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Biodiversity in a changing environment

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Abstract

What happens to biodiversity as the environment changes? Are species able to adapt and survive or will they go extinct? These are important questions that are unfortunately difficult to answer. This is because all kinds of communities and their inhabitants react differently to changes. Habitat degradation and loss, habitat fragmentation and climate change are the three major threats to biodiversity. All kinds of ecosystems are threatened and humans will also be affected. A combination of the effects of the threats enlarges the severity of the threats. Human activities also attribute to the severity of it.
Nature provides a lot of different services to us, however, nature will only be able to provide these services if a broad level of diversity is maintained. This is of course a very important factor to make sure that biodiversity will be conserved.

Content

Introduction

Biodiversity includes all life on planet Earth. The tropical rainforest, the Great Barrier Reef but also the pasture right outside your door hosts an enormous biodiversity. In addition, there are a lot of species of which we still do not know the existence. Nature services us with fresh water, food, medicine, recycling and much more. However, if a large diversity of species is not preserved nature will not be able to service us any longer (Groom *et al.* 2006). This shows the great importance of biodiversity.
In the eighteenth century the Industrial Revolution started. Factories expanded, cars were introduced and houses were built. More and more people needed a home, water and food to survive. With this the landscape changed. Land was converted for agricultural purposes and this had a huge effect on ecosystem diversity (Groom *et al.* 2006). The combined effects of these threats enlarge the impact of the threats and can lead to the extinction of species (Myers 1987). Moreover, the use of natural resources and transformation of the landscape caused a decline of the natural rates of replacement. (Groom *et al.* 2006).
Recently, climate change plays a big role in the biodiversity change. It happens everywhere and at any time. The consequences of climate change nowadays become very clear. Droughts, changes in soil salinity and changes in evapotranspiration are some major consequences. In addition, the land ice on the poles is melting and some species are seriously threatened. Temperature rises affects sea-level and it will be responsible for a mean sea level increase of one mm of sea level per year (IPCC 2001a). One can conclude that climate change affects everything and everyone.

Communities and their inhabitants all react differently to changes. This makes it hard to predict their responses. In this review I will to explore what happens to biodiversity if the environment changes. First, I introduce the term biodiversity (short of biological diversity). Secondly, I will describe the three major threats to biodiversity. At the end, I will compare two models of extinction processes. The models both try to estimate the extinction rate of species due to human disturbance of the environment.

Biodiversity

Biodiversity, which is a contraction of biological diversity, is the accumulation of all living things on our planet. Walter Rosen first described this term in 1986 (Wilson 1988). When you read about biodiversity, two things stand out. First, biodiversity is very complex and secondly, it changes all the time (Noss 1990).
Our planet contains 6.79 billion people and every day this number increases with thousands of people (U. S. Census 2009). All these people need fresh drinking water, food, clothes and a home. Of course this causes problems and not only wildlife is affected by it.

Importance of biodiversity
Ecosystems are of great importance for conservation, because they provide a large amount of goods and services essential for human continuation. Fresh water, food, air purification, nutrient cycling, cultural heritage are just a few matters which we could not live without (Costanza *et al.* 1997 and Millennium Ecosystem Assessment 2005b). However, nature can only serve us if diversity of native species is maintained at a broad level (Groom *et al.* 2006). Tilman and Downing examined this in 1994. They showed that drought resistance was bigger in a prairie plot with high species richness than in low species richness plots. In addition, many researchers have hypothesized that species rich communities are more able to resist invasive species than poor species communities are, because species rich communities utilize their resources and niches (Elton 1958; MacArthur 1970; Levine & D'Antonio 1999; Tilman 1999).

Species diversity
Biodiversity is often linked to species diversity, but biodiversity is much more comprehensive. It comprises more than one organizational level: the genetic, population, ecosystem, community and landscape levels of biodiversity. It also involves different spatial and temporal scales (Noss, 1990). All levels are of equal interest. Here I will concentrate on species biodiversity, because they are the key element of evolution and of great interest of conservationists (Groom *et al.* 2006).
To determine the number of species in a certain area, you could use one of the three commonly used measurements categories for this purpose, like species richness (Groom *et al.* 2006). Species richness is the total number of species in a certain area. You can also measure the differences between species, biotas or populations by indices of similarity. This diversity indice is often used to obtain insight into the adverse effects of all kinds of environmental disturbance (Groom *et al.* 2006).
The Shannon-Weiner diversity index H' measures species richness as well as species evenness (See figure below). S stands for species richness and p_i for the relative abundance of species i. N is the number of individuals. If species richness increases, H' will increase. The maximum value of H' will be realized if all p_i are equal (evenness) (Armsworth *et al.* 2004).

$$H' = -\sum_{i=1}^{S} p_i \ln p_i - [(S-1)/2N]$$

There are some shortcomings to the measurements with species richness. It does not make a distinction between native and nonnative species. In addition, it does not indicate the degree of species interactions among communities. Nevertheless, communities are defined by species and their interactions (Groom *et al.* 2006).

Habitat degradation and loss

Biodiversity is threatened by human activities (Armsworth *et al.* 2004). With the increase of the human population, accompanied by increasing consumption, human beings completely changed the landscape with the expansion of agricultural land. This has had an enormous influence on the form and diversity of all ecosystems. Moreover, the use of natural resources and transformation of habitats, have caused a decline of natural rates of replacement. Overall, the growth of human population caused the sixth great mass extinction on Earth. The other five extinctions happened during the history of the planet and were not caused by humans (Groom *et al.* 2006).
In this section I will discuss the first major type of threat to biodiversity. Ecosystems are confronted by various threats. The combined effects of the threats can eventually cause biodiversity losses. Overexploitation combined with non-native predators can cause the extinction of a bird species (e.g. Dodo (*Raphus cucullatus*)) (Myers 1987). In addition, the effect of a threat can increase as it progresses. This is called the snowball effect and returning to the original state of the system will be very difficult (Groom *et al.* 2006).

Habitat degradation and loss means transformation of a habitat type into a polluted and dangerous habitat for species to live in. Both cause loss of biodiversity at all levels (from the genetic to the community level of biodiversity). This makes habitat degradation and loss the most serious threat to biodiversity and the primary cause of biodiversity losses. The difference between habitat degradation and habitat loss is that habitat loss has severe impact on (nearly) all species or on species of which the recovery time is very long. Habitat degradation influences a smaller amount of species. If the habitat is degraded the habitat will not be able to support all species anymore. This may reduce the survival of these species, but it is not impossible to survive (Groom *et al.* 2006).

Consequences of habitat degradation and loss
The degradation and loss of habitats is caused by human activities like industry, agriculture plus the use of pesticides, fishing, urbanization and pollution (Groom *et al.* 2006). The last 300 years, almost 50% of the forest systems is transformed to agricultural land and pastures (Millennium Ecosystem Assessment 2005b). Temperate grasslands were transformed most heavily (Groom *et al.* 2006). Between 1990 and 2000, the world's forest cover decreased from 30.4% tot 29.7%, which is equal to an annual loss of forest area of the size of Egypt (UN Environment Programme 2002). This has a huge impact on ecosystems as well as on humans. Deforestation can cause erosion and flooding, which can result in an increased runoff of sediments and can cause flooding of cities (Groom *et al.* 2006). The increase of sedimentation on wetlands and water converted streams into still and shallower waters (Poff 2002). The clearing of forests can also cause climate change. It is thought that the deforestation in the tropics will attribute to global as well as to regional warming (Houghton *et al.* 2000). Logging of forests on a large scale will decrease the amount of evapotranspiration, which is the evaporation and plant transpiration together. This could result in regional drying and might alter temperatures (Betts 2004). It could also result in conditions, which are favorable for fires (Nepstad *et al.* 1999). These fires affect not only wildlife, but also humans by increased agricultural losses and causing respiratory illness. As a consequence of deforestation by burning

down the trees, the Brazilian Amazon has turned into a major source of carbon dioxide emission instead of being a carbon sink (Houghton *et al.* 2000).
Not only terrestrial ecosystems are affected by habitat degradation. Also marine ecosystems suffer from human activities. Coral reefs have experienced the influence of humans by pollution, sedimentation and scuba diving recreation sites. These influences are a deathly combination and threaten 27% of all coral reefs (Bryant *et al.* 1998).

Habitat fragmentation

The second major threat to biodiversity is habitat fragmentation or "disruption of continuity". It could happen at any time at any place in all habitats (Lord and Norton 1990). Habitat fragmentation exists of two parts. The first part includes a reduction in a habitat type area while the second part includes division of a habitat (habitat configuration). This means that the habitat will become divided into small and isolated patches (Harris 1984; Wilcove *et al.* 1986; Saunders *et al.* 1991). It is the result of urbanization, intensive resource extraction and agriculture (Curtis 1956).
Humans initiate the fragmentation of ecosystems. In terrestrial ecosystems it starts with gap formation of the landscape. Habitats in the landscape are only little affected by this. However, if the gap formation continues the gaps grow and the landscape will become totally fragmented. This means that the connection with the original vegetation has disappeared and the landscape will not be able to support (some) species (Wiens 1989).

Consequences of habitat fragmentation
Elimination of species that only inhabit a specific portion of the landscape (endemic species) is the most evident effect of habitat fragmentation. Endemic species only have a small range of distribution. Mountain building has caused that the ranges of many taxa have become separated and created regions with many endemic species. The result of patchiness is that the quality of a habitat differs spatially for species. If the habitat quality declines, species will have to move to another suitable habitat. If dispersal between patches gets impossible, because of the distance or lack of corridors, and the species is not able to adjust to the current changes in his habitat, the species will extinct. (Groom *et al.* 2006). In addition, fragmentation obstructs migration of species in reaction to climate changes (Davis 1981; Clark *et al.* 1998; Peters and Darling 1985; Noss 2001).
Freshwater ecosystems suffer also from declining area. The biggest threat to these systems is the loss of connectivity by fragmentation of rivers by dams (Pringle 2001).
A combination of different habitats or resources is necessary for many animal species to accomplish life history needs. Each habitat has its own function. For example, there are food patches, mating sites and breeding spots. If barriers isolate the different habitats, it will destroy the advantages of these specific habitats, because they become isolated. If species are not able to reach these specific habitats, populations will decline and might extinct (Groom *et al.* 2006). There can be an interaction of impacts, which also threatens species. For example, if species are isolated in small populations for a long time they could lose functional genetic diversity. This decreases their ability to react to stresses like habitat degradation or climate change (Groom *et al.* 2006).
Habitat fragmentation does not only decrease biodiversity, but also influences the top down and bottom up forces in food webs (Hanski 1988, 1999; Kruess & Tscharntke 1994). Therefore, predators may find it difficult to trace prey patches. Practical, this will mean that biodiversity loss will disrupt food chains and causes changes in trophic dynamics.

Climate change

The third important threat is climate change. Climate change is a threat that exists everywhere; globally, regionally and locally (Groom *et al.* 2006).
The Earth's atmosphere acts as a greenhouse that warms the surface of the Earth. Human activities like burning fossil fuels, cars, logging forests and urbanization enhance this effect by emitting carbon dioxide to the atmosphere (Primack 2004). Svante Arrhenius already predicted that the world would be warmed by the emission of carbon dioxide due to the industrial revolution (Weart 2003). Between 1860 and 1998 the mean global temperatures have risen with 0.6 ºC (IPCC 2001a) and carbon dioxide levels in the Earth's atmosphere are still rising. They are already 30% higher than before the eighteenth century (Groom *et al.* 2006).
All sort of models, well tested by scientists, show that warming of the Earth will have the biggest impact on the temperature at the poles and the smallest in the tropics (IPCC 2001a). Off course this will have a big effect on biodiversity at these sites. As temperature rises, more land ice melts and the habitats area of many species will decline. In addition, the landscape will become more fragmented. This obstructs species dispersal (see section Habitat fragmentation).With the large volume of the oceans, a temperature change can have a big effect on sea level: it will be responsible for a mean sea level increase of one mm of sea level per year (IPCC 2001a). Sea level rise can cause an increase of the ground water salinity. As an example, pine forests in the Florida Keys have been pushed out their habitat because of the higher salinity of the ground water and have been forced to found a new habitat. This resulted in habitat loss of species that were dependent of these tree species (Ross *et al.* 1994).
Overall, climate change caused an increase of the mean global temperature and sea levels. This influenced not only biodiversity but also humans. Viability of populations, the amount of species and their distribution, and the organization of ecosystems are changed, resulting in biodiversity loss. Eventually, it reduces the access to natural resources and stability of the climate (Kappelle *et al.* 1999).

Estimating the direct effect of climate change on biodiversity is difficult, because climate changes go slowly (Kappelle *et al.* 1999). Fossils are now being used to estimate community responses to the climate shifts. Communities are defined by species that live within it and their interactions. The species composition changes over space, because each species adapts differently to the environment. This is why communities and their residents will all react differently to (climate) changes, which makes it even harder to predict responses. The overall effect may be that species invade and some will go extinct as their quantity changes. Some ecosystems may be replaced by other ecosystems as they disappear. (Groom *et al.* 2006). Invasion of a species results in (resource) competition, parasitism predation or other interactions with the native species. Also, the introduction of predator species can lead to the extinction of native species. A good example is the introduction of the brown tree snake (*Boiga irregularis*) at the island Guam. The species gradually spread across the island until the 1960s, when they emerged at large numbers. During the spread of the snakes, native bird species disappeared. This had a big impact on the bird community. The big question was why do these birds disappear? Nowadays, we know that the nocturnal brown snake ate the bird species and it resulted in the extinction of fifteen bird species (Groom *et al.* 2006).

Extinction

Extinction can occur at global and local scales. The difference is that with global extinction the species extinct all over the world, where as with local extinction the loss of a species is only locally (Redford 1992). Climate change seems to intensify population decrease and species that will totally disappear. There are two cases of extinctions that are attributable to climate change. This involves the extinction of the golden toad and the harlequin frog in Costa Rica (Masters *et al.* 2004)

When the human population expanded, overexploitation, habitat modification (degradation/transformation) and the introduction of new species (invasive) were the main anthropogenic factors that caused extinction. We have ruined natural ecosystems and turned them into places where no species ever will or can live. The remaining habitats are surrounded by wasteland and species are not able to survive in these habitats (Groom *et al.* 2006). Nowadays, pollution, diseases and climate change are also major factors that have a huge impact on extinction (Myers 1987; Myers and Knoll 2001). Pathogens cause declines and or disappearance of species. A well-studied example is the *Batrachochytrium dendrobatidis* (a chytrid fungus). It was found in dying and dead frogs that lived in Australia and Panama (Berger *et al.* 1998; Longcore *et al.* 1999). *B. dendrobatidis* can kill frogs that are metamorphosing by producing a toxin or by disturbing the skin functions (respiration, osmoregulation) of the frogs (Berger *et al*. 1998; Rachowicz & Vredenburg 2004). Climate change can induce droughts, whereby frogs (amphibians) must aggregate around water. This increases their exposure to waterborne diseases such as *B. dendrobatidis* (Pounds *et al.* 1999; Burrows *et al.* 2004) and will lead to extinction.

The future of biodiversity

In this section, I will review two models that estimate extinction rates. First, I will sum up the methods, results and conclusion of both the models.

The first model is from Thomas *et al.* 2004, "Extinction risk from climate change". Thomas *et al.* used species' future distributions for future climate scenarios to assess extinction risks. They used three different climate change scenarios with different climate warming ranges (minimal, mid-range and maximum) for 2050. Eleven hundred animal and plant species were used representing about 20% of the Earth's terrestrial surface.

Method

The probability of extinction is strongly correlated to the geographical range size. Therefore, they estimated current distributional areas of the species by using modeled associations between current climates (like temperature and precipitation) and present-day distributions. This represents the conditions under which species' populations now persist with competitors and natural enemies. The authors distinguished two distribution scenarios. The first one represents no limits to dispersal and the second scenario comprises incapability of distribution. You can project future distribution for future climate scenarios

Thomas *et al.* explored three methods to estimate extinction, based on the species-area relationship [$S = cA^z$]. This describes how species richness relates to the area: S is the species richness, A represents the area, c and z are constant values (here: z =0.25). Qualitative conclusions are independent of z. This relationship predicts the amount of species that become extinct or threatened if their area is reduced by habitat destruction.

- Method 1/ traditional species-area approach: analyses the overall changes in distribution areas, summed across species.

Regional extinction: $E_1 = 1 - (\sum A_{new} / \sum A_{original})^z$

$A_{original}$ = initially occupied area by a species.
A_{new} = future area, summed across species.

- Method 2/ species-area approach: is based on the average change in distribution area, averaged across species. Halving the habitat area leads to the proportional loss of half the distribution of each species.

Regional extinction: $E_2 = 1 - \{(1/n)[\sum(A_{new} / \sum A_{original})^z]\}$

n = number of species.
$A_{new} / A_{original}$ = proportional distribution change of each species separately.

- Method 3: estimate the extinction risk of each species separately by averaging across species.

Regional extinction: $E_3 = (1/n) \sum[1- (A_{new} / \sum A_{original})^z]$

At first, they found a gap in the data. They used a logit-linear model fitted to the extinction risk data to produce estimates for missing values in the extinction risk table. This way you get balanced estimates of extinction risk and you will be able to calculate the average across all data sets of each scenario.

Results
The results show the proportions of species that will extinct as a consequence of climate change over the next 50 years. It does not estimate the number of species that will become extinct during this period.
When one looks at the three climate change scenarios and the dispersal range, one sees that at maximum climate change with dispersal, 21-32% is expected to be extinct. Without dispersal, this will be 38-52%. For the mid-range climate change with dispersal 15-20% will go extinct and without dispersal 26-37%. 9-13% will go extinct at minimal climate change with dispersal. 22-31% will go extinct without dispersal.
The average of the three methods and two dispersal scenarios shows that in minimal climate change a lower projection of species is predicted to go extinct (18%) than in mid-range change (24%) and maximum change scenarios (35%).

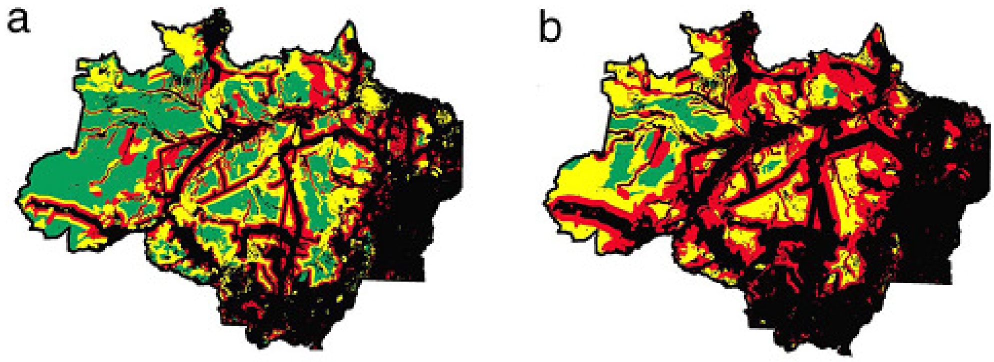
At the end, climate warming is the greatest threat to animal and plant species. The impact of climate change is likely be caused by interaction of threats.

The second model comes from <u>Hubbell *et al.* 2008: "How many tree species are there in the Amazon and how many of them will go extinct"?</u>

Their main question is how many of the species that live in the Amazon will go extinct from habitat loss during the next several decades? To answer this question, they first estimated the abundances of species in the Amazon. There are two hypotheses to estimate this. The Preston lognormal hypothesis and the Fisher logserie hypothesis. Fisher's logseries predicts a far larger number of species to go extinct- and that a far larger fraction of these species is rare to very rare- than does the lognormal hypothesis.

Method
After estimating the abundance of species, the question what is the extinction risk of tree species in the Amazon over the next several decades can be answered. Therefore they confronted their estimations of species abundance and range sizes with maps of projected loss of Amazon forest cover. Laurance *et al.* produced a detailed map that consists of two graphical scenarios of the future of the Brazilian Amazon. One scenario is to be considered optimistic and the other non-optimistic. They evaluated human impact and then classified land-use into four categories. The optimistic scenario includes that 36.7% of the Amazon is a heavy impact area and the non-optimistic scenario includes a 49.4% heavy impact area (see figure below). Hubbel *et al.* digitized the maps at a spatial resolution of 10 x 10 km cells. After that they classified each of the cells into one of the four land-use categories. So they looked at what extend land-use affects extinction. There are three extinction scenarios to estimate the extinction risk:
Scenario 1: Species goes extinct if its range lies entirely in heavy impact areas.

Scenario 2: Species go extinct if their range lies partially or entirely within in temperate or light impact areas. In addition, species still go extinct if their range lies entirely in heavy impact areas. This scenario predicts the most extinction.
Scenario 3: Even if a species is limited to a heavy impact area, it has a chance tot survive. This is the most conservative scenario.



Scenarios of the future of the Brazilian Amazon (Laurance *et al*. 2001)
Graphical scenarios
a) Optimistic scenario
b) Non-optimistic scenario

Land use categories:
Black: heavy-impact area; Red: moderate-impact area;
Yellow: light-impact area; Green: pristine area.

Results
Under the non-optimistic geographical scenario, 32.6% of the tree species will go extinct compared to the optimistic scenario, which estimates 19.9% extinction rate.
In scenario three 27. 5% of the tree species will go extinct. This includes 3085 species.
Scenario one predicts that 21.5 % of the tree species will go extinct (2414 species).

Discussion Thomas *et al*. & Hubbell *et al.*
Thomas et al used for their study only endemic species. It would be better if they had used more and different plant and animal species. This way the samples represent a bigger area size of the Earth and it prevents that the outcome is species specific.
Extinction of species is correlated with geographical size. Here fore they used a statistical match between climate variables and present-day boundaries of distribution. There are two (extreme) dispersal possibilities. One: species have no limits to dispersal and two: species are incapable of distribution. In real live most species do not fit in these extreme dispersal ranges, but will operate between these ranges. Their will always be limits to dispersal, for example by lack of corridors, distance and habitat fragmentation.
The extinction measurements are based on the species area relationship. However, this is an empirical relationship. Thomas *et al*. assume that the outcome of the measurement is automatically valid, but they make no distinction between distribution loss by habitat destruction or by unsuitable climates.

Thomas *et al.* discuss that it is better if the climate change scenarios are standardized and that the extinction risks might be higher if future locations of appropriate climate do not overlap with other crucial resources. In addition, land use should be included into the analyses. Land-use can alter the landscape and results in habitat degradation and fragmentation. Hubbell *et al.* do use land-use in their study to estimate the extinction risk. However, their study only includes tree species and no other plant or animal species. The results they produce are for that reason less applicable to animal species.
The tropical rainforest is a very large ecosystem and hosts many species. All these species interact with each other and these interactions have an effect on the survival of species. Hubbell *et al.* did not pay attention to these interactions in their study. This could influence the extinction measurements. The authors of this study used graphical maps to estimate extinction, but they do not know the exact location of the species they are using plus the exact number of the species. This makes it difficult to get good results.

Both studies estimate extinction risk, but Thomas *et al.* examine the effect of climate change on extinction and Hubbell *et al*. examines the effect of land-use on extinction. In this way one could say that both studies examine the effect of anthropogenic influences on the extinction of species, but ecology is left out. Both studies seem to be statistical approaches and do not look at patterns of extinction or historical records. These patterns can be good predictors of extinction, just as abiotic and biotic factors. A flat and low landscape will promote extinction just as nutrient rich soils. Contrary, species rich diversity and the presence of terrestrial mammals will delay extinction (Steadman & Martin 2003). The authors could look at these factors and concentrate less on the statistical methods.

Conclusion

Environmental changes have a negative effect on the biodiversity. Natural habitats are being destroyed or turned into wastelands and no ecosystems are left out. As well as terrestrial as marine ecosystems are being destroyed. The role humans play in this cannot be neglected. They have caused the sixth great mass extinction on our planet and more importantly, they have caused a decline of the natural rates of replacement. As human population grows, more food and houses are necessary to support these people. Here fore, natural habitats and land is transformed into land with agricultural purposes. Between 1990 and 2000, the world's forest cover decreased from 30.4% tot 29.7%. This is equal to an annual loss of forest area of the size of Egypt (UN Environment Programme 2002). Deforestation can cause erosion and flooding, resulting in an increased runoff of sediments and flooding of cities (Groom *et al.* 2006). As one can see not only wildlife is affected but humans will also become victims.

Habitat degradation, fragmentation and climate change are the three major threats to biodiversity. All three threats will eventually lead to species extinction. If habitats become fragmented, they will become small isolated patches. If the habitat of species changes, they have rather two options. Whether they adapt to these changes or move to another suitable habitat. If a species is not able to adapt properly or to find a new habitat, the species will soon go extinct.

Climate changes are enlarged by human activities. Humans enhance the warming of the Earth's surface (Primack 2004). This will have the biggest effect on the temperature at the poles. If the temperature rises, more land ice will melt and the structure of many habitats will change. The habitats areas will decline and the landscape will become more fragmented. With the melting of land ice, the temperature changes will be responsible for a mean sea level increase of one mm of sea level per year (IPCC 2001a). Imagine the consequences this will have for our small country with all our dikes. Moreover, a combination of effects of threats will be more dangerous for species. It increases the impact of the several threats (cascade effect).

Ecosystems provide a large amount of goods and services essential for human continuation. However, nature can only serve us if diversity of native species is maintained at a broad level (Groom *et al.* 2006). This points out the great importance of maintaining biodiversity. Others may say that changes are natural, but human activities expand the impact of the consequences these changes have (Noss 1990). This is why humans have a great responsibility in keeping the biodiversity at a high level.

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