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**Review Article**

# **Impact of Climatic Change on Avian Populations: Implication for Long Term Conservation in Wildlife Genetic Resources**

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**Abstract:** Climate change is a multidimensional challenge on bird population indirectly. Wildlife species are not equally at risk when facing climate change. Several species-specific attributes have been identified as increasing species vulnerability to climate change, including diets, migratory strategy, main habitat types and ecological specialization. Conservationists mostly used small number of species as surrogates to help them tackle conservation problems. Having served as reliable indicators of environmental change for centuries, bird populations now indicate that global warming have set in motion as a powerful chain of effects in ecosystems worldwide. The effect of climate change on the variation of species distribution is a matter of conservation emphasis globally. Successful management and conservation of species and their respective habitat dilemma under climate change rely on our ability to model species-habitat interaction and predict species distribution under changing environmental condition. We realize birds every day and they contribute much to our personal lives through attracting public attention. Beyond their aesthetic, cultural and ecological values, activities associated with birds. Everywhere birds are an integral part of our natural ecosystems. Birds pollinate plants and disperse their seeds, thereby facilitating genetic exchange and seed germination. They can serve as sensitive ecological indicators of threats to environmental health. Habitat loss, highway expansion, environmental unfriendly infrastructures, pollution and climate change have already led bird species becoming listed as threatened or endangered under the endangered species act. Climate change will almost certainly cause more species to be added to these lists, as well as exacerbate the challenges rare, threatened and endangered species already face. Moreover, large contractions in the range of many currently common and widespread species are expected.

**Keywords:** Conservation Emphasis, Eco-climate Change, Hotspot, Megafauna, Scenario, Sensitive Indicators

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## **1. Introduction**

### **1.1. Historical Perspective**

Climate change is one of the greatest challenges faced by the current world. With the current rate of greenhouse gas emission, the global temperature is likely to increase by 1.5 to 4.5°C by 2100. This increase in temperature has affected the climate pattern causing cascading effect on biotic and abiotic components of the ecosystem [3]. Climate change is here and a threat to the survival of birds and people been as

clear or as urgent. Birds are far better known than most other animals, and they are powerful messengers for the natural world. They are telling us how climate change poses risks to nature and people worldwide. Birds help people to engage with nature and understand the impacts of climate change. They are sending us powerful messages: cut emissions, help species adapt, invest in nature-based solutions for people and act now [11; 13; 14]. As warming continues, threats to humans and birds will multiply and intensify. Although some species may benefit, most will not. A review of recent scientific research shows that as the planet warms: Climate

change will result in more losers than winners. Most bird species are expected to experience shrinking ranges, increasing the risk of extinction. Many species may not shift their distributions as fast as climate changes, resulting in population declines. Ecological communities and interactions between species will be disrupted. Current threats, including extreme weather and diseases, will be exacerbated. People will experience many of the same risks, and their responses could endanger nature [11; 13]. Current climate change is not just a concern for the future, but is already disrupting life on our planet. Birds are the planet's messengers, telling us that climate change is already posing danger. Recent research has documented impacts that include: Distribution shifts polewards and to higher ground to escape warming temperatures. Disrupted interactions with predators, competitors and prey. Mismatches in the timing of migration, breeding and food supply. Population declines resulting from these and other effects [11]. At the most basic level of biodiversity, climate change is able to decrease genetic diversity of populations due to directional selection and rapid migration, which could in turn affect ecosystem functioning and resilience [19]. In essence, the response of some species to climate change may constitute an indirect impact on the species that depend on them.

Climate change is not a new topic in biology. Greenhouse gas emissions from international trade are among the fastest growing in the world that exacerbating climate change and threatening wildlife globally. The terrestrial environment those ecosystems already at the extreme of their ranges will be particularly vulnerable. We are well on the way toward that CO<sub>2</sub> concentration, having started at preindustrial levels of 280 ppm [84]. Current atmospheric levels are 390 ppm of CO<sub>2</sub>, and are increasing at a rate above the worst case scenario of the Intergovernmental Panel for Climate Change (IPCC) [26]. Modern science is able to study past climate, so we now know that the last 10, 000 years were a period of unusual stability in the global climate. The natural world is as or more sensitive to climate than anything else. The study of biological diversity impacts to climate change has an ironic history in the scientific literatures, since long before there was political ramification [25]. Historically, habitat and land use change have had the biggest impact on biodiversity across biomes. Africa is one of the most vulnerable regions in the world to climate change.

Ethiopia is the largest landlocked country in Africa with an area of 1.13 million km<sup>2</sup> that is located in the northeast of Africa between 03° 40' and 15° N latitude and 33° and 48° E longitude. The country is one of the top 25 biodiversity-rich countries in the world, and hosts two of the world's 34 biodiversity cradle hotspots namely; the Eastern Afromontane and the horn of Africa hotspots harbor extraordinary biological and cultural diversity, contained in a mosaic of ecosystems [35]. The altitudinal difference with the highest peak at Ras Dashen (4,620 m abs) and the minimum 126 m bsl in the Afar depression is the main reason that makes Ethiopia as one of the very few countries that is rich in biological diversity [36; 86; 87]. The conservation of

biodiversity in Ethiopia has all been considerably influenced by the species or habitat dilemma and climate change. Geologic and gigantic ranges of climatic differentiation, together with migrations, are the foundation of biodiversity of the country. The country has grasped diverse flora and fauna. Currently, Ethiopia supporting more than 2,985 described species of fauna and 7,000 of higher flora species with 12% endemism [36; 94].

Regions of the world with high coastal zone biological productivity often support large numbers of avian population. The most important sources of this productivity are oceanographic upwelling created by winds and ocean currents and runoff from the land. Additionally, climate change effects on winds and ocean currents will potentially affect the timing and magnitude of coastal biological productivity, and that bird populations will seek new levels and distributions in response to these changes.

Globally, the distribution of birds is uneven. The different biogeographic realms vary substantially in terms of the number and types of bird species they hold. By far the richest is the Neotropical realm which holds 36% of all known land bird species. The bird diversity with respect to biogeographic regions consists about 32% in Neotropic (3370 species, 86 families); 19% in Afrotropic (1950 species, 73 families); 16% in Indomalasia (1700 species, 66 families); 15% in Australasia (1500 species, 64 families); 9% in Palearctic (937 species, 73 families); 7% in Nearctic (732 species, 62 families) and 2% in Oceania (187 species, 15 families) [86; 7; 46]. This implies that biogeographic regions of the world with high coastal zone biological productivity often support large numbers of bird population. However, climate variability also affects bird distribution and abundance indirectly through trophic level impacts on food availability, fluctuations in the timing of migration and breeding effects on bird populations around the world.

Climate change will affect all the ecosystems but in different ways. This review demonstrates the very real vulnerabilities of birds and their habitats to climate change by providing an overview of major issues highlighted. A scientific assessment of current research data, achieved by surveying hundreds of research articles and reports on the topic of climate change and birds were compiled. This review seeks to provide a global survey of the climate threat to birds by compiling hundreds of individuals of studies to resolve the large picture of impacts and to correlate it to our country.

We are living in a time of unprecedented extinctions [1].

Current extinction rates have been estimated to be 50–500 times background rates and are increasing an estimated 3000–30,000 species go extinct annually [89]. Projected extinction rates vary from 5–25% of the world's species by 2015 or 2020. Approximately 23% of mammals, 12% of birds, 42% of turtles and tortoises, 32% of amphibians, 34% of fish, and 9–34% of major plant taxa are threatened with extinction over the next few decades [46; 1]. Natural habitats and species are declining by rate of 0.5 and 1.5% per year [6; 10]. Almost 12% birds, 25% mammals and 32% amphibians are threatened with extinction in the next century [48]. Over

50% of animal species are considered to be critically endangered, endangered or vulnerable to extinction [1; 6; 10]. Climate change is the biggest threat that birds face this century. Efforts to safeguard birds are both crucial and challenging. We must reduce carbon pollution to limit the magnitude of these impacts. We must intensify our conservation practices to reduce the impact for the ecological changes that climate change is already causing.

IUCN's Red List of threatened species currently lists more than 19,000 species as being threatened globally [1; 4; 6]. Threatened species include those species which are classified as vulnerable, endangered, or critically endangered. Other categories used by IUCN to describe the conservation status of species include near threatened, least concern, extinct in the wild, extinct or data deficient. The proportion of species considered not threatened also differs markedly with 78% of birds, 56% of mammals and 39% of amphibians being listed as least concern. The relatively large numbers of least concern bird species are no reason to be complacent as many common bird species are in decline across the world [6; 9; 10]. Clearly indicates that a large number of mammal, bird and amphibian species are close to extinction, with 27% of the species evaluated listed as globally threatened because they have small and/or rapidly declining populations and/or small ranges. In total 405 mammals, bird and amphibian species are critically endangered and face an extremely high risk of extinction in the immediate future [55; 56].

### ***1.2. The Current Conservation Status of Birds and Climate Vulnerability***

Global climate change is one of the most relevant topics on the current international environmental agenda. It cuts across economies, trade and political decisions in our globalized world. Biological diversity implies to the planet's sum total of species, ecosystems and genetic diversity. There is a broad scientific consensus that climate change has already had a widespread and coherent impact on biodiversity [43] and that it is an increasingly significant driver of biodiversity loss [79]. Significant impacts already underway include changes in the distribution of species, population sizes, timing of migration or reproduction, and increase in outbreaks of pests and disease [70]. Climate change affects ecosystems, habitats and species with increasing velocity and continuity. Studies are already linking climate change to declines in population and breeding success in bird populations around the globe. Climate change puts many bird species at risk of extinction, even those currently considered safe [7] and the stronger the climate change the stronger the risk. With a global mean surface temperature increase of 1-2°C above pre-industrial levels, many unique and threatened ecological systems will be at risk and numerous species will face extinction [55; 78]. The threat of climate change to migratory birds is equal to the sum of all other human-caused threats combined with 84 per cent of migratory bird species facing some type of climate change threat [29].

Birds that are habitat specialists are at higher risk than generalists [37; 65]. Birds breeding in arid environments [12]

and those with low population numbers, poor dispersal ability, already poor conservation status, and restricted or patchy habitats or limited climatic ranges are also at elevated risk from climate change [70; 35]. The overall extinction risk of climate change to birds is still being quantified. However, first-cut estimates present the possibility of the extinction of more than a third of European bird species under a maximum climate change scenario, if birds cannot shift to new climatically suitable ranges [71]. Compelling evidence shows that birds are responding to climate change, which makes them pioneer indicators" for changes related to global warming [2]. Climate change will often act in combination with major threats such as habitat loss and alien invasive species, making their impacts considerably worse [6].

Birds comprise nearly 10,000 living species as the indicators and building blocks of biodiversity. Birds are found nearly everywhere, but each species is unique in its ecology and distribution. Many have small ranges and most are restricted to particular kinds of habitat. Taken together, they provide a picture of how biodiversity is distributed, and serve as valuable indicators for global environmental change [3]. A total of 153 bird species is believed to have become extinct since 1500. Avian extinctions are continuing, with 18 species lost in the last quarter of the twentieth century and three more known or suspected to have gone extinct since 2000. The rate of extinctions on continents appears to be increasing, principally as a result of extensive/ expanding habitat destruction and climate change [11; 67]. Bird Life International is the official IUCN Red List Authority for birds and, in this capacity, coordinates the categorization and documentation of all bird species for the IUCN Red List. In the latest assessment in 2008, 1,226 species (one in eight of the total) were considered threatened with extinction. Threatened species are not evenly distributed among bird families. According to the IUCN Red List status report [42] for all birds indicates that almost 7,729 (78%) least concern, 835 (8%) near threatened, 66 (<1%) data deficient and 1,226 (12%) were recorded as threatened. However, globally threatened birds indicates that about 4 (<1%) extinct in the wild, 190 (15%) critically endangered, 363 (30%) endangered and 669 (50%) vulnerable [84]. The threats leading to population declines in birds are many and varied: agriculture, logging and invasive species are the most severe, respectively affecting 1,065 (87%), 668 (55%) and 625 (51%) globally threatened species. These threats create stresses on bird populations in a range of ways, the commonest being habitat destruction and degradation, which affect 1,146 (93%) threatened species. Bird Life classifies the extinction risk of all the world's birds using the categories and criteria of the IUCN Red List. According to [15] assessment concluded that 1,313 species (13% of extant species or roughly one in eight) are globally threatened with extinction. Highly sensitive to climate and weather, birds are pioneer indicators of climate change [3; 5; 10]. As global warming brings changes in temperature, altered moisture and precipitation, more extreme weather and a generally more variable climate, birds from the Arctic to Antarctic are already responding. In future,

global warming will also affect birds indirectly through sea level rise, changes in fire regimes, vegetation changes and land use change. With a doubling of atmospheric CO<sub>2</sub>, climate change could eventually destroy or fundamentally alter 35% of the world's existing land habitats [88]. There is compelling evidence that birds, along with other animals and plants, are already shifting their ranges in response to climate

change [56]. Global warming of 3-4°C could eliminate 85 per cent of remaining wetlands worldwide, critical habitat for migratory birds [72]. Because birds and the key species they interact with are unlikely to shift as intact communities. Birds will be brought into contact with different prey species, parasites, predators and competitors, as their habitats change or they are forced into areas less suited to them.

## 2. Global Change and Extinction

*Table 1. Bird extinction rates in four regions (Source: Data from [71]).*

Region	Predicted bird species extinction		Warming scenario	Current number of species
	With dispersal	No dispersal		
Europe	4-6%	13-38%	Maximum	524
South Africa	28-32%	33-40%	Mid-range	951
Australian Wet Tropics	49-72%	N/A	Maximum	740 (Australia-wide)
Mexico	3-4%	5-8%	Mid-range	1060

Extinctions are irreversible, unlike many other environmental threats that we can reverse. Current and recent rates of extinction are 100 times faster than the background rate, while future rates may be 1000 times faster. Recent studies estimate that climate change threatens about 15–37% of species within the next 50 years depending on which climate scenario unfolds [71]. Even more species are at risk if one looks to climate changes beyond 50 years. More detailed, regional modeling exercises in Australia [86] and South Africa [36] have led to predictions of the extinction of many species with narrowly-restricted ranges during this or longer intervals. The critical question is whether these extinctions, which are predominantly of small-ranged species, are the same as those predicted from habitat destruction or whether they are additional [61]. In many cases, they are certainly the latter. For example, the Atlantic coast humid forests of Brazil have the greatest numbers of bird species at risk of extinction within the Americas [50].

These global analyses of threats mask some important regional differences that could influence conservation decisions. For example, in the US, the most pervasive threat to vertebrates is habitat destruction, affecting over 92% of imperiled mammals, birds, reptiles, amphibians, and fish. This was followed by alien species (affecting 47% of imperiled vertebrates), pollution (46%), overexploitation (27%), and disease (11%) [89]. In contrast, the most pervasive threat to imperiled vertebrates in China is overexploitation, affecting 78% of species, followed by habitat destruction (70%), pollution (20%), alien species (3%), and disease (<1%) [49]. Ecologists have long recognized that island ecosystems are more vulnerable to alien species than most continental ecosystems. 98% of imperiled birds and 99% of imperiled plants are threatened at least in part by alien species. Comparable percentages for imperiled birds and plants in the continental US are 48% and 30%, respectively [89].

*Table 2. The number of percentage of species assessed for climate change susceptibility and in the 2008 IUCN Red list of birds.*

Birds	Threatened			
		Yes	No	Total
Climate change susceptible	Yes	976	2,462	35%
		10%	25%	
	No	246	6,172	65%
		2%	63%	
	Total	12%	88%	9,856

Threatened- according to the IUCN Red List [12] and climate-change-susceptible

## 3. Mechanism of Climate Change that Pushes Birds out of Ecological Synchrony

When this section examines how climate change is forcing a shift in the key life cycle events of birds, such as nesting and migration. It will show how birds' behaviour, in many

cases, is shifting in response to climate change at a different rate from that of key species (e.g. prey and parasites) and natural events upon which birds depend to complete their life cycles. Climatic boundaries change bird distributions are expected to shift too [29]. It demonstrates how these differential shifts threaten birds breeding success and survival. Birds' life cycles and behavior are closely tied to the changing seasons. Seasonal variables including temperature

and precipitation also affect the availability of flowers, seeds, insects and other food sources for birds [54]. The study of the timing of recurring natural phenomena such as migration, nest building and egg laying, especially in relation to climate, is known as phenology. The effects of climate change on these important behavioural or biological events is already well documented, with robust studies showing a strong response to climate change in birds. We know with certainty that birds are already responding to climate change. One analysis of more than sixty phenology studies worldwide [66] found birds had advanced timing for spring phenological phenomenon at an average rate of 6.6 days per decade. Furthermore, these shifts were in the direction consistent with climate change [65]. Large numbers of studies in Europe have also documented shifts in migration, timing of mating, nest building, egg-laying and clutch size in response to climate change.

#### *Impacts of Climate Change on Species*

Bird populations are most vulnerable to the current human-forced rapid climate change. Climate induced effects differ among species based on their body physiology. Warmer temperature, alteration in habitats and changed climatic pattern may alter bird's reproductive strategies. Birds start breeding earlier than their usual breeding season or produce lesser off springs due to reduced reproductive rate resulting in population decline [14; 95]. Change in temperature and humidity indirectly affects the activity and behavior of birds. Abandonment of habitat due to unfavorable climate hinders important activities such as feeding and breeding displays. Erratic heavy rainfall leading to lower temperatures during breeding season in the mountains can even postpone their breeding activity [96]. Generally, in response to climate change, birds start breeding earlier than their usual breeding period. As birds require optimum temperature for egg laying and incubation, extended cold spells and snow fall events either postpone breeding activity or leads to breeding failure in both terrestrial and aquatic birds. Well designed intensive study is urgently required to understand the breeding status of birds in high elevation areas and probable impact of climate change in their reproductive behavior. Climate change has severely affected the breeding activity of birds especially in the higher elevation areas leading to reproductive failure.

Elevational gradients provide complex situations displaying various climatic, ecological and physiological effects that impose limitations on species range extensions. Hence, range extension is limited or almost unaccomplished in most bird species due to their physiological and ecological constraints resulting into high extinction risks or mass extinctions [96]. High elevation species are facing higher risk of extinction compared to low elevation species particularly where there is no land or habitat available at higher elevations. The most vulnerable to extinction risks are endemics and restricted range species with little or no space for upward movement or their inability to shift upwards due to intolerance to physiological limits imposed by geographical gradients. In many cases the effect of climate

change on birds is indirect. Unusual weather events and warming temperature has multifarious effect on forests and bird habitats. Alteration in habitats prompts birds to shift their ranges vertically and horizontally [96]. Climate induced effects differ among species based on their body physiology. While some species might not get affected, the rate of effect differs among others so that all species in a community do not synchronize their shifting behavior. Asynchronous shift results in changed species assembly and community structure along the elevation gradients. As the area and also the resources decrease at higher elevations, interspecific competition also increases posing fatal effects to high elevation residents. In some cases, migrant species can completely dominate their upland congeners pushing them further upwards or leading them to extinction.

It was recently adopted as an indicator of climate change impact on biodiversity by the Pan-European framework supporting the Convention on Biological Diversity. The cumulative effects of climate change will have drastic effects on species of conservation concern. Species with low adaptability and/or dispersal capability will be caught by the dilemma of climate forced range change and low likelihood of finding distant habitats to colonize, ultimately resulting in increased extinction rates [67]. Birds' ability to shift to new, climatically suitable ranges may be complicated by landscapes which are fragmented or rendered unsuitable due to human land use. Furthermore, many centers of species richness for birds are currently located in protected areas, from which birds may be forced by climatic changes into unprotected zones. Island and mountain birds may simply have nowhere to go, as they are confined to increasingly smaller patches of habitat. In addition, even moderate climate change is expected to cause rates of change that will exceed the ability of many plants and animals to migrate or adapt [67].

#### *Range Shifts*

Species have ranges that are limited by environmental conditions, geographical barriers, food source and pollination requirements, and predation or competition. It is not always evident what limits species ranges, but in many species, high latitude and high altitude boundaries are correlated with environmental conditions, such as temperature, precipitation, or length of growing season. There is accumulating evidence that recent climate change is leading to changes in the distributions of species. These can be movements of species into areas where they were not previously found, the disappearance of species from a region where they once were, or a shift in the abundance and location of individuals within a species range [55].

#### *Phenological Shifts*

Specific temperature or precipitation cues are essential for breeding, reproduction, and other behavioral traits in many plant and animal species. In plants, timing of spring events such as budding and flowering are often cued by temperature, and occasionally by precipitation. In animals, food availability, timing and rates of reproduction, and migratory patterns are often driven by climatic cues. In the majority of

cases, increased temperature has the potential to accelerate these processes. An analysis of 143 studies found that, on average, species are beginning spring events earlier in the year at a rate of 5.1 days per decade, with many bird species shifting their schedule by as many as 24 days per decade [67]. Migratory birds in particular face challenges in this respect, as the timing of migrations is dependent on water, food, and habitat availability at specific times along migration routes [39]. Studies have shown that spring migrations among many species have shifted 1.3–4.4 days earlier per decade [40]. Warmer temperatures also result in a lengthened growing season; a 2006 review of 866 studies found that, in the northern hemisphere, the growing season (measured as the time between the last spring and first fall frosts), has grown longer at a rate of 1 to 5 days per decade since 1951 [54]. This will have effects on ecosystem productivity, competitive abilities of plant species, and fluctuations in population growth rates and abundances of animal species.

#### *Evolution*

The question arises of whether species can themselves adapt to new conditions through genetic processes of evolution. Estimates vary widely on the extent of species' ability to evolve to keep pace with rapid climate change. There is some evidence that evolutionary changes are already occurring, most noticeably the higher frequencies of already-existing heat-tolerant genotypes in the core of species ranges, and a trend toward greater dispersal distances [51]. However, there is mounting belief that evolution to climate related traits may be slow or difficult. In many cases the genetic variability necessary for evolution may not be present within a species, if new conditions are outside of that species experience. For example, the range of budburst dates in beech and pine tree populations was recently found to be too narrow to allow these species to track changes in climate [89]. Species with small population sizes, isolated or fragmented ranges, or long generation times are poorly suited toward rapid climate-induced.

#### *Extinction*

Human beings have influenced Earth's ecosystems for many millennia. One of the most significant factors in the extinction of species will undoubtedly be climate change. According to by 2020, the extinction of known threatened species has been prevented and their conservation status, particularly of those most in decline, has been improved and sustained. However, a 2004 model of the associations between climate and species distributions worldwide found that under many climate change scenarios, 21–52% of species would completely lose their habitat [71]. As species experience environmental change, altered species interactions, and habitat change across their historic ranges, they will be faced with the pressures of moving (range shifts) or adapting (evolution). If a species is unable to do either of these well or quickly, there is likelihood that it will face extinction. Especially at risk are narrowly endemic species, those with small ranges or specific habitat requirements, populations on the edges of species ranges, species in fragmented landscapes, and poor dispersers [89]. A recent model predicts that,

worldwide, every degree of warming will lead to an increase in bird extinctions of 100–500 species [74] and a model of climate change effects on vertebrate species in the Americas predicts 11–X% species loss [89]. Researchers have already noted the disappearance of local populations or severe population reduction in a number of charismatic or endangered species. In addition, climate change has the potential to compound extinction risk from numerous other factors from pollution to habitat destruction [19; 20; 67].

## **4. Climate Change and Wildlife Their Risk and Opportunity**

Climate change is already changing the natural world. A combination of the rate of climate change, habitat fragmentation and other obstacles will impede the movement of many wild animal species, possibly leading to a progressive decline in biodiversity. Plants and animals are adapted to certain climatic conditions that they require to survive and thrive. As the climate changes, becoming more or less favorable, species will be impacted by and will have to respond to the new conditions. There is abundant evidence of this already occurring. This report aims to document some of the impacts of climate change on wildlife that we've already seen changes we might expect in the future and some of the possible conservation responses that could benefit both wildlife and people.

According to IUCN's biodiversity conservation group results reveal 21% of all known mammals, 30% of all known amphibians, 12% of all known birds, and 28% of reptiles, 37% of freshwater fishes, 70% of plants, 35% of invertebrates assessed so far are under threat. Of the world's 5,490 mammals, 79 are extinct or extinct in the wild, with 188 critically endangered, 449 endangered and 505 vulnerable. Efforts to safeguard birds are both crucial and challenging [30]. We must reduce carbon pollution to limit the magnitude of these impacts. We must intensify and modify our conservation practices to reduce the impact of these changes when possible and we must manage for the ecological changes that climate change is already causing. There are 9,787 known living species of birds of which 21% (or 2,055 bird species) are currently extinction-prone due to a wide variety of threats [4; 9; 73], from habitat destruction to poaching. The conservation status of birds has continued to deteriorate since the first complete global assessment of this group was made in 1988 [38]. Since 1994, the number of bird species at risk has increased by 400 and trends suggest 600 to 900 more bird species could soon be deemed at risk [39]. Habitat destruction and fragmentation is the most pervasive threat, impacting 86% of threatened birds. However, climate change is emerging as a very serious threat to biodiversity as well, with mid-range climate change scenarios expected to produce greater extinction rates in animal and plant species than habitat loss [70; 67].

## **5. Bird Migration**

Globally, bird populations are under pressure. A study by

Birdlife International published in 2000 warned that 1,200 species, 12% of the world's total bird species, faced extinction over the next century. In its overview report, *Winged Messengers—The Decline of Birds*, the World Watch Institute states that, human related factors threaten 99% of the most imperiled bird species. Birds are indeed winged messengers that can be heralds of wider environmental impacts. While many bird species are native to particular habitats and regions, allowing specific measures to be taken by individual countries to help arrest declines nearly 20% of the world's estimated 10,000 bird species undertake regular migrations beyond their breeding grounds, using flyways that pass over and through numerous countries. This makes them especially vulnerable to any changes to their stop-over roosting and feeding sites. More than 11% of migratory birds are classed as threatened or near threatened on IUCN's Red List. Human related factors threaten 99% of the most imperiled bird species [36].

About one-fifth of African bird species migrate on a seasonal basis within Africa and an additional one-tenth migrate annually between Africa and the rest of the world [36; 90]. One of the main intra-Africa migratory patterns is flown by waterfowl, which spend the austral summer in southern Africa and winter in central Africa. Palearctic migrants spend the austral summer in locations such as Langebaan lagoon, near Cape Town, and the boreal summer in the wetlands of Siberia. If climatic conditions or specific habitat conditions at either end of these migratory routes change beyond the tolerance of the species involved, significant losses of biodiversity could result. Although the species involved have some capacity to alter their destinations, in a world of intense human land use the probability of finding sufficient areas of suitable habitat is small.

## 6. The Vulnerability of Long-Distance Migration and Global Change

Birds are perhaps the best group of animals on which to monitor the effects of climate change. They are diurnal in habits, conspicuous and easy to identify, and popular with many people, including scientists. In various parts of the world, their distributions and numbers have been well monitored for several decades, as has the timing of their migrations and breeding. Among birds, raptors are especially important due to their utility as indicators of biodiversity. Migratory birds are perhaps more vulnerable than most species, because they can be influenced by conditions in their breeding and wintering areas, as well as by conditions at sites on their migration routes. Climatologists predict that, in many regions, that migrants will suffer greater weather-induced losses, which could cause noticeable reductions in their populations, regardless of other changes. Changes in the migratory behavior of birds, in association with trends in climate, have already been recorded. Many species are migrating earlier in spring than formerly, and some are also migrating later in autumn, so that individuals now stay for

longer on their breeding areas. In addition, some species which were once wholly migratory, are now partially migratory, with increasing numbers of individuals now staying year-round in their breeding areas. In yet other species, individuals are now migrating less far than formerly, and wintering further north. This is exemplified by the increasing numbers of White Storks which are now remaining to winter in southern Spain, rather than migrating to Africa. Long-distance migration would be itself at risk. Evidence suggests that in songbird's long-distance migrants are responding more to global climate change than are short-distance migrants [20; 90; 91; 93]. Likely responses to global climate change in birds; greater survivorship among resident populations in high-latitude areas, increased competition between long-distance migrants and residents on the breeding grounds, a substantial shift away from migratory behavior, particularly long-distance migration, including a reduction in largescale movements along well-established thermal corridors. A simple model suggesting that resource allocation between migrants and resident species will shift as a function of global warming and that the proportion of long-distance migrants will decline as a result. Some measures taken to combat the causes of climate change, such as the development of wind farms, could themselves have severe impacts on migratory birds. This is particularly so if wind farms are badly sited, on major migration routes. Large numbers of birds could then be destroyed through collision with the rotor blades. Some other potential causes of bird mortality, like power lines, must be considered.

Long distance migrants have an extra handicap to adjust their breeding date to climate change, because on the wintering grounds it is often impossible to predict changes in the onset of optimal conditions in the breeding grounds [83]. Long-distance migratory birds do not appear to be responding to climate change (by shifting their migration timing) as rapidly as short-distance migrants, according to several pieces of research [19; 20]. The different responses are believed to stem from different underlying processes that determine migration timing of these two bird groups. It suggests that long distance migrants are more likely to suffer from of climate change-induced mismatch with their environment [14; 83]. As a result, they may be more likely to suffer as a result of climate change. For species that do not migrate, local weather and vegetation act as reliable cues to start breeding. However, migrating birds, and especially long distance migrants, are removed from the Food sources at the other parts of the migratory path. Instead they respond to internal clocks environmental stimuli unrelated to temperature [24] or weather circumstances along the migration route [19; 89; 90; 91]. Climate change may advance events such as insect emergence in the migrants' breeding areas; but if a given species' spring migration does not advance in keeping with their prey, they are at a greater risk of being out of synchrony [14; 80] Some researchers argue that past selection pressure could have promoted a very stable timing of migration due to the severe reproductive consequences of arriving either too early or too late in spring

breeding grounds [14]. Genetically speaking, this means that long-distance migrants could lack the ability to change the timing of migration [14; 64; 91; 93]. According to [64] if this were true, the adaptability of long-distance migratory birds would be limited, which would explain the vulnerability of this group of birds to environmental changes. Climate change-induced mismatch is probably a widespread phenomenon and strong evidence already ties it to major population declines in some long-distance migrant bird populations [18]. There is concern it could cause further collapse in breeding populations of such birds in the future [71].

## 7. Conclusion

Climate change presents several new challenges. Conservation of our biodiversity is important not only for the preservation of our genetic resources and national heritage, but also to provide opportunities to improve our health, economy and international reputation. The impacts are now better understood and more needs to be done to reduce the size of our ecological footprint in order to protect, preserve and restore our rich biodiversity particularly bird genetic resources. Climate change will tip the balance for some species unless effective action is taken. Birds have served as reliable sensitive indicators of environmental change for centuries and now indicate that global warming has set in motion a powerful chain of effects in ecosystems worldwide. In this global status review there is growing evidence of climate change affecting birds' behavior, ability to reproduce and even to survive. Furthermore, the march toward major bird extinction may be underway, with evidence of climate change linked to unprecedented breeding crashes, and declines of up to 90% in some bird populations. Forecasts of bird extinction rates depend on the potential resilience of ecosystems, and vary from 5% to over 70% based on current emission and warming trajectories. Thus if conservation efforts are to meet the climate threat, a fundamental change in approach to bird conservation will be needed if bird species diversity is to be maintained. The most fundamental variable in the future impacts on birds will be the extent of global warming, which is dependent on to what extent and how quickly emissions of greenhouse gases are reduced. Interventions that reduce future greenhouse gas concentrations and therefore warming levels could also lessen the extinction rates of bird species and other groups. Intentionally conservationists should need to arrive a new era of conservation mechanism one in which last-ditch stands to save species where they currently exist may not be enough. Conservation response to climate change should address means to ensure adequate habitats are available and mitigating against climate change impact on ecological processes that support birds. Our review indicates that climate change will likely result in increased fluctuations in biological productivity, which will be reflected in the numbers of avian population both resident

and migratory. As the range of impacts is more fully considered, further research is expected to upgrade estimates of climate change risk to birds. Furthermore, climate change is expected to shift important, species-rich bird communities out of protected areas. If conservation efforts are to meet the climate change threat, a fundamental change in approach to bird conservation is needed to preserve species diversity. Biodiversity conservation is vital for long-term environmental sustainability, and directly affects issues such as health, water, sanitation and many other aspects of peoples' lives. Future conservation issue through harmonized mainstreaming in biodiversity conservation and of impacts assessments will be aided by a better mechanistic understanding of ecological, behavioral, and evolutionary responses to complex patterns of climate change and in particular to impacts of extreme weather and climate events. Conservationist should need to design climate-smart projects on taking urgent action to reduce those drivers affecting ecosystems particularly vulnerable to climate change. Climate-smart projects involve evaluating current and projected changes in climate factors, linking those changes to sensitive species, systems or processes, and ranking vulnerability. An integrated approach to environmental management is needed to ensure sustainable benefits and conservation for wild animals. The impact of climate change on the megafauna is sever the genetic resources in our country especially on the endemic birds. Climate change will increase ecosystem fluctuation and only those species capable of adapting to a more variable environment can successfully survive climate change. For the remaining species, these environmental alternations bring changes in their distribution, abundance and certain aspects of their biology. Identifying and protecting important climate refuges both ecological and evolutionary, conserving the large-scale migration and connectivity corridors that operate at continent scales including regional networks of habitat patches and habitat stepping stones, maintaining viable populations of all extant species to maximize intra-species genetic diversity and thus options for local adaptation, reducing all current threatening processes at the landscape scale across the continent and protecting and restoring key large scale ecological processes especially hydro-ecology and ecological fire regimes. Finally, underpinning climatic adaptation responses must be a thorough understanding of the special role our country extensive intact landscapes will play in the future protection of native biodiversity.

## References

- [1] Baillie, J. E. M., Hilton-Taylor, C. and Stuart, S. N. (Editors) 2004. 2004 IUCN Red List of Threatened Species. A Global Species Assessment. IUCN, Gland, Switzerland and Cambridge, UK. Xxiv+ 191 pp. ISBN: 2-8317-0826-5.
- [2] Barnosky AD, Matzke N, Tomiya S et al (2011) Has the Earth's sixth mass extinction already arrived? *Nature* 471 (7336): 51–57. doi: 10.1038/Nature09678.



- [3] Basundhara Chettri and Bhoj Kumar Acharya. (2012). Effect of climate change on birds, Herpetofauna and Butterflies in Sikkim Himalaya: a preliminary investigation. 9 chapter effects of climate change on Butterflies. Pp 141-160. [August, 2012].
- [4] Berthold P., Møller A. P. & Fiedler W. (2004) Preface. In: Møller, A., Berthold, P. & Fiedler, W (Eds) *Birds and Climate Change*, pp. vii. *Advances in Ecological Research* 35. Elsevier Academic Press.
- [5] Bird Life International. (2008). *State of the world's birds: indicators for our changing world*. Cambridge, UK: Bird Life International.
- [6] Bird Species and Climate Change: The Global Status Report version 1.0. A report to: World Wide Fund for Nature. ISBN: 0-646-46827-8.
- [7] Birdlife (2004a). *State of the world's birds 2004. A report*.
- [8] Birdlife (2004b). *Birds in the European Union: A status assessment*.
- [9] Birdlife (undated a) Birdlife Europe Program. Available at: <http://www.birdlife.org/regional/europe/index.html>.
- [10] BirdLife International (2012) *Threatened birds occur in nearly all countries and territories*. Presented as part of the BirdLife State of the world's birds website. Available from: <http://www.birdlife.org/datazone/sowb/casestudy/110>. Checked: 06/09/2016.
- [11] BirdLife International and National Audubon Society. (2015). *The messengers: what birds tell us about threats from climate change and solutions for nature and people*. Cambridge, UK and New York, USA: BirdLife International and National Audubon Society. ISBN Number, 978-0-946888-97-9.
- [12] Birdlife (undatedb) Birdlife website: Available at: <http://www.birdlife.org/worldwide/national/southAfrica/index.html>.
- [13] BLI (Bird Life International). 2004. *State of the world's birds: indicators for our changing world*. Cambridge, UK: Bird Life International.
- [14] BLI (Birdlife International), 2008. *State of the World's Birds: Indicators for Our Changing World*. Bird Life International, Cambridge, UK.
- [15] Bolger D. T., Patten M. A. & Bostock D. C. (2005). Avian reproductive failure in response to an extreme climatic event. *Oecologia* 142: 398-406.
- [16] Both C. & Visser M. E. (2001) Adjustment to climate change is constrained by arrival date in a long-distance migrant bird. *Nature* 411: 296.
- [17] Both C., Artemyev A. V., Blaauw B., Cowie R. J., Dekhuijzen A. J., Eeva T., Enemar A., Gustafsson L., Ivankina E. V., Jaervinen A., Metcalfe N. B., Nyholm N. E. I., Potti J., Ravussin P.-A., Sanz J. J., Silverin B., Slater F. M., Sokolov L. V., Toeroek J., Winkel W., Wright J., Zang H. & Visser M. E. (2004) Large-scale geographical variation confirms that climate change causes birds to lay earlier. *Proceedings of the Royal Society of London B* 271: 1657.
- [18] Both C., Bouwhuis S., Lessells C. M. & Visser M. W. (2006) Climate change and population declines in a long-distance migratory bird. *Nature* 441: 81.
- [19] Botkin, D. B., Saxe, H., Araujo, M. B., Betts, R., Bradshaw, R. H. W., Cedhagen, T. et al. (2007). Forecasting the effects of global warming on biodiversity. *Bioscience*, 57, 227–236.
- [20] Brooke, M. L., Butchart, S. H. M., Garnett, S. T., Crowley, G. M., Mantila-Beniers, N. B & Stattersfield, A. J. (2008). Rates of movement of threatened bird species between IUCN Red List categories and toward extinction. *Conserv. Biol.* 22: 417–427.
- [21] Brooks, T. M., Mittermeier, R. A., da Fonseca, G. A. B. et al. (2006). Global biodiversity conservation priorities. *Science*, 313, 58–61.
- [22] Butler R. W, and Taylor W. 2005. *A Review of Climate Change Impacts on Birds*. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191.
- [23] Camille Parmesan. 2006. Ecological and Evolutionary Responses to Recent Climate Chang. *Annu. Rev. Ecol. Evol. Syst.* 2006. 37: 637-69. /Annual Review of Ecology, Evolution, and Systematics, Vol. 37 (2006), pp. 637-669. Published by: Annual Reviews Stable URL: <http://www.jstor.org/stable/30033846> Accessed: 25/10/2012 11: 39.
- [24] Canadell, J. G., Quéré, C. L., Raupach, M. R., et al. (2007). Contributions to accelerating atmospheric CO<sub>2</sub> growth from economic activity, carbon intensity, and efficiency of natural sinks. *Proceedings of the National Academy of Sciences of the United States of America*, 104, 18866–18870.
- [25] Coppack T. & Both C., 2002 - Predicting life-cycle adaptation of migratory birds to global climate change. *Ardea*, 90: 369-377.
- [26] Cotton P. A. (2003). Avian migration phenology and climate change. *Proceedings of the National Academy of Sciences* 100 (21): 12219.
- [27] Crick, H. Q. P. (2004). The impact of climate change on birds. *Ibis* 146 (suppl 1), 48.
- [28] Department of Environment, Food and Rural Affairs (DEFRA; 2005). *Climate change and migratory species. A report by the British Trust for Ornithology*. Available at: <http://www.defra.gov.uk/wildlife/countryside/resprog/findings/climatechangemigratory/index.htm>.
- [29] Durbin LS, Hedges S, Duckworth JW, Tyson M, Lyenga A, and Venkataraman A. (IUCN SSC canid Specialist Group-Dhok working Group) 2008. Cuonalpines. In: IUCN 2012. *IUCN Red List of Threatened species*. Version 2012.2. [www.Iucnredlist.org](http://www.Iucnredlist.org). Downlod on 5 December 2012.
- [30] Erasmus, B. F. N., van Jaarsveld, A. S., Chown, S. L., Kshatriya, M., and Wessels, K. (2002). Vulnerability of South African animal taxa to climate change. *Global Change Biology*, 8, 679–693.
- [31] Ethiopian Biodiversity Institute (2014). *Ethiopia's Fifth National Report to the Convention on Biological Diversity*. Ethiopian Biodiversity Institute, Addis Ababa.
- [32] Ethiopian Biodiversity Institute (2016). *Ethiopia's National Biodiversity Strategy and Action Plan 2015-2020*. Pp. 1-138.
- [33] Hannah L., Lovejoy T. E. & Schneider S. H. (2005) *Biodiversity and Climate Change in Context*. In: Lovejoy T. E. & Hannah. L. (Ed.) *Climate Change and Biodiversity*, pp. 3. Yale University Press, New Haven & London.

- [34] Hockey, P. A. R. 2000. Patterns and correlates of bird migrations in sub-Saharan Africa. *Journal of Birds Australia*, 100: 401-417.
- [35] Hoorn, C, F. P. Wesselingh, H. ter Steege, M. A. Bermudez, A. Mora, J. Sevink, I. Sanmartín, A. Sanchez-Meseguer, C. L. Anderson, J. P. Figueiredo, C. Jaramillo, D. Riff, F. R. Negri, H. Hooghiemstra, J. Lundberg, T. Stadler, T. Särkinen, and A. Antonelli. 2010. Amazonia through Time: Andean Uplift, Climate Change, Landscape Evolution, and Biodiversity. *Science* 330: 927-931. DOI: 10.1126/science.1194585.
- [36] [http://www.birdlife.org/datazone/userfiles/docs/SOWB2004\\_en.pdf](http://www.birdlife.org/datazone/userfiles/docs/SOWB2004_en.pdf) 10 Winged Messengers – The Decline of Birds, World Watch paper 165, Howard Youth, March 2003.
- [37] Huntley B., Collingham Y. C., Green R. E., Hilton G. M., Rahbek C. & Willis S. (2006). Potential impacts of climate change upon geographical distributions of birds. *Ibis* 148: 8.
- [38] Inkley, D., M. G. Anderson, et al. (2004). Global climate change and wildlife in North America. K. E. M. Galley. Bethesda Maryland, the Wildlife Society.
- [39] Inouye, D. (2000). "Climate change is affecting altitudinal migrants and hibernating species." *Proceedings of the National Academy of Sciences of the United States of America* 97: 1630-33.
- [40] International Union for Conservation of Nature (IUCN; 2004) 2004 IUCN Red List of Threatened Species: A Global Species Assessment. The Red List Consortium.
- [41] IPCC (2001b). Climate Change 2001: Impacts, Adaptation and Vulnerability. Cambridge University Press.
- [42] IPCC (2001c) Climate change 2001: Synthesis report. Summary for policy makers. Cambridge University Press, Cambridge.
- [43] IPCC. 2007. Summary for Policymakers. Pp. 7-22 in Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, edited by M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, and C. E. Hanson. Cambridge: Cambridge University Press.
- [44] IUCN (2015). IUCN-Ramsar Collaboration. Supporting the Wise Use of Wetlands. Gland. Switzerland: IUCN.
- [45] IUCN, UNEP-WCMC 2014. The World Database on Protected Areas (WDPA), August 2014. Cambridge, UK: UNEP-WCMC.
- [46] IUCN. 2001. IUCN Red List Categories and Criteria: Version 3.1. IUCN Species Survival Commission. IUCN, Gland, Switzerland and Cambridge, UK.
- [47] Jankowski, J. E., Robinson, S. K. and Levey, D. J. (2010) Squeezed at the top: interspecific aggression may constrain elevational ranges in tropical birds. *Ecology* 91: 1877-1884.
- [48] Jiguet, F. et al. Climate envelope, life history traits and the resilience of birds facing global change. *Glob. Change Biol.* 13, 1672-1684 (2007).
- [49] Kessler, M., S. K. Herzog, J. Fjeldsø, and K. Bach. 2001. Species richness and endemism of plant and bird communities along two gradients of elevation, humidity, and land use in the Bolivian Andes. *Diversity and Distributions* 7: 61-77.
- [50] Lamoreux, J. F., Morrison, J. C., Ricketts, T. H., et al. (2006). Global tests of biodiversity concordance and the importance of endemism. *Nature*, 440, 221-214.
- [51] Lawler, J. J., Shafer, S. L., White, D., Kareiva, P., Maurer, E. P., Blaustein, A. R., Bartlein, P. J. (2009) Projected climate-induced faunal change in the Western Hemisphere. *Ecology* 90: 588-597.
- [52] Li, Y. and Wilcove, D. S. (2005). Threats to vertebrate species in China and the United States. *BioScience*, 55, 147-153.
- [53] Manne, L. L., Brooks, T. M., and Pimm S. L. (1999). Relative risk of extinction of passerine birds on continents and islands. *Nature*, 399, 258-261.
- [54] Millennium Ecosystem Assessment (2005). *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington, D. C.
- [55] Mineau, P. (2009). Birds and pesticides: is the threat of a silent spring really behind us? *Pesticide News* 86: 12-18.
- [56] National Wildlife Federation/American Bird Conservancy (NWF/ABC 2002). *A birdwatcher's guide to global warming*.
- [57] Ngigi, S. N. 2009. Climate Change Adaptation Strategies: Water Resources Management Options for Smallholder Farming Systems in Sub-Saharan Africa. The MDG Centre for East and Southern Africa, The Earth Institute at Columbia University, New York. 189p.
- [58] Noble I., Parikh J., Watson R., Howarth R., Klein R. J. T. Abdelkader A. & Forsyth T. (2005) Climate Change. In: K. Chopra, R. Leemans, P. Kumar and H. Simons (Eds) *Ecosystems and Human WellBeing: Policy Responses*, Volume 3. Findings of the Responses. Working Group of the Millennium Ecosystem Assessment. Island Press, Washington, DC.
- [59] Parmesan C. & Yohe G. (2003) A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421: 37.
- [60] Parmesan, C. 2006. Ecological and evolutionary responses to recent climate change. *Annual Review of Ecology, Evolution, and Systematics* 37: 637-669.
- [61] Parmesan, C. and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. *Nature* 421: 37-42.
- [62] PCC. 2007. Mitigation. Contribution of Working group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK.
- [63] Pimm, S. L. (2008). Biodiversity: climate change or habitat loss-which will kill more species? *Current Biology*, 18, 117-119. Press, New Haven & London.
- [64] Pulido F & Widmer M., 2005 - Are long-distance migrants constrained in their evolutionary response to environmental change? *Annals of the New York Academy of Science*, 1046: 228-241.
- [65] Reid W. V., Mooney H. A., Cropper A., Capistrano D., Carpenter S. R., Chopra K., Dasgupta P., Dietz T., Duraipapp A. K., Hassan R., Kasperson R., Leemans R., May R. M., McMichael A. J., Pingali P., Samper C., Scholes R., Watson R. T., Zakri A. H., Shidong Z., Ash N. J., Bennett E., Kumar P., Lee M. J., Raudsepp-Hearne C., Simons H., Thonell J., & Zurek M. B. (2005) *Ecosystems and Human Well Being. Millennium Ecosystem Assessment Synthesis report*. Island Press, Washington DC.

- [66] Root T. & Hughes L. (2005) Present and future phenological changes in wild plants and animals. In: Lovejoy T. E. and Hannah. L. (Eds.) *Climate Change and Biodiversity*, pp. 61. Yale University.
- [67] Root T. L., Price J. T., Hall K. R., Schneider S. H., Rosenzweig C. & Pounds J. A. (2003) Fingerprints of global warming on wild animals and plants. *Nature* 421 (6918): 57.
- [68] Root, T. L., J. T. Price, K. R. Hall, S. H. Schneider, C. Rosenzweig, and J. A. Pounds. 2003. Fingerprints of global warming on wild animals and plants. *Nature* 421: 57-60.
- [69] Root, T. L. and L. Hughes. 2005. Present and Future Phenological Changes in Wild Plants and Animals. In Lovejoy and Hannah (eds.), *Climate Change and Biodiversity*. Yale University Press. New Haven, Conn.
- [70] Royal Society for the Protection of Birds (RSPB) & Worldwide Fund for Nature (2003). Global climate change and biodiversity. Green R. E., Harley M., Miles L., Scharlemann J., Watkinson A. & Watts. O. (Eds).
- [71] Sanz J. J., Potti J., Moreno J., Merino S. & Frias O. (2003) Climate change and fitness components of a migratory bird breeding in the Mediterranean region. *Global Change Biology* 9 (3): 461.
- [72] Secretariat of the Convention on Biological Diversity. (2009). Connecting Biodiversity and Climate Change Mitigation and Adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change. Montreal, Technical Series No. 41, 126 pages.
- [73] Sekercioglu (2004) Ecosystem consequences of bird declines. *Proceedings of the National Academy of Sciences*. 101 (52): 18042.
- [74] Sekercioglu, C. H., S. H. Schneider, et al. (2008). "Climate change, elevational range shifts, and bird extinctions." *Conservation Biology* 22 (1): 140-150.
- [75] Sekercioglu, C. H., Primack, R. B. and Wormworth, J. (2012). The effects of climate change on tropical birds. *Biological Conservation* 148: 1-18.
- [76] Sekercioglu, C. H., Schneider, S. H., Fay, J. P., and Loarie, S. R. (2008) Climate change, elevational range shifts, and bird extinctions. *Conservation Biology* 22: 140-150.
- [77] TEEB [The Economics of Ecosystems and Biodiversity] (2008). The economics of ecosystems and biodiversity: an interim report. European Commission, Brussels.
- [78] Thomas C. D., Cameron A., Green R. E., Bakkenes M., Beaumont L. J., Collingham Y. C., Erasmus B. F. N., De Siquiera M. F., Grainger A., Hannah L., Hughes L., Huntley B., Van Jaarsveld A. S., Midgley G. F., Miles L., Ortega-Huerta M. A., Peterson A. T., Phillips O. & Williams S. E. (2004). Extinction risk from climate change. *Nature* 427: 145.
- [79] Thomas, C. D., Cameron, A., and Green, R. E., et al. (2004). Extinction risk from climate change. *Nature* 427, 145–148.
- [80] Thornton P, Cramer L (editors), 2012. Impacts of climate change on the agricultural and aquatic systems and natural resources within the CGIAR's mandate. CCAFS Working Paper 23. CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS). Copenhagen, Denmark. Available online at: [www.ccafs.cgiar.org](http://www.ccafs.cgiar.org).
- [81] UNEP. (2006). Summary of the second global biodiversity outlook. Note by the Executive Secretary. Conference of the Parties to the Convention on Biological Diversity, 8<sup>th</sup> Meeting, p. 6.
- [82] United Nations Environment Program (UNEP; 2005). Biodiversity and climate change. Online fact sheet available at: <http://www.unep-wcmc.org/climate/impacts.htm>.
- [83] Van Vliet A. & Leemans R. (2006) Rapid species' responses to changes in climate require stringent climate protection targets. In: Schellnhuber H. J., Cramer W., Nakicénovic N., Wigley T., & Yohe G. (Eds) *Avoiding Dangerous Climate Change*, pp 135. Cambridge University Press, Cambridge.
- [84] Visser M. E., Both C. & Lambrechts M. M. (2004) Global climate change leads to mistimed avian reproduction. In: Møller, A., Berthold, P. & Fiedler, W. (Eds): *Birds and Climate Change*, pp. 89. *Advances in Ecological Research* 35. Elsevier Academic Press.
- [85] Walther, G. E., Post, E., Convey, P., Mentzel, A., Parmesan, P., Beebe, T. J. C., Fromentin, J., Guldberg, O. H. and Bairlein, F. (2002) Ecological responses to recent climate change. *Nature* 416: 389-395.
- [86] Watson, J., Rao, A. Kang, L. Xie, Y. (2012). Climate change adaptation planning for biodiversity conservation: A review. *Adv. Clim. Change Res.* 3 (1). pp. 1-11.
- [87] Weldemariam Tesfahunegn Bezabh, 2016. A Guide to a Complete Annotated Checklist of the Birds of Ethiopia. *International Journal of Current Research*, 8, (06), 33029-33050.
- [88] Wilcove, D. S., Rothstein, D., Dubow, J. A., et al. (1998). Quantifying threats to imperiled species in the United States. *BioScience*, 48, 607–615.
- [89] Williams, S. E., Bolitho, E. E., and Fox, S. (2003). Climate change in Australian tropical rainforests: an impending environmental catastrophe *Proceedings of the Royal Society of London B*, 270, 1887–1892.
- [90] Woodruff, D. S. 2001. Declines of biomes and the future of evolution. *Proceedings of the National Academy Sciences, USA* 98: 5471–5476.
- [91] World Conservation Monitoring Centre (cited as WCMC). 1992. *Global Biodiversity: Status of the Earth's Living Resources*. London: Chapman and Hall.
- [92] World Wildlife Fund (WWF; 2000) Global warming and terrestrial biodiversity decline. Malcolm J. R. & Markham A.
- [93] Wormworth, J. and Sekercioglu, Ç. H. (2011). *Winged Sentinels: Birds and Climate Change*. Cambridge University Press.
- [94] WWF. (2002). *Habitats at risk: Global warming and species loss in globally significant terrestrial ecosystems*. Malcolm J. R., Liu C., Miller L. B., Allnutt T. & Hansen L.
- [95] Xu, J., Grumbine, R. E., Shrestha, A., Eriksson, M., Yang, X., Wang, Y. and Wilkes, A. (2009) *The Melting Himalayas: Cascading Effects of Climate Change on Water, Biodiversity, and Livelihoods*. *Conservation Biology* 23: 520-530.
- [96] Žalakevicius M. & Švažas S. (2005). Global climate change and its impact on wetlands and water bird populations. *Acta Zoologica Lituanica* 14 (3): 211.