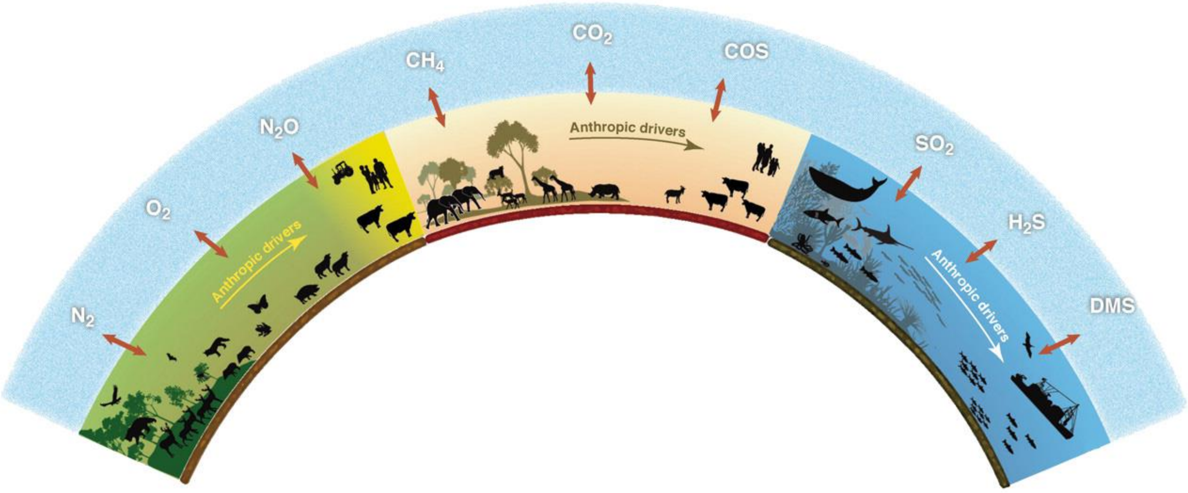

Sustaining threatened species in an anthropogenic world

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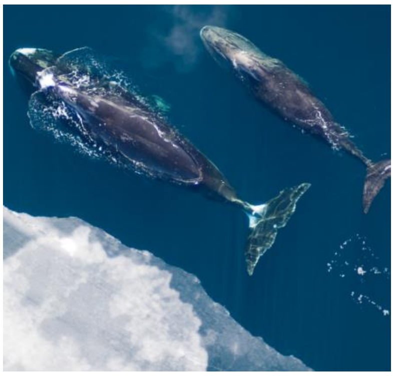

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Top picture: edited from Naeem *et al.,* (2012)

Threatened species pictures from left to right: ©Eric Kilby, ©own picture, ©Ice Whale Foundation

1. Summary

The current trend of species decline greatly emphasizes the onset of the world's sixth mass extinction. What makes this extinction distinctive is that the main drivers are human caused. Humans have turned over half of the planet anthropogenic, enhancing great threats to mammals and wildlife altogether. The greatest threats being habitat transformation and overexploitation, but smaller threats such as pollution, climate change and invasive species and the interactions amongst all threats play a big role too. Human-wildlife conflict arises more due to these threats and influences conservation strategies. The future of wildlife population depends on their ability to coexist with humans. This paper aims to address the question how wildlife populations can sustain under increasing human pressures. To try and answer this I examined existing literature of human pressures and its consequences on wildlife. Then, I focused on why conservation of wildlife is important for humans and how to protect increasing endangered species populations while protecting the welfare of human communities. Mammals had the main focus in this paper. The literature showed that wildlife populations can influence the ecosystem in such ways that they decrease fires, increase biodiversity and even contribute to minimizing climatic changes. These ecosystem services in combination with aesthetic values highlights the necessity for humans to conserve threatened species. The dominant conservation strategy to protect habitat and species loss is increasing protected areas. The 2010 Convention of Biological Diversity targeted to have 17% terrestrial and 10% marine area protected within 10 years. In 2020 this target was not reached, and many existing protected areas do not function adequately. Because of this I suggest that steps need to be taken in order to let protected areas function to their full potential. These steps include research in highlighting the importance and usefulness of adequate funding for establishment and management of protected areas. In addition to this, protected areas should be in ecological hotspots to sufficiently cover threatened species. And lastly, perhaps the most important step is to involve the local community and focus on their wellbeing and role in conservation.

2. Introduction

Humans have always lived alongside other species competing for resources and space. We effectively outcompeted many species, ultimately leading to evolution and expansion of human populations. To survive with wildlife, humans eliminated or reduced the most threatening populations or species and minimized threats from species that survived. As humans advanced, global landscapes transitioned from mostly wild to over 50% being anthropogenic by the early 20th century (Ellis *et al*. 2010). However, in the recent decades increasing awareness of biodiversity and its important roles have allowed a focus on coexisting with wildlife rather than erasing species altogether. The focus has now shifted towards more sustainable conservation efforts and the amount of protected wild areas is increasing.

As result of human generated changes, wildlife populations and distributions are declining at a 'mass extinction' rate (Ceballos *et al.,* 2017). Even with the increase in protected areas biodiversity continues to decline outside and inside of these areas (Watson *et al*., 2014). Moreover, the human population is increasing rapidly, with a rate of 1.08% per year and an expected peak of 11 billion humans around the year 2100 (United Nations, 2019). The growing human population increases pressure on wildlife, as humans need more resources and space. The biggest pressure on wildlife is habitat loss, followed by overexploitation, especially in mammals. A combination of many smaller threats such as pollution, climate change and human introduced invasive species also form a large part of the pressures that affect species (Baillie *et al.*, 2004). With increasing human population and with that increasing occupancy of wildlife habitats, humans and wildlife will have to reside amongst each other.

Living along wildlife causes human-wildlife conflicts. These conflicts always affect both parties involved. Wildlife can cause crop damages, predate on livestock, or harm humans. Humans can kill, poach, or negatively impact species and wildlife habitats (Frank, 2015). In an example of Northeast India, when Asian elephants (*Elephas maximus*), migrate, they move through villages and tea estates or other land use areas destroying much of the property in their path or causing harm to the inhabitants. On the other hand, the elephants have very little habitat left to move through due to forest destruction and fragmentation by humans; and increasing poaching incidents leave injured animals that often retaliate by killing humans and damaging their property (Choudhury, 2004). Between 1980 and 2003, this led to more than 1150 humans and 370 elephants dying (Choudhury, 2004).

One major issue of conservation lays in these conflicting needs of wildlife and humans. However, the future of many wildlife populations depends on their ability to coexist with humans. Literature on human wildlife coexistence in combination with various conservation efforts is rapidly increasing (Nyhus, 2016) and the focus is starting to be on a future where people and wildlife can coexist. To work towards this future this paper aims to address the question how wildlife populations can sustain under increasing human pressures. I focus in particular on mammal populations. To try and answer this I first examine the existent literature of human pressures and its consequences on wildlife. Second, I focus on why conservation of wildlife is important for humans and how to (properly) protect species using the most common conservation strategy: protected areas. In the end, I try to emphasize the most sustainable solutions in how to balance protecting and increasing endangered species populations while protecting the welfare of human communities.

3. Human pressure and its consequences on animal (mammal) populations

Humans have the highest biomass of any species on earth and the population keeps growing. Although the extreme population growth is declining, it is still expected to reach 11 billion humans at the end of this century (United Nations, 2019). Increasing human population means increasing competition with other species for resources and space. The major pressures humans have on wildlife come from landscape transformation and from overexploitation, and a combination of other smaller threats. These activities have consequences for humans and for wildlife populations.

3.1 Landscape transformation

One alteration humans have made to the planet is landscape transformation. The terrestrial biosphere transitioned from mostly still wild around 1700 to mostly anthropogenic by the beginning of the 20th century (Ellis *et al*. 2010). The intentional removal of forest is one of the most significant ways in which humans transformed landscapes. The world has lost an estimated 40% of its original 60 million km^2 of forest due to human activity and this loss continues with around 14.6 million hectares of forest destroyed each year, the most affected places being Africa and South America (Baillie *et al.*, 2004). Immediate causes for deforestation are the increased human land use mostly for intensive agricultural practices (Goudie, 2018). Urbanization is another way the lands have turned anthropogenic. There is an increase in dense built environments with high human populations and more rural settlements with high and fragmented populations (Ellis *et al*. 2010). These urban areas are all connected by a major infrastructural network. The current and increasing infrastructure is one of the main causes of habitat fragmentation (van Bohemen, 1998). Habitat fragmentation, the separation of habitats or ecosystems into smaller, more isolated units, separates (sub)populations and feeding and breeding grounds (van Bohemen, 1998).

As a result of landscape transformation many species have lost a very large part of their natural ranges. A striking example of a species that lost their range is the lion (*Panthera leo*). Lions have lost around 75% of their historical range with the most critical situation in west Africa where almost 99% of the habitat was lost (Henschel *et al*., 2014). Lions used to range in most of Africa, parts of southern Europe and in the Middle East up to India. Now, however, only remain scattered populations in sub-Saharan Africa and one small population in India (Ceballos *et al*., 2017). Other species greatly under pressure due to habitat loss are the Bornean, Sumatran and Tapanuli orangutans (*Pongo pygmaeus, P. abelii, P. tapanuliensis* respectively). Natural forests are cleared for oil-palm plantations, logging and other agricultural practices that can cover hundreds of square kilometres and many of the ranges of the orangutans falls within these areas marked for conversion (Singleton *et al.,* 2017). These are just two noticeable examples but mammals across the world are losing their geographical range. Ceballos *et al.,* (2017) found that most of the 177 mammals they studied have lost at least 40% of their geographic ranges and half of them lost more than 80% of their ranges in the period between 1900-2015 (Fig. 1). The primary category of range contraction is 80% or more and this holds for at least 40% of the species in Africa, Asia, Europe, and Australia. The Americas have lower range reductions, although still 22% of the species lost 80% or more of their range (Fig 5; Ceballos *et al.,* 2017).

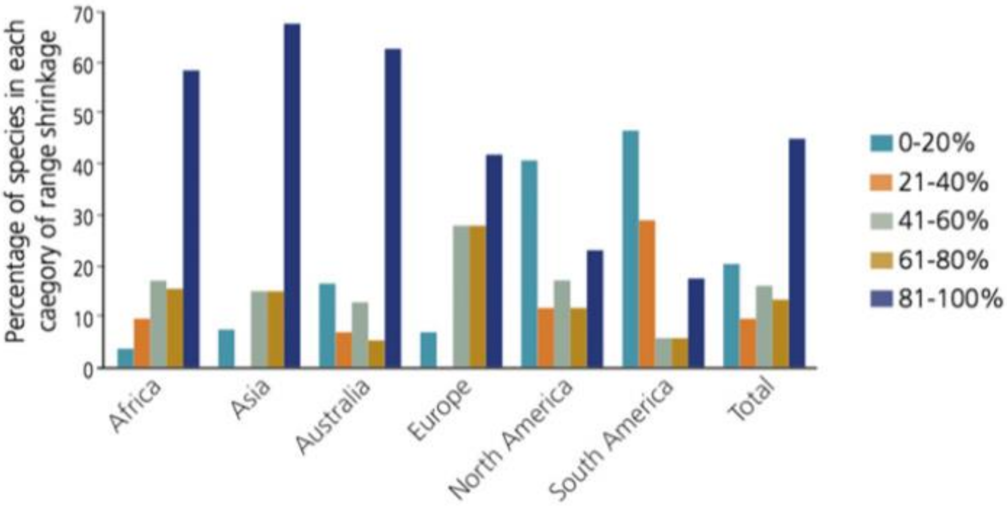

Fig. 1: The percentage of species of land mammals from five major continents/subcontinents and the entire globe undergoing different degrees (in percentage) of decline in range in the period ∼1900–2015. From Ceballos et al., 2017.

Human alterations to the earth are not limited to the terrestrial biosphere. In fact, the marine environment is highly affected by anthropogenic activities as well. The recent dramatic loss of sea ice offers humans almost unlimited access to the arctic. This provides ample opportunity for increasing offshore activities such as seismic airguns, pile driving, cargo vessels, icebreaking, dredging and small boat driving. All these activities generate sounds in a wide range of frequencies, creating increasing levels of underwater noise (Moore *et al.*, 2012). These sounds can affect marine mammals because groups such as cetaceans and pinnipeds rely on sound to sense their environment, particularly for communication, echolocation and predator avoidance (Moore *et al.*, 2012). Along with this is that the frequencies marine mammals use and hear fall within the range of frequencies of the most common offshore activities (Fig. 2). One major way sounds affect marine mammals is by masking: the reduction in the area over which marine mammals can hear and communicate, resulting from increasing low-frequency sound from anthropogenic activities, mostly commercial shipping (Moore *et al.*, 2012). It degrades the marine-mammal acoustic habitat, a form of habitat reduction.

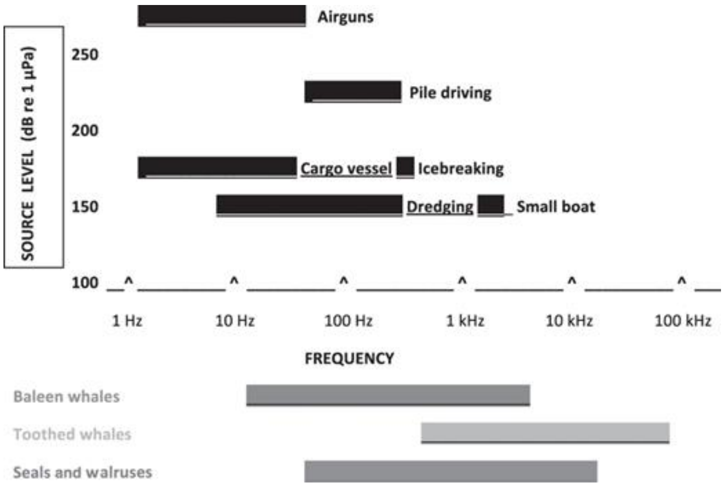

Fig. 2: Approximate frequency bands and source levels for common offshore activities in the Arctic relative to frequencies used by Arctic baleen and toothed whales, seals, and walruses. Abbreviations: dB, decibels; Hz, hertz; kHz, kilohertz; µPa, micropascal. From Moore et al.*, 2012.*

For humans most of the landscape transformation is beneficial in the short-term. One main way we use the land is for agricultural practices. Livestock systems for example are a major economic force on the planet. They occupy about 30% of the earth's (ice-free) terrestrial surface area, contribute to one-third of the global agricultural GDP, employ an estimated 1.3 billion people, and directly support the well-being of around 600 million smallholder farmers in developing countries (Thornton, 2010). Another way we use the land for is urbanization. The expansion of cities and villages and the infrastructural network provides human with many goods and services to increase living standards. Similarly, using the marine system provides us with oil and gas and with supplies and food. However, most of these anthropogenic activities are not sustainable in the long term and can lead to overexploitation.

3.2 Overexploitation

Human have exploited species for survival, food, medicine, fuel, material and cultural use for centuries. For a long time, factors underlying overexploitation were mostly poverty and an associated "have-to-eat-today" principle, since wild meat is a vital source of protein and generates valuable income for rural populations (Mainka and Trivedi, 2002). However, currently with increasing wealth in for example Asia, overexploitation is used for booming commercial markets. Overexploitation can be a simple source for some economic assurance in uncertain market situations (Mainka and Trivedi, 2002). The growing markets and increasing demand, improved access and transportation and modern hunting techniques, have allowed for intensive exploitation beyond sustainable levels (Baillie *et al.*, 2004). Overexploitation is a major threat to wildlife populations. The 2004 IUCN Global Species Assessment (Baillie *et al.*, 2004) reported that for 33% of the threatened mammals for which data is available are affected by overexploitation, and larger mammals, especially ungulates and carnivores, are particularly targeted. Mammals are widely used in the bush meat trade, especially in tropical Africa and in southeast Asia and some mammal species are also harvested for medicinal use, particularly in eastern Asia (Baillie *et al.*, 2004). Take the black rhino (*Diceros bicornis*) for example, the species main threat is poaching to supply the illegal international rhino horn trade (Emslie *et al*., 2020). Poaching of the black rhino has crashed the number from hundreds of thousands in the early 1900s to around 2400 in 2004 (Goudie, 2018). Although the population trend of the black rhino is increasing it is still greatly affected by poaching and it remains listed critically endangered by the International Union for Conservation of Nature (IUCN).

A striking way in which overexploitation affects mammals is in the marine ecosystems. According to a study on threats to endangered species in Canada (Venter *et al.,* 2006) 88% of Canadian marine mammals are affected by overexploitation, making it their main threat. The study then compared this to global levels in the IUCN report of Baillie *et al.*, 2004 that included fewer mammals than the Canadian study. When adjusting for this difference in frequency of taxa they found that overexploitation threatened almost the same number of mammals globally as it did in Canada. Whales are a well-known example of overexploitation due to commercial whaling. Many of the great whales (baleen and sperm whales) were severely exploited by whaling until an implementation of a moratorium on commercial whaling by the International Whaling Commission in 1986 (IWC). Many whales still experience strong influences of this depletion. For example, blue, fin, sei, and North Pacific right whales are classified as endangered predominantly due to their declines through commercial whaling and some subspecies like the Antarctic blue whale, although recovering, was in 1998 still at only 1% of what it was before whaling (Thomas *et al.*, 2015). Species are also not equally distributed over their range. The humpback whale is now listed as least concern on a global scale, but still has individual populations determined as endangered (Thomas *et al.*, 2015). Marine species are also affected by overexploitation of other animals. Currently humans undertake massive scale fishing, and this has led to 82% of assessed fish populations (n=1320) being in various states of depletion (Palomares et al., 2020). This current trend of large-scale commercial fishing also has high numbers of bycatch, which poses a great threat to already threatened species and 6% of mammals of which data is available are affected by this (Baillie *et al.*, 2004).

Carnivores specifically are affected by overexploitation in two distinct ways. Many large species such as the lion, tiger (*Panthera tigris*), and leopard (*Panthera pardus*) are killed because of conflict or are hunted for trophies or high value products (IUCN red list of threatened species, 2020). However, another way many carnivorous species are affected by overexploitation is by depletion of their prey. A study by Wolf & Ripple (2016), showed that prey endangerment leading to loss of prey base is a big threat to many large carnivores. Many prey species of carnivores have declining population trends (Fig. 3). The clouded leopards (*Neofelis diardi, N. nebolusa*), dhole (*Cuon alpinus*), tiger and leopard are all species listed as vulnerable or endangered themselves and have over 50% of their prey species declining (Fig. 3). The prey species themselves, which are largely smaller mammals, face threats from humans due to high human population densities, hunting and habitat loss (Wolf & Ripple, 2016). Depletion of prey is also a big concern for marine mammals such as the orca (*Orcinus orca*) of which populations can have very specific dietary specialisations. Due to their specific diets some populations are especially vulnerable, particularly fish-eating populations. Declines in

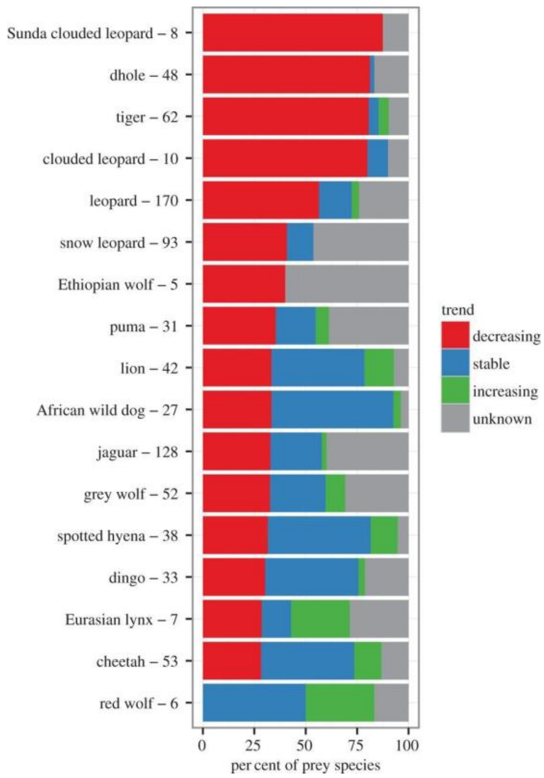

Fig. 3: Population trends of large carnivores' prey. Carnivores are sorted by percentage of prey with decreasing population trends. The numbers of prey species are shown after the large carnivore names. From Wolf & Ripple (2016).

survival of Pacific Salmon populations in British Columbia for example correlate with declines in resident orcas (Reeves et al., 2017). Since predators are highly dependent on their prey, insufficient prey availability can cause carnivore population to decline, possibly becoming locally extinct.

3.3 Other threats

There are other threats to animals that are in itself not the biggest threat but do contribute to the pressure on species. Pollution is one of these examples, affecting mostly birds (29%), but also 4% of threatened mammal species is affected (Baillie *et al.*, 2004). Although this paper's focus is on mammals, a recent example of pollution threats on vultures is interesting to note. In South Asia, vultures (genus Gyps) had declined by over 95% due to toxic effects of the veterinary drug Diclofenac (Nambirajan *et al*., 2018). The drugs were administered to livestock and vultures traditionally disposed of livestock carcasses in cities, villages and the countryside, helping with sanitation and thus improving human health. In 2006 the drug was banned in some South Asian countries, however still vultures are dying of poisoning by Diclofenac, and poison cases have even been found in vultures in Spain as the drug is not banned in Europe (Nambirajan *et al*., 2018). It is an interesting case of pollution and can have broader implications for other species incidentally feeding on livestock or their carcasses such as lions, leopards, and hyenas (Fam. *Hyaenidae*).
Pollution in marine and freshwater aquatic systems is the most prominent. Many seabirds, fish, corals and other aquatic species are affected by pollution. Run-off from the land, oil, heavy metals and turbidity are all forms of pollution mostly found in marine and freshwater environments (Goudie, 2018). One marine system that experiences high stress due to pollution is coral reefs. Specifically, increased sedimentation and eutrophication from land and sea use causes increased turbidity and reduced levels of oxygen (Tkachenko, 2017). The poor water quality deprives the corals of light and oxygen necessary to grow. For instance, in the Nha Trang Bay area of Vietnam the coral cover has declined from 50-70% to 5-7% due to increased sedimentation and eutrophication in combination with overexploitation of herbivorous fish (Pavlov *et al.,* 2004; Tkachenko, 2017). Coral reefs are of fundamental importance because they provide habitat for one-quarter of all marine species, protect coasts from wave impacts and are an important source of revenue for coastal tropical countries (Tkachenko, 2017, Goudie, 2018).
Substances from the different forms of pollution can appear in higher trophic levels such as in mammals like orcas. High concentration of polychlorinated biphenyl (PCB) was found in orcas in Europe and similar substances have been found in north-eastern Atlantic and British-Columbian populations (Reeves et al., 2017). PCB can cause immunotoxicity, neurotoxicity, and reproductive impairment (Reeves et al., 2017). This accumulation of substances in the food chain imposes risks in the higher trophic levels.

The climate on earth in undergoing profound changes, which result from human activities such as fossil fuel burning. Climatic changes have occurred throughout the planet's history. However, these recent changes are different because they are much faster and are unlikely to be reversed by natural processes (Baillie *et al.*, 2004). Climate change is not often identified as a threat on itself, but the multiple effects together might impact many species. Climatic changes might alter species' distribution, habitat suitability, abundance phenology, morphology and genetic composition (Baillie *et al.*, 2004). Climate changes happen at a rapid speed and many species will probably not be able to keep up with the changes.

Invasive species defined by the IUCN as 'an alien species which becomes established in natural or semi-natural ecosystems or habitat, is an agent of change, and threatens native biological diversity' is another human induced threat. Humans have intentionally and accidentally transported many species to different parts of the world. When these alien species establish themselves, it can have catastrophic consequences. Invasives can affect native species by competition, introducing parasites and diseases or by destroying or degrading their habitat (Baillie *et al.*, 2004). Since invasive species is such a major topic by itself this paper will only touch on it briefly. Island species are particularly affected by invasive species, because of their isolated history. For example, the introduction of black rats (*Rattus rattus*) long ago to the Marquesas Islands in French Polynesia is related to the extinction of four species of endemic monarch birds (flycatchers) in five of the Marquesas Islands (Thibault & Meyer, 2001). Moreover, newer introductions of invasive species such as aggressive birds (e.g., the red-vented bulbul, *Pycnonotus cafer*) and alien plants cause direct harm, competition and the reduction of suitable breeding habitats for the remaining vulnerable monarch species (Thibault & Meyer, 2001).

3.4 Human-animal conflict

One more threat, both to humans and wildlife, resulting from the above threats is human-wildlife conflict. Conflicts arises most in areas where the land humans use overlaps with the habitat of wildlife and since the major loss of habitat for many species this occurs substantially. Human-wildlife conflict affects both parties involved. Research by Kissui (2008) showed that approximately 5% of cattle, goats and sheep are killed by lions, leopards or spotted hyenas (*Crocuta crocuta*), which is around a 2% economic loss. Over his study period (19 months) the livestock killed by lions positive correlated with lions killed by humans in retaliation for their livestock losses. Very few hyenas and leopards were killed during the study time (excluding the use of poison on hyenas in 3 villages) and an explanation for this could be the nature of the lion kill. Lions predominantly killed cattle which is of more value to the local people, and they are more likely to defend the carcass against human exposing themselves (Kissui, 2008). In contrast, leopards and hyenas kill smaller livestock and hide themselves with their prey. This type of conflicts results in economic loss for humans and killing for part of the wildlife involved.

Animal size is often important in human-wildlife conflict because large predators and herbivores can cause significant damage to property, livestock and humans (Nyhus, 2016). Inskip and Zimmermann (2009) found that the severity of human-felid conflict increased with species' body mass and the most severe conflicts arose with lions, leopards and tigers. For carnivores, the large home ranges and dietary requirements are part of the reason for conflict besides size. Predators are much rarer than their prey species and a common rule for carnivore density is that about 10000kg of prey supports about 90kg of carnivore species (Carbone & Gittleman 2002). To have a viable population these species therefore need disproportionately large amount of space which they do not commonly have or which they share with humans (see 3.1 habitat loss) and large prey populations which are also often unavailable (see 3.2; Fig. 3) (Macdonald & Sillero-Zubiri, 2002). Habitat reduction, depletion of prey and limited livestock husbandry, make livestock an interesting dietary option of carnivores (Inskip & Zimmermann, 2009). Moreover, human and carnivore ranges overlapping can cause carnivores to attack in order to protect prey, young or their territory (Inskip & Zimmermann, 2009). Since their home ranges overlap with humans, livestock is available for them to prey on and their size and teeth can do significant damage the families Felidae and Canidae are particularly common in conflict (Nyhus, 2016; Inskip & Zimmermann, 2009). An example of felid-human conflict due to these reasons can be found in tigers. Tigers need a large area and a large amount of prey to be viable, both of which they do not have (Goodrich et al., 2014; Fig 3). Conflict with tigers happens mostly in intermediate disturbance areas such as reserve borders where tigers, livestock and people overlap (Nyhus & Tilson, 2004). In Sumatra, Indonesia, tigers killed 146 people, injured 30, and killed at least 870 livestock between 1978 and 1997 showing the significant damage of conflict with these larger species with high requirements for viable populations (Nyhus & Tilson, 2004).

Large herbivores, specifically Proboscidea (elephants) and Artiodactyla (e.g., swine, deer, hippopotami) also often come into conflict with people by damaging or consuming vegetation or harming humans (Nyhus, 2016). Megaherbivores (weighing over 1000kg) rank amongst the most problematic herbivores since they are dangerous to humans. Elephants (*Loxodonta africana*) are often the focus in human-herbivore conflict, but the hippopotamus (*Hippopotamus amphibius*) frequently come into conflict with humans throughout Africa as well (Kanga et al., 2012). Human-wildlife conflict (as with the tiger example) predominantly happens at protected area borders. Hippo-human conflict differs in this because for their dual requirement of water and open grazing range hippos inhabit wetlands that often extend into agricultural landscapes (Kanga et al., 2012). When grazing at night hippos can cause agricultural-related conflicts such as crop damage and livestock mortalities. In Kenya for example 4493 human-hippo conflicts were reported between 1997 and 2008, of which about 63% were related to agriculture (Kanga et al., 2012). In turn, hippo mortalities recorded during that period were highly correlated with the conflict incidences due to wildlife managers often killing the offending animals and thus potentially negatively affecting the population status (Kanga et al., 2012)

This 'killing the offender' strategy of humans is predominantly done to prevent (further) economic losses or human life losses. Inskip et al. (2014) surveyed the motivations for tiger killing by villagers in the Sundarbans, Bangladesh. Their results show that the main motivations were worry and fear of harm by tigers, a perceived lack of support from local authorities, retaliation for losses and personal and social benefits. Unresolved and unmitigated conflict leads to decreased local support for conservation efforts, some of which will be discussed in the next section.

4. Conservation efforts and approaches that sustain wildlife and human well-being.

4.1 Why do we want to conserve species?

Habitat loss, overexploitation, pollution, climate disruption, and invasive species, as well as the interactions among them have caused a massive decline in numbers and sizes of mammal populations across the world (Ceballos *et al.,* 2017). The dominant percentage range of mammal population losses is that of 70% or more and is globally spread except for some South and North American areas where loss is mainly around 25% (Ceballos *et al.,* 2017). The rate of these extinctions is evidence that we now entered a sixth mass extinction event that is characterised by the loss of apex consumers and of larger-bodied animals in general (Estes *et al.,* 2011). Species extinctions are irreversible and may have significant effects in the long run. These effects can range from loss of the planet's inspirational and aesthetic resources to destruction of ecosystem functioning and services.

Healthy ecosystems provide us with goods such as foods and medicines and with services such as purification of air and water, the binding of toxins, decomposition of wastes, mitigation of floods, moderation of storm surges, stabilization of landscapes, and regulation of climate (Alcamo *et al.,* 2003). Not all species are equally important for ecosystem functioning. The removal of species from high trophic levels, called apex consumers, can have great consequences for nature, referred to as trophic downgrading (Estes *et al.,* 2011). These larger predators and herbivores modify their landscape to such an extent it can influence ecosystem functioning and services.

Forest and wildland fire is a vital process that initiates natural cycles of vegetation succession and supports ecosystem viability (Levine *et al.,* 1999). However, uncontrolled or misused large wildfires cause harmful impacts on the environment and human society. Wildfires can burn down great areas of land and have high economic costs that can reach up to billions (Bowman *et al.,* 2009). Moreover, these fires (which are due to human activity up to 90% of the time) can have a negative impact on the composition and chemistry of the atmosphere, on the Earth's climate and on human health (Levine *et al.,* 1999). Vegetation plays a large role in fires as it accounts for the 'fuel' of the fires. Herbivory, vegetation and wildfires are linked and play important roles in sustaining each other: fire and mammal grazers both consume grass, and both are important modifiers of ecosystems (Estes *et al.,* 2011). A great example of this can be found in the South African savanna where Waldram et al. (2009), found that the removal of white rhinos (*Ceratotherium simum*) affected fire by increasing the fuel load and continuity of the fire. This is because white rhinos are short grass grazer and the study found that when present they maintain short grass patches resulting in small, patchy fires instead of large, continuous fires when absent. Similarly, Holdo et al. (2009), found that the return of wildebeest (*Connochaetes gnou & C. taurinus*) populations after elimination of the rinderpest drove the system in the Serengeti from shrublands to grasslands (Fig. 4a), decreasing the fuel loads and thus the frequency and intensity of wildfires.

Biodiversity is important in sustaining healthy ecosystems that in turn ensure ecosystem services benefiting humanity (Naeem *et al.,* 2012). Apex consumers are an important part of the diversity that sustains the functioning of ecosystems (Estes *et al.,* 2011). There are important trophic cascades when apex predators and herbivores are not present in an ecosystem. For example, the return of the grey wolf (*Canis lupus*) after 70 years of absence in Yellowstone National Park decreased elk (*Cervus elaphus*) populations, increased vegetation and increased beaver (Caster *canadensis*) and bison (*Bison bison*) numbers (Fig. 4; Ripple & Beschta, 2012). Another big cascade was found on the Aleutian archipelago. Here the presence of foxes limits the amounts of seabirds and thus reduces nutrient inputs from sea to land, driving the ecosystem from grasslands to tundra (Fig. 4; Croll *et al.,* 2005). These are examples of how larger mammals influence biodiversity which is a very important part of keeping ecosystems and their services healthy.

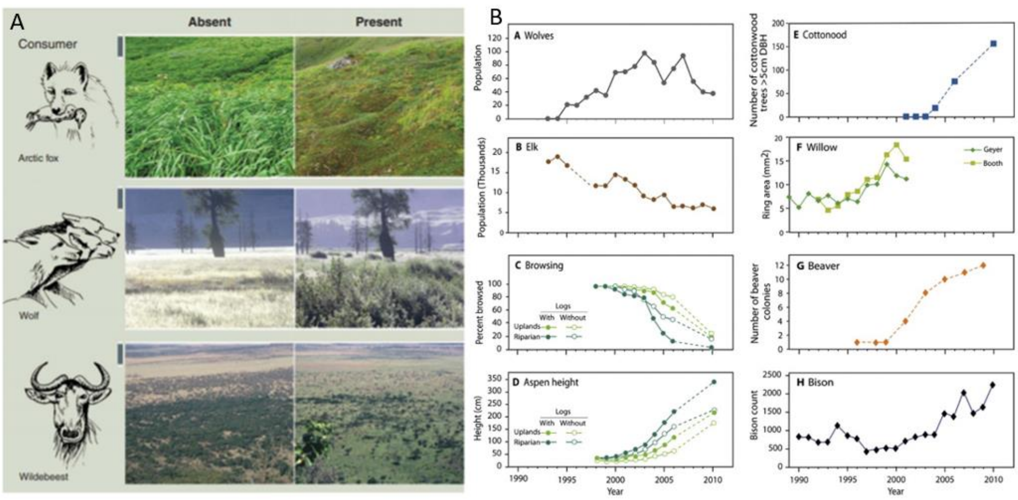

Fig. 4: Landscape-level effects of trophic cascades from three terrestrial ecosystems. ***A****: (Top) Foxes drive terrestrial ecosystems from grasslands to tundra (ref). (Middle) Reintroduction of wolves in Yellowstone NP increases vegetation after 70 years of absence. (Bottom) return of wildebeest populations drove the system in the Serengeti from shrublands to grasslands. See text for details and refs.* ***B:*** *Trends in (A) wolf populations, (B) minimum elk populations from annual counts, (C) percentage of aspen leaders browsed, (D) mean aspen heights (early springtime heights after winter browsing but before summer growth), (E) cottonwood recruitment, (F) willow ring area, (G) number of beaver colonies, and (H) summer bison counts after reintroduction of wolf to Yellowstone NP. Illustrations of A from Estes et al., 2011. Graphs in B from Ripple & Beschta, 2012*

Climatic changes partially come from the increased greenhouse gasses such as CO_2. The world has a carbon cycle, and the marine environment is a big part of that. Mammals such as whales play a role in this. As stated before, commercial whaling greatly reduced whale numbers across the oceans. Research by Pershing *et al*., 2010 suggests that whales now store 9.1×10^6 tons less carbon than before whaling. Pershing and colleagues suggest that rebuilding whale populations would remove and estimated 1.6×10^5 tons of carbon each year through sinking whale carcasses and this makes them comparable to large trees.

This ecosystem functioning and services provide great reasons for humans to conserve wildlife. Moreover, wildlife as an inspirational or aesthetic resource, is also part of the benefits of wildlife. Wildlife tourism is found to provide psychological benefits of human–wildlife encounters that go beyond the experience we get from wildlife seen on holidays for example (Curtin, 2009). Curtin's study (2009) shows that watching wildlife has the potential to bring humans to a space where it is possible to reconnect and restore our mental well-being to a state of equilibrium. These psychological benefits were found to be present even from seeing wildlife in back-yard and cities. Providing even more reason to conserve biodiversity in every part of the world.

4.2 How to conserve species?

These examples above, all show how significantly wildlife influences the environment we so greatly rely on. In turn the future of wildlife populations greatly relies on their ability to coexist with humans. Conservation efforts range from protecting species in isolated protected areas to emphasizing ways for human-wildlife coexistence and involving the community in conservation.

Protected areas and their effectiveness

The dominant strategy for the conservation of species and habitat is the formation of protected areas (Watson *et al*., 2014). Establishment of protected areas (PAs) of land and sea has increased substantially since the 1900s (Fig. 5; Watson *et al*., 2014). In the 2010 Convention on Biological Diversity (CBD) the 2020 targets were to have 17% of terrestrial land protected and 10% of marine and coastal areas. These areas were to be 'effectively and equitably managed, ecologically representative and well-connected systems of protected areas' (Aichi Biodiversity Targets, 2010). In 2018 we were not close in reaching this target. According to Saura *et al*. (2018) the global coverage of terrestrial protected area was only 14.7% and only 7.5% of that area was connected. Similarly, in 2014 only 12.5% of the terrestrial surface was protected (Watson *et al*., 2014). This slow growth rate was maintained and according to the World Database of Protected Areas, the current terrestrial protected area is 15.7% and 7.7% for marine areas (World Database of Protected Areas, 2021).

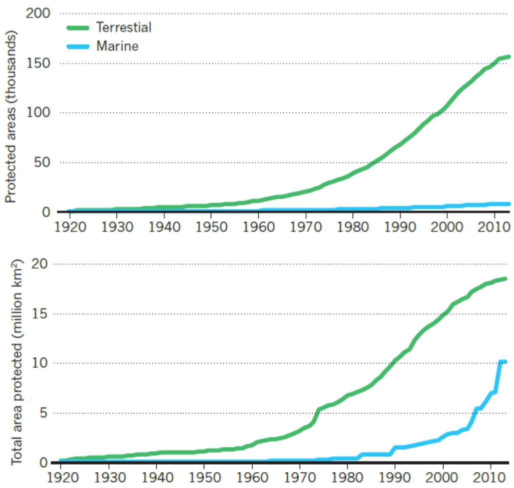

Fig 5. Growth of the modern terrestrial and marine protected area estate. From Watson et al., 2014

To determine if more effort should be made on reaching these targets, it is important to look at the effectiveness of the protected areas. A focus of PAs is to protect species and habitat. The current protected areas might cover roughly 16% of terrestrial land, but they are mostly located in areas that are cheap to protect and not necessarily important for species richness (Venter *et al.,* 2014). A global analysis of all threatened birds, amphibians and mammals (n = 4,118) found that 17% are not found in a single protected area and that 85% are not sufficiently covered to sustain in the long-term (Venter *et al.,* 2014). Only roughly 15% of all examined species was found the covered adequately by PAs. The CBD's target of expanding PAs can only be useful for the future of threatened species when new protected areas are sited more strategically than they are now.

PAs are found to be effective in the conservation of forest cover (Geldmann *et al*., 2013), but for other habitats and the conservation of species the data is very lacking (Geldmann *et al*. 2013). In fact, in a review of PA effectiveness Geldmann and colleagues (2019) found that protected areas, except for forests, experience increased human pressure and in the tropics these pressures are even higher than in the non-protected area they were compared with. These findings are consistent with an example of the Serengeti-Mara ecosystem in Tanzania and Kenya, which is one of the largest PAs in the world. This ecosystem has core protected areas formed by the Serengeti National Park, the Mara Reserve and several adjacent areas with management similar to the national parks (Veldhuis *et al*., 2019). Because of this official core part of the ecosystem, it is known for its soft-edge land-sharing conservation strategies. However, Veldhuis *et al*. (2019) found that particularly at these edges human land use is intensifying. Pastoralists have been intensively using these edges for their livestock to graze, even bringing them as far as 10km into the core protected area. Veldhuis and colleagues research (2019) found that wildlife biomass in the first 15 km of the core area was reduced by 75% in the wet season and by 50% in the dry season. Moreover, their data suggests that this compression of the ecosystem has cascading effect all through the ecosystem. The intensity of grazing by wildebeests in the Serengeti National Park increased, fires in the core area decreased without extra fire management, and the wildebeest we found to have been displaced from preferred grazing grounds. In turn, the higher grazing intensities may have weakened mutualistic relationships that assists nutrient acquisition to plants and increased belowground carbon inputs.

The so-called 'Serengeti squeeze' is a remarkable example of increased human pressure on PAs. The review of Geldmann *et al*., 2019 shows that protected areas have changes inside that are more positive than in the compared non-protected area when the areas are well managed. However, they indicate that reaching the 17% PAs target without ensuring appropriate mechanisms and resources to manage human pressure can lead to average negative effects. These human pressures are often from local communities and the well-being of these communities is sometimes reduced by traditional area-based PAs resulting in illegal use of protected areas (Geldmann *et al*., 2019). However, indigenous people are also found to be very successful at maintaining biodiversity in their lands (Schuster *et al*., 2019). In Australia, Brazil and Canada, three of the six largest countries on earth, indigenous managed lands were found to have similar species richness in all taxa compared to those countries PAs (Fig. 6). Moreover, for specific taxa (e.g. for mammals in Canada) the species richness was higher than in PAs (Schuster *et al*., 2019). For this reason, collaborating with indigenous

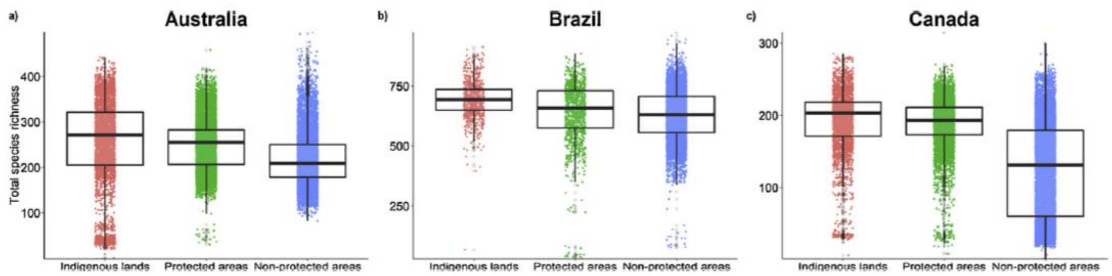

Fig. 6: Total vertebrate species richness for a) Australia, b) Brazil, c) Canada on Indigenous lands, protected areas and non-protected areas. Colored jitter plots show the distribution of the raw data and the boxplots show summarized data in form of median, first and third quartile. From Schuster et al., 2019

nations and organization to support and enhance their management practices highlights a strategy to achieve biodiversity protection and protected local well-being and rights to land at the same time.

Community conservation

As the example of indigenous managed land shows, there is great potential for biodiversity protection when involving the local community. However, these native people have to gain something from this since they are often involved in conflicts with wildlife and often fall under the poorest communities in the world. In several countries programs to involve locals dealing with poverty in wildlife management are established, some with clear positive outcomes. For example, in Namibia the government created a Community Based Natural Resource Management programme (CBNRM). With this program locals on communal land could create a management committee with a wildlife management strategy and a plan to distribute any benefits generated (Boudreaux & Nelson, 2011). These areas are then declared a conservancy and provide income for the local community, while protecting wildlife. With this income conservancies drill boreholes for domestic water use, provide members with transport, medical care and scholarships, support teachers, traditional authorities and sports teams and create human/wildlife self-insurance schemes (Boudreaux & Nelson, 2011). There are also rural communities that traditionally have very negative attitudes towards wildlife, especially predators, that have been included in community conservation with very positive outcomes (Dolrenry *et al.,* 2016). The traditional Maasai people in the Amboseli-Tsavo ecosystem are now actively involved in monitoring lion populations, mitigating human-wildlife conflict and helping their own communities live with lions (lionguardians.org; Dolrenry *et al.,* 2016). Scientist in the study of Dolrenry et al. (2016) employed traditional warriors and gave them literacy and skill enhancement training. During the program, the now Lion Guardians worked in their own community and took pride in their newly gained skills. Because they were still actively engaged with their culture people who were once lion killers are transformed into lion protectors (lionguardians.org; Dolrenry *et al.,* 2016).

These community-based conservation (CBC) strategies have positive results and in general CBC is an effective approach (Brooks *et al.,* 2012) when well-designed. Nevertheless, there are drawbacks to this approach as well. CBC works when these projects balance economic incentives, community empowerment and secure rights (Brooks *et al.,* 2012). In rural Africa, where population growth is the highest, some of these programs have a hard time succeeding. Hackel (1999) found that CBC can be a useful tool to educate about conservation and to produce better relationships between people and wildlife. However, this only sustains a secure future for wildlife if it vastly improves the lives of rural Africans, since they may reject a project if a better economic alternative is presented.

Lack of sufficient investment is a problem to PAs in general. Watson *et al. (*2014) found that many countries do not invest adequately in management of protected areas. The Covid-19 pandemic highlighted this problem. The loss of revenue generation to already underfunded PAs in Africa was so serious that half of 23 operation and programs surveyed reported that only very basic operations could be performed during the strict COVID-19 restrictions (Waithaka, 2020). The 23 operations stated that the financial loss had a huge impact on their ability to fulfil obligations including payment of salaries and protecting biodiversity and other resources.
The return of investment in conserving areas is often overlooked. In Canada for example, in 2009 the government spent $800 million Canadian dollars on Canadian Park sides, but they contributed $6 to Canada's Gross Domestic Product for every dollar invested by the government and supported 64,000 jobs (Canadian Parks and Wilderness Society, 2020). A similar return of investment was found in 2017-18 in the Canadian Parks. Part of the return of investment is not measurable in monetary

terms and a better understanding of all these returns on investment would help to ensure proper funding of PAs and their management, especially with poorer local communities involved.

5. Conclusion and suggestions

The current trend of species loss highlighting the sixth mass extinction in combination with the importance of wildlife to humans, calls for an increase in conservation efforts worldwide. With habitat loss and overexploitation being the greatest threats to wildlife populations the establishment of fully functional protected area is increasingly important. International goals such as the CBD 2020 Aichi Biodiversity Targets of the United Nations should be focus point for all countries. Currently, in 2021, many countries have not met these targets and the protected areas do not deliver their full potential. Adequate steps should be taken to ensure a future where wildlife populations are sustained, and human well-being is accounted for.

One important step is to increase funding for protected areas and their management. Whatever management strategy is used, with inadequate resources PAs will not be well-managed. The Covid-19 pandemic showed how loss of resources reduces the ability to manage protected species. Since investments are usually based on what comes out of the investment, research in the return from investment in PAs is crucial. This includes direct returns such as ecosystem services, economic benefits and job opportunity, but also indirect benefits such as human psychological and mental well-being.

Another important emphasis for protected areas should be to focus protected areas on ecological hotspots instead of only focusing on increasing the area. 85% of the threatened species is not adequately covered by protected areas. To sustain these populations protected areas should be connected and located in places with high species richness. Research should aim to understand threatened species' habitat and needs and to locate the most biodiverse hotspots.

Perhaps the most important step to take is to involve the local community and to follow strategies of indigenous people in managing their land. Since native people have great benefits (e.g., ecosystem services and salary) from managing land and these lands are often already part of their culture, involving them in community-based conservation affects wildlife and people positively. Projects such as the Lion Guardians are great examples of protecting species while keeping locals close to their culture and increasing their well-being. Well-funded, well-managed community-based conservation efforts might provide the most sustainable solution towards a future where people and the world's extraordinary biological diversity can coexist.

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