Semya Islands, it is shown that after the number of sea otters decline on an island, the kelp density declines as well (Fig. 2). Amchitka Island had the greatest decline followed by Kiska Island. Both of these islands belong to the Rat Island group which is one of the western most of the Aleutian Islands. The Rat Island group had the highest percent change of sea otters from 1992 to 2000 with a percent change of 87%. (Fig. 5). Because these islands had the greatest loss of sea otters in the 1990s compared to the other major island groups it makes sense that this was followed by the greatest change in kelp density.

On some of the same islands, kelp density decreased following an increase in sea urchin biomass (Fig. 3). Again, Amchitka and Kiska Island had the greatest loss of kelp density. These islands, as part of the Rat Island group, also had the greatest loss of sea otters from 1992 to 2000 (Fig. 5). This lends evidence to the idea that sea otters control the sea urchins which, in turn, allows kelp density to remain abundant and stable. If kelp density declines then so does the health of the surrounding marine system. Kelp forests provide homes for various marine life as well as slowing the degradation and erosion of shores (Jackson 1984).

Overall, there has been a trend of sea otter decline from the mid-1980s until approximately 2001 (Fig. 6). The major island group, the Islands of Four Mountains lost the least amount of sea otter from 1992 to 2000, however, it was a small sample size compared to the other island groups. In 1992 this island was only inhabited by 72 sea otters and declined to 52 by 2000. This island group is located in the Eastern Aleutian Islands meaning that it is closer to the Alaskan mainland than the Rat Island group. It is possible that the Rat Island group had the greatest loss of sea otters because it is very far from the Alaskan mainland. Being far from the mainland means that it most likely does not experience great human disturbance, however, it likely suffers from a lack of sea otter immigration. It is possible that a lack of immigration would cause inbreeding among the sea otters, leading to ample disadvantageous mutations staying in the population.

Even islands that are not part of the six major island groups experienced sea otter decline from 1989 to 2001 (Fig. 6). These islands are still considered part of the Aleutian Islands, however, and contribute to the Southwest Alaskan stock (Fig. 7). Andronica Island, for example, experienced a 100% decline in sea otters during these years. The average decline in sea otters across these islands was 54%. This means that across these various standalone islands that at least half of the sea otter population disappeared in a span of only 12 years. Unless the population begins to recover, at this rate only approximately 25% of the sea otters that inhabited these islands in 2001 will inhabit them now. It is likely, however, that these numbers were skewed by the Exxon oil spill which occurred in 1989 (Estes 1991). The long-term effects of this oil spill could also explain why the least amount of sea otters reside in the Southcentral region of Alaska. This region of Alaska is where Prince William Sound is located which was also where the oil itself was spilled.

Conclusion

Sea otter populations are declining at a rapid rate. Although some populations are stable, most are experiencing a rate of decline that has landed the sea otter on the Endangered Species list. Research shows that sea otters indirectly cause many positive effects in regards to the marine system. When the number of sea otters on an island decreases, the sea urchin biomass then increases. When sea urchin biomass increases it has been shown that kelp density decreases as a result. Because kelp forests are such an integral part of local marine health it is important to make sure that they are left in tact and healthy.

One way to help sea otter populations would be to set up reserves along the Aleutian Islands. Preferably large reserves would be established instead of several small, separate reserves. If possible, reserves should also be relatively close together and connected by some type of corridor. Although this may be difficult to do because of where the Aleutian Islands are located it can be done. Also, minimizing direct and indirect anthropogenic effects would be ideal. This includes both the direct destruction of sea otter habitats

and hunting of the animals themselves. Killer whales have also begun feeding on sea otters due to overhunting of sea lions, the preferred prey of the killer whale. If humans allow sea lion populations to remain stable or increase then sea otter populations have a better chance of increasing. If sea otters, an important keystone species, are able to increase in number then the entire marine ecosystem would benefit. Conservation of these creatures is still possible and their importance has never been more clear.

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