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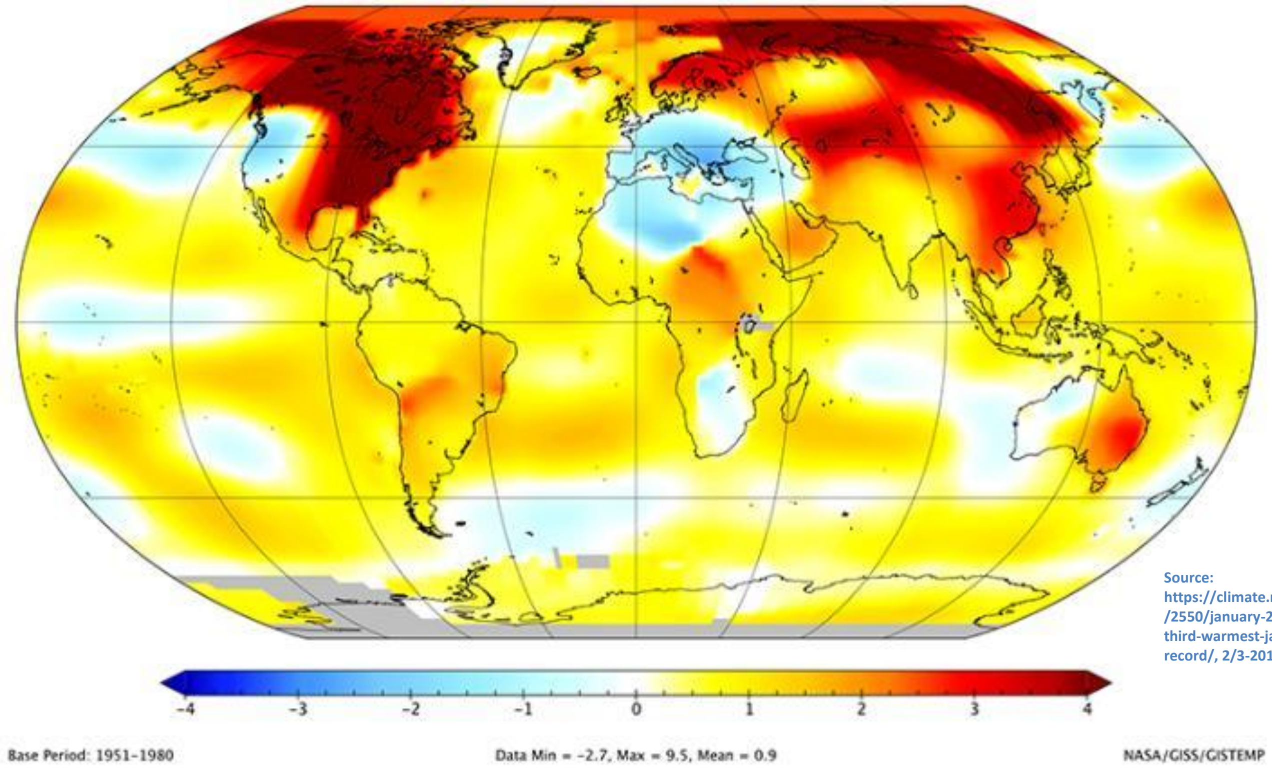

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Effects of Climate Change on Biogeography

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Abstract

Climate changes have always occurred on Earth during recorded history. Facilitated by locomotion of lithospheric plates, landmasses have been formed and degraded, volcanic activities have created islands, and oceans have expanded. These natural processes have surely led to climatic changes that have been the cause for both extinction and migration. In the existence of Gondwana climatic fluctuations occurred as well, ranging between glacial conditions to the possible warmest period in the history of Earth in the Cretaceous. Never in recorded history have the climatic change been as rapid and extreme as currently, and the Earth is possibly facing its sixth mass extinction. The difference between historical climate changes and the current is that the current is almost entirely caused by anthropogenic activity.

Biogeography is a scientific field that aims to explain the geographical distribution of organisms, and understand the spatial patterns of biological diversity. The current climate changes effects many ecosystems, species distribution, and conditions of existence. For this reason, it is of interest to review the overall consequences that the current climate changes have on the biogeography, and try to predict what impact it will have on the future.

This thesis reviews the effects that climate changes have on the biogeography. The following questions will be answered during this thesis: (i) Extinction, speciation, and dispersal have always occurred, so how will the current climate changes affect these processes? (ii) What adaptations are likely to exist in the future, and which will completely disappear? (iii) What link between ecology and evolution are likely to affects future ecosystems?

Based on my literature review, I conclude that many species with low capability to adapt or migrate will face extinction, specialized- and polar species will be particularly vulnerable. With respect to the ocean, organisms that depend on calcification will likely die out due to ocean acidification, if they are not capable to adapt. Speciation will be based on the remaining species, which will have a higher robustness to extreme climatic events, and radiate to fill out niches left by species that went extinct. Pole ward and upslope species migration in order to escape the warming will be unavoidable.

Future adaptations will favor life in warm and drought conditions, and in case of upslope migrators, life under more hypoxic conditions will be favored. Likely future adaptations include longer loops of Henle, the ability to undergo estivation, increased oxygen affinity, bigger lungs, and bigger heart.

Climate changes are changing the ecology on Earth. Polar habitats are melting away, and thus is the sea level rising. The rising ocean creates barriers for dispersal, and isolates many species on islands, leading to increased allopatric speciation. The species development follows the predicted by The Red Queen Hypothesis, which states that species need to keep evolving to cope with changing environmental conditions in order to keep existing.

The introduction of this thesis has three sections: The Influence of Climate Changes on Environment and Biodiversity, Biogeography, and Conservation and Sustainability. In the Discussion section the aim for this thesis is discussed based on these three subjects.

Aim

The aim of this thesis is to, through a literature review, describe the current understanding of how climate change will effect current and future biogeography, mainly in terms of extinction, speciation, dispersal, and adaptation to the environment. This is of interest because climate change put pressure on multiple ecosystems, which promote species extinction (Parmesan et al., 2005). In the history of Earth five previous mass extinctions have been recorded (Barnosky et al., 2011). These were caused by natural events, like asteroid strikes, volcanic eruptions, and natural climate shifts, whereas the current is almost entirely caused by anthropogenic activity (Barnosky et al., 2011; biologicaldiversity.org, 2017).

Many species are at risk of extinction because of anthropogenic activity, primarily habitat loss, introduction of exotic species, and global warming (Svenning et al., 2009). For these reasons it is important to clarify how the current climate changes are going to affect processes like extinction, speciation, and migration, and further estimate what adaptations that are likely to be important in the future, and which that will completely disappear. Moreover, it is relevant to investigate the link between ecology and evolution that are likely to affect the ecosystems in the future.

Method

The current study is a literature review, based on scientific papers, books, and web pages written in English. Papers used In the first and second sections in the introduction, ”The Influence of Climate Changes on Environment and Biodiversity” and ”Biogeography”, was accessible on either of the databases Web of Science, Oria, Google Scholar, or Google. The primary database used was Web of Science. When decided on suitable topic for the subsections in the first section, relevant terms was searched on in the online databases. Reference lists of used papers were checked and useful references was used. The subsection ”Ocean” is primarily build on Bollmann et al. (2010) and literature from its reference list. The second section is mainly based on Lomolino et al. (2010), and chapter six and seven from Futuyma (2013) and their references, but other chapters from Futuyma, and additional articles were used as well. Literature used for the last section ”Conservation and Sustainability” is mainly papers that was handed out in a previous attended conservation course (NNMK14000E International Nature Conservation, at University of Copenhagen), and references from these articles. For all the sections, additional papers was found by searching in the online databases by using relevant terms like conservation, climate change, biogeography, and other relevant subjects. Plagiarism was checked on www.paperrater.com.

The Influence of Climate Changes on Environment and Biodiversity

Most scientists believe that anthropogenic caused climate changes do exist, and is resulting in a particularly fast warming of the globe (Garbolino et al., 2016; climate.nasa.gov, 2017). Fast global warming will change both the structure and functioning of many ecosystems on Earth (Garbolino et al., 2016). Scientists rely on evidence from historical clues, like growth rings from trees (Gao et al., 2017; powerhousemuseum.com, 2017), and bubbles of atmospheric gas in polar ice (Aydin et al., 2016). The necessary information is collected using modern tools, and from this data scientists create a picture of how the Earth’s climate is developing (powerhousemuseum.com, 2017). Each year a tree live they grow a new growth ring (Stokes

and Smiley, 1996, p. 14), this growth ring provides information about age and environmental conditions at the time it was created (Helama, 2015; Gao et al., 2017).
As the snow falls atmospheric gases get trapped, and can end up as bubbles in the ice (Langway Jr. and Hansen, 1970, p. 63). This makes it possible for scientists to sample air bubbles from ancient time, and investigate what the content of gases was in the ancient atmosphere (powerhousemuseum.com, 2017). This method provide the most direct record of past atmospheric gas compositions (Ohno et al., 2004).

The effects of climate changes have caused massive changes in the distribution of ecosystems and vegetation types, with many species becoming locally or globally extinct, resulting in broad ecological responses that effects processes ranging from primary productivity to biogeography and evolution (Harley et al., 2006; Stork et al., 2009), but predicting the outcomes of climate change remains a significant challenge (Bryne, 2011).

Since the Little Ice Age the Earth have been undergoing a trend of global warming (Diez et al., 2014), and currently fast climatic changes is leading the Earth to enter a new phase in its history (Bollmann et al., 2010, p. 10).

Mechanisms

A vast amount of climate-relevant trace gases has been released into the atmosphere, causing the Earth's radiative heat balance in the atmosphere to get out of equilibrium and the global mean temperature to increase, and thus leading to global warming (Harley et al., 2006; Bollmann et al., 2010, p. 14). These trace gases includes carbon dioxide, methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFC), hydrochlorofluorocarbons (HCFC), perfluorinated hydrocarbons, and sulphur hexa-fluoride (SF_6), where of carbon dioxide is especially critical for the climate because the worldwide output is so enormous (Eeley et al., 1999; Malmsheimer et al., 2008, p. 125; Bollmann et al., 2010, p. 14). The total annual anthropogenic greenhouse gas emissions in 2010 were 49 ± 4.5 $GtCO_2$-eq/year, 65 % was carbon dioxide from fossil fuel and industrial processes, 11 % carbon dioxide from forestry and other land use, 16 % from methane, 6.2 % from nitrous oxide, and 2 % from fluorinated gases (IPCC, 2014, p. 5). In 2015 greenhouse gas emissions decreased with 0.1 % (Olivier et al., 2016, pp. 4, 70). Carbon dioxide is primarily released through burning of fossil fuels such as oil, natural gas, and coal (Bollmann et al., 2010, p. 14), and more than 80 % of the global energy use releases carbon dioxide (Miles et al., 2007). Unfortunately, the process of changing the global energy system is slow, and in the meantime, the burning of fossil fuels continues to accelerate climate changes (Reuveny, 2007).

The climate-relevant trace gases allow the incoming shortwave radiation from the sun to pass through. This energy from the sun gets transformed into heat at the surface of the Earth, and is then emitted back as long-wave radiation (Bollmann et al., 2010, p. 15). The trace gases in the atmosphere is trapping this long-waved heat radiation that would otherwise re-radiate into space, and thus the surface of the Earth warms up, this is known as the greenhouse effect (Harley et al., 2006; Bollmann et al., 2010, p. 15).
Climate has varied naturally in the past, and before anthropogenic caused global warming a natural greenhouse effect not directly affected by human activities existed. The natural greenhouse gases include water vapor, carbon monoxide (CO), and nitrogen oxides (NO_x), where water vapor is the most common (Karl and Trenberth, 2003; Malmsheimer et al., 2008, p. 125; climate.nasa.gov, 2017).

Threats

Currently ecosystems are under pressure, threatened by global warming, exotic invasions, land-use change, habitat fragmentation and pollution, which are changing the life conditions and distributions of many species (Parmesan et al., 2005). The current climatic change is also increasing the average fluctuations in the daily temperature, giving colder nights and warmer days, which have the strongest effect at higher latitude (Parmesan et al., 2005). The organisms that can not cope with the changed environmental conditions due to climate change will need to either adjust through physiological plasticity like acclimation, genetic adaptation, or via dispersal to more thermal suitable habitats (Blier et al., 2014). The biodiversity on Earth have been shaped by the climatic and environmental conditions throughout evolutionary time, which have affected speciation, extinction and dispersal (Wiens, 2011). But currently anthropogenic activities are influencing the climate more than ever before, and the effects of climate change on ecosystems around the globe are becoming increasingly visible (West, 2009; Diez et al., 2014; Harvey, 2016). The global climate has naturally fluctuated drastically multible times through the history of the Earth (Bollmann et al., 2010, p. 36), but never as rapidly as is currently experienced (Hoffmann and Sgrò, 2011; Santos et al., 2016). The rate of warming has been faster than any that has occurred on Earth during the past 10,000 years (Lashof et al., 1997), and the prediction is that Earth will become warmer than at any period in the past 1-40 million years (Thomas et al., 2004). The mean global temperature is expected to increase to 2.4-2.8°C above preindustrial at equilibrium latest in 2020 (Table SPM.5 in IPCC, 2007). Even if greenhouse gas emissions are stabilized at present levels, the temperature will continue to rise for several centuries (Harley et al., 2006).

The rising temperatures affect land processes, especially through increased evaporation, desertification, and melting of polar ice (Hunt, 2002). Multiple ecosystems are also affected through a wide variety of indirect mechanisms, like warming-induced change in the frequency or intensity of fires (Lashof et al., 1997). Global warming have increased both the intensity and frequency of extreme events, including sea level rise, increased frequency of drought and extreme precipitation, flooding, severe storm activity, ocean acidification and ocean warming (Balling et al., 1992; Whetton et al 1993; Mortreux and Barnett, 2009; Bednaršek et al., 2016a).

Some habitats have been changed to a degree where the stress has become too great for many species to cope with (Bollmann et al., 2010, p. 102). Like many species of corals suffers from decreased fitness and slower growth rates because their habitat has become too acidic (Horwitz et al., 2017). Climate changes often introduce several of its stressors at the same time, and combinations of these can be the cause of species extinctions (Bollmann et al., 2010, p. 102). Especially endemic species are vulnerable, because they are specialized to specific ecological conditions, which make them unlikely to migrate, and the only possible way of survival will be through acclimation or adaptation (Feeley and Rehm, 2012).

History

Fossil fuels formed in the sea over a period of millions of years, as the remains of animals and plants sank to the ocean floor and over time become buried and compressed into layers of sediment several kilometers thick (Bollmann et al., 2010, p. 142). During the millions of years that passed, the dead plants and animals slowly decomposed into organic materials and formed fossil fuels (U. S. Department of Energy, 2017). The industrial oil extraction began in the mid-19th century, since then 147 billion tons of oil has been pumped from reserves around the world, half of it during the past 20 years (Bollmann et al., 2010, p. 142).

During the 12,000 years between the last ice age and the onset of the industrial revolution at the beginning of the 19th century, the concentration of carbon dioxide in the atmosphere changed only slightly (Bollmann et al., 2010, p. 28). Compared with the pre-industrial value, the atmospheric level of carbon dioxide has risen from about 281 ± 2 ppm in 1800 to 359 ± 0.4 ppm in 1994, and with this increase the temperature have risen with 0.6 ± 0.2°C over the 20th century, which is about 0.15°C higher than the estimated value (Sabine et al., 2004; Bollmann et al., 2010, p. 14; IPCC, 2017). In 2003 the level had increased to more than 370 ppm (Karl and Trenberth, 2003). Recently the amount of atmospheric carbon dioxide has exceeded 400 ppm, which is the highest level in recorded history (Horwitz et al., 2017), and is expected to rise to more than 1500 ppm between 2100 and 2200, unless the emissions of carbon dioxide can be reduced (Pörtner et al., 2004). The increased atmospheric level of carbon dioxide is causing a reduction of the ozone layer, resulting in an increased ultraviolet radiation at the Earth's surface (Harley et al., 2006).

Over the past several decades the temperature record has shown short periods of cooling, but in a long term there is a warming trend, as can be seen in Figure 1 (skepticalscience.com, 2017).

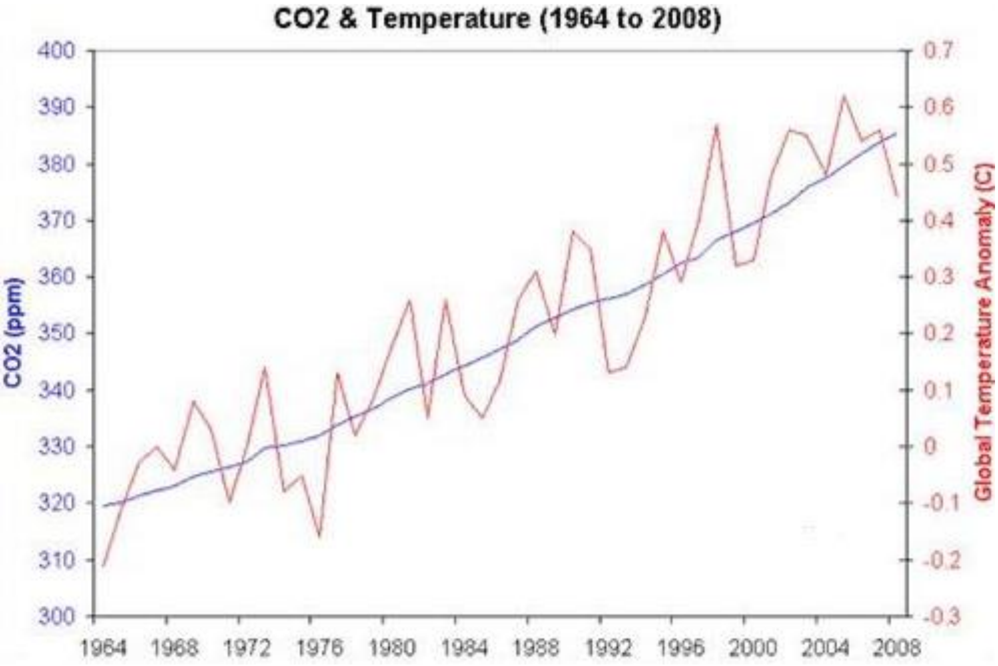

Figure 1 The relationships between atmospheric carbon dioxide (ppm) and the anomaly global temperature (°C) for the period from 1964 to 2008. The red line is the temperature, and the blue line is the atmospheric carbon dioxide (skepticalscience.com, 2017)

Between the early 19th and the end of the 20th century, 400 Gt carbon dioxide was released from anthropogenic sources, during the 1990s about 6.4 Gt carbon was burned as fossil fuels every year, since 2006 this number has increased to 8 Gt (Bollmann et al., 2010, p. 29).

Furthermore, the history of humans has been affected by the climate, and our geographical ranges changed during glacial cycles. The Anatomical Modern Human migrated and replaced archaic human species stepwise as the climate fluctuated toward the peak of the last Ice Age (Stewart and Stringer, 2012) and the evolutionary trends among other mammals have likewise been profoundly influenced by changing climates over the past 66 million years, and by tectonic events (Janis, 1993). Like the effects of present climate change, the climate changes in the past also caused shifts, contractions, and expansions of biogeographical ranges (Knoll et al., 1996; Pörtner and Gutt, 2016).

Ocean

Ocean warming, ocean deoxygenation, and ocean acidification is the three major stressors that climate changes induces the ocean (Bryne, 2011; Lischka et al., 2011; Bednaršek et al., 2016a).

A reason why the ocean have played a dominant role in the climate system throughout the history, is because it stores and transports heat from the tropics to higher latitudes (Bollmann et al., 2010, p. 9; Riebesell et al., 2009). The density of the water varies depending on salinity and temperature, cold and salty water is heavier than warm and lesser salty water. When the heavier salty and cold water sinks to great depths in the ocean it causes circulation of millions of cubic meters of water. As this heavier salty surface water sinks by convection, water flows in from nearby warmer regions, from the direction of the equator. This water is then cooled in the Arctic (always just above -1.86°C) near the polar ice sheets, where it begins to sink due to its high density. Then it flows towards the lower latitudes underneath the surface current of warmer and less dense water that flows towards the poles, and so on do this current continue (Bollmann et al., 2010, p. 16; Willmer et al., 2011, p. 400). Before the water sinks, it absorbs a huge amount of carbon dioxide and other trace gases at the sea surface, which are transported towards equator (Bollmann et al., 2010, p. 16; Sabine et al., 2004). A term used for this water flow is the microbial loop (Anderson and Ducklow, 2001).

The oceanic uptake of carbon dioxide increases as the temperature increases, since the partial pressure of carbon dioxide in surface ocean water doubles for every 16°C the temperature increases (Takahashi et al., 2002; Riebesell et al., 2009). Beside of absorbing trace gases, the current in the microbial loop also transports larva, of e.g. crabs and fishes, through the ocean, and is important for their population dynamics (Harley et al., 2006; Bollmann et al., 2010, p. 25). In the Equatorial Pacific, there are regions of upwelling where oxygen-poor water from medium depths is transported toward the surface where it becomes oxygenated (Sabine et al., 2004; Chan et al., 2008).

As the sea surface has warmed, the current in the microbial loop has been reduced (Riebesell et al., 2009). If Arctic get warmed to a degree where the water will no longer be cooled down and sink, the current in the microbial loop will completely stop, and thus its transportation of heat, larva, and gases will stop (Harley et al., 2006; Bollmann et al., 2010, p. 25).

Ocean Acidification

Ocean acidification can happen due to increased levels of carbon dioxide in the atmosphere, because carbon dioxide can diffuse passively into the ocean, this decreases the oceanic pH and causes hypercapnia (Takahash et al., 2002; Pörtner et al., 2004; Miles et al., 2007; Bollmann et al., 2010, pp. 35-36). When carbon dioxide gets absorbed by the water it dissolves easily, and can react chemically with the water molecules. This partly converts carbon dioxide into carbonic acid (H_2CO_3), which causes a shift in the concentration of bicarbonate (HCO_3^-) and carbonate (CO_3^{2-}) ions (Bollmann et al., 2010, pp. 14, 29, 38). It is the hydrons (H^+) from this reaction that causes the ocean acidification. When the carbonate reacts with carbon dioxide, it forms bicarbonate which leads to further uptake of carbon dioxide, see *equation 1* (Bollmann et al., 2010, pp. 36, 38). Due to increased hydron concentration, and decreased concentration of carbonate ions, the seawaters carbonate chemistry changes (Maas et al., 2016), and impacts chemical and biological processes in the ocean (Bollmann et al., 2010, p. 27).

$$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^- \leftrightarrow 2H^+ + CO_3^{2-} \qquad equation\ 1$$

The reaction of carbon dioxide in water (Bollmann et al., 2010, p. 38).

The ocean is a major natural sink for atmospheric carbon dioxide (Watson et al., 2009), and accounts for 48 % of the uptake of anthropogenic emitted carbon dioxide (Sabine et al., 2004). Therefore it has been of great importance in slowing the rate of anthropogenic caused climate change (Watson et al., 2009). Due to a slow respond to changes in the atmosphere (Bollmann et al., 2010, p. 9), the ocean is currently not able to absorb the carbon dioxide from the atmosphere as fast as it is emitted (Bollmann et al., 2010, pp. 14, 32). It is predicted that in 2100 the overall possible net uptake of carbon dioxide will be about half of what was observed in 2004, and at some point a further uptake is no longer possible (Riebesell et al., 2009). In 2100 the partial pressure of carbon dioxide in the ocean will likely be the double of the pre-industrial levels (Hall-Spencer et al., 2008).

Since the beginning of the industrial revolution, the oceans have taken up about half of all the carbon dioxide produced by burning of fossil fuels (Bollmann et al., 2010, p. 14). Since the early 1900s, the carbon dioxide emission have caused an estimated 30 % increase in the oceanic surface water hydron concentration, and may lead to a decrease of the pH of up to 0.5 units by 2100, which is equivalent to an increased hydron concentration of 200 % (Hall-Spencer et al., 2008; Bollmann et al., 2010, p. 36). The ocean acidification and warming have been the cause for changes in distribution, community structure and productivity of many marine ecosystems (Cheung et al., 2016).

Adaptation, Acclimation, and pH Regulation due to Ocean Acidification

Different organisms can have different responses to a changing environment, from biochemical buffering, through physiological mechanisms and genetic adaptation, to behavioral and ecological modification (Peck et al., 2014). Ocean acidification will expose many marine species to conditions that they may not have been exposed to during their evolutionary history, and for this reason is not adapted to. This can have detrimental impact for both species and ecosystems if they are not able to cope with the conditions (Riebesell et al., 2009).

Carbon dioxide can enter organisms by diffusion and pass through cell membranes into the blood or haemolymph (Pörtner et al., 2004). Changes in the body fluids pH value is likely to disturbe internal functions, so all living organisms aims to maintain the fluctuations within a tolerable range. The organism’s ability to regulate pH and ions depends on the efficiency of various genetically determined mechanisms. When the energy spend on regulating pH and ions increases, it can have the consequence that the growth rate and reproductive capacity decreases (Bollmann et al., 2010, p. 36-37; Busch et al., 2014; Bednaršek et al., 2016a). The mechanism used for pH and ion regulation varies between taxas. Vertebrates can buffer their blood chemically with bicarbonate, phosphate, and protein buffers, in order to regulate pH, and remove phosphoric-, uric- , and lactic acids, and some ketones through the kidneys (Willmer et al., 2011, p. 364). Fish transfer acid-base relevant ions with the surrounding water to stabilize pH during hypercapnia (Hayashi et al., 2004; Ishimatsu et al., 2005). This regulation will always be coupled with the problem of osmoregulation due to the required uptake of appropriate counter ions, which can lead to an additional load of natrium chloride of up to 10 % in marine fish (Pörtner et al., 2004). Mussels, starfish, and sea urchins do often not have the ability to accumulate large amounts of bicarbonate to buffer their body fluid in order to compensate for acidification. Under acidic conditions they reduce their metabolic rate to minimize their intake, and thus grow more slowly. This protective mechanism comes with the drawback that it reduces their competitive fitness (Pörtner et al., 2004; Bollmann et al., 2010, p. 40). Lower marine invertebrates are especially affected by ocean acidification, because their capacity to compensate for disturbances in extracellular ion and acid-base status is low, and their metabolism is in general sensitive to disturbances (Pörtner, 2008).

Possible acclimations and adaptations to ocean acidification includes many mechanisms and strategies, like changes of life cycle patterns, increasing the rate of shell formation, counteracting shell dissolution by increasing the calcification, or changing the mineral polymorphism in the shell to more stable constituents (Bednaršek et al., 2016a). The main differences between acclimation and adaptation, is that acclimation is when organisms gradually and reversibly habituate to changed environmental conditions (Rasmussen, 2005, pp. 14). Acclimation can be used as a buffer against immediate impacts, and provide time for adaptation to catch up (Sunday et al., 2014). Whereas adaptation is an evolutionary process, where organisms become more suitable adjusted to their environment, and involves selection on genetic variation that shifts the average phenotype toward the fitness peak (Sunday et al., 2014; Rasmussen, 2005, p. 22).

It is likely that the capacity for evolutionary adaptation is greater in species with r-selected life history strategy, like temperate copepods and amphipods, than in slow-developing species. Species with long life span, slow development and long generation time is likely to have reduced genetic variation, which limits the scope for evolutionary responses (Bryne, 2011). Clonal organisms are likewise sensitive to climate change, because of their low effective population size and small potential for adaptation to rapid changes (Harley et al., 2006).

Decalcification of Organisms

Ocean acidification is decreasing the carbonate ion concentration to levels where calcium carbonate ($CaCO_3$) (for both aragonite ($MgCO_3$) and calcite which are two common types of calcium carbonate, secreted by marine organisms) shells begin to dissolve, see *equation 2* (McNeil and Matear, 2008; Lischka et al., 2011). Carbonate ions together with calcium carbonate forms the basic building blocks of carbonated skeletons and shells (Feely et al., 2004; Bollmann et al., 2010, pp. 36, 39). When shells dissolve, it have a negative effect on various groups of calcifying organisms, which rely on the production of, e.g. calcified shells for survival, like bivalves, gastropods, mollusks, crustaceans, calcified algal species, sea urchins, corals (Miles et al., 2007; Riebesell et al., 2009), and thus the successful formation of reefs (Miles et al., 2007; Bollmann et al., 2010, p. 39).

$$CO_2 + CaCO_3 + H_2O \leftrightarrow 2HCO_3^- + Ca^{2+} \qquad equation\ 2$$

The reaction between carbon dioxide and calcium carbonate in water (Feely et al., 2004)

Even a very slight increase in the carbon dioxide level can reduce the growth rate in shelled and calcified organisms (Pörtner et al., 2004). When the growth rate decreases, the organisms juvenile life stage increases, this stage is more vulnerable, and thus survival rate decreases (Vinagre et al., 2013). Also, these juveniles produce a weaker skeleton, which have negative impacts on their swimming and feeding efficiency, and thus increase their vulnerability to predation and physical damage (Bryne, 2011). Since juvenile life stage compared to any other time in their life cycle is particular affected by climate changes, this stage may be a bottleneck for species to persist in a changing ocean (Bryne, 2011; Lischka et al., 2011).

Also many groups that uses calcium as internal or external structural elements, such as crustaceans, cnidarian, sponges, bryozoa, annelids, brachiopods, tunicates, squid, and fish might possibly be affected (Riebesell et al., 2009). Many echinoderms, reef-building corals, calcified pteropods, and heteropod mollusks are at particular risk, as they use aragonite as a part of their construction, both as adults and juveniles (Feely et al., 2004; Miles et al., 2007). Aragonite is a 30 times more soluble (Miles et al., 2007) and thermodynamically unstable form of calcium carbonate (Hunt et al., 2008; see also Lischka et al., 2011).

Coral Reefs

Coral reefs are known for their high biodiversity (Scheffer et al., 2001), they are also the marine ecosystems that are most threatened by environmental changes (Rodgers et al., 2015). Coral reefs are especially vulnerable under the 21st century climate changes (Rodgers et al., 2015), and ocean acidification and global warming is driving them towards a functional collapse (Hall-Spencer et al., 2008). Many reef-building corals live very close to their upper thermal tolerances, and warm episodes have resulted in widespread coral bleaching and mortality (Harley et al., 2006). Coral bleaching occurs when the thermal tolerance of their photosynthetic algal endosymbionts (*zooxanthellae*) is exceeded (Jones et al., 2008). The temperature of the sea in many tropical regions have increased by almost 1°C in the past 100 years, and are currently increasing about 1-2°C every century. Many corals capability for acclimation is already exceeded, and adaptation will be too slow to stop a decline (Hoegh-Guldberg, 1999). If the carbon dioxide emission continues as present, 70 % of all known tropical reef locations will be gone at the end of this century. This will further lead to detrimental effects, since coral reefs provides breeding grounds for commercially important fish, and protect shorelines from erosion and flooding (Riebesell et al., 2009). Some forms of corals can exist without their calcareous shell, but only for periods, and it makes them more vulnerable to predation. This is not possible for echinoderms because their skeletons support organismal functions (Pörtner, 2008; Bryne, 2011).

Rock corals are completely absent in acidified areas of the ocean, and the abundance of various species of sea urchins and snails is low, (Bollmann et al., 2010, p. 43). Not all coral mass extinction has been caused by anthropogenic activity. Four out of five times in the geological record it has been caused, at least partly, by periods of naturally occurring ocean acidification (Sunday et al., 2014).

Pteropods

Pteropods are pelagic and planktonic marine gastropod mollusks, also known as sea butterflies, they have a pair of parapodia wings for swimming instead of a gastropod foot (Gannefors et al., 2005; Hunt et al., 2008). They consist of two orders: the *Thecosomata* that have aragonite shells, and the *Gymnosomata* that are naked pteropods (Bednaršek et al., 2012b). They have an important role in the food web of various marine ecosystems, where they both are consumers and prey items (Comeau et al., 2009; see also Fabry et al., 2008). They are especially important in Arctic as a food source for top predators (Hunt et al., 2008), like seabirds and baleen whales (Lischka et al., 2011; Bednaršek et al., 2016a). Pteropods are also prayed on by multiple other animals, including amphipods, cephalopods, squid (Busch et al., 2014; Bednaršek et al., 2016a), and fishes (Armstrong et al., 2005).

Chronic exposure to increased temperatures and oxygen constraints will probably reduce their activity and growth (Bednaršek et al., 2016a). Heat induced stress do seemingly decrease the body size of adults, and decreases the egg production, and thus cause chronic suppression of their reproduction (Bednaršek et al., 2016a). Pteropods are also severely affected by ocean acidification, which have caused decline in the population, and a northward shift of their distribution. This have decreased their biogeographical distribution, and led to significant ecological impacts (Hunt et al., 2008; Pörtner, 2008). Pteropod larva exposed to ocean acidification has retarded development and shell calcification, increased mortality and degradation of skeleton (Lischka et al., 2011).

Like other marine organisms that produce calcareous shells or skeletons, the changes in ocean carbonate chemistry also pose profound challenges for shelled species of pteropod. Their shells are made of aragonite (Bednaršek et al., 2016a), which makes it highly soluble, and pteropods are expected to be among the first major group of calcifying organism to be adversely effected by ocean acidification (Fabry et al., 2008; Lischka et al., 2011). As the dissolution exceed calcification, the shell growth decreases, and the fragility and mortality increases (Bednaršek et al., 2016a). When their shell disintegrates, the vulnerability to predation and infections increases, and imposes an energetic cost (Bednaršek et al., 2016b).
The future of pteropods is under concern, and thus is those species that are dependent upon them as a food resource. A decline the Pteropods populations would likely cause dramatic changes to the structure, function and services of their ecosystems (Comeau et al., 2009). Some of their predators, e.g. Cod, Pollock, Haddock, Mackerel, would be able to switch to other prey types, which could result in greater predation pressure on juvenile fish (Fabry et al., 2008).

Heat and Melting Sea Ice

As the planet warms due to increased atmospheric carbon dioxide, so does the ocean (Bryne, 2011). Multiple marine organisms already live close to their thermal tolerance, and a further thermal increase will negatively affect the performance and survival of these (Harley et al., 2006).

Antarctic fish are adapted to survival at temperatures below 3°C to 6°C, and are significantly less capable to tolerate increasing temperatures, than lower latitude species (Bryne, 2011; Peck et al., 2014; Pörtner and Gutt, 2015). Their adaptation to permanently low temperatures has the trade-off that their temperature tolerance window is very narrow (Pörtner, 2001). The acclimation of Antarctic fish to warmer temperature takes, compared with species from temperate latitudes, 2-4 times longer (Peck et al., 2014).

Global warming has already caused migration of aquatic organisms (Perry et al., 2005), and a globally large-scale invasion into colder marine waters is expected in the future (Holopainen et al., 2016). When exotic species invades, they might shift their species range by becoming locally extinct in their natural habitat and newly established outside their former range (Bollmann et al., 2010, p. 104).

Melting Sea Ice and Osmoregulatory Challenge

The sea ice is melting due to the global warming (Riebesell et al., 2009; Bollmann et al., 2010, p. 145). Unfortunately, is the regions around the Antarctic Peninsula one of the fastest warming area on Earth, and the melting of its ice are accelerating (Meredith and King, 2005). In the years between 1992 and 2011, the Antarctic and Greenland ice sheets lost 1350 ± 1010 and 2700 ± 930 Gt of ice, respectively (Shepherd et al., 2012). Equivalently did the global mean sea level rise with 11.2 ± 3.8 mm (Shepherd et al., 2012). The melting ice causes habitat loss for animals like the polar bears (*Ursus maritimus*) (Dybas, 2012), and emperor penguins (*Aptenodytes forsteri*) (Jenouvrier et al., 2009). The scenario is that two-thirds of the world's population of polar bears could disappear by 2050, if the melting of sea ice continues (Dybas, 2012). The probability that emperor penguins will go extinct in Antarctica by 2100, as a response to melting sea ice, is 36% (Jenouvrier et al., 2009). The extinction can be prevented if they adapt by microevolutionary changes or phenotypic plasticity, but due to their long generation time this is unlikely to occur fast enough (Jenouvrier et al., 2009).

Sea ice acts as an insulating layer that prevents heat from escaping the water, this has a significant impact on heat exchange between the atmosphere and ocean, so when this ice melts it must affect the global climate (Bollmann et al., 2010, pp. 22-24). The melting ice consists of fresh water, meaning that it will contribute in making the ocean less saline, which decreases its density (Bollmann et al., 2010, p. 18). When the inflow of fresh water increases, it decreases the formation of dense deep water, which is needed for the formation of the oceanic current that is important for e.g. the transportation of warm water to eastern North America and western Europe (Scheffer et al., 2001).

Some organisms can face serious physiological challenges when the salinity changes (Holopainen et al., 2016), like osmoregulatory problems, if the organisms are adapted to life in relatively isoosmotic aqueous surroundings (Randall et al., 2002, p. 589; Willmer et al., 2011, p. 399). The inhabitants of the ocean can be challenged with swelling, caused by passive movement of water into their bodies down the osmotic gradient, if they are hyperosmotic to their surroundings. Moreover, they also become subject to a continually loss of body salts to the surrounding water (Randall et al., 2002, p. 589; Willmer et al., 2011, p. 399). The opposite situation will occur in enclosed areas in temperate zones, like the Mediterranean Sea and the Red Sea. The evaporation will increase due to global warming, and thus the salinity will increase (Willmer et al., 2011, p. 397), the organisms here will face the challenge of becoming hypoosmotic to their aqueous surroundings, and thus risk shrinking due to loss of body fluid (Randall et al., 2002, p. 589). Almost all truly marine invertebrates are stenohaline, meaning that they are very restricted in their tolerance to fluctuating salinities (Willmer et al., 2011, p. 397).
To be isosmotic to the surroundings means that the osmotic concentration of the body fluids is the same as the surrounding aquatic environment. Being hyperosmotic means that the body fluids is less diluted than the surrounding aquatic environment, and being hypoosmotic means that the body fluids are more diluted than the surrounding aquatic environment (Willmer et al., 2011, pp. 54, 72).

Another consequence of melting ice is that the oceans are expanding, and the sea level is currently rising at about 2 mm per year (Harley et al., 2006). When the ice melts, then the methane that was trapped in the ice get released to the atmosphere, and this contribute to further acceleration of global warming. Methane does not play a significant role in aquatic environments, because it is an order of magnitude less soluble in water than carbon dioxide (Hester and Brewer, 2009). Since 1951 and until present, the temperature of the air in the Arctic regions have risen with 3°C, and the sea surface temperatures to the west of the peninsula have risen by 1°C (Meredith and King, 2005). The global mean surface air temperature is still increasing, and is predicted to rise with another 2°C by 2100 (Eeley et al., 1999).

Recently Fast Climatic Changes

The rapid climatic changes have, among other things, the consequence that not all species can evolve in the same steps, and like predicted by The Red Queen Hypothesis (explained further on page 29), these are in

great risk of extinction (Bollmann et al., 2010, p. 117; Futuyma, 2013, p. 172). The climate change has already caused more extreme climatic conditions than ever before during recorded history, e.g. the polar ice is melting, and drought is an increasing problem in the terrestrial environment (Meredith and King, 2005; Allen et al., 2010; Quataert et al., 2015).
Most model predictions indicate alarming consequences for biodiversity, where the worst-case scenarios is, that the anthropogenic caused climate changes will lead to extinction rates that would qualify as the sixth mass extinction in the history of Earth (Thomas et al., 2004; Bellard et al., 2012). Also, land-use changes leads to destruction of natural habitats and contributes to mass extinction (Jetz et al., 2007; Stork et al., 2009). Comparing the effects of climate change and land-use change, it is seemingly in general grassland (Vermaat et al., 2017) and forest (Chomitz and Thomas, 2003) that are the habitats lost to land-use change. And in general wetland (Vermaat et al., 2017), polar areas (Bollmann et al., 2010, p. 25), and marine habitats (Quataert et al., 2015) that are mainly lost due to climatic changes.

Land Fragmentation

Land fragmentations have been created due to land-use changes, and since multiple species do not, or are not willing to, cross open clearings, even when this dispersal is crucial for their persistence in the fragmented landscapes, these populations will decline. Species that usually do not cross fragmented areas includes some large mammals, some bees, Nymphalid butterflies, and birds (Stork et al., 2009).

The rate of species extinction have over the past few hundred years increased by as much as 1,000 times over the background rates that have been typical for the history of Earth (Millennium Ecosystem Assessment, 2005, p. 4). The average rate of vertebrate species loss over the last century is even under conservatively low assumptions up to 100 times higher than the background rate (Ceballos et al., 2015), and is likely to increase another 10-fold (Joppa et al., 2008).

Drought, desertification, forest fire, and flooding as a consequence of global warming; climate change induced migration, and mismatch between plant and pollination; and the consequences for aquatic environments due to acidification and warming are explained more detailed below.

Drought, Desertification and Forest Fire

The elevated heat stress associated with climate change is causing an increase in the frequency, duration, and severity of drought in some regions (Allen et al., 2010). The warmer and more drought climate makes environmental conditions become more suitable for fires in many regions, and thus the fire frequency is increasing (Grose et al., 2014; Harvey, 2016; Garbolino et al., 2016). This can potentially change the composition, structure, and biogeography of forests in many regions (Allen et al., 2010). Wild land fires has a huge contribution to greenhouse gas emissions, in the United States alone these carbon dioxide emissions was 126.4 million tons during 2005 (Malmsheimer et al., 2008, p. 141).
Drought is defined as the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels causing hydrological imbalance that adversely affects land resource production systems (Le Houérou, 1996). The drought is having an impact on a wide variety of the world, e.g. the Australian continent, which contains most of the world's deserts, is projected to experience consistent and extensive increases in fire probabilities (Moritz et al., 2012). For instance, in the southern Australia 30 % of the years between 1961 and 2000 were warmer and drier than the mean value for the 140 year prior to the period, and 63 % of the years in the period between 2061 and 2100 are predicted to

be even warmer and drier (Matthews et al., 2012). In the eastern part of South Africa rainfall has decreased with 10-15 % which has caused regions with severe drought (Eeley et al., 1999).

Ecological Disturbance

The increased mortality of trees due to climate induced physiological stress and interactions with other climate-mediated processes such as insect outbreaks and wildfire are of concern (Allen et al., 2010). The elevated temperatures can affect insect population dynamics by accelerating their development and reproduction, this can exacerbate pest problems, like outbreaks of e.g. species of aggressive bark beetles, while at the same time the hosts susceptibility to insect attack may be reduced due to heat-induced drought stress (Allen et al., 2010; Szczepaniec et al., 2011). Insect-, herbivory- and plant diseases is a direct cause of large-scale forest decline, and have also been proposed as a mechanism whereby future climate change may lead to a decline of forest ecosystems (Hanson and Weltzin, 2000; Liu and Yin, 2013). When a former humid tropical forest is completely burned-down it is in general assumed that it will take 300 to 1000 years before it regains its original structure and species composition (Sombroek, 2001). Forest fires do also increase due to logging and fragmentation, which further favour species invasions, and edge-related changes (Stork et al., 2009).

Multiple tree species have shifted their geographic distributions to colder regions due to the global warming (e.g. Harsch et al., 2009; Gaire et al., 2014; Schwab et al., 2017; Kharuk et al., 2017). This trend is predicted to continue in the future, and juvenile trees will be found more concentrated in colder climates than older trees (Zhu et al., 2014; Bauer et al., 2016). Geographical redistribution of trees may affect many other components of forest ecosystems, possibly favoring invasive species (Bauer et al., 2016). This was the case when Bishop wood (*Bischofia javanica*) invaded the Bonin Islands of Japan, and outcompeted native species (Strayer et al., 2006).

Increased tree mortality because of drought and heat is a global issue, and has been reported for Africa, Asia, Australasia, Europe, North-, South- and Central America. It can take long time for trees to replace themselves, because they grow relatively slowly but can die within a few months due to e.g. severe drought (Allen et al., 2010). Forest die-off is critically because forests store considerably amounts of carbon and have an important role in the global carbon cycle. If these pools of carbon become released back into the atmosphere it will contribute to acceleration of further climate warming (Allen et al., 2010; Pan et al., 2011). An increase of the fire frequency in boreal forests can lead to an average net release of 0.3-0.8 Pg. carbon per year for a period of 50-100 years (Lashof et al., 1997).

Plants remove carbon dioxide from the atmosphere and store it in their roots, stems, trunks, and leaves through the process of photosynthesis (Malmsheimer et al., 2008, p. 132). Recent analyses have estimated that the global terrestrial carbon sink absorbs a range of 2.0 to 3.4 Pg. carbon per year. In the periods 1990 to 1999 and 2000 to 2007 these values were 2.5 ± 0.4 and 2.3 ± 0.5, respectively. But remark that measurement data of soil carbon flux in tropical intact forests are lacking in this statement, which may cause uncertainty of 10 to 20 % of the estimated total carbon sink in these forest areas (Pan et al., 2011). A carbon sink is a biomass production that removes carbon from the atmosphere, like the production of wood (Wiedmann, 2012; Guo et al., 2013).

Effect on Vegetation, Soil and Water Budget

After a forest fire the environmental conditions like light, water and nutrient availability are favoring grasses, and in this environment, the grasses can quickly outcompete the trees (Bachelet et al., 2000). Grasses can be killed by drought as well, this drought can further result in wildfire that can spread and kill other species (Bachelet et al., 2000). Wildfires are not a new phenomenon, and are recognized as an environmental process that has influenced the atmosphere and biosphere for hundreds of millions of years (Pechony and Shindell, 2010).

As forest retreats grassland might expand, but it is also possible that the vegetation cover will be lost (Scheffer et al., 2001; Wyckoff and Bowers, 2010), leaving space for the persistence of open area species (Ribeiro et al., 2016). Loss of perennial vegetation, like trees, is often cited as one of the main ecological threats facing the world today (Scheffer et al., 2001). In general, it is the herbs that absorbs water from the upper soil layer and trees that absorbs from the lower soil layer, when the vegetation cover is lost, runoff increases, and water entering the soil quickly disappears to deeper layers where it cannot be reached by plants like herbs (Scheffer et al., 2001; Liu and Yin, 2013). Wind and runoff can erode fertile remains of the topsoil which make it harder for seedlings to recolonize (Scheffer et al., 2001). Erosion by rain water is also likely to occur when the soil surface is not protected by permanent vegetation, and the elevated wind speeds at the unprotected soil surface increases the evaporation and aridity (Le Houérou, 1996).

The solar energy fluxes that reach ground level and reflects back to the atmosphere also changes when the vegetation cover is gone. This can also potentially change the ecosystems water budgets due to increased evaporation and reductions in the groundwater deposit (Allen et al., 2010).

Desertification

The soil erosion and vanishment of protective vegetation creates the basis for desertification. In fact 15 % of the Earth´s terrestrial surface is subject to various degrees of desertification (Le Houérou, 1996). Desertification means land degradation leading to desert conditions, or expansion of these areas. Its creation can be triggered by climatic changes, unsustainable use of the soil (Rasmussen, 2005, p. 211), or drought, but not necessarily (Le Houérou, 1996). Desertification has long lasting effect with permanent and sometimes irreversible consequences on the ability of the environment to maintain its long-term productivity (Le Houérou, 1996). This desert state can be impossible for perennial plants to recolonized owing to the soil conditions, even if perennial vegetation was the original for the region (Scheffer et al., 2001).

Changes in vegetation due to climate induced consequences like desertification have occurred through history, forest has always expanded and contracted in response to the changing environmental conditions associated with glacial and interglacial cycles (Eeley et al., 1999). Desertification might be what shaped the Sahara Desert. During the early and middle Holocene about 10,000 to 5,000 years before present much of the Sahara was dominated by vegetation cover, lakes and wetlands. Around 5,000 years before present the climate changed and the desertification began (Scheffer et al., 2001).

Trees filter solar radiation and removing the trees can increase the maximum surface temperatures 10°C to 40°C (Wilkin et al., 2016). Over a multi-year period the leaf size in the canopy will be retarded due to drought to an extend that will allow more penetration of solar radiation, which can lead to modifications of microclimates within the forest community and potentially over successional time scales change the future species composition (Hanson and Weltzin, 2000). When the canopy cover decreases the flammability increases because of lower fuel moisture content (Kalabokidis et al., 2015). A decreased rainfall is projected for many of the world's deserts, including large parts of the Saharan, northern Arabian, the Sonoran, and central and western Asian deserts (Lashof et al., 1997). Drought is also a serious issue for human populations, and both small local villages and large urban centers need to be prepared to overcome the risks posed by the scarcity of water. Some populations are already experiencing shortages in water distribution and drainage services (Duran-Encalada et al., 2017).

Fire as a Natural Mechanism

Ecosystems in Mediterranean-type climate zone of South Africa is becoming warmer and the precipitation have decreased, which have led to more frequent and intense periods of drought (West, 2009). Fires have always been present in, for example, Mediterranean ecosystems where they are important natural mechanisms of many forest ecosystems and contribute to vegetation dynamics by altering interspecific competition and initiating forest gap dynamics (Harvey, 2016; Mitsopoulos et al., 2016). Flora in Mediterranean environments is particularly adapted to frequent and severe drought caused stressors. They are dominated by woody species, and include many plants selected by fire and therefore possessing large amounts of underground reserves to resprout. In addition to this, other survival strategies are used by these plants, including long lifespan and soil seed-banks (Vennetier and Ripert, 2009). After wild fires, the soils content of organic matter is increased, which contributes in providing plants with nutrients (Marin-Spiotta et al., 2014). Species that are native to areas with a natural high fire frequency are adapted to these conditiond (Harvey, 2016), the robustness of plant communities towards fire is governed by life history key traits like resprouting, seed dormancy and dispersal, these varies among species (Hammill et al., 2016).
As a result of increased heat and dry conditions, the frequency of forest fires have reached unnatural high levels (Bachelet et al., 2000; Liu and Yin, 2013; Harvey, 2016).
Mediterranean biomes, together with the biomes montane grasslands and shrub lands, desert and xeric shrub lands, and temperate coniferous forests show an increased fire probability compared to other biomes across most of their area (Moritz et al., 2012). The increased occurrence of forest fires have led to slower forest recovery between the fires (Harvey, 2016). Changes like this in the vegetation dynamics can further lead to changes in the global carbon and hydrology cycle, as well as a feedback to climate change (Liu and Yin, 2013). Vegetation is needed to provide enough fuel for a fire outbreak to occur, and drought make the vegetation particularly flammable, together with a low level of moisture the dry vegetation creating ideal conditions for fire occurrence and spread (Liu and Yin, 2013; Dash et al., 2016; Garbolino et al., 2016). The different types of vegetation have different responses in terms of fuel availability and flammability (Kalabokidis et al., 2015). Some deserts are projected to experience consistent and extensive increases in fire probabilities because invasive herbs species are invading these areas (Moritz et al., 2012).

The occurrence of fire outbreaks decreases in relation to the mean distance to water bodies, due to a more moisture environment around water bodies. In this way water bodies can act as physical barriers for the spread of fire (Dash et al., 2016) Understanding influences like this of the land cover on the fire-regime responses to climate change is thus essential for projecting how changes will occur (Dash et al., 2016). In the coming century the temperatures are predicted to rise significant virtually everywhere on the Earth in response to anthropogenic caused climate change. Future wildfire activity is projected to increase dramatically in both size and frequency, and longer fire seasons and more severe fire effects are expected as well (Pechony and Shindell, 2010; Moritz et al., 2012; Kalabokidis et al., 2015; Dash et al., 2016). With warmer temperatures within the next century, especially tundra areas may become more favorable to plant growth, and thus fire could rapidly become a novel disturbance in these areas (Moritz et al., 2012).

For species that are sensitive to fire, landscape locations with reduced fire frequency will serve as a climate change refugia. These climate change refugiums are areas that buffer the effects of climate change, the fire regime in these areas may be dramatically different from the surrounding landscape (Wilkin et al., 2016). These refugiums have attracted attention as important conservation areas (Wilkin et al., 2016). Refugiums can be important also in regard to other factors than fire (see page 25), and is defined as a special case of suitable habitats for organisms to live, for which there is evidence that the range of the organisms has contracted and can potentially expand from under changing environmental conditions (Rosen, 1984, p. 219; Wilkin et al., 2016).

Flooding

Associated with rapid climatic warming, the occurrence of heavy rainfall events and flooding are increasing in some areas (Whetton et al., 1993; LeRoy Poff, 2002; Hirabayashi et al., 2008). The reason why the flooding increases in some areas, while drought is a severe problem in other, is the differences in the geography. Areas with closer proximity to aquatic areas will experience more rainfalls caused by evaporation, which will hence not happen in areas very distant to aquatic areas (Natugonza et al., 2016; Mac Nally et al., 2017).

The rise of sea level is one of the most serious consequences of global warming, since the end of the last ice age and to the present day it has risen by around 125 meters by melting of glaciers (Bollmann et al., 2010, p. 56). It could rise by a further 5 meters within just 300 years if the melting continues, and thus cause many low-laying coastal areas around the world to be lost in the coming centuries (Bollmann et al., 2010, pp. 55-56). In fact it is predicted that the global sea level will rise up to 59 cm by 2100 (Bollmann et al., 2010, pp. 57-58). Floods can be generated by the increased water vapor available for rainfall (Whetton et al., 1993; Hirabayashi et al., 2008), due to the melting of accumulated snow and ice (Arnell and Gosling, 2016), or the rising ocean (Soepadmo, 1993). The characteristics of the flooding will vary depending on the mechanism that generated it (Arnell and Gosling, 2016). Since the 1950s the winter snow covers have declined by 10 %, Northern ice thickness fell by 40 %, and the sea level has risen 20 cm (Reuveny, 2007). It is expected that the global mean sea level will have risen about 1.0 m in 2060. This extensive rise in the sea level will cause extensive flooding in low-lying coastal areas (Soepadmo, 1993).

Rainfall are more likely to occur under warmer climatic conditions with higher temperatures and increased evaporation (Garbolino et al., 2016), and the number of rainy days over the oceans increases with increased temperature of the sea surface (Whetton et al., 1993; Hirabayashi et al., 2008). In fact, the ocean provides 85 % of the water vapor in the atmosphere (Bigg et al., 2003). The transportation of moisture over the oceans generates coastal flooding in warmer maritime regions, putting especially tropic coastal areas at risk of flooding (Whetton et al., 1993; Hunt, 2002; Hirabayashi et al., 2008; Diez et al., 2014). Continental precipitations start the hydrologic cycle, resulting in soil infiltration and surface runoff. The presence of urban development and landscape represent important modifying factors, because filtration is reduced due to the relative impermeability of the urban soil surfaces, the quantity and the speed of runoff consequently increases regardless of the slope because there is less friction (Diez et al., 2014). The interior mountain catchment floods are projected to decrease in magnitude by 7 %, in volume by 38 %, and in frequency by 23 %, with little change in duration (LeRoy Poff, 2002).

Missing Coastal Protection and Prevention Against Flooding

In the past 50 years, the frequency and impact of floods has increased significantly due to clearance of mangrove forest, leading to a downstream flooding (Millennium Ecosystem Assessment, 2005, p. 9). The mangrove forests acts as a highly effective natural flood control mechanism, and are already used as a coastal defense against extreme climatic events (O'Brien et al., 2012). In ccoastal zones are experienced a rapid increase in storms and flooding (Ferrario et al., 2014), the hazards following these are likely to increase in the future with predicted climate change (Quataert et al., 2015). Coral reefs provide substantial natural protection against wave induced hazards by reducing wave energy by an average of 97 % (Ferrario et al., 2014), because they are highly resistant to waves and their complex limestone structure attenuates the wave action (van de Koppel et al., 2015). Unfortunately, ocean acidification and increased temperature reduces the coral cover e.g. by coral bleaching, resulting in decreased hydrodynamic roughness of coral reefs (Quataert et al., 2015). This decrease in functional coral reefs leads to less protective effects on the coastal zones and increased wave heights, and wave-driven flooding (Quataert et al., 2015).

Besides of flood prevention, coral reefs offer both physical protection and attenuation of wave stress for sea grasses and mangroves, allowing these habitats to develop in the shallows behind them (Moberg and Folke, 1999; van de Koppel et al., 2015). In this way, the coral reef ecosystems facilitate series of other keystone habitats through long-distance interactions (Gillis et al. 2014; van de Koppel et al., 2015). The mangrove forests that the coral reefs protect further reduce erosion of soil and thereby contributing to the maintenance of terrestrial habitats, and thus prevent near-shore sea grass beds from becoming a tidal wetland because of excessive sedimentation (van de Koppel et al., 2015). Sea grasses and mangrove forests do also act as nurseries for fish that later migrate to coral reefs (van de Koppel et al., 2015), these long-distance interactions can be important for coastal defense against globally rising seas and increased storm frequencies (Barbier et al., 2011). Unfavorably, the sea grass meadows and mangrove forests are strongly decreasing each year (Valiela et al., 2001; Waycott et al., 2009). Moreover, are both coral reefs and mangroves around the world severely affected by habitat destruction, degradation, and overfishing (Olson and Dinerstein, 1998).

In some areas the flooding also comes with a significant increase in the transmission of malaria, because water from the flooding accumulates and persists in small ponds, which provides breeding grounds that allow the mosquito larvae to complete the full life cycle in areas that normally are too inhospitable for them (Boyce et al., 2016). Flooding is further significant associated with outbreaks of waterborne diseases, specifically because pathogens can spread through floodwaters within watersheds (Levy et al., 2016).

Migration

Climatic changes are causing ecological responses such as biogeographical range shifts, leading to migration, and changes in productivity and biodiversity (Thomas et al., 2004; Harley et al., 2006). Tropical regions hold the world's greatest biodiversity of marine species, here the ocean conditions are generally at the edges of specie's environmental preferences, and sea surface temperature started to exceed the historical ranges early in the 21st century. This facilitates species migration towards colder regions (Rodgers et al., 2015). Especially over the past 30 years climate change has been the reason for numerous of species to shifts distributions and abundances (Thomas et al., 2004).

Fluctuations in the climate represent a major influence that can occur at both large and small time scales and may affect species distributions at multiple spatial scales (Ribeiro et al., 2016). It can affect distributional area of each species independently, and for most marine organisms their thermal specialization causes them to follow the shifting isotherms in the oceans. Thermal ranges as well as the capability of species to acclimate differ depending on latitude and temperature variability (Thomas et al., 2004; Pörtner and Gutt, 2016). A consequence of the occurring climate induced migration is that it can cause conflict between migrants and original species in receiving areas (Reuveny, 2007). The migrant species can evolve to use local species as food, avoid local enemies, or match their life-history traits to local environmental conditions (Strayer et al., 2006).

Pollination

The interactions between plants and pollinators are among the most ecologically important relationships in nature, and fundamental keys to global biodiversity, and an important selective force during evolution (Fiz et al., 2008; Giannini et al., 2012; Schmidt et al., 2016). But unfortunately global warming is having an impact on this relationship (Bolmgren and Eriksson, 2015; Schmidt et al., 2016). For multiple species of plants there is a strong and complex relation between air temperature and pollen release, the influence from the temperature is different depending on the species and on the area where the plants grow. Meaning that the global warming leads to an earlier onset of the pollen season in some species (Tedeschini et al., 2006). Global warming effects the phenology, local abundance, and large-scale distribution of plants and pollinators. All of which generate strong temporal mismatches among mutual partners if one of the partners halt or accelerates their future response relative to the other (Hegland et al., 2009; Forrest, 2015; Hua et al., 2016).

Climate Change Induced Mismatches Between Pollinators and Hosts

Climate changes have been so rapid that even some highly mobile pollinators cannot track all their ancestral hosts flowers if these flowering seasons have shifted (Hegland et al., 2009; Coristine et al., 2016). Some butterfly species and ranges of bumblebees frequently fail to track climate change rapidly enough (Bedford et al., 2012; Lozier et al., 2015). It has been observed that many flowering plants appear to have reacted to increasing temperatures by earlier flowering during the last 20-50 years (Hegland et al., 2009). The length of the pollen season of ragweed has increased by as much as 13 to 27 days at latitudes above 44°N in the United States and Canada (Bush, 2011). The season can also decrease, as described by Schmidt et al. (2016), due to current arctic warming, the flowering season in Arctic Greenland has become 8.5 days shorter per decade while the duration of the pollen transfer season has increased with 2.4 days per decade. This has led to a 5.4 days decline in the overlap between the pollen transfer season and the flowering season (Schmidt et al., 2016).

These kinds of mismatches contribute to decreased pollination efficiency, and have led to measurable impacts on the plants reproductive success (Molnár et al., 2012; Forrest, 2015; Schmidt et al., 2016). In some cases, the mismatches lead to extinctions of both the plant and the pollinator, which further results in consequences on the structure of plant-pollinator networks (Bellard et al., 2012). A temporal mismatch among plants and pollinators may alter selection pressures and result in rapid evolution in pollination and reproductive traits in plants, and foraging and phenological traits in pollinators as indirect responses to climate warming (Hegland et al., 2009; Hua et al., 2016). Mismatches have also caused desynchronization between great tits and flycatchers and their main food supply during the nesting season (Devictor et al., 2012).

The increased warming and water defect might also decrease the amount and accessibility of nectar for the pollinator (Schweiger et al., 2010), and it is most likely that specialized pollinators will end up being left with no food plants. Meanwhile, the generalist pollinators will just experience diet reductions following phenological shifts (Hegland et al., 2009). These kind of phenological shifts are among the best documented ecological indications of climate change (Hua et al., 2016).

Natural fluctuations in the climatic conditions are not always identical from year to year, even at the same location, and biological responses to changing environmental conditions are also unlikely to be uniform on geographical scales (Molnár et al., 2012). Species with shorter life spans have shorter generation times, and for this reason can adapt faster to changing conditions, whereas longer-lived plant species might show more phenotypic plasticity that might allow them to track environmental conditions associated with climate change more accurately compared with shorter-lived species (Molnár et al., 2012).

Importance of Pollination

Despite of being important for the biodiversity, pollination interactions is also beneficial for humans and provide vital ecosystem services (see page 32) to agriculture and natural systems (Hegland et al., 2009; Giannini et al., 2012). Further is pollination essential for the maintenance of organisms which livelihood depends on flowering plant (Gallai et al., 2009; Kaloveloni et al., 2015). Since one-third of agricultural production depends on pollination by animals, the pollination is fundamental in ensuring the food-production (Giannini et al., 2013). It is estimated that 60-80 % of wild plants and 35 % of the global crop production depends on the animal pollination (Schweiger et al., 2010), and that the economic value of pollination corresponds to 9.5 % of global agricultural production (Giannini et al., 2012).

A decline in insect pollinators may therefore be a threat for the food security, and will lead to an increased demand for agricultural land (Polce et al., 2014). Many different animals are pollinators, including lizards, birds, mammals and insects. Most of them are insects, and because insects are small and poikilothermic, it is likely that temperature will be critical for their life cycle development and activity patterns (Hegland et al., 2009). Bees are the most important pollinators for many wild and cultivated plant species, and there is a clear relationship between early spring temperatures and the first appearance dates of honey bees (*Apis mellifera L.*) (Hegland et al., 2009). Between 2001 and 2007 bumble bees extended their spring flight times by around 2 weeks, this was probably caused by the higher soil temperatures, which ended the queens winter hibernation (Hegland et al., 2009). Also the pollinator’s thermal budgets, energy demands and water balance can be affected by the temperature. Large and dark-colored bees both warms up and cools down faster than small and light-colored bees, which results in differences in resource exploitation and might lead to shifts in pollinator assemblages with increasing temperatures (Schweiger et al., 2010). The flight metabolic rate of honeybees and other larger endothermic insects decreases with increasing temperature, meaning that such species may be able to spend more time foraging when temperatures are rising (Schweiger et al., 2010). Also flies are effected by the temperature, they appear to become more abundant in colder and wetter areas, whereas bees are often more abundant in warmer and drier habitats (Hegland et al., 2009). This indicates that the overall composition and dominance of pollinator composition may change with climate warming (Hegland et al., 2009). Species may have the potential to adapt to changing environmental conditions. However, current and predicted climate changes are expected to be rapid, therefore necessitating equally fast and matched evolutionary adaptations (Schweiger et al., 2010).

Biogeography

In Lomolino et al. (2010) the field of biogeography is defined as "*the study of the geographic distribution of organisms, attempting to document and understand spatial patterns of biological diversity*" (Lomolino et al., 2010, p. 4).

The ideas behind biogeography started in 1761 with Buffon's law, which basically describes the principles behind allopatric speciation, and that different species inhabits different areas (Nelson, 1978). Biogeography can be divided in subdisciplines, one of them is ecological biogeography. The focus of ecological biogeography is how ecological processes and mechanisms influence the distribution of organisms. Another subdiscipline is historical biogeography, which focus on how geological events that influence the distribution of organisms and their evolution (Liberman, 2003a).

Climate changes have always occurred on the Earth (Rogério de Mello et al., 2015), and the climate has never really been constant (Tedeschin et al., 2006). The surface of the Earth is continually changing, and during history changes like formation and erosion of mountain ranges, expansion and contraction of seas, and formation of islands have occurred. These conditions have a strong influence on the distribution of species (Crisci et al., 2006). There is a close correlation between climatic fluctuations and geological events, and this have through history influenced the distribution and evolution of organisms (Bacon et al., 2013; Pörtner and Gutt, 2016). Species that inhabits Earth will continuously have to respond to changing environmental conditions, and if they cannot adapt they are likely to go extinct (Hoffmann and Sgrò, 2011). The climate is one of the most important physical limiting factors (Stanley, 1987, p. 10), and many species have faced extinction due to climatic events (Parmesan et al., 2005).

The present day climate changes are more rapid than what have ever occurred during recorded history. This put pressure on multiple species and ecosystems (Hoffmann and Sgrò, 2011; Santos et al., 2016). The increased temperatures is causing migration that is changing the geographical distribution of both terrestrial and marine organisms, and is leading to local extinction of previously common species (Pörtner et al., 2004).

Extreme changes in climatic conditions have had, and will probably have a huge impact on the future biogeography, and effect processes like speciation, extinction and distribution.

History of Gondwana

Gondwana (also known as Gondwanaland) was the Paleozoic supercontinent that formed about 550 million years ago (table for geographical time scale can be found in the Appendix) (Meert and van der Voo, 1997). Gondwana have been inhabited by multiple species during its existence, species have both originated and disappeared (Hoffmann and Sgrò, 2011), and in its early years multicellular organisms, like trilobites, evolved (García-Bellido et al., 2013). Like in all other geological times, did species go extinct if they were not able to adapt (Hoffmann and Sgrò, 2011). It is estimated that 95-99 % of the four billion species that have evolved on- and inhabited the Earth over the last 3.5 billion years have suffered from extinction (Stanley, 1987, p. 1; Barnosky et al., 2011; Jablonski, 2012, p. 491). Some of Gondwanas remnant taxa, like anteaters and the nematode genus *Beatogordius*, are still existing (Schmidt-Rhaesa and Bryant, 2004; Futuyma, 2013, p. 147). In the late Jurassic period species that belong to the archosaurs clade of crocodyliform was widespread over Gondwana because the climate was warm and moist. The distribution of these reptiles is at present day limited to tropic areas, because they are not able to tolerate low temperatures (Carvalho et al., 2010). Likewise is most clades of amphibians that inhabited Gondwana geographically restricted to few continents because of their inability to tolerate colder environmental conditions (Gouveia et al., 2012). Also many of the plant genera that originated on Gondwana can only be found at tropical and temperate latitudes (McGlone et al., 2001). Dinosaurs was distributed all over Gondwana during the early Jurassic, but in the Cretaceous only several specimens belonging to the family *Abelisauridae* was left on what is now South America, Madagascar, and India (Sampson et al., 1998).

Climatic and tectonic fluctuations also occurred on Gondwana, but in general the climatic conditions was tropical and moist (Myers and Giller, 1988, p. 130). Gondwana remained a relatively stable position in the Southern Hemisphere, drifting just slightly between Equator and the South Pole (Lomolino et al., 2010, pp. 291-292). Species that developed under the narrow tropical conditions on Gondwana tend to be less tolerant to more variable climatic conditions (Gouveia et al., 2012; see also Brown, 2014).

The Breakup of Gondwana

In the early Aeronian (440.8 million - 438.5 million BP) the Gondwanan ice sheets was melting as a result of climatic changes, and thus led to a rapidly rise in the sea level (Loydell, 1998). Cretaceous was a period where Gondwana was almost free of ice, and possibly one of the warmest in recorded history (Carvalho et al., 2010). Cretaceous was a highly active period, where tectonics uplift, atmospheric circulation, volcanism and several configurations of landmasses occurred (Hay, 1996), the locomotion of lithospheric plates led to one of the major volcanic event in the history of Earth (Bellieni et al., 1984). The many volcanic events in the Early Cretaceous led to the break-up of South America and Africa in Western Gondwana, which resulted in the opening of the South Atlantic Ocean (Piccirillo and Melfi, 1988, p. 600). South America rotated clockwise with respect to Africa, it took almost 40 million years before South America was completely separated from Africa (Franke, 2013). The level of atmospheric greenhouse gases increased in the Late Cretaceous due to volcanic activity and lithospheric movements, which accelerated global warming (Carvalho et al., 2010).

When Gondwana broke apart, it formed among others what today is known as Africa, Madagascar, Seychelles, India, Sri Lanka, Arabia, Australia, and Antarctica, as illustrated in Figure 2 (Reeves and de Wit, 2000; Chatterjee et al., 2013).

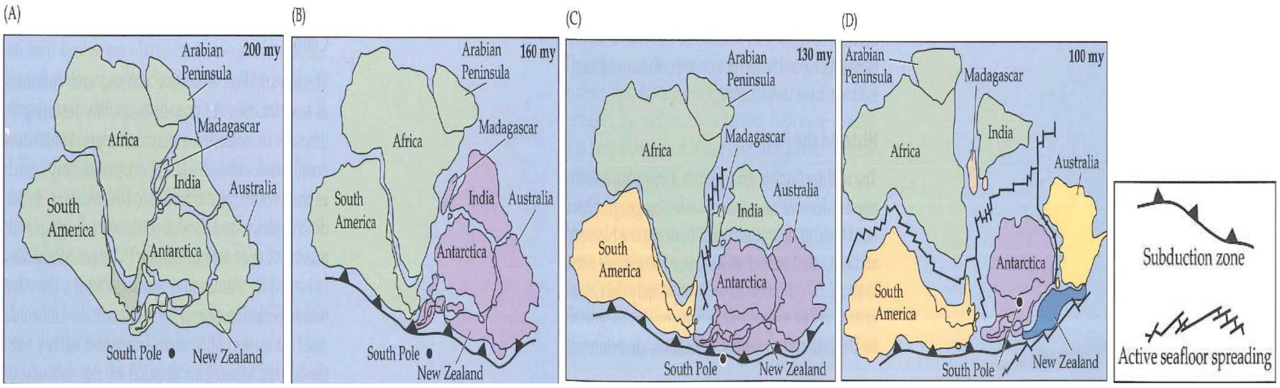

Figure 2 Separation of Gondwana. (A) The initial breakup, landmasses started to separate. (B) Initial rifting followed by seafloor spreading, the continents shown in purple was separated from the rest of Gondwana. (C) Active seafloor spreading had begun, India and Madagascar separated from Antarctica and Australia. (D) Madagascar separated from India and the Seychelles Landmasses. Extensive drifting of continents resulted in collisions and mixing of biotas that had been isolated since the initial

rifting. Australia and New Zealand separated from Antarctica. Black lines with triangles symbolize subduction zones and the zig-zagging black line symbolizes active seafloor spreading (imported from Lomolino et al., 2010, pp. 294-296). Detailed overview of the continental drift, formation and splitting of Gondwana can be found in Lomolino et al., 2010, pp. 287-290.

When studying the evolutionary history of Gondwana, distribution of landmasses, and climate, the origination and distributed of many organisms can be explained (Myers and Giller, 1988, p. 3; Lomolino et al., 2010, p. 273).

The Influence that Continental Drift have on Speciation and Climatic Conditions

In 1863 (Briggs, 1987, p. 7) it was recognized by the early biogeographer Alfred Russel Wallace that many higher taxa have roughly similar distributions, and that the taxonomic composition of the biota is more uniform within certain regions than between them (Futuyma, 2013, p. 137). Wallace´s Line (see Figure 3) is one of the most recognized biogeographical barrier (Bacon et al., 2013). It is a sharp break between two areas that have different evolutionary history, biological development, taxonomic composition of species, but have the same physical conditions, and similar species adaptations (Ricklefs, 1987; Futuyma, 2013, p. 137). Wallace´s Line is situated among the islands that lie between Southeast Asia and Australia, which is on each of their lithospheric plate, which approached each other only recently (Futuyma, 2013, p. 137). The zone between these lithospheric plates is an ancient deep water barrier, and a remain of tectonically disruption (Hall, 2001).

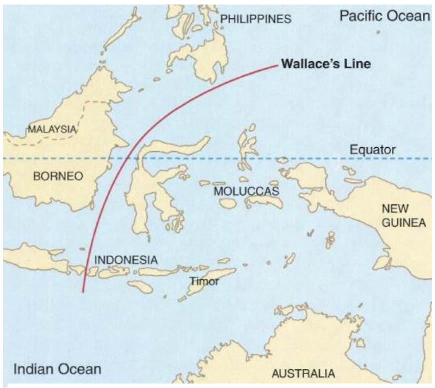

Figure 3 Wallace's Line, marking the geographic separation of Asian and Australian faunas in the Malay Archipelago. Imported from Hickman et al., 2011, p. 810

Species Distribution and Migration

Combinations of biotic and abiotic aspects in the environment affect the distribution of species (Futuyma, 2013, p. 140). A biotic aspect can e.g. be the distribution of predators, competition and parasites, whereas an abiotic aspect can be the geographic distribution of environmental factors (Parmesan et al., 2005).

As the lithospheric plates have circulate on the surface of the Earth´s crust, the species that inhabits them are forced to evolve (Parmesan et al., 2005). Most species is restricted in their distribution to small geographic areas and a limited range of environmental conditions (Lomolino et al., 2010, p. 4). The climate is strongly influencing the migration of species (Lashof et al., 1997), and the fluctuations of the global climate have during the past three million years forced multiple species to change their distribution by migration (Hewitt, 2000; Vennetier and Ripert, 2009). Because species are evolutionary adapted to a specific range of temperatures, they are more likely to migrate in order to follow the moving isotherms than they are to stay and adapt to the changing climate (Pörtner and Gutt, 2016). Since higher altitudes and latitudes have colder climatic conditions, many taxonomic groups worldwide have migrated pole ward and upslope to escape the heat (Feeley and Rehm, 2012; Bauer et al., 2016). Species that are native to these regions cannot migrate further pole ward or upslope, and they become more restricted in their distribution (Lomolino et al., 2010, p. 96). In the Alps the biodiversity of plants has increased during the past century because of upslope migration of species that previously have been restricted to lower elevations (Jackson and Sax, 2009). Also marine species are migrating pole wards, or to greater depths, due to increased ocean temperature and reduced sea ice coverage (Dulvy et al., 2008; Kortsch et al., 2015). This migration pattern will likely continue in the future, where more habitats in northern areas will be colonized, and some already existing communities will be invaded, and possibly outcompeted (Bauer et al., 2016).

The global biodiversity decline from the tropic to the poles (Hinojosa et al., 2016). An explanation for this can be that many lineages originated in a tropical climate during the Cretaceous and the first 40 million years of the Cenozoic, and relatively few lineages have evolved adaptations to lower temperatures (Wiens and Donoghue, 2004; Futuyma, 2013, p. 159). Also the fact that mountain regions in the tropics have a greater range of life supporting environments, which provides more opportunities for newly formed species to survive, might partly explain the higher biodiversity in the tropics (Hewitt, 2000).

Invasive Species and Plant Migration

Ecosystems can be changed completely when species shifts their distribution, this can lead to either loss or gain in the biodiversity (Bauer et al., 2016). Climate change induced shifts of species distribution have often favored invasive species, new habitats can be created for invasive species in areas where they previously would not have been able to survive (Holopainen et al., 2016). Invasive species, also known as alien species, is defined as taxa that are new to a region and have established self-maintaining populations in the wild (Schweiger et al., 2010). When animals migrate, it does also lead to a spreading of seeds from the plants that these animals are feeding on. This seed dispersal might result in the spread of invasive plant species, this is only possible if the conditions of soil, water, and nutrients meet the plants requirements (Lashof et al., 1997; Liu and Yin, 2013).

Because climate changes cause the geographic distribution of some food resource to shift, it is likely that some species will migrate to follow its movement, and thus becomes invasive in some areas (Futuyma, 2013, pp. 609-611). Pressure from e.g. predation and competition restricts the invaders possibility to settle (Peck et al., 2014).

Refugia During Glaciation

Many species shifted their geographic ranges during the Epoch of Pleistocene glaciations, due to changes in the climate and sea level (Lomolino et al., 2010, p. 546; Futuyma, 2013, p. 154). Some northern species became distributed far to the south of their present distribution, where the different species occupied different glacial refugiums (Hewitt, 2000). These species recolonized the northern regions when the climate became warmer again. By allowing species to persist during times with unfavorable environmental conditions, and expand when the environmental conditions became suitable again, the refugiums acted as buffers to climate changes (Futuyma, 2013, p. 141; Wilkin et al., 2016). Refugia are complex habitats, they are influenced by species interactions, climate, and other environmental conditions that interact with one another (Wilkin et al., 2016).

When a population becomes divided between different refugiums, the subpopulations will tend to differentiate between refugiums, this is because the natural selection acts in response to the specific conditions in the different refugiums. These subpopulations might mix and merge again when reunited (Stewart and Stringer, 2012). Multiple species have used refugiums during glaciations. In the southeastern United States populations of Spotted sunfish (*Lepomis punctatus*), Bowfin (*Amia calca*) and Pocket gopher (*Geomys pinetis*), was probably isolated in two different refugiums during the Pleistocene glaciations. Evidence for this can be found in their gene trees, which show a sharp division between the eastern and the western subpopulation (Soltis et al., 2006).

In Europe some subpopulations of hedgehogs and grasshoppers become genetically different enough to form hybrid zones after expanding from their separate glacial refugiums (Hewitt, 2000; Parmesan et al., 2005). Because the climate changes were ccyclical through the Pleistocene, rapid speciation was catalyzed (Dawson et al., 2014).

Effects of Land Bridges

Facilitated by a warm and moist climate, and a land bridge between North America, Europe, and Siberia, many species of both plants and animals spread throughout the northern regions of North America and Eurasia during the early Tertiary. In the western North America many of these species became extinct in the late Tertiary due to mountain uplift, and a cooler and drier climate (Wen, 1999; Sanmartin et al., 2001).

When the Isthmus of Panama formed in the Pliocene, it created a land bridge that connected North- and South America, and made dispersal between them possible (Futuyma, 2013, p. 141). Temperate and arid regions of North- and South America seem ecologically similar (Paruelo et al., 1995), and the formation of Panama facilitated waves of migration, called the Great American Interchange (Lomolino et al., 2010, p. 297). Bisons were originally restricted to North America, but after the formation of Panama they expanded their distribution to include South America (Mack and Thompson, 1982). Other animals that similarly migrated to South America include llamas and deers (Futuyma, 2013, p. 148), whereas armadillos are an example of a species that migrated from South America to North America (Futuyma, 2013, p. 142).

In the Pleistocene, glacial fluctuations caused variations in the sea level, in the order of 120 m (Jordan et al., 2005). When the sea level declined, lowland and coastal areas expanded, and some former isolated areas became connected through land bridges (Jones and Jordan, 2015).

Barriers

Barriers for species distribution can be geographical barriers or barriers caused by ecological conditions to which they are not adapted (Futuyma, 2013, pp. 140-141), and when a barrier disappear it might lead to range expansion for multiple species (Lieberman, 2003b). If a population of a species becomes divided by a barrier, the two subpopulations might undergo allopatric speciation as a consequence of this barrier (Myers and Giller, 1988, p. 368). When the distribution of a species become geographically divided, and leads to the origin of two closely related species that is geographically separated, it is termed vicariance (Rasmussen, 2005, p. 646). Vicariance occurred in the time after the breakup of Gondwana, and similar geological events, where speciation occurred in ancestral taxon that have been separated on different land fragments (e.g. Sampson et al., 1998; Upchurch et al., 2002; Van Bocxlaer et al., 2006).

Vicariance do also occur when barriers are created as a consequence of habitat fragmentation due to deforestation, because it restricts the dispersal of many forest species that are unwilling or unable to cross fragmented areas, like many species of tropical birds (Feeley and Rehm, 2012). If animals stop crossing certain areas, it might create a barrier for the dispersal of some seeds (Feeley and Rehm, 2012).

Movement of Lithospheric Plates and Its Effect on Biogeography

The lithospheric plates are in constant motion on the surface of the Earth, and have led to changes in the distribution of water and landmasses, volcanic activity that have created mountain chains and islands, and climate changes (Rosen, 1984, p. 239; Harris, 2002; Lomolino et al., 2010, p. 259; Bollmann et al., 2010, p.

11; Vermeij and Roopnarine, 2013; Chekhovich et al., 2014). Volcanic activity is often present along plate boundaries, and do in some cases provide species with an option of dispersal (Hall, 2001).

The movements of is also termed plate tectonic or continental drift (Rosen, 1984, p. 239). Throughout history the lithospheric plates have changed in number, shape, and size, new plates have formed and expanded, and plates have faded (Lomolino et al., 2010, pp. 281, 306). Lithospheric plates can drift between climatic zones, and their position is determining their climatic conditions, and thus what species that is able to inhabit them (Harris, 2002). As an example showing how influencal the geographical position is for the species distribution is that Antarctica had a position between South America and New Zealand in the time of Gondwanas existence, during the Mesozonic and Lower Tertiary they all had similar climatic conditions and was inhabited by a southern biota. Currently both South America and New Zealand is areas of high endemism and inhabited by several sister-group species, while Antarctica is an almost biotic blank (Myers and Giller, 1988, p. 362). These differences are caused by movements of lithospheric plates, which placed Antarctica over the South Pole which triggered the development of a great polar ice cap (Myers and Giller, 1988, p. 362; Lomolino et al., 2010, p. 296).

The relocation of landmasses due to the breakup of Gondwana, and afterwards the split between Cuba and Hispaniola, have caused the family of freshwater fish termed Cichlidae to split (Sparks and Smith 2004; Chakrabarty, 2006). This led to allopatric speciation due to vicariance and formed several species (Chakrabarty, 2006), where the species in tropical America (*Cichlinae*) and Africa (*Pseudocrenilabrinae*) is a monophyletic sister groups, that are more distantly related to species in Madagascar (*Paretroplus*) and India (*Etroplus*) (Sparks and Smith 2004). The species on the Greater Antillean are sister species, and a clade of the Middle American species, two species can be found on Cuba (*Nandopsis tetracanthus* and *N. ramsdeni*), and (*Nandopsis haitiensis*) can be found on Hispaniola (Chakrabarty, 2006).

In the existence of Gondwana, India was connected to East Africa, Madagascar, Antarctica and the Seychelles (Plummer, 1995; Briggs, 2003). When India, still connected with the Seychelles, splitted from Madagascar 84-96 million years ago, it moved northward parallel with Africa, and splitted from the Seychelles 65 million years ago. On its way to Asia it transported a variety of African species, and picked up species of frogs, caecilians, and lizards on its way, these survived because India stayed in the climatic zones they were adapted to (Briggs, 2003). When India and Madagascar separated, a frog population splitted, and underwent allopatric speciation, where two subfamilies was formed. The subfamily *Mantellinae* only live on Madagascar, and *Rhacophorinae* live in India, and is spreading through Southeast Asia. (Campbell et al., 2008, pp. 493-494). When India reached Eurasia about 50 to 55 million years ago (Briggs, 2003), it resulted in an uplift of the Tibetan Plateau, and the creation of the Himalayan mountain range (Chatterjee et al., 2013). This is possibly one of the most extreme tectonic events that have occurred during the past 100 million years (Rowley, 1996). The materials that the Himalayan consists of, derived from the Indian plate, and not the Asian (Molnar, 1984).

Island Biogeography

As stated in Myers and Giller (1988, p. 129) "*islands can in an ecological sense be both land surrounded by water and mountains surrounded by lowlands, what they have in common is that populations on islands are isolated from their former biotas*". Anthropogenic activities have through history caused island conditions in many places of the globe, due to e.g. land fragmentations (Lomolino et al., 2010, p. 538). The flooding of lowland areas due to the building of the Panama Canal transformed, hilltops into islands, leading to decline, separation and isolation of some populations (Willis, 1974; Karr, 1982). Islands have a great influence on the biogeography (Powledge, 2003), and each island have its own unique set of physical characteristics that influences the organisms that inhabits it (Peck et al., 1999).

On islands the chances for biotic isolation and speciation (if greater than 3,000 km^2 [Losos and Schluter, 2000]) are in general higher than in continental areas (Myers and Giller, 1988, p. 367), which contributes to species diversity (Brown and Lomolino, 2000). The tendency is that the biodiversity increases with island size, regardless of taxonomic group or ecosystem type, since larger islands have a greater capacity to support larger population at equilibrium, but this relation is not linear (Lomolino et al., 2010, p. 513; Burn, 2015). The size of the island also influences the ecological interactions between species (Gravel et al., 2011). In 1967 the equilibrium theory of island biogeography was proposed, it basically stated that the species richness on an island depends both on its isolation, which determines its immigration rate, and on its area, which determines its extinction rate. This indicates that the area of an island can be used as an indirect measure of its biodiversity (Peck et al., 1999; Chen and He, 2009; Fernández-Palacios, 2016). Island size, isolation, altitude, emergence and submergence events, resulting in fission/fusion between islands have been affected by the glacial cycle (Fernández-Palacios et al., 2016).

Because many abiotic factors, such as sea level and climate, can either increase or decrease the speciation, islands are unlikely to have a constant speciation rate (Chen and He, 2009; Santos et al., 2016), and most recorded extinctions have occurred on islands (Santos et al., 2016). The relation between species and area is one of the most important and frequently studied pattern in biogeography (Kilburn, 1966), and can be described by the Arrhenius equation, see *equation 3* (Lomolino et al., 2010, p. 514).

$$S = cA^z \qquad equation\ 3$$

S is the number of species on the island, A is the area, c is a fitted constant, and z is another fitted parameter representing the slope when both S and A are plotted on a logarithmic scale (Lomolino et al., 2010, p. 514).

Larger islands tends to have more environmental diversity, like higher mountains, more aquatic habitat, and larger areas of most of the vegetation types that also exists on smaller islands (Power, 1972; Johnson 1975; Triantis et al., 2003). These larger islands can support larger populations, which because of their size, has lower probability of extinction (Burns, 2015). Older islands tend to a higher diversification, and more species due to speciation, than younger islands (Chen and He, 2009). But this is also affected by past physical and bioclimatic conditions (Weigelt et al., 2016).

In order for organisms to colonize isolated islands, they must be able to traveled a long distance, and establish themselves in their new habitat (Peck et al., 1999). Remote isolated islands, like the Hawaiian Islands, receive new colonists very rarely (Wilson 1959; Peck et al., 1999), meaning that many potential niches might be empty (Gillespie, 2004). This fuels speciation and adaptive radiations on these islands (Gillespie, 2004; Mendelson and Shaw, 2005). Endemic species often originate on these isolated islands (Briggs, 2003), and their endemism is roughly proportional to their isolation (Myers and Giller, 1988, p. 129). Many isolated oceanic islands are in focus for conservation, because they are hotspots for biodiversity, and inhabited by multiple threatened species (Myers et al., 2000; Fernández-Palacios, 2016; Santos et al., 2016). Like the Southern Brown Kiwi (*Apteryx australis*), Hawaiian Goose (*Branta sandvicensis*), and Fijian Monkey-faced Bat (*Mirimiri acrodonta*) (IUCN, 2017a). Some species that live isolated on islands have evolved unusual adaptations, like the blood sucking Sharp-beaked Ground Finch (*Geospiza difficilis septentrionalis*) native to Galápagos Islands (Koster and Koster, 1983). Many species that inhabit islands have smaller population size, and are geological limited in their options for dispersal, which is likely to cause extinctions due to climate changes (Cronk, 1996; Olson and Dinerstein, 1998; Wright et al., 2009).

The Red Queen Hypothesis

The Red Queen Hypothesis was formulated by Van Valen in 1973, and its original purpose was to give an understanding of the adaptation dynamics between species (Vermeij and Roopnarine, 2013). The principles of The Red Queen Hypothesis is clearly formulated in McCune (1982), that states ”*all taxa are running on a treadmill powered by an environment which deteriorates at a stochastically constant rate. The result is that an ancient taxon is no better adapted than a younger one; it has just been running in place longer*”. Basically it means that, in order for species to survive they need to evolve fast enough to have fitness that can compete with predators, parasites etc., who also are continually evolving (Castrodeza, 1979; Futuyma, 2013, p. 172). The Red Queen Hypothesis mainly acts on species level and below (McCune, 1982), and equals a zero-sum game, everytime a species gain fitness, it is counterbalanced by an equal gain of all other interacting species, and no species ever wins (Stenseth, 1979). For species to exist, they must minimally be well-designed, and if better designed they might be more suited for future circumstances (McCune, 1982), maladapted species will be eliminated by natural selection (Castrodeza, 1979).

Organisms evolve due to changes (Van Valen, 1969), when environmental conditions changes, species who was optimally adapted through selection to these previously conditions, will need to evolve further (Rosenzweig et al., 1987). If living in a continuously fluctuating environment, the genetic recombination of alleles might continually create genotypes that are selectively favorable. These can be favorable or unfavorable in future generations (Salathé et al., 2009).

Butterflies are among the many groups of herbivorous organisms that coevolve with plants (Ehrlich and Raven, 1964). Butterflies need to feed on the plants that are available in their ecological range, and some species overlaps geographically and ecologically in their feeding ranges (Deteier, 1952). Multiple species of butterflies and moths lay their eggs on certain plants (Merz 1959 in Ehrlich and Raven, 1964), when the larva emerge it will feed on this plant, and in some cases consume all of it (Ehrlich and Raven, 1964). As a response, selection will modify the plant species in order to limit the acceptability for larva. This was the case with the moth larva of *Lasiocampa quercus* who normally feed along the edge of leaves of holly (*Ilex aquifolium*), but after modifications that gave the plant sharper toothed leaves it was not possible for the larva to feed on it (Ehrlich and Raven, 1964).

Adaptive Radiation

Adaptive radiation is an evolutionary process where a species diversity, leading to origination of multiple species which are adapted to different ecological environments (Rasmussen, 2005, p. 23). About ten million years after the dinosaurs died out, mammals underwent adaptive radiation, where animals as different as bats, whales and larger dogs originated (Stanley, 1987, p. 8). Adaptive radiation is not a continuous process, it happens in steps when the ecological conditions favors it (Vermeij and Roopnarine, 2013), like when new niches are created due to climatic changes or tectonic events (Stanley, 1987 p. 21; Gillespie, 2004).

When Madagascar became isolated from India, its flora and fauna underwent adaptive radiation. Because Madagascar have a large surface area with a varied microclimates and habitats, its long-term geographical isolation gave rise to more than 40 species of lemuriforms that descended from a single common ancestor that colonized Madagascar via transoceanic dispersal from Africa (Yoder and Yang 2004). Similarly, groups of New World monkeys and guinea pigs originated in South America during the Tertiary from species that invaded through transoceanic dispersal from Africa (Futuyma, 2013, p. 147).

Conservation and Sustainability

The anthropogenic caused climate change is rapidly changing habitats, and it is unsure if biodiversity and aspects of nature that is needed and valued can be saved (Barnosky et al., 2017). Over the past century, conservationary work has resulted in both victories and failure. Unfortunately is the rapid climate change placing the future of the conservation legacy in a vulnerable position (Stein et al., 2014). In order to refine conservation methods, it is essential to project the future ecological responses of future climate, which is a major challenge (Jenouvrier et al., 2009; Oliver et al., 2016).

The extensive growth of the human population is together with unsustainable consumption of natures goods and resources the main cause for the current climate changes (Barnosky et al., 2017). The supplies of clean water and other goods have come from converting intact nature into agriculture, and draining of rivers and wetlands, which contributes a reduction of the biodiversity (Mace et al., 2011; Mace, 2014).

The IUCN (International Union for Conservation of Nature) Red List is the worldwide accepted standard for assessing the global risk of species extinction according to established quantitative criteria (Schipper et al., 2008; Hoffmann et al., 2010). According to their own statement, the IUCN ”*has been assessing the conservation status of species, subspecies, varieties, and even selected subpopulations on a global scale for the past 50 years to highlight taxa threatened with extinction and promote their conservation. This programme co-operate with the Species Survival Commission and many partners in order to provide the world with the most objective and scientifically-based information on the current status of globally threatened biodiversity, and provide the foundation for making informed decisions about conserving biodiversity from local to global levels*” (IUCN, 2017b).

Sustainable Development

Decreasing the greenhouse gas emission through a more sustainable anthropogenic consumption is possible. Some resourses can be recycled, like paper can be produced from recycled fibers, and this production have increased during the past 30 years (Matthews and Hammond, 1999). Also transport can be fabricated to be a lesser burden for the environment, for instance a few recent models of cars use hybrid energy that produce far less carbon dioxide, and prospective hydrogen fuel-cell car would emit only water vapor (Myers and Kent, 2003). Solar energy is an energy source that is free and does not cause any environmental damage, and will be favorable to use to a larger extend (Dravid et al., 2012; United Nations in India, 2015). In a solar cooker the solar energy can be used as environmentally friendly fuel for cooking (United Nations in India, 2015; Topriska et al., 2016). A solar cooker is basically a device which utilizes solar energy to cook food; they also enable some other functions, such as pasteurization and sterilization (Cuce and Cuce, 2013). The use of solar energy is particularly of importance in rural areas with frequent power cuts or no power supply. In some rural areas they have a fundamental importance in health care, since they are used to fuel the autoclave that sterilize and disinfect medical instruments (Dravid et al., 2012). Solar cooking technology is very promising with its potential in order to narrow the gap between renewable and conventional power sources (Cuce and Cuce, 2013). Especially in rural areas of the developing world, the provision of solar cookers may be a very good opportunity to avoid deforestation (Cuce and Cuce, 2013). It is estimated that if around 24 million families in Costa Rica changed from using firewood to use solar cookers, roughly 16.8 million tons of firewood will be saved yearly, and thus the emission of carbon dioxide will be reduced with 38.4 million tons yearly (Nandwani, 1996; Cuce and Cuce, 2013). The only drawback about the use of solar energy is that its efficiency depends on the weather (Dravid et al., 2012), but this can be solved by using thermal energy storage techniques (Cuce and Cuce, 2013).

Status Summary

Conservation efforts tends to focus on biodiversity (Brooks et al., 2006), but recently the importance of goods and ecosystem services that ecosystems provides for humans, like water purification, and pollination of crops have started to be acknowledge (Naidoo et al., 2008). For the future to be sustainable, it needs to involve proactive measures that promote transformations, including adaptive management, learning, innovation, and leadership capacity to manage risks and uncertainty (IPCC, 2012).

Land-use Change and Deforestation

The deforestation has historically been more intensive in Europe than in the tropics, and Europe have only remained a small fraction of its original forests. Mainly through conversion to agriculture, around 70 % of the original Mediterranean forests, temperate forests, and grasslands, were lost in Europe by 1950 (Millennium Ecosystem Assessment, 2005, p. 26). During the past five decades, anthropogenic activities have changed multiple ecosystems more rapidly than have ever before been recorded. The reason for this have partly been to meet the growing demands for food, fresh water, timber, fiber, and fuel., and have caused irreversible loss of biodiversity (Millennium Ecosystem Assessment, 2005, p. 1). The demand for agricultural land is increasing, and one of the main causes of deforestation, and thus loss of biodiversity (Bongaarts, 1996). In the developing world, the area used for agriculture has increased by more than 20 % since 1961 (Green et al., 2005). If the current demand continues, the tropical forests of the Amazon, equatorial Africa, and the boreal forests of Siberia and Canada will not be able to survive in their current form (Matthews and Hammond, 1999).

Tropical forests stores around 46 % of the world’s living terrestrial carbon pool, and the tropical soils stores about 11.55 % of the world's soil carbon pool, and due to deforestation and harsh fire events greenhouse gases become released to the atmosphere (Soepadmo, 1993; Reijnders and Huijbregts, 2008), 25 % of the total carbon emissions on Earth is believed to be caused by deforestation (Skutschet al., 2007). Between 1 and 2 million km^2 of tropical forests are destroy by anthropogenic actions every decade (Millennium Ecosystem Assessment, 2005, p. 39; Joppa et al., 2008). If the land-use change and deforestation activities were limited, the global greenhouse gas emission and pressure on the biodiversity will be reduced (Malmsheimer et al., 2008, p. 120; Pereira et al., 2010).

Areas most likely to escape anthropogenic impact, are areas that have small or no commercial value, like remote areas, steep mountain slopes, or areas with poor soil (Joppa et al., 2008). Deforestation and agricultural expansion have resulted in significant anthropogenic impacts on ecosystems, like destruction and fragmentation of many habitats, which is the leading cause of species endangerment lead (Lashof et al., 1997; Joppa et al., 2008). It is mainly through the fragmentation of habitats that 80 % of vertebrate taxa have become globally endangered (Pereira et al. 2012). Deforestation can directly influence climatic conditions, e.g. by changing the microclimate along forest edges (Feeley and Rehm, 2012). Lowland Amazon rainforests is very sensitive to global climate change, it is already heavily degraded and its deforestation continues at an alarming rate. This induces many serious threats to its future and communities, an optimistic scenario is that a quarter of the Amazonian rainforests will be lost by 2050 (Feeley and Rehm, 2012). The deforestation in the Amazonian rainforest has led to an overwhelmingly cattle production concentrated in large holdings (Chomitz and Thomas, 2003).

Ecosystem Services

Ecosystem services are the benefits that humans gain from natural ecosystems, and can be delivered directly or indirectly (Mace et al., 2012; Giannini et al., 2013). There includes, among others, fresh water, capture fisheries, air and water purification, and pollination interactions (Millennium Ecosystem Assessment, 2005, p. 1; Hegland et al., 2009). Caused by the fast increasing anthropogenic consumption of natural resources, around 60 % of them are being degraded or used unsustainably (Millennium Ecosystem Assessment, 2005, p. 39), among the terrestrial ecoregions that are priorities for conservation 47 % are considered critical or endangered, 29 % vulnerable, and 24 % relatively stable or intact (Olson and Dinerstein, 1998). As a response to a doubling of the human population between 1960 and 2000, the demand for ecosystem services grew significantly, the food production increased around two-and-a-half times, water use doubled, and production of timber increased by more than half (Millennium Ecosystem Assessment, 2005, p. 5). As the human population keeps increasing and expanding, conflicts between the needs for protected areas and anthropogenic demand to use ecosystem services will likely continue in the future (Joppa et al., 2009).

Protected Areas

Because the establishing of protected areas prevents habitat from being lost, it is a sufficient method to protect ecosystem services, biodiversity, and prevent species endangerment (Millennium Ecosystem Assessment, 2005, p. 19; Joppa et al., 2008; Adeney et al., 2009; Hoffmann et al., 2010). Protected areas, including strictly protected areas such as national parks and areas managed for the sustainable use of natural ecosystems, is covering about 11.7 % of the terrestrial surface, and 0.17 % of the sea (Millennium Ecosystem Assessment, 2005, pp. 18-19; Spalding et al., 2013). The sizes of the protected areas are influencing their efficiency, and the smaller will likely lose some species, but the protection will still contribute in protection of the habitat (Joppa et al., 2008). The equilibrium theory of island biogeography can be used to find the size, shape, and distance between, which will give the most sufficient outcome for protected areas. In general, the most sufficient is to have protected areas that are bigger, closer to each other, and circular in shape (Margules and Pressey, 2000), corridors between protected areas can be favorable for the biodiversity, because many animals do not cross open areas in the landscape (Shafer et al., 1999). In cases where it is only possible to establish smaller protected areas, connections between them through corridors are a sufficient way to increase their biodiversity (Joppa et al., 2009).

Because of the increased demand of land for anthropogenic use, it is currently not be possible to establish national reserves and parks in Asia and Africa to the same extend as it was done in the 1950s and 1960s. Beside of the pressure on the land, most developing countries do not have the financial resources to develop or even manage conservation projects, and will primarily be dependent on donations of financial resources from developed countries (Le Houérou, 1996).

Another problem with protected areas is that due to global warming some species are shifting their range away from the protected areas and towards areas that are unprotected (Araújo et al., 2004; Hannah et al., 2007; Carvalho et al., 2011). In order to achieve positive effects on the global biodiversity, Tittensor et al. (2014) suggest that the solution can be to globally redoubled the conservation effort. Currently the choice of protected areas is biased toward areas with small potential for other purposes (Joppa and Pfaff, 2009).

Extinction

Anthropogenic activities have during the past 500 years been the cause of extinction, threat, and decline in populations that is comparable with the five previous mass extinctions with respect to both rate and magnitude (Barnosky et al., 2011). Many ecological stressors are currently more extreme than what most extant organisms have previously been exposed to, these includes rapidly warming above typical interglacial temperatures, rising levels of carbon dioxide, expanding human population (Pereira et al., 2010), overhunting (Milner-Gulland et al., 2003), deforestation, habitat fragmentation, competition from invasive species, pathogens (Hoffmann et al., 2010), and pollution (Schipper et al., 2008). The average species extinction is 0.72 % per year, which is two to three orders of magnitude higher than the normal background extinction, and faster than the rate of origination (Hoffmann et al., 2010; Barnosky et al., 2011; Mora et al., 2013). It is expected that the biodiversity will decline extremely in the twenty-first century, and within less than 2 million years over 75 % all currently existing species will be extinct (Hoffmann et al., 2010; Barnosky et al., 2011).

The existence of multiple species around the globe is vulnerable to extinction. 13 % of birds, 41 % of amphibians, and 25 % of mammals are currently threatened with extinction (Schipper et al., 2008; Hoffmann et al., 2010), and about one-fifth of all existing vertebrate species are classified as threatened by IUCN (Hoffmann et al., 2010). In the Western Hemisphere about 25 % of the land bird species is expected to be extinct or in great risk of extinction by 2100 (Sekercioglu et al., 2008). Also butterflies and moths (*Lepidoptera*) have suffered from climate changes, there is strong evidence that their abundance have declined 35 % globally over the last 40 years (Dirzo et al., 2014). About 36 % of the wild living species that humans use for food or medicine is threatened with extinction (Butchart et al., 2010).

Pressure

An increased anthropogenic consumption fuelled by urbanization and less sustainable patterns of human needs is rapidly increasing the per capita consumption, and is a great driver for climate changes. There has been enormous concern about the ecological consequences this development will lead to (Matthews and Hammond, 1999; Tilman et al., 2001; Lutz et al., 2001; Myers and Kent, 2003).

For the biodiversity, the pressure from climate change and land-use change poses serious challenges (Sala et al., 2000), since they can change species distribution, population structure, function of communities and ecosystems, and thus lead to extinction (Yang and Rudolf, 2010; Fung et al., 2017). An assessment of the consequences on nature that these pressures will lead to is essential for conservation science, especially in relation to understanding where and how pressures increase or decrease relative to conservation interventions (Geldmann et al., 2014).

Biofuel

The pressure from the increasing demand for biofuel as an energy sources will likely cause agricultural expansion at the expense of native habitats, and biodiversity (Righelato and Spracklen, 2007; Danielsen et al., 2008). Because the majority of palm oil plantations are situated where there formerly was tropical rainforest, biofuel produced from palm oil is not sustainable (Reijnders and Huijbregts, 2008; Danielsen et al., 2008). It is an ecological burden for the globe when rainforest get converted to palm oil plantations, due to the differences in their stored carbon, the conversion emits 163 t/ha carbon to the atmosphere. The average annual production of crude palm oil is 3.7 t/ha (Danielsen et al., 2008). The demand is expected to increase from 28 Megatons/year to 50 Megatons/year by 2030, and will likely lead to the conversion of about 4 to 6 million hectares of rainforest into plantations (Reijnders and Huijbregts, 2008). The Indonesian government is planning to convert a further 5.6 million ha into palm oil plantations over the next decade to meet global demands for biofuels (Mangubhai et al., 2012). These plantations have a lower biodiversity than the formerly forest, only 23 % of the vertebrate species found in the formerly forests do still persist in the palm oil plantations (Danielsen et al., 2008), and in some is the honey bee family (*Apidae*), which are important forest pollinators, completely absent (Liow et al., 2001).

Unsustainable Dietary Trend

The worldwide projection is that the global demand for food will double over the next 50 years, which poses huge challenges for the sustainability of food production (Tilman et al., 2002). It have been a question in the past two decade if the food production is able to keep up with the demand from a increasing human population (Bongaarts, 1996).

Currently there is a dietary shift towards a more meat based diet (Myers and Kent, 2003), and the consumption has tripled since 1961 (Matthews and Hammond, 1999). This development is unsustainable for multible reasons, partly because it consumes a large amount of water and crops. It can take up to 8 kg of grain to produce just 1, 2, or 4 kg of beef, poultry or pork, respectively (Tilman et al., 2001; Myers and Kent, 2003). Expansion of the livestock do often come with the consequences of overgrazing, loss of wildlife habitat, deforestation, greenhouse gas emissions, and overloading of the fields (Matthews and Hammond, 1999; Myers and Kent, 2003; Millennium Ecosystem Assessment, 2005, p. 47).

Between 1990 and 2000 the amount of grain fed to livestock increased in China, Malaysia, and Indonesia with 31 %, 52 %, and 63 %, respectively. Because it takes around 1,000 tons of water to produce 1 ton of grain, this increased their problem of water shortages (Myers and Kent, 2003). In developed countries, a total of 70 % of the entire crop production is used to feed the livestock (Tilman et al., 2001). If the current dietary trends continues, the global cropland would likely increase with $3.5*10^8$ hectares by 2050 (Tilman et al., 2001). With respect to a solution, it has been suggested by Myers and Kent (2003) to introduce a tax on less sustainable food products. Moving towards a more plant based diet will be even more sustainable, since it will save more land, and water resources (Pimentel and Pimentel, 2003).

Possible Solutions to Conserve Biodiversity

Conservation is strongly depended on actions from organizations, like government agencies and private conservation organizations (Hunter and Hutchinson, 1994). Unfortunately, the funding for conservation action is limited, and every endemic species is irreplaceable, and thus it is necessary for governments, donors, and conservation groups to prioritize biota that are either endemic or globally endangered (Hunter and Hutchinson, 1994; Olson and Dinerstein, 1998; Brooks et al., 2006). It also of importance to perform conservation work in order to maintain healthy populations of species that are currently not yet at their edge of extinction, and it is both easier and uses less resources (Hunter and Hutchinson, 1994).

The resources needed for conservation work to succeed have increased due to climate change (Jump and Peñuelas, 2005). The rate of climate change is likely to be so fast that the genetic adaptation of many species will not be able to cope (Jump and Peñuelas, 2005; Heller and Zavaleta, 2009), nor is it likely for many species that their migration will be fast enough (Davis and Shaw, 2001).

Relocation of Species

Maintenance of habitats is usually important in order to maintain endangered species (Hunter and Hutchinson, 1994), and Bellard et al. (2012) claims that ”*species will go extinct when they no longer have any suitable habitat*”. But under rapidly changing climatic conditions the challenge of maintaining and restoring habitats can be very difficult (Maxwell et al., 2015; Butt et al., 2016a), and conservation workers must often use more proactive methods, such as removing invasive competitors or relocating populations to new habitat, even that this is often both expensive and risky (Hunter and Hutchinson, 1994).

Relocation and intentional release of species have been used to establish populations of nonnative species, reestablish populations, and restore native species for centuries (Griffith et al., 1989; Payne and Bro-Jørgensen, 2016). Relocation of species to areas outside their present or historical range, where their survival is expected to be favoured, is a tool that can be used to conserve biodiversity under future climate. By using this method, the problem of dispersal barriers is solved, meaning that it is letting species survive climate change by altering their geographic distributions (Griffith et al., 1989; Millar et al., 2007; Barnosky, 2009; Tricarico, 2016). This method was used in 1907, when 15 American bisons (*Bison bison*) were relocated into a newly established reserve in Oklahoma (Kleiman, 1989; see also Seddon et al., 2007). Some species of sea turtles have been relocated to cooler regions to counteract the climate change induced female-biased sex ratio of their offspring (Butt et al., 2016b). Also species of trees have been relocated to match expected climate changes, in order to save them from extinction (Allen et al., 2010). Relocation of species it not exclusively success, relocated species are in general likely to have a higher mortality rate than what is found naturally in the wild or in captivity (Kleiman, 1989), and not all species are equally successful to establish themselves after relocation (Griffith et al., 1989). Herbivore species have in general been more successful after relocation than either of carnivores and omnivores. Also early breeders with large clusters have been more successful than species that breed late and have small clusters, and wild-caught animals is more likely to succeed after relocation than captive-breed animals (Griffith et al., 1989). Species that have major ecological roles are riskier to move than species of lesser ecological importance (Soulé et al., 2003; Hunter, 2007). A failure of most reintroduction programs is that they have not provided any preparation or training of the animals before release, and approximately half of them have not succeeded (Kleiman, 1989). The risky part of species relocation has shown when moving bumblebee species for pollination, and they became a threat to native faunas, this competition with native faunas is, together with spread of diseases, the greatest risks of species relocation (Lozier et al., 2015).

Conservation through Hybridization

Populations that are exposed to rapidly climatic changes may experience decreased fitness and population size. This is likely to limit their opportunity to reproduce at a rate sufficient for maintenance of the population, and thus decreases the spreading of their genotype (Gonzalez et al., 2013). It may be necessary to carry out hybridizations between some populations of endangered species in order to increase their genetic variation (Hamilton and Miller, 2015). When using hybridization successfully a large amount of new genetic variance may be introduced into the population very fast, which increases the populations’ capacity to adapt to changing climatic conditions (Lewontin and Birch 1966; Hamilton and Miller, 2015).

Hybridization is possible for many species, including many ecologically important genera of trees in temperate and boreal regions, like (*Picea*), pine (*Pinus*), poplar (*Populus*), and oak (*Quercus*) (Aitken et al., 2008). Hamilton and Miller (2015) encourage to acknowled the value that the use of hybridization can have for conservation under conditions with climate changes.

Using hybridization between populations can have a downside if the populations have started to speciate or become genetically different to a certain extend, since it can result in offspring with lower fitness and reproductive success than the parent populations. In some cases the offspring are born sterile or with retarted development that makes them incapable to survive to an age where they can reproduce, which have the consequences of reproductive isolation (Campbell et al., 2008, pp. 489, 491; Seehausen, 2013).

Improve Restoration and Conservation Afford to Avoid Climate-related Risks

The establishment of no-take reserves and marine protected areas is strategies that can be used to protect the marine biodiversity. This might be beneficial due to climate change since intact communities seem to be more resistant to climatic fluctuations, heat waves, and storms (Harley et al., 2006). A marine habitat that especially needs increased protection is coral reefs (Groves et al., 2012).

Naturally formed wetlands are important to protect, because they perform important functions such as reduce flood damage, decrease erosion from severe storms, flood control, pollution filtration, nutrient recycling, and provides a habitat for some wildlife biota (Hartig et al., 1997; Groves et al., 2012). A way to increase the cover of both wetlands and forest is by using more sustainable land-use practices (LeRoy Poff, 2002). Even under conditions with climatic changes, the restoration of streams can be favourable for the conservation of native plants and terrestrial communities and improve carbon sequestration (Mantyka-Pringle, 2016). Improved restoration of forest areas will also be favourable, because these can counteract some of the damage caused by increased flooding during climate change (LeRoy Poff, 2002). When forestry is carried out sustainably, its ability for flood prevention will increase (Balmford et al., 2002).

Ex situ conservation is a very important tool for conservation in a world with fast climatic changes. Basically ex situ conservation when species are moved into artificial ecosystems like zoos, gardens, or aquariums, this way of conservation is less risky than relocation of species in the nature. Ex situ conservation might be the only option for saving species that live near the geographic end of climatic gradients, like polar and alpine species do (Hunter, 2007). It needs to be acknowledge that conservation currently is a huge task because the distribution of many species and many ecological processes are changing at much faster than in the past (Groves et al., 2012). Humanity can slow the climate crisis by reducing energy consumption, promote conservation work, and carry out a more sustainable way of living (Barnosky, 2009).

Discussion

Climatic changes have occurred on Earth through the evolutionary history (Rogério de Mello et al., 2015). Facilitated by the movement and reorganization of lithospheric plates, continents has formed and broken apart, volcanic processes has occurred, sea beds has expanded and contracted, mountain ranges have risen and eroded, islands have been formed and they have faded (Bellieni et al., 1984; Crisci et al., 2006). Equally are species adaptation, extinction and dispersal not a recent phenomenon (Hoffmann and Sgrò, 2011). Especially in the time of the breakup of Gondwana major changes occurred to a variety of ecosystems (Tedeschin et al., 2006; Lomolino et al., 2010, p. 226). As explained in Carvalho et al. (2010), did the breakup of Gondwana create volcanic activity that increased the amount of atmospheric greenhouse gases, which accelerated climatic warming. The difference between previous extreme climatic events and the current is that they never before in recorded history have been caused almost entirely by anthropogenic activities (Barnosky et al., 2011; Santos et al., 2016). The species extinction is currently happening at an alarming rate, and some scenarios project that the climate change will lead to the sixth mass extinction on Earth (Bellard et al., 2012). Previous mass extinctions and climate changes on Earth have occurred due to natural events, which increases the uncertainty of the outcome. Lithospheric activity will surely continue to infinity, and thus habitats will be created and lost.

Communities around the globe that rely on the forest for essential services such as timber and fresh water might possibly not exist in the future, because the current climatic changes make the forests increasingly vulnerable to higher background tree mortality, and the warming and drought will increase further in the future (Allen et al., 2010). The increased mortality of trees is likely to place many forest dwelling species at risk of extinction, if they are not able to successfully undergo adaptations or migrate.

It is possible to save some species from extinction to some extend through conservation work. There are conservation methods that have shown the ability to produce a positive outcome, these includes relocation of species, hybridization of populations in order to increase the genetic variability, establishment of protected areas, and restoration of habitats. Relocation of species might not be possible to infinity, since at some point it will be impossible to find a climatic suitable habitat in a changing world. In extreme cases like this, where the natural habitat is gone or not sufficient enough to house certain species, ex situ conservation where artificial environment are created in a zoo or similar, can be the last option in order to avoid extinction. No matter the method, the conservation will always be limited by the funding.

The establishment of long-term perspective solutions is essential for the conservation (Eeley et al., 1999). There is certainly a possibility for developing a more sustainable future, one of the core actions that humanity will need to take, is to save energy and significantly reduce greenhouse gas emissions (Bollmann et al., 2010, p. 53). The human consumption will need to be reduced, and the environmental impacts will need to move towards sustainability (Myers and Kent, 2003). Unfortunately do greenhouse gases such as carbon dioxide, methane and nitrous oxide have atmospheric lifetimes as long as decades and centuries, which results in accumulation in the atmosphere (Karl and Trenberth, 2003). Because the concentrations of atmospheric greenhouse gases are dominated by accumulated past emissions, it takes many decades for any change in emissions to have much effect (Karl and Trenberth, 2003). Even long after the stabilization of carbon dioxide levels, the climate will still further continue to change, sea level rise may continue for centuries, ecosystems will undergo fundamental change, and species will be lost (Karl and Trenberth, 2003; Bollmann et al., 2010, pp. 15, 117). Because the climate system reacts slowly to changes, some damage caused now will first show up in the future, and some caused damage is already irreversible. It is strongly needed to bring the climate changes to an end as soon as possible (Bollmann et al., 2010, pp. 25, 53). These facts clarify the importance of taking immediate action, and eliminate the emission of climate-relevant trace gases, it is to some extend just a question about changing habits and live in a more sustainable way. There are multiple options for a more sustainable anthropogenic consumption, including the use of solar energy for solar cooking and similar, recycling of fibers to produce new product, and a shift towards more sustainable dietary trends. If no action is taken, the accumulation of greenhouse gases in the atmosphere will continue, and thus create more irreversible damage.

Future Perspective for Extinction, Speciation, and Dispersal

Extinction is most likely to occur when threats emerge that the species have not been exposed to during their evolutionary history, or occur faster that the species can adapt (Brook et al., 2008). The current climate change is such a threat, it has already caused extinction and is predicted to be tha cause of further severe consequences on the biodiversity (Bakkenes et al., 2002; Cabral et al., 2013). It is very likely in the future that more sensitive species will be heavely reduced and some go extinct, while certain species that are more adaptive will spread, speciate and become more abundant (Bollmann et al., 2010, p. 117; Holopainen et al., 2016). Surely long term conservation work is needed in order to save multiple species from extinction, since the threat from climate change is progressing. Anthropogenic actions during the past few hundred years have caused a decline in the biodiversity, and the extinction rate has increased to about 1,000 times over background rates typical for the planet's history (Millennium Ecosystem Assessment, 2005, p. 4). In Thomas et al. (2004) it is claimed that in 2050 an estimated 15-37 % of taxas will be extinct, and if the speciation rate do not increase at the same level the biodiversity will be severely reduced in the future and leave many niches empthy. The empty niches will possibly favor adaptive radiation of the remaining species.

Some areas and forest types may be important for refugia and evolutionary centers (Eeley et al., 1999). It is possible that many forests will collapse due to drought, and hence these refugia will disappear. If the forests die out a net carbon sink will disappear, this will further contribute to acceleration of climate change (Allen et al., 2010). If this is the scenario, then many species that are dependent on the forest will go extinct, if it is not possible for them to either migrate to another suitable habitat or adapt.

Because trees grow and develop relatively slowly and can die within months due to unfavourable environmental conditions, species that rely on trees for survival will be extremely vulnerable. Increased mortality of trees can result in very rapidly ecosystem changes (Allen et al., 2010). An example of such forest species which is likely to go extinct in the future is the koala (*Phascolarctos cinereus*). Since they are obligate tree-dwellers (Lunney et al., 2014), feed exclusively on leafs from Eucalyptus trees (natgeo, 2017). Multible severe droughts in Australia have over years repeatedly triggered widespread Eucalyptus mortality (Allen et al., 2010). According to Lunney et al. (2002), iIt is unlikely that even with substantial improvements in mortality and fertility that it will be possible to prevent the koala population from declining towards extinction.

Limited Options for Climate Change Related Dispersal

Landscape fragmentations are an increasing problem that limits species in their capacity to disperse among regions, and to find climate refugia (Pearson and Dawson, 2003; Lunney et al., 2014). Many species are for different reasons unwilling to cross the fragmented areas. One of the reasons can according to Lauranc et al. (2004) be that some species are adapted to the dark and humid conditions of forest interiors and the habitat fragmentation probably seem too harsh or unfamiliar for them, so they are not willing to cross it even if they could. Another possibility for not crossing cleared areas can be that some species may have had little reason to cross clearings in their evolutionary history, and for this reason avoid forest edges and clearings as an innate response (Lauranc et al., 2004). It might also be the risk of predation from predators that tend to hunt along forest edges, like White Hawks (*Leucopternis albicollis*) and Bat Falcons (*Falco rufigularis*) that makes some species avoid cleared areas (Lauranc et al., 2004). No matter the reason for not crossing the fragmented landscape, it creates geographic isolation between population and hereby can

lead to allopatric speciation. During total allopatric speciation reproductive isolation creates speciation islands, where no gene flow occurs between subpopulations (Wang et al., 2016). A combination of separation and local species adaptation will result in significant differences in the types of species that inhabit the different separated regions (Millennium Ecosystem Assessment, 2005, p. 35).
Some species, like earthworms, do migrate but their migration capabilities are very low (Malcolm et al., 2002), which might put them in a vulnerable position due to future fast climatic changes. Seemingly the overall distribution of species will be more homogeneous, as a result of decreased biodiversity, but due to barriers for the gene flow, there will be inter-specific differentiation between subpopulations. If the subpopulations are kept separated to an extend where it will result in either prezygotic or postzygotic reproductive barriers, it will be impossible to hybridize them due to conservation work, and thus can lead to extinction.
Smaller populations have an increased vulnerability to climatic changes, and are more likely to go extinct than larger populations (Brook et al., 2008), meaning that species which are living in small fragmented pattern that do not migrate have an increased risk of extinction. This problem can partly be solved by connecting smaller fragmented areas with corridors. It is very likely that climate change will cause many species to migrate in the search of climate refugiums, and the species not capable or willing of migrating in the fragmented landscape will be especially vulnerable to extinction. For species that are eurytherm enough, or capable of rapid enough adaptation to stay in their current habitat will likely speciate to fill empty niches.

Pollination is fundamental, but climate change induced mismatches between plant and pollinator is unavoidable (Forrest, 2015). However there can be a chance for species of pollinators, which are not too restricted by specializations to a specific host plant, to find another ecologically equivalent floral food resource (Rafferty et al., 2015). This may not affect all the pollinators, but if the plant does not equally get another pollinator, it will likely go extinct.

Polar Areas

The increased future mean annual temperature of the ocean will contribute to the melting of ice at Polar Regions (Holopainen et al., 2016). The Greenland ice sheet can potentially be completely melted within millennium. This enormous amount of fresh water will dilute the ocean, and thus decrease the salinity, which will favour the existence of euryhaline organisms over stenohaline organisms.

When the ice melts trace-gases that was trapped in the ice become released, and will further accelerate climate warming (Bollmann et al., 2010, p. 24). Since Antarctic fish adapt very slow (Peck et al., 2014), and do not have the possibility to migrate to colder regions, they will likely go extinct due to the lacking of a thermal suitable habitat. It is very likely that the majority of polar species will be history in the future, if they are not conserved through ex situ conservation. Their specialization to arctic habitats will no longer be sufficient in the future, since these habitats are disappearing. Maladaptation will probably decrease their fitness and make them unable to compete with many invadeding species.

Migration Pole Ward and Upslope

In order to escape the global heating some species migrate pole ward or upslope (Feeley and Rehm, 2012; Bauer et al., 2016). This trend has already been observed for more than 1000 species, especially birds, insects and marine invertebrates, which have a high capacity for dispersal (Bellard et al., 2012).

Species that manage to reestablish at a more Northern Hemisphere might be expected to either out-compete some already existing communities or be out-competed themselves (Bauer et al., 2016). Species native to polar areas cannot migrate further pole ward (Lomolino et al., 2010, p. 96), meaning that these might be particularly vulnerable to climate change. If they cannot cope with the rising temperatures they are likely to go extinct, and even if they are able to adapt their will likely be competition between native species and invaders.
As species need their food patches for feeding, migration can be tricky for species feeding on vegetation, since e.g. trees do not migrate that easy and it can take years for a seed to grow into a tree that can provide a long term food source of fruit, leaves etc. This might lead to extinction of species that in principle could have survived if they migrated, but their food was absent in the new habitat.
Species that have an r-selected life history strategy is in general more successful when invading new environments (Ramos et al., 2015). Whereas species that have a K-selected life history strategy, and hence longer generation time, lower fecundity, and lower replacement rates are less successful in a changing environment (Brook et al., 2008). For this reason it might be expected that in the future the majority of species that successfully migrate and establish a stable population will have r-selected life history strategy, and they might probably outcompete species with K-selected life history strategy.

Over evolutionary times severe climatic conditions have occurred on mountain areas, which have resulted in native species that are highly specialized for growth and survival at high altitudes (Thuiller et al., 2005). The partial pressure of oxygen in the ambient air decreases with increased altitude (Hawkes et al., 2013). In order to cope with the decreased partial pressure of oxygen, vertebrate taxa that are native to the high altitudes have a tendency to have hemoglobin with an increased affinity for oxygen compared with lowland relatives, as explained by Storz (2016). This indicates that it might be quite a challenge for lowland species to survive, and have sufficient fitness to establish and maintain a stable population after migrating upslope, which could potentially lead to extinction.

Ocean

It is estimated that over the next several thousands of years about 90 % of the anthropogenic carbon dioxide emissions will end up in the ocean and contribute to further ocean acidification. It is possible that the ocean may become a less efficient sink for carbon dioxide in the future because it capacity might be reached (Sabine et al., 2004). Ocean acidification severely effects calcifying organisms (Fabry et al., 2008; Lischka et al., 2011), and increased future ocean acidification will very likely threaten the existence of organisms like corals and pteropods (Hunt et al., 2008; Quataert et al., 2015). If the corals disappear then many fish species for which the corals acts as a nursing ground might go extinct. Further might coastal flooding increase if the corals are no longer present to reduce the wave energy before reaching the coastline.

Pteropods are prayed on by multiple animals (Busch et al., 2014; Bednaršek et al., 2016a), and constitute a major important dietary component for many species (Bednaršek et al., 2016a). Because pteropods are an important food item at the bottom of the food chain, it is likely that multiple marine food-webs will collapse in the future if they disappear. If their predators, or species preying on their predators, are not able to shift to another food source they might be likely to go extinct.

Likely Future Adaptations

The currently fast climate changes may result in that species will no longer be adapted to the environmental conditions in their habitat (Bellard et al., 2012), and one of the crucial questions on ecological effects of climate change is whether or not species will be able to adapt fast enough (Lavergne et al., 2010). The extend of the climate change induced ecological consequences strongly depend on species ability to adapt, and their rate of possible adaptations will set an upper limit to the rate at which temperatures can increase without biodiversity being lost (Visser, 2008). Whether it will be possible or not for evolutionary adaptations to be favorable in future climate change will also strongly depend on the plasticity of adaptive traits within populations (Wilczek et al., 2014).

Adaptations and dispersal to more suitable habitats, is often the most used alternative mechanisms whereby a population can respond to changing environmental conditions (Visser, 2008; Lavergne et al., 2010). When species respond with adaptation it can either be by genetically adapt to new conditions through mutations or selection of existing genotypes, or it can be by changing the phenotype without changing the genotypes via phenotypic plasticity, where the response is short-term but provides the potential for organisms to respond rapidly and sufficient to environmental changes (Charmantier et al., 2008; Visser, 2008; Bellard et al., 2012). Rapid evolution through mutation and selection in order to adapt to very severe and rapid environmental changes might only benefit species with rapid life cycles, who hence uses an r-selected life history strategy (Bell and Gonzalez, 2009; Bellard et al., 2012).

Ocean Warming and Acidification

Ocean warming, deoxygenation, and acidification is predicted to increase in the future and be the cause for changes in the productivity and biogeography of marine organisms and ecosystems (Bellard et al., 2012; Cheung et al., 2016). With an acidity that is expected to reach twice its present value by the end of this century (Bollmann et al., 2010, p. 36), exspecially calcified organisms will be in danger. This is confirmed by Hoegh-Guldberg et al. (2007) and Bellard et al. (2012), who claims that especially calcifing marine organisms, like reef-building corals, will be at risk as thay will undergo decalcification, and further because of their relatively long generation times and low genetic diversity, their rate of adaptation is relatively slow. Because their rate of adaptation is slow, there is a risk that it will be to slow in order to cope with the future rate of acidification, and thus extinction is likely.

Some fish species seems to successfully cope with the warming ocean by dispersal, since the proportion of warm-water fish species has increased significantly over the last 25 years. This may affect community functioning (Butt et al., 2016a). Adaptations to a warmer ocean do apparently differ between different species (Gibbin et al., 2017). For instance, female marine sticklebacks (*Gasterosteus aculeatus*) that have developed at 21°C produces smaller eggs but larger clutches, that grew to become smaller offspring than females that developed at 17°C. For sticklebacks elevated temperatures have also shown to cause a higher degree of incubation failure and mortality (Shama and Wegner, 2014). The smaller body size makes the offspring more vulnerable to predation, and hence threatens their existence. It can also be possible that the smaller offspring body size and larger clutches will turn out to be favorable. It can be that the smaller body size makes it easier for them to hide, and the larger clutches will result in more offspring. Some warm-water fish species will likely be favored by the warmer ocean, while it will be a disadvantage for others.

Seemingly marine polychaete (*Ophryotrocha labronica*) is adapting to a warmer and more acidic ocean. Their fitness improves for every generation that has been exposed to ocean warming and acidification.

Through phenotypic plasticity, they have prevented extinction at a population level, and provided a temporal buffer for genetic variation to respond via natural selection (Gibbin et al., 2017).
Marine metazoan (*Platynereis dumerilii*) is another organism with the ability to physiologically adapt to a chronically acidified environment. It seems like this ability came with the cost of a reduced body size, since the mean body size of adult individuals collected from carbon dioxide vents was approximately 80 % lower than adult individuals collected at non-acidified areas (Calosi et al.,2013). The reduced body size might potentially come with some disadvantages. Since both of this species of marine invertebrates have found their way to cope with ocean acidification, they will likely have a great chance of surviving and becoming dominant in the future.
The paedocypris (*Paedocypris progenetica*) from Southeast Asia is a miniature fish that live in naturally highly acidic environments. They are adapted to their environmental conditions by having a poorly mineralized skeleton (Britz and Conway, 2009). This adaptation is very likely to become common in the future, also for other aquatic species, since the ability to live and function with a poorly mineralized skeleton seems like a favorable solution to cope with an acidic environment.

Migrating Upslope

When migrating to high-altitude areas, it is the adaptations to hypoxia that is the main physiological challenge that threatens survival, development, and reproduction (Brown, 2012). For the avian embryo the high-altitude environment imposes unique physiological problems on the respiratory function. The first barrier between the embryo and the environment is the egg shell, which contains pores through which oxygen diffuses in, and water and carbon dioxide diffuses out (Monge et al., 1988). Birds that live and reproduce at high altitude are adapted in different ways. Their eggs shells have larger pores to facilitate the uptake of oxygen, and quantities of yolk in some high-altitude species is relatively higher than in low-land species, which may better facilitate growth and survival for the embryos in a hypoxic environment (Jia et al., 2016). It is likely that many bird species will migrate to high altitudes in the future because of the global warming, and their eggs will face the same adaptation of increased pore size.
A drawback for the increased pore size is that the embryo loses more water than egg with smaller pore size (Monge et al., 1988). If some species undergo evolutionary adaptations that will overcome the problem of increased water intake that comes with the bigger pore size, then this species will likely have a better rate of offspring survival, and hence better chances for outcompeting other species.

In general do red blood cells and their vital role in oxygen transport and delivery play an important role in adaptations to hypoxia (D’Alessandro et al., 2016), and animals at high altitudes in general have hemoglobin with a higher oxygen affinity, than animals who live in normoxia (Monge and Léon-Velarde, 1991). Several physiological parameters that efficiently promote the blood oxygen-carrying capacity is found in high altitude species, such as larger heart, and lungs, lower venous blood pH, and higher hemoglobin concentration (Zhang et al., 2016). A possible adaptation to life at high altitudes, is a hypoxia signaling system that triggers a response that increases tissue oxygenation, by increasing the oxygen carrying capacity of the blood (Ge et al., 2012). Low metabolic oxygen demand in tissue, and cardiac muscle adaptations for performance at high altitude is also favorable (Jia et al., 2016). Moreover do some high altitude animals have a shorter body and smaller limbs than low-land relatives (Monge and Léon-Velarde, 1991), which gives a shorter way for the blood to travel before getting reoxygenated. It seems likely that shorter body size and shorter limbs, larger lungs and heart, and hemoglobin with higher oxygen affinity will be some of the favorable adaptations to undergo for animals that migrate to high altitudes.

Drought and Desertification

A favorable adaptation to drought stress for plants is to be annual, because during the driest times on the season they can exist as dormant seeds. In this way the plant can avoid the need to be tolerable to heat and aridity (Milton and Dean, 2004; Boughalleb et al., 2014). Some plants can increase their efficiency of water-use and decrease their sensitivity to drought (Wyckoff and Bowers, 2010), this ability will undoubtedly be useful in the future. Due to the increased fire frequency, there will likely be a selection for plant species that can survive fire. This can possibly be through the ability to resprout fast after a fire, or having seed banks in the soil that are ready to sprout after a fire. If the adaptation of annuality becomes common, it might be in the future that much of the vegetation will be stored as dormant seeds in the warmest period of the season. This is likely to cause detrimental consequences for animals that feed on these plants, and might also very likely miss up the plants and pollinator relation.

Some terrestrial animals, including lungfish, frogs, many insects, and desert snails, can escape periods with food scarcity and drought by using estivation (Rasmussen, 2005, p. 27; Willmer et al., 2011, pp. 212-213). Estivation is a state where the body is at rest, and the metabolic rate is substantially reduced, despite the high environmental temperatures (Rasmussen, 2005, p. 27; Willmer et al., 2011, p. 213). They can survive estivation without any excretion of nitrogenous waste products, like urea (Willmer et al., 2011, p. 559), this ability is water conserving. To use estivation will be a highly favorable adaptation in the future, since it helps the animal to survive under extreme heating and drought, and conserve water in the body by allowing nitrogenous waste products to accumulate in the body, instead of using water to excrete it. By decreasing the metabolic rate during estivation, the energy consumption, and thus demand for food also decreases. Meaning that the animal save both energy and water by using estivation under conditions with drought.

Osmoregulation under Drought Conditions

In animals the adaptations to drought stress have been best studied in small desert rodents such as the kangaroo rats (Willmer et al., 2011, p. 633). Their long loop of Henle, in proportion to their body size makes them able to produce hyperosmotic urine, which is a favorable desert adaptation to lose excess salt while excreting very little water (Willmer et al., 2011, p. 633). Similar adaptations is to be found in some desert birds and reptiles, where the nasal salt glands is the organ used to offload excess salts and conserve water (Willmer et al., 2011, pp. 110, 633). In order to cope with future heat and water scarcity, it will be likely that some animals will undergo adaptations that will result in longer loops of Henle in order to conserve water in the body.

The abilities for osmoregulation seem to be adaptive within a species at the population level. For instance, there have been shown significant anatomical differences in the relative medullary thickness between kangaroo rats living under drought conditions, compared with more moisture conditions (Schwimmer and Haim, 2009). After severe drought events, the surviving individuals presumably would have some degree of genetic resistance that might be inherited by the next generation (Allen et al., 2010). Because of global warming this genetic resistance might be important for the survival of many species in the future. And since osmoregulation seems to be adaptive, many species might have a fair chance to persist in a world with increasing drought.

Link Between Ecology and Evolution

Earth is continually undergoing climate change and changes in environmental factors, both at ecological and evolutionary scales (Crisci et al., 2006; Rogério de Mello et al., 2015). Just with respect to the breakup of Gondwana, the ecology of Earth did definitely change tremendously. Populations became separated, for some it caused extinction, while others underwent allopatric speciation (Campbell et al., 2008, pp. 493-494; Wang et al., 2016). Despite this, it is only in the past few hundred years that the rate of species extinction have increased by up to 1,000 times over the background rates that have been typical for the history of Earth (Millennium Ecosystem Assessment, 2005, p. 4). Since the difference between the current and earlier recorded climate change events, is that the current is anthropogenic caused (Barnosky et al., 2011; Santos et al., 2016), it seems reasonable to argue that it is anthropogenic activity that is the core reason for the extent of the current climatic changes, and thus the increased extinction.

Under the split of Gondwana, volcanic activity released ash to the atmosphere (Bollmann et al., 2010, p. 11; livescience.com, 2017), the ash might partly have blocked the sunlight and decreased the photosynthesis, and thus the partial pressure of oxygen. This could have lead species to undergo selection, where species with high oxygen demands did not survive. A similar event might happen again in the future, since smog also have the capability of blotting out the sun (McKirdy, 2014).

Gondwana formed, and existed for most of the time, in a moist, tropical and relatively stable climatic zone (Lomolino et al., 2010, pp. 291-292), and many of its inhabitants originated under stable and narrow climatic conditions (Gouveia et al., 2012). It is confirmed by Gouveia et al. (2012) that species that evolved under narrow climatic conditions will be less tolerant to a more extreme climate. This might fuel extinction of many of the species that originated on Gondwana, like anteaters and clades of crocodyliform. This indicates that Earth likely will be dominated by species that are either tolerable or able to adapt to more extreme climatic conditions.

Extinction and speciation due to changing environmental conditions have always been a part of the Earth's history, and in fact 95-99 % of the species that have ever inhabited the Earth have died out (Barnosky et al., 2011; Jablonski, 2012, p. 491). Many species likely died out because their rate of adaptations was not fast enough to keep up with changing ecological conditions.

The impacts of climate change that currently are measurable do not yet reflect the total extent of climate change already caused by anthropogenic activity in the past. Meaning that the future still is unsure to some extent, and many ecological consequences can potentially show up. What is sure is that biodiversity and habitats undoubtedly will be lost due to global warming (Bollmann et al., 2010, pp. 15, 102; Khailani and Perera, 2013).

Polar areas are melting, and thus is the ocean rising (Willmer et al., 2011, p. 397; Barbier et al., 2011), this will likely result in the formation of isolated islands where the ocean creates a barrier that will isolate multiple populations. As explained by Myers and Giller (1988, p. 129), when species become isolated from their former biota on islands they must evolve under new conditions. This can be a great opportunity for adaptive radiation, which will fill out empty niches. If the islands become too small, it can cause too small gene pools, and thus inbreeding that might lead to extinction. Particularly for species on smaller islands, the possibility for locomotion like flying or swimming will be favorable in order to prevent isolation.

Conclusion

Climate changes have always occurred on Earth, but never in recorded history as rapid as is currently experienced. This effects the biogeography in the way that it put pressure on ecosystems, and if species are too limited in their options of migration, they basically have two options: adapt to the changing climatic conditions or going extinct. Currently the rate of extinction is higher, more rapidly, and less gradual than the normal background extinction. This indicates that it is accelerated by the anthropogenic caused climate changes. Because the climatic changes are now happening faster, the time that populations have for adaptation has decreased, which selects for fast adapting species.

Equally will species with low capability or, for different reasons, willingness to migrate, be vulnerable to extinction. Since most species follow the moving isotherms rather than stay and adapt, pole ward and upslope migration is unavoidable. In the higher altitudes the environment is more hypoxic, and adaptations like higher affinity for oxygen in the hemoglobin, larger heart, and lungs to favor oxygen transportation will likely occur in upslope migrating species.

In the ocean, organisms that are dependent on calcification, like calcified pteropods and many species of corals, will likely die out due to the acidification. Meanwhile will invertebrate species like marine polychaete and metazoan likely spread and speciate. The composition of fish will also change due to climate change. The habitat for warm-water species will keep increasing, while other species, will become more vulnerable to extinction. Due to the ocean acidification, it is likely that a wide variety of fish will undergo adaptations similar to paedocypris, who is capable to exist with a poorly mineralized skeleton.

The rising ocean will facilitate the formation of isolated islands, which creates barriers for migration. These barriers will for some species result in isolation that can lead to inbreeding, and thus increased risk of extinction. Even if species migrate, survival is not ensured, e.g. the new area might be inhabited by highly competitive species, or not offer sufficient food supply.

Since many species will suffer extinction, and the speciation will rely on the remaining species, adaptive radiation will likely occur in order to fill out empty niches. Since the only genes that will be carried on in the future will be from species that are able to survive in an extreme changing climate, the Founder effect will likely shape future speciation.

The pattern in extinction and speciation due to climate changes follows the predication of the The Red Queen Hypothesis, which states that species have to keep evolving due to their environment and pressure from competition, in order to continuously exist.

Since the globe is heating up due to global warming, and polar areas are melting, adaptations to live in polar areas will likely disappear in the future. Meanwhile, will adaptations to live in a warmer and more drought climate be selected for. These include the ability to undergo estivation, and for mammals develop longer loops of Henle. Similar adaptations will be likely for some birds and reptiles, where the nasal salt glands might be more efficient.

It is likely that the climate change induced mismatches between plant and pollinator will cause a decline in the pollination effect, leading to less sufficient production and hence the food-production will claim more land. Surely forest areas will be sacrificed in this process, meaning that the carbon sink on Earth will decrease, which will contribute to further acceleration of global warming. This loop will continue if actions are not taken.

The solution is to save energy and significantly reduce greenhouse gas emissions. This can be done through reforestation, and sustainable anthropogenic consumption.

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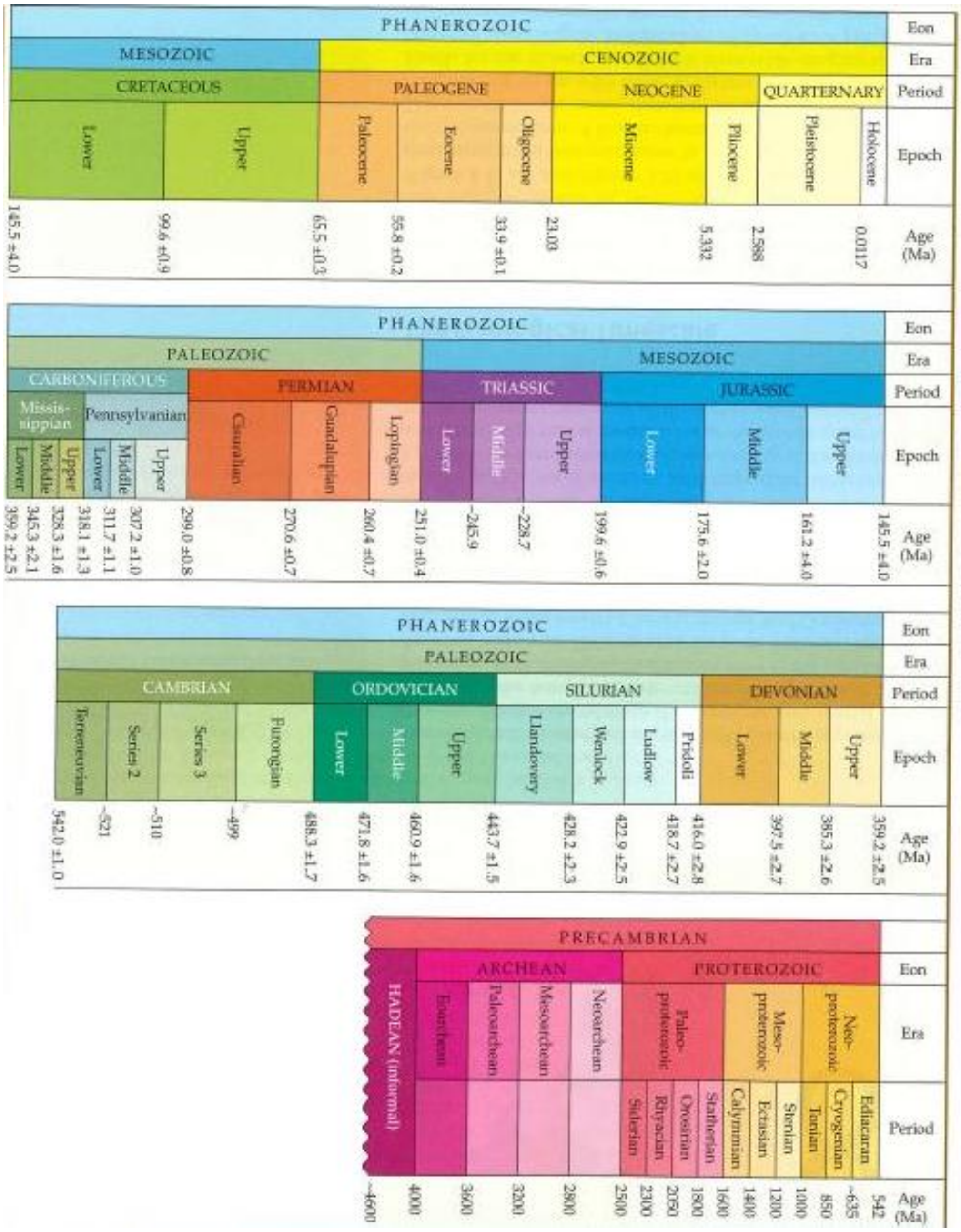
Appendix

Table 1 Geological time scale, remark that all numbers are in millions of years. Imported from Lomolino et al., 2010, p. 260



PHANEROZOIC										Eon
MESOZOIC		CENOZOIC								Era
CRETACEOUS		PALEOGENE			NEOGENE		QUARTERNARY			Period
Lower	Upper	Paleocene	Eocene	Oligocene	Miocene	Pliocene	Pleistocene	Holocene		Epoch
145.5 ±4.0	99.6 ±0.9	65.5 ±0.3	55.8 ±0.2	33.9 ±0.1	23.03	5.332	2.588	0.0117		Age (Ma)

PHANEROZOIC																Eon
PALEOZOIC									MESOZOIC							Era
CARBONIFEROUS						PERMIAN			TRIASSIC			JURASSIC				Period
Missis-sippian			Pennsylvanian													
Lower	Middle	Upper	Lower	Middle	Upper	Cisuralian	Guadalupian	Lopingian	Lower	Middle	Upper	Lower	Middle	Upper		Epoch
359.2 ±2.5	345.3 ±2.1	328.3 ±1.6	318.1 ±1.3	311.7 ±1.1	307.2 ±1.0	299.0 ±0.8	270.6 ±0.7	260.4 ±0.7	251.0 ±0.4	~245.9	~228.7	199.6 ±0.6	175.6 ±2.0	161.2 ±4.0	145.5 ±4.0	Age (Ma)

PHANEROZOIC															Eon
PALEOZOIC															Era
CAMBRIAN				ORDOVICIAN			SILURIAN				DEVONIAN				Period
Terreneuvian	Series 2	Series 3	Furongian	Lower	Middle	Upper	Llandovery	Wenlock	Ludlow	Pridoli	Lower	Middle	Upper		Epoch
542.0 ±1.0	~521	~510	~499	488.3 ±1.7	471.8 ±1.6	460.9 ±1.6	443.7 ±1.5	428.2 ±2.3	422.9 ±2.5	418.7 ±2.7	416.0 ±2.8	397.5 ±2.7	385.3 ±2.6	359.2 ±2.5	Age (Ma)

PRECAMBRIAN															
HADEAN (informal)	ARCHEAN				PROTEROZOIC										Eon
	Eoarchean	Paleoarchean	Mesoarchean	Neoarchean	Paleo-proterozoic				Meso-proterozoic			Neo-proterozoic			Era
					Siderian	Rhyacian	Orosirian	Statherian	Calymmian	Ectasian	Stenian	Tonian	Cryogenian	Ediacaran	Period
~4600	4000	3600	3200	2800	2500	2300	2050	1800	1600	1400	1200	1000	850	~635	Age (Ma)
														542	