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Apex Predator Conservation through Ecosystem Service valuation

Arjit Agarwal
arjitagarwal45@gmail.com

ABSTRACT

Large predators are the most well-known type of animals around the world, ranging from tigers, lions, bears and wolves who roam terrestrial ecosystems, to sea otters and Nile crocodiles who maunder aquatic ecosystems. Despite their ubiquitous popularity, their populations are in imminent danger. Large carnivore and predator populations are experiencing a precipitous decline which can lead to a colossal imbalance in ecosystems. Over the past two centuries, predators have experienced geographic range contractions, fragmentation of habitat, and loss of individuals through hunting. This literature review analyses and explains how the decline in large carnivore and predator populations can lead to indirect consequences within and across ecosystems. Using an ecosystem services valuation approach, this paper demonstrates how large predator conservation is not only economically justified, but imperative for widespread ecosystem stability.

Keywords— *Predator, Predators, Conserve, Conservation, Ecosystem, Ecosystem Services, Apex Predators, Protection*

1. INTRODUCTION

Predators play an important role in mediating the abundance and diversity of other animal populations (Menge & Sutherland 1976; Wallach et al 2015). All organisms can be classified into certain categories by looking at their trophic level. A trophic level is the position that an organism occupies on the food web, which is a succession of organisms that eat other organisms and may, in turn, be eaten themselves. The trophic level that an organism is located at is measured by counting the number of steps it is from the start of the food web (Lindeman 1942). Furthermore, the more notable and powerful trophic interactions can be called 'trophic cascades' (Hairston et al 1960; Fretwell 1987; Paine 1980).

There are two types of cascades, bottom-up and top-down cascades. Bottom-up cascades are caused by the population decline of a producer or primary consumer. Top-down cascades are caused by the population decline of a top predator. The interactions between individuals across multiple trophic levels is essential to maintaining extant biodiversity in ecosystems, but when large predators are extirpated from the food web, it rearranges all trophic interactions that take place between organisms in each of the levels. Loss of top-down trophic cascades concurrently results in lost ecosystem services (***refer to 'Predator ecology & ecosystem services' for definition***), produced by the apex predators or carnivores who have been extirpated from their ecosystems. Loss of ecosystem services can lead to some issues that will be discussed within this literature review, including overgrazing, carbon release, and nutrient diffusion and distribution. It is crucial, however challenging, that we as humans take on the responsibility to reduce detrimental impacts to predator populations to restore ecosystem processes for humans and animals alike (Estes et al 2011; Ripple et al 2014; Rasher et al 2020).

2. PREDATOR ECOLOGY AND ECOSYSTEM SERVICES

Borrowed from Latin predator, the English term 'predator' by definition is an organism that eats all or part of the body of another organism. In ecology, there are four distinct types of ecological interactions that can take place between organisms: carnivory, herbivory, parasitism, and mutualism. Scientifically, they are considered predation as they are acts of one organism feeding on parts of another organism, despite the common view of predation being the act of an animal killing and eating another animal. Carnivory takes place when a predator consumes meat, rather than plants, and consequently kills its prey, such as lions or tigers. Herbivory is a type of predation in which organisms consume autotrophs - individuals that produce their own food- such as plants, algae, and photosynthesizing bacteria such as deer, caterpillars or koalas. Parasitism takes place when one organism benefits at the expense of another, such as hookworms or lice. Mutualism is similar to parasitism except both species benefit from this interaction such as sea anemones protecting clownfish.

This literature review focuses on predators in a more conventional sense, specifically organisms that are classified as carnivores or omnivores. Animals that are required to hunt and kill other animals for either the majority or a part of their lives tend to receive more attention and attract an inherent interest from people, despite the irony being that they are highly endangered by human action (Schmitz et al 2010). Ecologists in particular are fascinated by predators due to the roles they play in their ecosystems, and through those roles, the ecosystem services they produce (Ripple et al 2014; Rasher et al 2020).

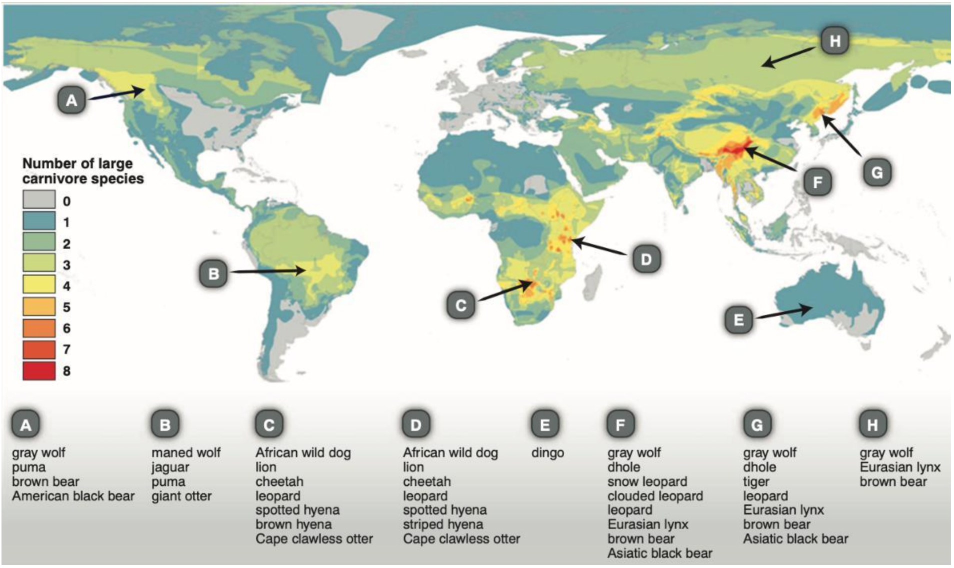

Figure 1: The overall distribution of a huge range of large and apex predators on a global scale. The letters assigned to predator populations are dictated by the geographical location where they live.

Graph credits: Ripple et al 2014

An ecosystem service is a beneficial by-product of an organism's activity across its lifetime , such as killing other animals and keeping populations under control or spreading nutrients across miles and different biomes. These activities can drive ecosystem processes and be exploited for human benefits (Boyd & Banzhaf 2007). There are a variety of distinct ecosystem services produced by all sorts of organisms such as apex predators such as tigers and lions, to microbes and bacteria like phytoplankton and zooplankton. Even though the form and impact of an ecosystem service can vary across animals, some animals can produce ecosystem services at a greater magnitude than others (***i.e., sea otters or grey wolves; Table 1***), which can be a deciding factor in prioritising species for conservation (Bonifacio et al 2016). Ecosystem services can be quantified; experts can exploit an ecosystem service produced by a certain species, and estimate the monetary value of that service (CITE). This quantification plays an important role in deciding whether the cost of conservation outweighs the benefit of the ecosystem service.

The following sections explore four important ecosystem services produced by a variety of predators. These four services are by no means a comprehensive list, but serve to mechanistically demonstrate how large predator conservation can translate into specific benefits for humans. Some of these ecosystem services can also be monetised, or have a monetary value assigned to it which could raise cause and reason to further conserve a variety of species who produce the ecosystem service.

Table 1: Effects after predator population decline

Predator Population Decline	Increasing Prey Population	Decreasing Producer Population	Ecosystem Service Lost
"Bengal tiger" by Dilan Damith Prasanga's is licensed under CC BY-NC 2.0 	 Sambar Deer	 Deciduous trees	Carbon Storage
"European grey wolf" by hehaden is licensed under CC BY-NC 2.0 	 Caribou	 Shrubs & grass	Nutrient Distribution
"African Lion" by Tasshu Rikimara is licensed under CC BY 2.0 	 Ungulates	 Shrubs & grass	Preventing Overgrazing
"Sea Otter floating in the Bay" by Alan Vernon. is licensed under CC BY-NC-SA 2.0 	 Sea Urchins	 Kelp	Carbon Storage

This table shows the impact of predator species population decline, displaying the species whose population would increase due to a decline in a certain keystone predator species population, as well as a species whose population would decrease, along with the ecosystem service produced by the keystone predator species.

2.1 Preventing overgrazing

Overgrazing is the excessive consumption of primary producers by herbivores, which leads to prolonged effects such as soil erosion, land degradation, and famine in agricultural systems. The prevention of overgrazing, and its possible side effects, is one of the many important and pivotal ecosystem services provided by larger predators. Overgrazing occurs when there is a lack of herbivore population management or overstocking of livestock (Mysterud 2006).

Overgrazing could also cause invasive plant species to dominate native or indeginous species, which could heavily change the way grazers and herbivores get their food (Baiser et al 2008). The trophic interaction between predators and herbivores is a key interaction that keeps the plant biomass in-check, because without predators, grazers would completely eliminate vegetation due to the speed of consumption.

Predators can control overgrazing through consumptive and non-consumptive effects. Consumptive effects are caused by the direct predation of prey populations (i.e., herbivores). Through predation, predators reduce the number of herbivore individuals within a given ecosystem, which means there are more primary producers holding soil together through their root structure (Schmitz et al 2000). If predators are conserved and protected successfully, they are able to consumptively control grazer populations, thus providing a useful ecosystem service by preventing overgrazing (Ripple et al 2014).

Non-consumptive effects occur through several ecological pathways and include inspiring fear within lower trophic levels across territories occupied by large predators such as tigers, lions, wolves, reptilians such as crocodiles, and other large or apex predators (Table 1; Schmitz et al 1997; Fortin et al 2005; Preisser et al 2005;). The fear of predation can reverse mesocarnivore and grazer population impacts on plant density throughout a vast area which they cover (Surci et al 2016). For example, during regular territory patrols, large predators make their presence known through various means, usually by urine or feces which can be detected by other animals in the area. (Figure 2). The mere presence of large carnivores gives rise to a ''landscape of fear'', buffering and interrupting lower trophic levels from overconsumption by large herbivores, grazers, and mesocarnivores (Surci et al 2016), (Figure 2). Failing to consider fear risks substantially underestimates the role large carnivores play in an ecosystem, since fear can be as or more important than consumptive effects within trophic cascades (Suraci et al 2016).

Figure 2: This figure represents the impact of fear of large/apex predators on herbivores and grazer populations as a non-consumptive method for preventing overgrazing.

2.2 Increasing levels of carbon storage in plant biomass

Indirect trophic interactions can have numerous impacts on carbon cycles that are not yet widely appreciated. Carbon dioxide (CO_2) is the primary greenhouse gas emitted from human activity that is harmful and damaging to the multiple layers in our atmosphere, as well as the ozone layer. An excess of carbon dioxide creates a thick layer around our planet which prevents heat from escaping into space, trapping it, boosting climate change and contributing to respiratory disease from smog and air pollution. Consequences of climate change for humans include extreme weather, food supply disruptions, and increased wildfires. Predators who also promote and aid in carbon storage help buffer climate change, biodiversity enhancement, reestablishment of native plant diversity, riparian restoration, and even regulation of diseases. By protecting a range of predator populations and conserving predator-herbivore trophic interactions, this can be avoided and significantly reduced through carbon storage.

Similar to overgrazing, predators have consumptive and non-consumptive effects that result in the retention and storage of carbon (Strickland et al 2013). Through predation, predators control herbivorous populations that would otherwise excessively feed on carbon-storage plant species Sea otters (***Enhydra lutris***) are examples of predators who contribute substantially to carbon storage (Table 1). Despite a large decline in sea otter populations in the early 18th and 19th centuries, conservationists increased populations across the eastern side of Kodiak Island, continuing westward through the Aleutian archipelago, and in Russia (Ripple et al 2014; Kenyon et al 1969; Estes et al 1998; Estes et al 19974). Sea otters limit herbivorous sea urchins and, in turn, enhance the abundance and distribution of kelp and other feshy macroalgae in coastal inshore ecosystems (Figure 3). The restoration of sea otter populations have the potential to reduce sea urchin populations in turn allowing kelp forests to fourish and result in a 4.4 to 8.7 teragram (a teragram is 10^12, or a trillion) increase in carbon being retained in kelp valued at an estimated $205 to $408 million (in U.S dollars). Furthermore, a bonus side effect of increased kelp densities in the coastal ecosystem helps dampen coastal waves and currents, allowing for more predictable patterns (Ripple et al 2014; Estes et al 2010).

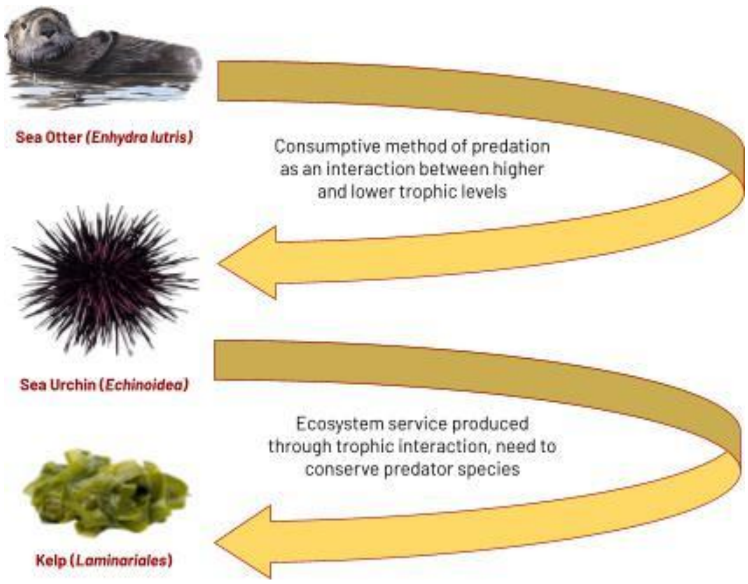

Figure 3: This figure displays a trophic interaction between sea otters and herbivorous sea urchins, furthermore explaining the trophic interaction along with its benefits and impact/effect on the production of ecosystem services.

Another example of predators increasing carbon storage is with the Gray wolves and their interactions with moose populations (Ripple et al 2014; Schmitz et al 2013). In North America, grey wolf populations predation on moose populations are responsible for a net increase of carbon uptake through a decreased amount of browsing and increased net primary y production.

The non-consumptive effect of predators in increasing carbon storage follows a similar ecological process as in overgrazing. Carbon storage is increased up to 1.4-fold more when carnivores are present compared with when they are absent. Carbon storage is higher in both aboveground and belowground plant biomass driven by predator non-consumptive (fear) effects on herbivores (Strickland et al 2013). An example of non-consumptive carbon storage through fear effects is the Bengal tiger. A large portion of the Bengal tiger diet consists of spotted and sambar deer, who eat all kinds of foliage, but are primarily browsers, meaning they tend to eat leaves. Through fear, tigers and other predators are able to disperse dense herds and populations of these deer (Strickland et al 2013), meaning there are less trees being eaten, resulting in a larger amount of carbon being retained through terrestrial and aboveground fora increasing, carbon storage as a whole.

2.3 Nutrient distribution and dispersion across a landscape

Nutrients are the required building blocks for any living organism on the planet. If nutrients aren't cycled, then vital elements such as nitrogen, oxygen, phosphorus and carbon would be locked in the waste and dead matter, leaving less carbon dioxide for photosynthesis, minimal oxygen to ensure the survival of organisms, and not enough plants would receive enough nitrogen to survive. Proper nutrient cycling is a requisite for the maintenance of ecosystems , therefore making this an essential ecosystem service. The popular belief holds that microbial species and microbial activity are the most critical factors that contribute to nutrient dynamics due to their capacity to convert organic matter into mineral elements for plants (Schmitz et al 2010). However, predators also play an important role in influencing nutrient cycles. Like almost any other ecosystem service, consumptive and non-consumptive predator effects play a role in nutrient cycling and distribution.

For nutrient distribution, there are a variety of consumptive effects by predators. These effects occur when predators consume nutrients through their prey, and then store these nutrients within them and then relocate to another area and then release these nutrients into the environment (Schmitz et al 2010). Various experiments in Persson & Svensson (2006) on benthivorous fsh (fsh that feed on organisms who live in benthic zones, essentially near lakes, rivers, and other such water bodies) showed that these fsh species can increase inorganic phosphorus 1.5 to 1.8-fold and inorganic nitrogen 1.3 to 1.5-fold in the water columns of lakes. Furthermore, an uptake of the inorganic nutrient released into the lakes through plants have been cycled repeatedly and have been found on terrestrial ecosystems. Another example is when insectivorous frogs (***Eleutherodactylus coqui***) release nitrogen and phosphorus on the plants and vegetation around them. This release of nitrogen and phosphorus quickly increases nutrient concentrations on leaves of various trees and plants between 1.4 to 2 folds, indirectly impacting and enhancing decomposition rates in various areas. (Schmitz et al 2010. This massive infux of nitrogen and phosphorus positively impact their surroundings. Nitrogen is part of the chlorophyll molecule, which gives plants their green colour and is involved in creating food for the plant through photosynthesis. When frogs and other insectivorous organisms release nitrogen directly on vegetation, plants are able to exponentially increase their growth (Schmitz et al 2010).

Furthermore, direct consumption of prey species through carnivory predation is another consumptive effect that similarly benefits nutrient distribution and cycling. Crocodiles (***Crocodylinae***), Grizzly bears (***Ursus arctos***) and river otters (***Lontra canadensis***) consume a variety of fish species within rivers (Figure 4). These fish species usually migrate to these rivers from connected oceans and open seas (Schmitz et al 2010; Crait & Ben-David 2007). Through their migratory journey, these fish species carry and release marine or salt water nutrients, such as nitrogen and phosphorus up to 1000 meters away from their original location. These nutrients are eventually delivered into other nutrient hotspots (nutrient hotspots are locations where the concentration of nutrients are above average or unusually high) through defecation. (Schmitz et al 2010; Hilderbrand et al 1999; Crait & Ben-David 2007). This large-scaled contribution to fast paced and slow-paced nutrient cycles aid in sustaining heterogeneity (diversity within the soil) soil and nitrogen and phosphorus concentrations in foliage simultaneously increase across landscapes.

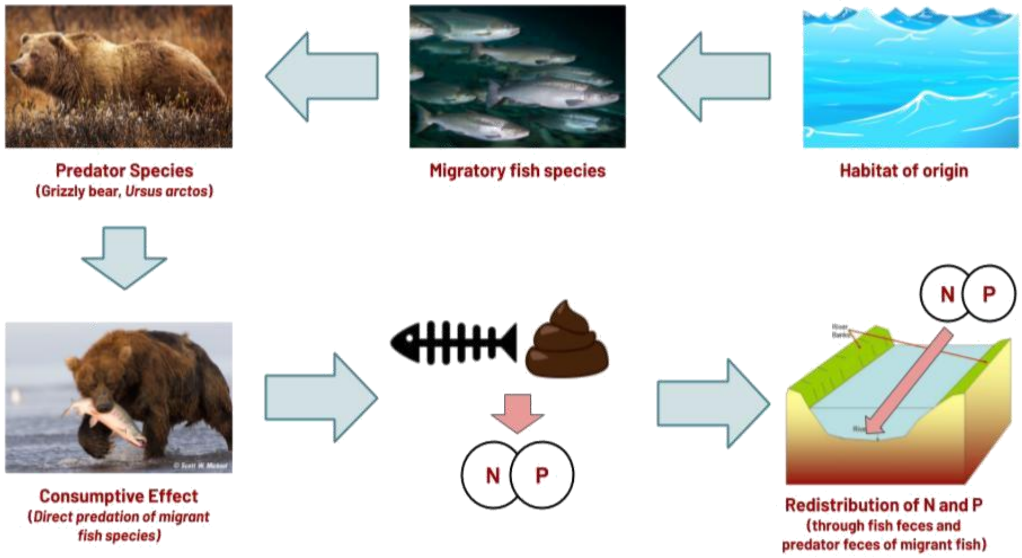

Figure 4: This figure represents the general cycle through which marine-born river fish such as salmon travel hundreds of thousands of meters away from their home carrying valuable nutrients and how they are able to directly or indirectly distribute nutrients across such large distances

In various ecosystems, prey populations tend to be vulnerable to predators and predation due to their individual population sizes. This means there are differences in the distribution of live prey and left-over carcasses of the same prey populations across the same landscape where they are killed. These left-over carcasses are converted into nutrient hotspots, promoting rapid nutrient cycling in that general area (Schmitz et al 2010). An example of this is the interactions between wolves and their prey, which are caribou and elk (Table 1). When grey wolves make a kill, either caribou or elk, the area in which the carcass remains receives a huge influx and increase in nitrogen, phosphorus and potassium levels that are added into the nutrient cycle pathway. This influx of nutrients is so evident, the increase can range from 100-600% in the soil, heavily increasing and enhancing nutrient cycling (Schmitz et al 2010). This large influx of nutrients also affects nutrient cycling in the surrounding trees, increasing the ability of leaves to grow in size and retain more carbon up to 25%. Comparing wolf-killed caribou and elk to those who have died of natural causes, wolves killed up to 12 times more prey individuals (Schmitz et al 2010). This shows how the strength of consumptive effects in direct comparison to non-consumptive effect, illustrating consumptive effects as a more efficient and better means of helping nutrient cycling across landscapes. Overall, predators have a range of consumptive effects that benefit and increase nutrient distribution and cycling throughout different ecosystems.

Non-consumptive effects on nutrient cycles and distribution arise when predators elicit antipredator responses in prey through either or all of three general ways (Schmitz 2010):

1. Habitat shifts that provide refuge to prey populations from predators
2. Dietary shifts that increase foraging and decrease risk from predators
3. Stress-induced changes in prey that demand different nutrients

A large non-consumptive effect on nutrient cycles and redistribution is the redistribution of nutrients across large spaces through prey habitat shifts and relocation inspired by predator presence and fear. By forcefully pushing prey to other locations and areas, predators can largely affect nutrient processes across large landscapes and ecosystems (Schmitz et al 2010). An example of this is when the presence of crocodiles in rivers and lakes force river fish such as tilapia into burrows and holes (Table 1). This retreatment increases nutrient diffusion into the riverbed and increases the general amount of organic matter that enters sediments within burrows. This non-consumptive effect can cause an increase in the amount of organic matter within the sediment layer up to fve folds, which is then decomposed and mineralized and later taken up by various other plants (Stief & Holker 2006). In addition, grey wolves have a larger range of impacts on nutrient cycles that just consumptive effects. Before wolf introductions into the Yellowstone National Park, ungulates and herbivorous grazing populations were highly concentrated in grassland sites The introduction of wolves altered grazing activity of various ungulates, especially moose and pronghorn (***antilocapra americana***), decreasing grazing up to 80% in these introduction sites. Furthermore, this leads to a reduction of grazing impacts such as a decline in nitrogen, phosphorus and macronutrient content between 60-90%. (Schmitz et al 2010). Another non-consumptive effect that predators have on nutrient distribution and diffusion is predator-induced foraging shifts and alterations within herbivores. Such effects via foraging activity shifts are especially evident in marine seagrass systems, where blue crabs (***Callinectes sapidus***) populations influence foraging patterns of their prey. In these systems, blue crabs directly reduce amphipod and is pod (crustacean subspecies) foraging and grazing activities regularly, contributing to an increase in organic matter at sediment surfaces and promoting positive responses from bacterial biomass at sediment levels who decompose organic matter and boost nutrient cycling (Schmitz et al 2010). This shift in bacterial community composition can alter organic matter decomposition and nutrient availability to plants (Spivak et al. 2009).

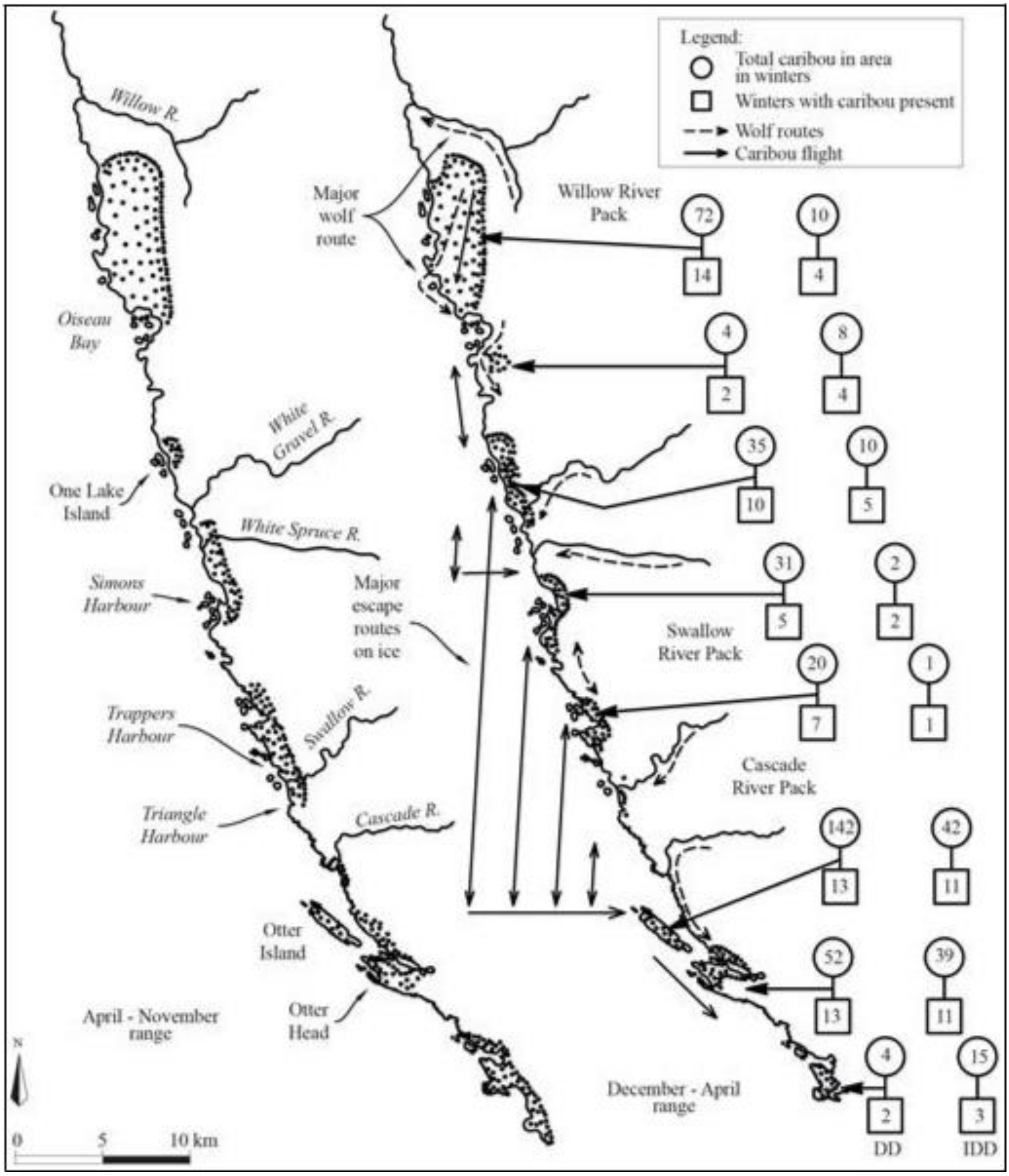

Figure 5: This figure represents wolf movement (in dash-lines) and the influence on caribou travelling routes (in normal arrows). In addition, this figure represents how nutrients are carried across landscapes due to non-consumptive effects of Grey Wolves. Furthermore, Bergerud et al 2014 conducted research and experiments to see how Moose travelling routes were impacted by regional decline, and how wolves adapted to moose shifting to areas near the coast, further pushing and driving moose populations across the river.

Figure from : Bergerud et al 2014

3. ECOSYSTEM SERVICE VALUATION

The ecosystem services provided by predators are vital in maintaining and regulating natural processes and cycles such as carbon storage, nutrient cycles and distribution, as well as preventing overgrazing. It is important to note however, that ecosystem services do not originate from distinct ecological processes - these ecosystem services arise through predator individuals engaging in standard behaviour, such as consuming food, defecating, and migrating or moving around. It is also important to note that sections above illustrate just a few examples of ecosystem services provided through predators. Even though ecosystem services do not necessarily originate from entirely distinct ecological processes, they do result in entirely distinct ecosystem services. By simply walking around, predators are able to impact nutrient cycles across large areas and landscapes. By simply surviving by consuming prey populations, predators are able to improve carbon storage in foliage and plant biomass, as well as prevent overgrazing. The valuation for carbon storage will vary largely from how nutrient distribution and preventing overgrazing are valued for humans. These reasons support the urgency to boost conservation efforts for a variety of predator populations and to understand the mechanisms as they produce various services for humans and are economically justified.

Predators are crucial and essential for ecosystems as a whole, as well as other individual organism populations on all the trophic levels. However, this clearly isn't enough to motivate more people to focus more valuable conservation efforts towards protecting a number of predator species that produce vital and important ecosystem services. Conservation for predator populations are justified not only by the variety of ecosystem services that they produce, but also because of the monetary application to those ecosystem services, and how humans can benefit from them. The case study below is a cost-benefit valuation of an ecosystem service. It assesses the magnitude of a service provided by a predator species relative to the costs associated with the conservation of that species. The case study should serve as an example for future valuation of ecosystem services.

4. CASE STUDY: SEA OTTER ECOSYSTEM SERVICE VALUATION

4.1 Quantifying ecosystem services

Firstly, it is important to understand that there are many ways and different methods that can be used to quantify ecosystem services and apply monetary values to them. Sea otters are extremely helpful and useful when it comes to aiding plant biomasses that retain more carbon dioxide, as one of the largest ecosystem services they produce is carbon storage. Sea otters are also known as the 'gardeners of the kelp forests', due to the significant role they play in conserving kelp forests and protecting them from herbivorous marine creatures that would otherwise feed on kelp as food (Ripple et al 2014).

In this case study, in order to quantify the ecosystem service of carbon storage provided by sea otters, a specific ecosystem will be targeted. This is the marine ecosystem in the Bering Strait, located between Alaska and the most eastern part of Russia. In order to quantify the ecosystem service there are three steps:

1. The ecosystem needs to be defined in both space and time. Spatially, the geographic range by area or volume needs to be measured. Regarding the aspect of time, a time range that includes the population of the animal that is providing the ecosystem needs to be defined.
2. The end-value of the ecosystem service will need to be defined.
3. The link between the predator population that is driving an ecosystem process and the monetary end-value of that process needs to be established.

Step 1: Defining the space and time parameters for valuation

The selected ecosystem for this case study is the sub-Arctic marine-seagrass ecosystems, including sea otter predators and forests of kelp. To parameterize the scope of the valuation, I focused on the Bering Strait, which lies between the eastern-most part of Russia, and the western-most side of Alaska. At its narrowest (from East to West), the Bering Strait is only 88 kilometres across and at its longest (from North to South), the Bering Strait is 1500 kilometres. The area inhabited by sea otter populations equates to 132,000 kilometres squared. In this case study, the Southwest metapopulation of otters, including individuals in the Aleutian Archipelago, the Alaska Peninsula, Kodiak Island, and Bering Strait, are listed as threatened under the United States Endangered Species Act (ESA) with a population of 20,000 individuals as of 2019, a drastic decrease from their original population numbers in the 1800's that lay between 150,000-300,000 individuals. The USGS (United States Geological Survey) and FWS (United States Fish and Wildlife Service) claimed that 20,000 individuals are still below optimum sustainable population numbers, and need to increase by at least 8,000-10,000 more.

Step 2: Defining the end-value of the ecosystem service

CCSA (The Carbon Capture & Storage Association) estimated that the cost of carbon storage ranges from \$69 - \$103 per tonne of captured and stored carbon. In a separate study by Estes et al (2014), kelp forests can capture an average of 6.55 tera-grams every year globally. A moderate estimate of the value saved in carbon sequestration services; healthy kelp forests would approximately save an average of \$563 million dollars. However, it is important that for this case study, all values have been scaled to the Bering Strait, as shown below in Table 2.

All values provided below refer to annual values for each category

Table 2: The total amount of USD that would normally go in storing 6.55 teragrams of carbon which can be avoided if we preserve healthy kelp forests through the conservation of sea otters

Kelp carbon storage (Bering Strait)	Average cost for carbon capture	Total cost of carbon capture by kelp
49,621.21 kilograms	$86	$4,267,424.06

Step 3: Linking the predator with the end-value of the ecosystem service

Sea otters are the apex predators responsible for preserving and maintaining healthy kelp forests . They are often called the gardeners of the kelp forests due to the vital role they play in keeping sea urchin populations under control. This role they play is what provides us with their ecosystem service of carbon storage within these kelp forests. All values below have been taken directly from the Coastal Conservancy Sea Otter Recovery Fund of the State of California, listing annual costs for them to preserve their sea otters which can be applied in a general sense to sea otter conservation as a whole, therefore the values shown below can be spatially applied to sea otter conservation in the Bering Strait. I'm about to estimate an annual cost required to fund sea otter conservation, then the annual cost of humans manually capturing and storing carbon, further estimating how much money sea otters can help humans avoid funding carbon storage systems, then calculate a final profit we can earn through the ecosystem of carbon storage through sea otters. These values need to be estimated because it supports cause and reason to help conserve sea otter populations as they are endangered animals.

Table 3: An organiser used to represent all the monetary values that go into preserving sea otters, and then sums up a total profit humans can gain from conserving sea otter populations for their ecosystem service of carbon storage.

Annual cost of conservation programs	Total annual cost to preserve sea otters	Total annual cost of carbon capture	Total annual profit from preserving sea otters
Electronic Tags for Sea Otter Population Monitoring: **$95,000**			
Aquarium of the Pacific Sea Otter Surrogacy Enclosures: **$70,000**			
Be Otter Savvy Program: **$182,400**			
Sea Otter Awareness Outreach and Education: **$58,640**			
Investigating Sea Otter Use of Elkhorn Slough to Inform Restoration: **$121,562**	$1,251,182	$4,267,424.06	$3,016,242.06
Investigating Sea Otter Mortality Patterns: **$165,543**			
Risk Factors for Shark Bite Mortality in Southern Sea Otters: **$59,447**			
Investigating Anthropogenic Stressors for Sea Otter Recovery: **$498,690**			

Essentially, referring to when sea otters sexually mature, within 16 years we should aim to increase conservation efforts in order to boost sea otter populations to around 30,000 individuals. Once the otters reach the optimum population number required to stabilize and sustain their populations, we can slow down conservation efforts until they are once again classified as near threatened or least concerned in which case protection laws can be further enforced and the majority of sea otter conservation funds can be retracted. Sea otters would continue benefiting the economy of the US by approximately $3,016,242.06 every year until their populations increase, in which case the profit yield would grow as we are required to fund less money in sea otter conservation, and continue saving much more money in carbon storage.

Overall, the conservation of sea otters is much cheaper than the cost of carbon storage. Following the footsteps of the Coastal Conservancy in California, implementing interventions such as electronic tags to monitor individual sea otters, regular regional cleaning of invasive species, and clean-up of heavy metals that bioaccumulate, would be successful in the Bering Strait. Investing funds into research regarding mortality rates of sea otters, as well as educating the public and raising awareness about sea otters to boost unanimous efforts in conserving sea otter populations is important as it helps spread the problem sea otters face with their populations to the general public. Furthermore, observing sea otter populations for at least 2 generations (spanning 16 years) to increase populations to 30,000 individuals so that sea otters reach their optimum stabilization number is crucial as this milestone means otters would require less money being spent by humans to use a large array of methods to help conserve them. It could also be worth creating small protected non-fishing areas where sea otters can be free of fisheries draining their food supply in locations where sea urchins or other crustaceans may not be found as human-wildlife conflict interferes with sea otter natural behaviours, and direct temperament with their diet such as fishing negatively affects sea otters, potentially wiping out populations in those parts of the ocean.

5. CONCLUSION

Using an ecosystem services valuation approach, this paper demonstrates how predator conservation is not only economically justified, but imperative for preserving ecosystem functioning across the globe. While this paper and its valuation focused on a handful of large predators, it is important to point out that predators across taxa can drive ecosystem processes, regardless of their individual body size. Many ecosystem services are not yet widely appreciated by economists, which furthers the need for basic research in ecology. My hope is that through this paper, readers are more aware of the importance of predators, and why they should and need to be conserved across the globe, such as the case study on sea otters merely being 1 example among a variety of predators who similarly preserve the ecosystem and the planet.

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