Impacts of climate change on terrestrial and marine biodiversity in Europe

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Pictures taken from: http://biologisman46.blogspot.com/2012/02/bagi-siswa-kelas-x-berikut-ini-adalah.html and http://aris.ormansu.gov.tr/index.php?q=en/biodiversity/biodiversity

Abstract

Climate change is now recognized as one of the most serious challenges that the world is facing while warming is currently affecting most parts of the globe. In the last thousand years the extent and the rate of current climate change most likely exceed all natural variation. It is obvious that, human intervention is responsible for altering ecosystem processes by influencing the release of greenhouse gases and resulting in excess global warming and thus changing the resilience of ecosystems to environmental change. In turn, this affects the good and services that humans derive from ecosystems. Thus, climate change and biodiversity are tightly linked. Particularly, climate change is already underway threatening European biodiversity as noticed by changes in the range and distribution of species and ecosystem boundaries, shifts in reproductive cycles and growing seasons and change in the complex interaction between species while these effects vary according to different regions and ecosystems. The average temperature rise in Europe is predicted to be the highest compared to the rest of the globe and thus ecosystems and their species are seriously threatened by losses and extinctions. Much of the prediction could be prevented by returning to near pre-industrial global temperatures as faster as possible so that to slow down climate related extinction rate from being realized. The purpose of this paper is to summarize through available literature the impacts of future climate change on terrestrial and marine biodiversity and ecosystems especially in the European regions.

Introduction

Many periods of significant warming and cooling throughout history characterize the earth's climate. Unfortunately, the most rapid climate change on earth will be expected in the twenty first century [1]. Importantly, in the past three centuries fusel fuel combustion has increased atmospheric levels of carbon dioxide. Specifically, carbon dioxide has increased from 280 parts per million in the pre-industrial period to 375 ppm concentration up to 2003 while in 2100 atmospheric CO_2 concentration is predicted to increase to at least 486 ppm [2,3,4]. Other greenhouse gases such as methane released by agriculture, land use changes and other industrial processes have doubled since then and contribute also more global warming [1].For the near future many measurable impacts are expected while recently there is a great understanding for vulnerability of species. Ecological responses to climate change are already clearly visible even though the projected trends of global warming are at an early stage. Future warming has resulted to widespread loss and fragmentation of habitats while it has created many climatically suitable areas for some species but may be beyond the dispersal capacity of other species. Miss management of human activities may push ecosystems and species tolerance to their limits [5].

Climate change in Europe

The climate in Europe is continuously warming. The European average temperature has increased by 0.95 $^{\circ}$C compared to 0.7 $^{\circ}$C in the rest of the globe in the last 100 years. Importantly, in the year 2100 the temperature In Europe will increase by 2.0-6.3 $^{\circ}$C and globally by 1.4-5.8 $^{\circ}$C [2]. Also, there is an increase in frequency of extreme weather events, such as droughts, heat waves and floods while there is a decline in cold extremes [3, 6].

Precipitation and evaporation patterns show a more varied picture while changes are projected to continue. Specifically, Northern Europe has become 10-40% wetter and Southern Europe up to 20% drier the last 100 years. Eastern Europe's moisture limit ecosystems and the Mediterranean region are projected to have greater effects of climate change [7]. Also, particularly in Europe the water shortage risk in predicted to increase. Furthermore, European sea levels have risen by 0.1 to 0.2 m in the last 100 years while currently the sea level around the European coasts is rising at a rate of 0.8 mm/year to 3.0 mm/year depending on the geographical region [6]. Modern changing speeds make it hard for humans, other species and ecosystems for adaption to new conditions. In Europe, adaptation is generally low for natural systems because it is a highly urbanized and agriculture landscape and predominantly a region of semi-natural habitats [3, 4].

Impacts of climate change on biodiversity

Terrestrial biodiversity

Overall, recent climate change can affect the physiology and phenology of species, the range and distribution of species, the composition of and interaction within communities and the structure and dynamics of ecosystems. Specifically, the rapid increase in temperature and different weather patterns has occurred over an extremely short period of time and evolutionary processes are not able to match [5].

Ecosystems contain a range of species and thus climate change can shift ecosystem boundaries and ranges of species by high temperatures, flooding and sea level rise. The latter can also threaten wetlands and coastal ecosystems. The risk of flooding, erosion and wetland loss will substantially increase in European coastal areas [3]. Particularly, Southern Europe is more vulnerable to such changes, although the coast of North Sea suffers already by flooding. Interestingly, about 60% of mountain species are likely to be disproportionally sensitive to climate change while most change is expected in the Mediterranean region [3, 4].

Surprisingly, in Europe during the last 20 years the terrestrial carbon uptake of plants has had a positive balance and an increased plant growth. However, water shortage risk particularly in southern Europe will adversely affect vegetation [6, 8]. Also, with warmer trends species are expected to track their shifting climate and also shift their distributions pole ward in latitude and upward in elevation depending on the availability of resources [8]. The plant species diversity has probably increased in north Western Europe because warmer climate induces the northward movement of species although it has declined in other parts of Europe. Specifically, many tundra communities have been replaced by trees and shrubs while the tree line and the level at which alpine plants are found is moving towards higher latitudes. A high-range projected climate change scenario for 2040-2060 indicates that 83% of the species show positive pole ward shift while low range climate change scenario indicate similar trends. For example, European Alps have shifted in elevation by 1-4 m per decade due to general warming [7, 9, 10]. Also, 39 butterflies in Europe have shifted northward range up to 200 km, while in Britain 12 birds species have moved northwards by 18.9 km over a period of 20 years due to warm winter temperatures. Hence, scientists have suggested that only 32% of existing plant species would be present in 2050. Moreover, European insects, mammals and bird species have demonstrated range shifts northwards or southwards over the last decade [4, 7].

Nevertheless, the impacts of climate change on biodiversity will vary across regions. In addition, rates of climate change and species adaptation are crucially important. Some species may rapidly adapt to new conditions and may increase competition with others. Unfortunately, several regions include many species that cannot migrate and survive in any other habitats while immigrating species in these regions are more likely to favor the competition [11]. Suitable conditions may be created by climate changes that encourage invasive species to establish in new geographical areas. Importantly, climate-linked invasions may influence unwanted species such as epidemic diseases. As a consequence of human activities the natural process of extinction that is natural process is occurring at an unnatural rapid rate due to climate change while this linkage is difficult to procure. Already, we have caused the extinction of 5-20% of the species in many groups of organisms [1, 12, 13]. In specific, by 2080 more than half of European plant species are predicted to become more vulnerable. Under severe predicted scenarios, loss of species is likely to vary between 2-80% on average over Europe due to high temperature and moisture conditions [4, 8]. Thus, climate change poses a greater threat to the survival of many species compared to the destruction of their natural habitat [3, 4, 14].

Moreover, adverse effects on biodiversity could be due to increasing disturbances such as fire, wind, flooding and drought which reduce forest productivity in the Mediterranean region. Due to the long life span of trees that does not allow rapid adaptation, forests are particularly sensitive to environmental climate change [2]. Particularly, woodland will be more vulnerable to increased wind speeds and frequency and intensity of storms. Also, due to increased temperature the frequent forest fires are likely to increase while it creates conditions favorable to induce massive outbreaks of unwanted pests. Both will lead to loss of biodiversity because of widespread tree mortality [4, 11].

Furthermore, plant phenology and distribution of plant and animal species are mainly affecting the terrestrial ecosystems. The timing of seasonal activities of animals and plants is defined as phenology which is the simplest way to estimate changes in species ecology in response to climate change [5, 15]. In Europe, earlier egg laying, breeding or first singing of birds, earlier arrival of migrant birds, and earlier appearance of butterflies, earlier choruses and spawning in amphibians and earlier shooting and flowering of plants are the most common changes in the timing of spring activities which have occurred progressively earlier since 1960s [16,17,18].

Warmer winters, may increase favor of European resident bird species while there is a decline in long distance migrating birds in a particular lake region. Even though climate change is considered to be the dominant trigger that drives the phenology of species there is a differential responsiveness among species. These are revealed in differences in timing of species interactions within ecological systems such as food webs. Food requirement and availability are influenced by climate fluctuations [3, 11]. For instance, in UK breeding season changes in several species of amphibians have been precipitated by winter warming. In turn, this variability has altered temporal breeding ponds overlap with alarming consequences for tropic interactions. Also, the enhanced invasion of exotic species or the promotion of more competitive native species it may change interaction competition between plant communities while it yields dominance of certain species and change ecosystem patterns. Therefore, changes in the range of species and community reorganization have considerable impacts on species and trophic level interaction that affect the ecosystem’s functioning [8, 17, 18]. Temporal and spatial changes in the behavior and distribution of species are connected through interactions with other species at the same trophic level. Thus, changes in the lower trophic levels may affect the whole ecological network and induce feedback processes [8]. Obviously, a proportion of European plant species could become vulnerable from conservation prospective [3].

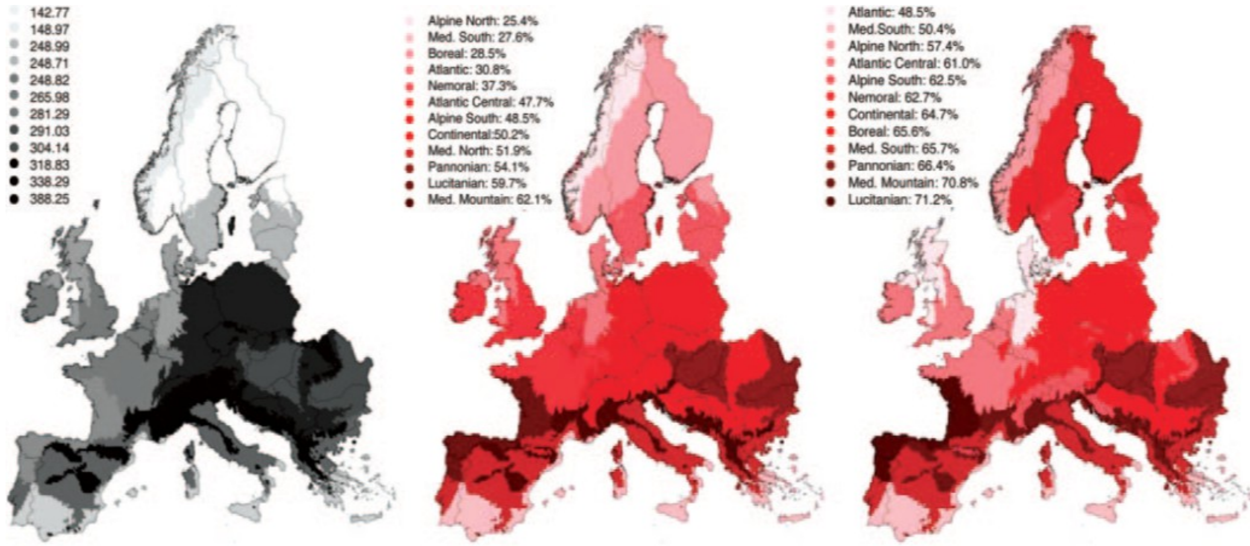
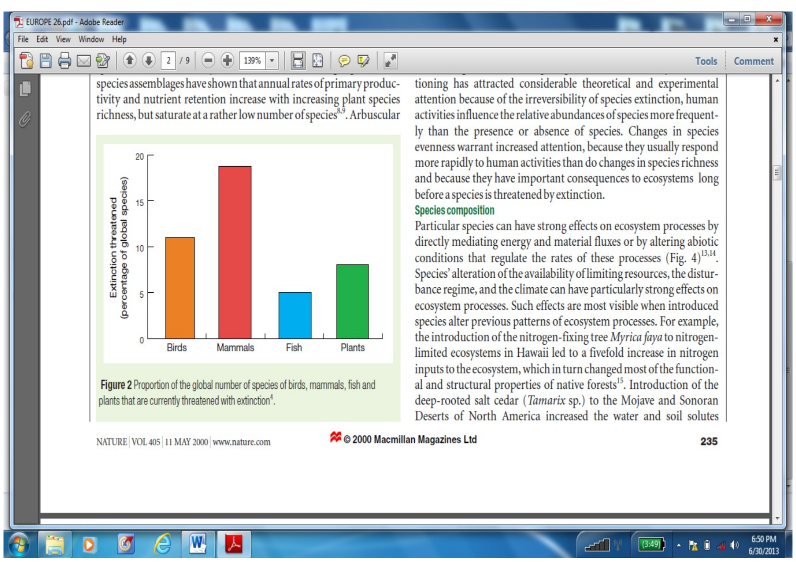


Figure 1: The figure shows the spatial sensitivity of plant diversity in Europe ranked by biogeographic regions. Mean percentage of current species richness (Left) and species loss (Center) and turnover (Right) by environmental zones under a climate change scenario [4].



species assemblages have shown that annual rates of primary productivity and nutrient retention increase with increasing plant species richness, but saturate at a rather low number of species[8,9]. Arbuscular

Figure 2 Proportion of the global number of species of birds, mammals, fish and plants that are currently threatened with extinction[4].

tioning has attracted considerable theoretical and experimental attention because of the irreversibility of species extinction, human activities influence the relative abundances of species more frequently than the presence or absence of species. Changes in species evenness warrant increased attention, because they usually respond more rapidly to human activities than do changes in species richness and because they have important consequences to ecosystems long before a species is threatened by extinction.

Species composition

Particular species can have strong effects on ecosystem processes by directly mediating energy and material fluxes or by altering abiotic conditions that regulate the rates of these processes (Fig. 4)[13,14]. Species' alteration of the availability of limiting resources, the disturbance regime, and the climate can have particularly strong effects on ecosystem processes. Such effects are most visible when introduced species alter previous patterns of ecosystem processes. For example, the introduction of the nitrogen-fixing tree *Myrica faya* to nitrogen-limited ecosystems in Hawaii led to a fivefold increase in nitrogen inputs to the ecosystem, which in turn changed most of the functional and structural properties of native forests[15]. Introduction of the deep-rooted salt cedar (*Tamarix* sp.) to the Mojave and Sonoran Deserts of North America increased the water and soil solutes

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Figure 2:

The figure highlights the proportion of the global number of species that are currently threatened by extinction including birds, mammals, fish and plants. Clearly, terrestrial biomes are threatened mostly compared to marine organisms [1].

Marine biodiversity

Most earth's surface is covered by oceans (71%) and therefore it is a necessity to understand how climate change can also affect marine biota [19, 20]. The extent of climate change can be impacted by the major role of oceans to the global carbon cycle [21]. Most carbon dioxide released in the atmosphere through human activities dissolves in the oceans and consequently reduces the PH. Over recent decades in many areas worldwide including Europe there is strong evidence for systematic changes in the abundance and community structure of marine organisms. Marine biodiversity similarly to terrestrial biomes is simultaneously impacted by a range of human activities such as pollution and habitat destruction [8].

Additionally, a clear picture over of major changes in plankton ecosystems over recent decades is emerging as concern of climate change impact [19]. Rising temperature can stimulate phytoplankton (indicator of climate change) growth which can increase the uptake of carbon dioxide affecting the marine systems especially in isolate basins like the North Sea and the Baltic Sea. Climate change can impact the pattern of marine biodiversity through modifying the distribution of species while numerous local extinctions are predicted in semi-enclosed seas such as the Mediterranean [22, 23]. Also, global warming and sea level rise enhance the introduction of new non-native species that may cross boundaries and become new elements of the biota and therefore disturb the food webs and rearrange the whole water ecosystem while existing and new species are mixed [7,22]. Across climate change scenarios for marine fish and invertebrates the global median rate of shifting is 45-59 km per decade. Thus, the range shifting of marine organisms is an order of magnitude higher than terrestrial animals such as birds and butterflies [3, 4, 24].

Latitudinal patterns of richness of species of marine fish and invertebrates at low latitudes have reached a plateau while there is high invasion intensity and overall increase in species richness in higher latitudes (>40◦N and >30◦S) due to pole ward movement [8, 25]. For instance, warmer water in the North Sea is driving cold water plankton further north and thus cod and sand eels are life shorted which is turn have contributed to the large breeding failure seen in Sea birds. This means that climate change can cause changes in the food chain. Therefore, shifting latitudinal and depth range is the way marine species respond to climate change as suggested by recent observational studies. Such responses of species may lead to local extinction and invasions resulting in changes in marine species richness pattern. For instance, future scenarios from 2000 to 2050 predict that the Atlantic Cod (Gatus Mohua) will increase the rate of decline of cod population in the North Sea. Specifically, the impacts of climate change on marine biodiversity are likely to intensify in the near future while it depends on ocean conditions and species sensitivity [1, 26].

Increased sea levels may lead to the reduction of important coastal habitats. Moreover, even minor changes in temperature may cause coral bleaching that lead to coral reef structure loss and negatively impact on the ecosystem of coral reefs because they are extremely sensitive. Increased frequency and scale of coral bleaching and mortality is predicted with excess warming. The reason is that, sea will absorb atmospheric CO2 and thus becoming more acidic and thus organisms like corals, plankton, shellfish and mollusks become unable to produce shells [4, 5, 26].

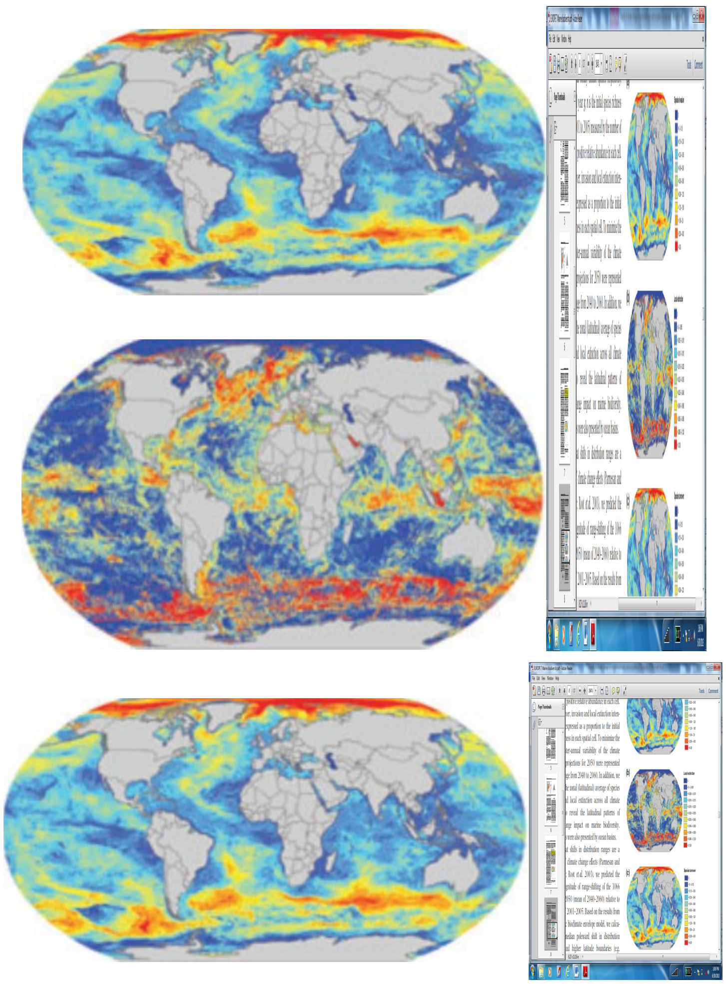

Figure 3:

The graph illustrates the predicted impact on distribution of biodiversity caused by warming-induced range shifts in marine metazoans. Biodiversity refers to: (a) invasion intensity, (b) local extinction intensity and (c) species turnover (invasion to and local extinction from a geographical area) in a high range climate change scenario of 2050 of 1066 for several species of fish and invertebrates relative to the mean of 2001-2005. The highest intensity of species invasion and turnover was seen in the Arctic although local extinctions are predicted mostly in the north Atlantic, the northern Pacific coast, the Mediterranean and Rea Sea [22].

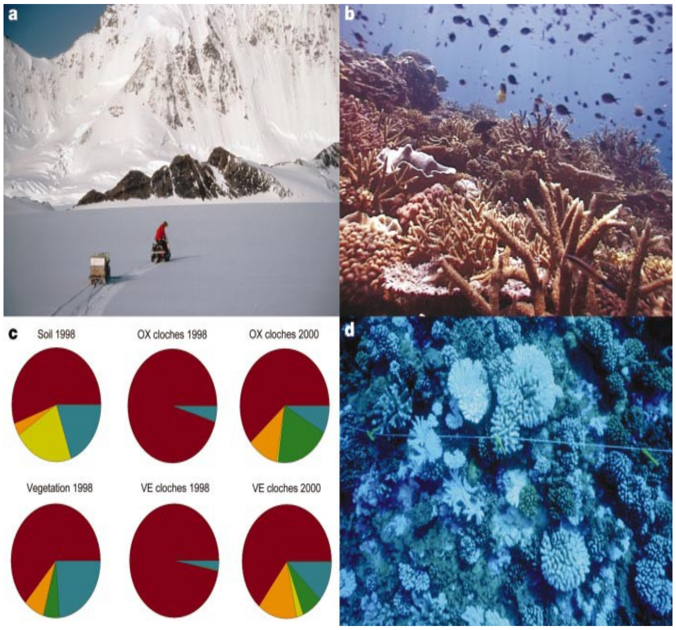

Figure 4:

The figure indicates the large scale coral bleaching in European Seas owing to physiological dysfunction and subsequent mortality that result from trophic anomalies of less than $1^\circ C$. Minor temperature changes can yield marine biodiversity loss and ecosystem disorganization especially in the European Seas [5].

Impacts of climate change on human health

Obviously, humans benefit from the biodiversity abundance and thus biodiversity loss can affect goods and services that they provide for survival [1]. Also, it is crystal clear that modern climate change is directly affecting the environment and thus the human health. Particularly, temperature rise will cause heat wave related health problems, tick-borne diseases and flooding damages. In recent decades there is increased frequency of these impacts while they are expected to escalate further due to continues rise in temperature. The frequency of extreme flood events in Europe is likely to increase due to climate change while in particular the frequency of flash floods that cause adverse physical and psychological human health consequences contributes to the highest fatality risk. A variety of diseases are transmitted by ticks such as tick-borne encephalitis (TBE) and Lyme disease (Lyme borreliosis). Interestingly, between 1980 and 1995 the tick-borne encephalitis cases have increased in central Europe and have remained high since then [1, 6].

Preventing measures

First and foremost, man-made impacts such as over exploitation and habitat disruptions should be reduced to restore the capacity of marine organisms and ecosystems to adapt to environmental changes. Secondly, further strategies and policies are required in the EU to substantially reduce greenhouse emissions and urgently minimize the predicted temperature rise and take into account the potential impacts of climate on biodiversity. In parallel, more integrated policy responses at international, regional and national levels are needed due to many linkages between climate change and biodiversity. Importantly, climate change can be prevented and main priorities to do so include reduction in energy consumption, increasing energy efficiency, and promoting renewable energy technologies [3, 6, 8, 22].

Conclusion

Conclusively, understanding how climate change will affect earth is a key element worldwide. Human activities and the resulted global warming has rendered an increased impassable landscape were species are forced to pass through. The extension of these climate change effects varies between regions, species and ecosystems were some are more vulnerable and likely to extinct compared to others. Nevertheless, current trends in temperature and precipitation level changes and sea level rise will continue regardless while there is much of concern for the unprecedented changing speed. Further exploring is required for activities which meet both climate and biodiversity objectives. Finally, examination on dynamic aspects of ecosystems and complex interaction among species is needed in order to understand the dependence and strengths of the linkage between individual species and their ecological systems.

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