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Review Article

The Effects that the Current Climate Crisis have on the Biogeography and Environment, Needed Adaptations and Conservation

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Abstract: This study is a literature review aiming to give a summary of the effects that the current anthropogenic caused climate crisis has on the biogeography and environment, and further give examples of likely future adaptations and needed conservation work. This study is based on scientific articles, primary from Web of Science and Google Scholar. The biodiversity is under pressure due to climate changes, the average species extinction is currently two to three orders of magnitude higher than the normal background extinction, and faster than the rate of origination. This development follows the predictions of The Red Queen Hypothesis that every species must constantly evolve due to environmental changes in order to avoid extinction. The natural environments are changing due to e.g. increased extreme weather events and ocean acidification. The increased heating is causing drought, and adaptations of the biota is needed, like more drought resistant flora and fauna with the ability to undergo estivation. The increased oceanic acidity can cause the shells of calcifying organisms to dissolve. These organisms will need to either spend energy on increased calcification or develop in a way so they can carry out live with lesser calcification. If organisms cannot develop, they are likely to migrate to colder regions. In the ocean this means towards polar areas and to greater depths, and in the terrestrial environment it is pole wards and to greater altitudes. Conservation is needed, and there are multiple options. Ex situ might be the only option for species whose natural habitat will be forever gone if the development of the climate change continues as present. To carry out conservation to infinity is unrealistic, and we are at a point where climate change is threatening our food security. It is possible to both slow down the current climate crisis and counteract its consequences.

Keywords: Climate Change, Biogeography, Conservation, Extreme Weather, Adaptations, Migration

1. Introduction

This paper provides the current knowledge about how the current anthropogenic climate crises is affecting the biogeography and our environment. Subjects that this paper is touching is: (1) the needed adaptations that species will need to undergo in order to avoid extinction, (2) ocean acidification and its consequences, for especially calcifying organisms, (3) problems with more extreme weather, like desertification in some areas while heavier rain will be more frequent in other, (4) the needed migration pole wards, to greater altitudes and greater oceanic depth in order to stay in the preferred thermal conditions, and (5) our food security is threatened by a climate changed induced mismatch between pollination and flowering season.

2. A Summary of the Current Climate Change Crises and Needed Adaptations

2.1. Extinction and the Need to Evolve

Extinction is a common phenomenon, and as described by The Red Queen Hypothesis, species will constantly have to respond to changing environmental conditions in order to avoid going extinct [1, 2]. The biodiversity on Earth have been shaped by the climatic and environmental conditions throughout evolutionary time [3], and organisms that cannot cope with the changing environmental conditions will need to either adjust or migrate to more thermal suitable habitats [4]. To survive, species need to constantly evolve fast enough to be suitable adapted to the environment, and have a fitness that can compete with predators, parasites etc., who also are continually evolving [5, 6, 7]. Meaning that for species to exist, they must minimally be well-designed, and if better designed they might be more suited for future circumstances [6], maladapted species will be eliminated by natural selection [5].

2.2. Be Adapted to Avoid Extinction

Being adapted to the environment in order to avoid extinction is essential, both with respect to the present climate changes due to anthropogenic activities and in an historical context. 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 [8-10]. Extinction has always occurred, but currently 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 [11, 9, 12].

The big driver for this extinction is climate changes, which is currently more rapid than what have ever occurred during recorded history [1, 13]. The expected global mean surface temperature for 2100 will be between 3.7°C and 4.8°C above the average for the period 1850-1900 if no drastic effort is taken to reduce the emission of greenhouse gases [14].

Since the industrial revolution, which started in the 19th century, the level of atmospheric carbon dioxide has increased from about 281 ppm to more than 400 ppm, which is the highest in recorded history [15, 16]. There are multiple greenhouse gasses contributing to climate change but the release of carbon dioxide to the atmosphere is especially critical because the worldwide output is so enormous [17, 18].

3. Ocean Acidification and Its Consequences

3.1. Oceanic Sink and Problems for Calcifying Species

The ocean is a major sink for atmospheric carbon dioxide [19], and accounts for 48% of the uptake [15], but someday the oceans capacity for taking up carbon dioxide might be reached, meaning that a further uptake will not be possible [15, 20]. Ocean acidification will expose many species to conditions that they have not been exposed to during their evolutionary history, and for this reason is not adapted to, which might cause extinction [20].

Carbon dioxide can enter some organisms and changes the pH of their body fluids. When organisms use energy on regulating pH, it can have consequences for growth rate and reproductive capacity [21-24]. The effect of ocean acidification is severe on calcifying organisms, because it can decrease their carbonate ion concentration to levels where shells dissolve [25, 26]. This have consequences for many ecosystems since reef-building corals and calcified pteropods are affected. Pteropods have essential roles in food webs of various marine ecosystems [27]. The coral reefs provide breeding grounds for multiple fish, protect sea grasses from wave stress, and protect shorelines from erosion and flooding [28, 20, 29].

3.2. Problems with the Stress from Heat

The heat is also a problem for corals, because they cannot make their own photosynthesis, they are dependent on their photosynthetic algal endosymbionts (*zooxanthellae*) in order to survive. But the thermal tolerance of *zooxanthellae* has been exceeded in many reefs, which have led to widespread coral bleaching [17, 30]. If the carbon dioxide emission continues as present, 70% of all known tropical reef locations will be gone at the end of this century [20].

3.3. Possible Adaptation the Acidic Environment

A species which have successfully undergone evolutionary adaptations to live in an acidified aquatic environment is paedocypris (*Paedocypris progenetica*), which is a miniature fish from Southeast Asia. They are native to caves with a naturally highly acidic environment and is adapted to these environments in the way that they are capable to live and function with a poorly mineralized skeleton [31].

4. Problems with Extreme Weather

4.1. Desertification

The global warming is causing an increase in the frequency, duration, and severity of drought in some regions [32]. A Drought climate will often result in increased wildfires, and thus vegetation will be lost [33-35]. Since plants remove atmospheric carbon dioxide, the terrestrial carbon sink will decrease due to increased wildfire [18, 36]. It is estimated that the global terrestrial carbon sink absorbs a range of 2.0 to 3.4 Pg. carbon per year [36]. If these pools of carbon become released back into the atmosphere it will contribute to acceleration of further global warming [32].

4.2. Not a New Phenomenon, and Some Species Are Already Adapted

Drought and wildfires are not new phenomena and has influenced the atmosphere and biosphere for millions of years [37]. In climate zone ecosystems like the Mediterranean-type, the native flora is particularly adapted to drought. These habitats are dominated by woody species, and plants that have a large amount of underground reserves to re-sprout and soil seed-banks [38, 39, 34, 40]. Lungfish, many insects, and desert snails, can escape periods with drought by using estivation, which is a state where the metabolic rate is substantially reduced and the body is at rest, despite the high environmental temperatures [41, 42]. They can survive estivation without any excretion of nitrogenous waste products [42]. The abilities for osmoregulation seem to be adaptive within a species at the population level, and there have been shown significant anatomical differences in the relative medullary thickness between kangaroo rats living under drought conditions, compared with more moisture conditions [43]. Species of mammals that live under constant drought stress have long loop of Henle in proportion to their body size, which makes them able to produce hyperosmotic urine. This is a favorable adaptation in where they lose very little water when excreting excess salts [42].

4.3. The Extreme Weather also Comes with the Problems of Flooding

The global warming is also associated with increased flooding in warmer maritime regions because the higher temperatures is increasing the evaporation from water surfaces [44, 45, 35]. The hazards that follows are likely to increase in the future with the predicted climate change [46]. The reason why the flooding increases in some areas, while drought is a severe problem in other, is because areas with closer proximity to aquatic areas will experience more rainfalls caused by evaporation, which will not happen in regions distant to aquatic areas [47, 48].

5. Migration

5.1. Some Species Need to Follow Their Thermocline Gradient

Many taxonomic groups worldwide have migrated pole ward and upslope to escape the heat [49, 50]. When migrating to high-altitude areas the adaptations to hypoxia is the main physiological challenge that threatens survival [51], and animals adapted to high altitudes in general have hemoglobin with a higher oxygen affinity, and larger heart and lungs [52, 53].

5.2. In the Ocean There Are Migration to Greater Depths

Due to increased ocean temperature multiple marine species are migrating pole wards or to greater depths [54, 55], and a globally large-scale invasion into colder marine waters is expected in the future [56]. This migration might cause conflicts between migrants and native species in receiving areas [57].

6. Pollination

6.1. Climate Change Is Threatening Our Food Security

The interactions between plants and pollinators are among the most ecologically important mutualistic relationships in nature, and fundamental for the global biodiversity, and further an important selective force during evolution [5-60]. But unfortunately, global warming is disturbing this relationship [61, 60].

6.2. Climate Change Induced Mismatches Gives Problems for the Pollination

For multiple species of plants there is a strong and complex relation between air temperature and pollen release [62]. The global warming leads to an earlier onset of the pollen season in some species [62], which can result in temporal mismatches between plant and pollinator [63-65]. In some places, like Arctic Greenland, this have led to a decline in the overlap between the pollen transfer season and the flowering season [60]. Shifted flowering seasons have made some pollinators incapable to track all their ancestral hosts flowers [63, 66]. These mismatches contribute to decreased pollination efficiency and have led to measurable impacts on the plant’s reproductive success [67, 64, 60]. In some cases, the mismatches lead to extinctions of both plant and pollinator [68]. It is likely that specialized pollinators will end up with no food plants, while pollinators that are more generalist will just experience diet reductions following phenological shifts [63]. Animals pollination is fundamental for the food security, because one-third of agricultural production depends on it [69]. A decline will lead to an increased demand for agricultural land [70]. Further is the pollination also essential for species that feeds on flowering plant [71, 72].

7. Conservation and Sustainability

7.1. Conservation Is a Huge Task

Conservationary work has through times resulted in both victories and failure, and currently the rapid climate change is placing the future of the conservation legacy in a vulnerable position [73, 74]. Conservation is currently a huge task because the distribution of many species and ecological processes are changing much faster than in the past [75]. The rate of climate change is likely to be so fast that the genetic adaptation of many species will not be able to cope [76, 77], nor is it likely for many species that their migration will be fast enough [78]. Unfortunately, along with that every endemic species is irreplaceable, the funding for conservation action is limited while the resources needed is increasing due to climate change [79, 80, 76, 81].

7.2. Consequences of Changed Ecosystems due to Anthropogenic Activities

Over the past five decades the anthropogenic activities have changed multiple ecosystems more rapidly than have ever before been recorded, which have caused irreversible loss of biodiversity [82]. Deforestation and agricultural expansion have resulted in destruction and fragmentation of many habitats, which have resulted in endangerment of many species [83, 84]. This fragmentation causes island conditions where many of the inhabiting species have smaller population size, and are geological limited in their options for dispersal, which is likely to cause extinctions [85, 80, 86]. Mainly due to habitat fragmentations 80% of vertebrate taxa have become globally endangered [87], and between 1 and 2 million km^2 of tropical forests are destroy by anthropogenic actions every decade [82, 84]. Destruction of the tropical forest is detrimental because it stores around 46% of the world's living terrestrial carbon pool, and the tropical soils about 11.55% [88, 89]. If the land-use change and deforestation activities were limited, the global greenhouse gas emission and pressure on the biodiversity will be reduced [18, 90].

7.3. Sustainability Is Likely to Be the Solution

Decreasing the greenhouse gas emission through a more sustainable anthropogenic consumption and way of living is possible. A more plant-based diet is more sustainable than a meat-based diet, partly because meat-production consumes a large portion of the crops and increases the problem of water shortages. It takes around 1,000 tons of water to produce 1 ton of grain, and it can take up to 8 kg of grain to produce just 1, 2, or 4 kg of beef, poultry or pork, respectively [91-93]. Resources like paper and fibers can be recycled [94], and the use of solar energy decreases the use of other energy sources [95-97].

7.3.1. The Need to Relocate Species and Establish Protected Areas

By establishing protected areas, the habitat will be maintained, which is a sufficient method to prevent losing habitat while protecting endangered species [79, 84, 98, 11]. Under rapidly changing climatic conditions the challenge of maintaining and restoring habitats can be very difficult [99, 100], and conservation workers must often use more proactive methods, such as removing invasive competitors or relocating populations to new habitat [79]. Relocation of species to areas outside their present or historical range, where their survival is expected to be favored, is a tool that can be used to conserve biodiversity under the future climatic changes. 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 [101-104]. This method can also be used to relocate some species of turtles into cooler regions in order to counteract the climate change induced female-biased sex ratio of their offspring [105]. 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 [106].

7.3.2. Ex Situ Conservation Might Be the only Solution for Some Species

Ex situ conservation is another important tool, which basically is 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 [107].

8. Discussion and Conclusion

The current climate crisis is caused by anthropogenic activities and have led to disruptions of multiple ecosystems. Among greenhouse gasses the main driver is the emissions of carbon dioxide [22]. The atmospheric carbon dioxide can be absorbed by carbon sinks, like the ocean and vegetations. Due to deforestation and urbanization, the terrestrial carbon sink is decreasing, and the capacity for oceanic uptake might reach its limit [15, 20, 32]. For these reasons actions like reforestation and limiting the output of atmospheric carbon dioxide is of importance.

Species might face extinction if they cannot develop fast enough to cope with the changing environment [7]. What differs between historical mass-extinctions and the current, is that the current is anthropogenic caused. Currently the average species extinction is 0.72% per year, which is two to three orders of magnitude higher than the normal background extinction [12], since this is faster than the rate of origination the biodiversity on Earth is declining.

Due to the acidification of the oceans many marine organisms will be exposed to conditions that they are not adapted to, which might be detrimental for their existence [20]. Under acidification some organisms reduce their metabolic rate, which have the drawback of reduced reproduction [21]. Especially calcifying organisms will need adaptations to a more acidic environment, either they will have to increase their rate of calcification to compensate for the acidification or they will have to manage life in a way similar to *Paedocypris progenetica*.

Many terrestrial ecosystems will become more drought [32]. Adaptations that likely will be more common in the future as a result of drought includes a flora dominated by woody species, and plants that have a large amount of underground reserves to re-sprout and soil seed-banks [38), [39]. Species like lungfish can escape periods with drought by using estivation, and many desert animals have evolved long loop of Henle in proportion to their body size [42]. These adaptations will likely be more common in the future due to the increased heat stress and more frequent occurrence of extreme weather events.

Some species migrate to escape the heating. Oceanic species can migrate pole wards or to greater depths [54, 55]. While terrestrial species can migrate pole wards and to greater altitudes [49, 50]. When migrating to greater heights, adaptations such as hemoglobin with a higher oxygen affinity, larger heart, and lungs are needed [52, 53]. It might be questionable is all the needed adaptations for migrating to greater heights can occur as fast as needed, and also when new species invades an already occupied arear in the heights it will undoubtedly lead to conflicts between established and invading species.

The climatic changes have also disturbed the pollination. In some areas it has shifted the flowering season and made pollinators incapable to track all their ancestral hosts flowers [63, 66]. In some cases, the climate induced mismatches have led to extinctions of both plant and pollinator [68]. The decline in the function of pollination is catastrophic for the future because a big part of our food security will be threatened.

Conservation actions are needed, and there are multiple options, like establishment of protected areas, relocation of species, and ex situ conservation [101, 107, 84, 98, 108]. 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 when the natural habitat is forever gone, e.g. polar and alpine habitats, ex situ conservation will be the only possibly option in order to avoid extinction. It is not possible to conserve to infinity, and at a point we will need to take action to change the reason why we have all the problems with global warming that leads to loss of habitats and biodiversity and even threatens our food security due to decreased efficiency of pollination. It is possible to slow down the crises and even counteract it. We can increase the carbon sink by actions like reforestation and we can decrease the anthropogenic emission by changing our way of living and consuming.

Concluding Remarks

The core problem is the emission of greenhouse gasses, but we keep trying to fix its consequences instead of stopping the problem. We need to be proactive, like stop to drill up fossil fuel and burn it to have energy, and we need to stop the continuing deforestation, we need the vegetation to suck out the carbon dioxide from the atmosphere so we can counteract the global warming. There are solutions on how to carry out life in a more sustainable way, but for it to work it requires actions. If we keep misusing the globe and its resources which we depend on the next candidate for extinction might be humans.

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