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Effects of Environmental Pollution on Avian Fauna

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ABSTRACT

Human activities contribute to the release of many different chemicals and other agents into the air. High concentrations of these things have resulted in four key environmental concerns that have a devastating effect on birds and other animals: air, light, and noise pollution, and global warming. Although climate change is getting a lot of attention, these four topics have been ignored. There is a high likelihood that the four problems will have combined effects, as they frequently occur at the same time. Most analyses have only considered the immediate effects of a problem, rather than its long-term effects. This paper is an attempt to remedy that gap. The overarching goal is to assess how bird populations have changed due to pollution.

I. INTRODUCTION

Anthropogenic activities discharge a vast variety of substances and agents into the environment. The biosphere suffers when these substances are present in greater quantities (Morrison 1986). Air pollution, light pollution, noise pollution, and global warming/climate change are the four main problems that have a negative impact on the ambient environment as a result of the emission of substances/agents from human activity. Birds and amphibians are the most endangered species (Foden et al., 2012; Bird Life International, 2012) in this regard.

The effects of these four issues are clearly felt in the animal kingdom as well as amongst humans. However, study into their effect on wildlife has lagged behind other issues, most notably global warming. Scientists have looked into how rising temperatures are affecting birds (Sekerciolu et al., 2012). However, the scientific literature does not shed light on the behaviour of the issue when additional environmental elements are present. Since these problems frequently co-occur, it's important to evaluate their combined impact. Aichi Biodiversity Targets (20 targets under five strategic goals) have emphasised reducing various forms of pollution to non-detrimental levels for ecosystem function and biodiversity (Target 8) and minimising climate change to maintain ecosystem function and integrity (Target 10) (Convention on Biological Diversity, 2012; O'Connor et al., 2011), which should give you an idea of how serious this problem is. In light of alarming trends in biodiversity loss, the Convention on Biological Diversity (CBD) approved the 'Strategic Plan for Biodiversity 2011-2020' in 2010. These goals are a fundamental aspect of this plan. The international community has committed to try to attain these aims by 2020 (Tittensor et al., 2011), and they are intended to facilitate global biodiversity conservation and guide regional and national-scale target formulation.

There is a high danger of harm from all four issues, and flying birds are frequently exposed to them. They offer a wealth of opportunity for the investigation of their combined impacts, which has not been done before. While these problems frequently occur concurrently, there is a gap in our understanding because no study has focused on them all at once. Birds are often forgotten about in this context (apart from the impact of climate change, which was already discussed). Birds provide providing, regulatory, cultural, and sustaining services to ecosystems, per the United Nations Millennium Ecosystem Assessment. They also help with things like ecosystem engineering, seed predation, seed distribution, and pollination (Whelan et al., 2008). Therefore, bird populations need to be protected, and effective protection requires knowing how to deal with all four threats.

In light of the foregoing, this review looks at the combined and individual effects of these four threats on avian populations. It also makes an effort to find interconnected patterns among the problems. To achieve this goal, it draws on databases maintained by organisations and institutions devoted to studying animals and the environment, as well as data extracted from published scientific publications.

AIR POLLUTION

Human-caused air pollution has far-reaching consequences for all forms of life on Earth. When doing studies of this kind, protecting human health has always been at the forefront (Gupta and Bakre, 2012). There are, however, several ramifications for birds, as will become clear in the following section.

Direct impacts

Because of their tiny pulmonary capillaries and rapid breathing rates, birds spend a great deal of time in the open air. As a result, they are extremely susceptible to pollution in the air. The respiratory systems of birds are particularly vulnerable to the inflammatory and fatal effects of ground-level ozone and nitrogen oxides. Long-term exposure to these contaminants can also cause blood vessel rupture (Qin, 2011). Blackened lungs and larger testicles have been linked to emissions in Beijing and Manila (Lovett, 2012). Changes in the tracheal epithelium, such as an increase in mucus cover, a reduction in the length of the cilia, and an uptick in secretory granules and vesicles, are caused by pollution from coal-fired power plants in songbirds (Llacuna et al., 1993). The percentage of ciliated and non-ciliated cells in the tracheal epithelium of goldfinches (Carduelis carduelis), rock buntings (Emberiza cia), great tits (Parus major), and blackbirds (Turdus merula) varies due to the emission of NO x, SO2, and particulates from such plants (Gorriz et al., 1994).

In the presence of SO2, NO x, and particles, the erythrocyte count in rock buntings and blackbirds drops but the erythrocyte size increases. In rock bunting, pre-albumins are elevated while -globulins are down. Transaminases (GOT and GPT) are elevated and body mass index is lowered in blackbirds (Llacuna et al., 1996). Sparrows in severely polluted metropolitan environments also show haematological impacts, with significantly reduced haemoglobin and antioxidant capacity. As pollution increases, so does the severity of this effect (European Commission, 2012). Polycyclic aromatic hydrocarbons (PAHs) are another category of hazardous pollutants. Long-term exposure can slow their development, decrease egg production and hatching, and increase the frequency with which mothers leave their young. Mutations in DNA caused by PAHs can be passed down through generations (as seen in the Canadian double-crested cormorant, Phalacrocorax audax). These changes may also contribute to cancer development (Qin, 2011).

Following increased emission, the aforementioned hazardous chemicals accumulate in bird bodies. Birds in Beijing, for instance, have been shown to have three to four times the levels of PAHs and other frequent by-products of fossil fuel burning in their lungs and livers compared to birds in places with better air quality (Lovett, 2012). Pollution from coal-fired power stations can also cause heavy metal accumulation; the extent to which it does so differs among various species. Blackbirds collect far higher levels of heavy metal residues compared to the great tit and the rock bunting (Llacuna et al., 1995), demonstrating this point.

Other issues arise as well, such as a decline in breeding success for great tits in southern Poland (Nyholm et al., 1995), for example. Great tit are sensitive to air pollution, which can alter their vocalisations as well as their health. The fact that male great tits sing less while located near emission sources has been documented (Gorissen et al., 2005; Isaksson et al., 2005). Eeva and Lehikoinen (1995) discovered that great tit and pied flycatcher (Ficedula hypoleuca) egg shell thickness, egg volume and content, clutch size, and hatching success were all negatively affected by copper smelter emissions. The feeding behaviour of the ruby-throated hummingbird (Archilochus colubris) is influenced by ozone (and other atmospheric contaminants). Ozone pollution is especially dangerous for these birds because they take in so much air relative to their size (Lewis, 2006).

Indirect impacts

Changes in habitat, an uptick in parasites, and a decrease in food supplies are just some of the ways that air pollution can harm birds (Morrison 1986; Graveland 1990; Eeva et al. 1994; Hörnfeldt and Nyholm 1996).

Plant carotenoids can be suppressed by emissions, reducing their availability to insects that eat plants (phytophagous insects). Carotenoids in insectivorous birds are reduced because phytophagous insects store fewer of them. Because of this, the nestlings of these birds do not receive a sufficient amount of carotenoids from their parents (which are essential for antioxidant protection and immunological competence). Carotenoids are also essential for oocyte maturation. Therefore, both chick and egg development may be impacted (Sillanpää, 2010). Great tit nestlings have less yellow plumage because emissions reduce the availability of carotenoids from the green caterpillars and sawfly larvae they feed. Air pollution can reduce the concentration of carotenoid derivatives in organs, interfere with carotenoid metabolism, and prevent carotenoid delivery to feathers. Therefore, nestlings living further away from pollution sources are more robust and brightly coloured. This fact suggests that pale nestlings have a decreased chance of survival. The selection of mates by female birds, competition between males, social dominance in winter groups, and the capacity to hide from predators are all influenced by plumage colour (Eeva et al., 1998).

Many insect species are threatened by the heavy metal air pollution produced by copper smelters. Great tits, which specialise in eating caterpillars, and pied flycatchers, which are opportunistic feeders, will have to adjust their diets accordingly. There is no change in how often or how much a person eats. However, both species have evolved to ingest different kinds of food. While the breeding success of pied flycatchers is unaffected by changes in food quality, that of great tits is. This suggests the former are more at risk when there aren't enough carotenoids-rich caterpillars. However, heavy metal pollution makes the pied flycatcher more vulnerable to a decline in calcium-rich food items (Eeva et al., 2005).

Acidification of water bodies can be caused by the release of sulphur dioxide and nitrogen oxides from the combustion of fossil fuels. Because of this, avian food supplies are impacted both quantitatively and qualitatively (Hare et al., 2002). Numerous crustaceans and mollusks have high calcium levels and are hence pH sensitive. Rapid extinction results from wetland acidification (Hare et al., 2002). Some bird species, such as the great tit and the pied flycatcher, experience a decrease in eggshell thickness as a result of acidification (Dudley and Stolton 1996). The effects of acidification, however, can be rather variable. There are less fish for ospreys (Pandion haliaetus) to eat in a lake with high levels of acidity. Diving in acidic lakes, where the water is clearer, could be beneficial for hunters (Hare et al., 2002). In addition, eutrophication can develop when there are more nitrogen oxides in the air. This has unintended consequences for the fish and invertebrates that birds rely on for sustenance. Nitrogen oxide buildup over time can promote the spread of nitrogen-loving invasive plants, which can outcompete native flora (like lichens) that provide feed and nesting material for birds and ultimately cause their extinction. Overall, the effects of emissions can reach up to bird habitats and cause significant changes in the landscape (Qin, 2011).

Earthworms absorb more of the dioxins in the air because they build up in the soil. However, earthworms can amass up to five times the concentration of these compounds found in the soil, despite being unaffected by them. Carcinogenic, reproductive, and immuno-toxic effects have been observed in birds who have consumed earthworms contaminated with this toxin (Hare et al., 2002). In Fig. 1 we can see the global effect of emissions on birds.

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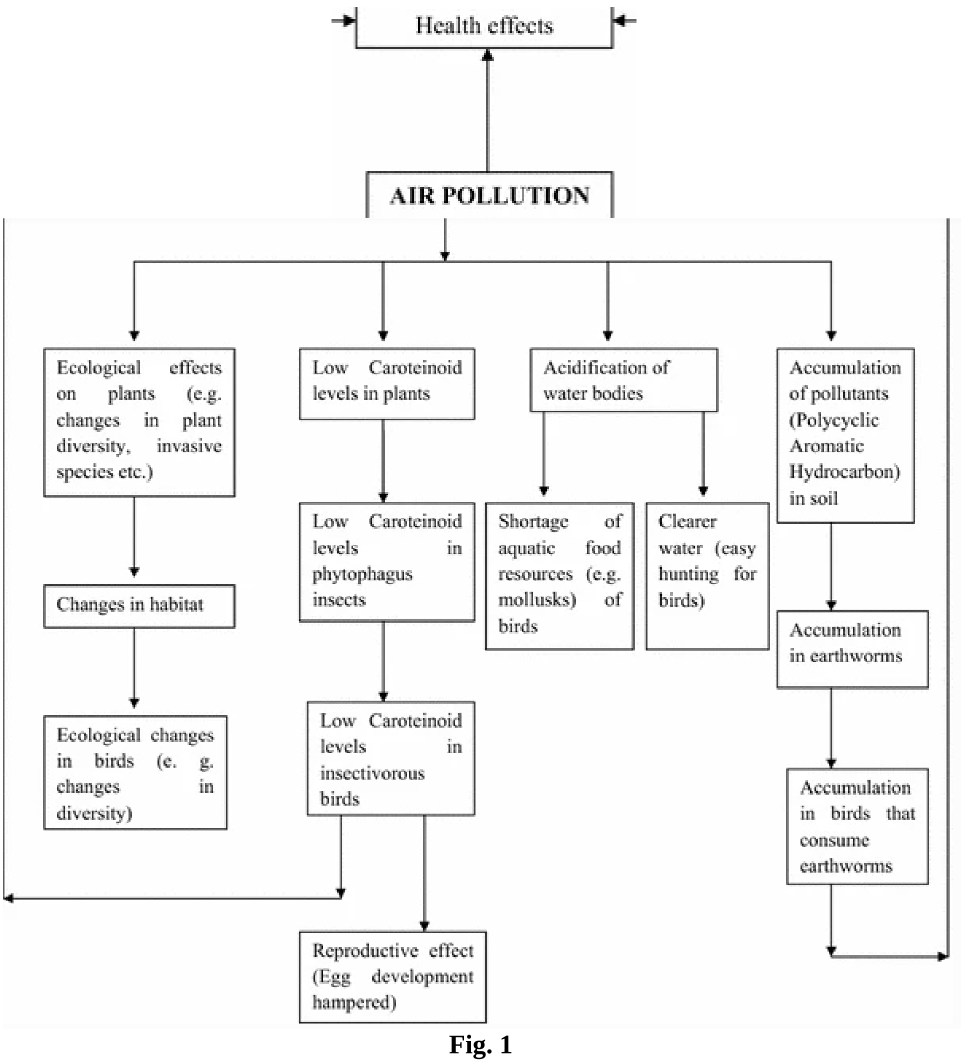


Fig. 1

NOISE

Noise as a problem

The introduction of more potent sources, the increased geographic distribution and mobility of noise sources, and the increased exposure to noise throughout the day all contribute to the rising levels of anthropogenic noise (Berglund and Lindvall 1995). It is a novel evolutionary selection pressure (Slabbekoorn &Ripmeester, 2008) with effects on both individuals and populations. There is mounting evidence that noise pollution is having a negative impact on animal processes across the globe (Barber et al., 2010; Tennessen et al., 2011). Animals' endocrine, digestive, blood, immunological, and reproductive systems can all be negatively impacted by noise (US Department of Transportation and Federal Administration, 2004).

There is a lack of knowledge about how noise affects natural populations and communities (Francis et al., 2012). The effects of noise on animals are poorly understood, despite the widespread curiosity surrounding them (Tennessen et al., 2011). For instance, physiological stress and reduced reproduction as sublethal consequences of noise have not been adequately reported (Kight and Swaddle, 2011). Even urban bird species that have adapted to a wide range of climatic conditions may be vulnerable to noise, according to research by Francis et al. (2011).

Impact of noise on birds

Avian calls

According to research by Gil et al. (2011), birdsong serves as a signal of territory occupancy and sexual maturity. In fact, mating and territorial defence cues used in audio communication are the result of sexual selection (Mockford and Marshall, 2009). Anthropogenic noise is becoming increasingly disruptive to bird communication, which is a crucial factor in sexual selection and social integration (Catchpole and Slater 1995). Actually, the level of ambient noise is the primary factor in determining whether persons hear verbal messages and whether or not they are effective (Patricelli & Blickley, 2006). As a result, noise acts as a selective pressure on the acoustic signals it encounters (Ryan and Brenowitz, 1985). Song-based evaluations in females are obscured when low-frequency male sounds are interrupted by noise. Therefore, less effort is used to produce eggs. Because of this, great tits that nest in urban environments tend to have smaller broods (Francis et al., 2011). In addition, female birds' capacity to recognise superior males can be impaired by such masking. Because lower-quality males' higher-frequency signals are less likely to be disrupted by background noise, they may be chosen for mating (Francis et al., 2011).

Changes in signal volume, frequency, timing, and length are all examples of faculty behavioural responses to anthropogenic noise that aim to reduce acoustic competition (Fuller et al., 2007). When singing coincides with aviation traffic, European bird populations have been found to significantly advance their timing. The level of progress depends on the disruption and the species' resilience. This adjustment is not related to circadian rhythms, but rather to adaptive change. Bird populations can adapt to loud situations by shifting their typical singing hours. However, it requires more energy and results in reduced competitiveness and resilience (Gil et al., 2011).

Urban traffic noise is another significant case in point since its low frequency directly disrupts bird acoustics (Mockford and Marshall, 2009). There is evidence that serins (Serinus serinus) enhance their singing in response to such sounds (Diaz et al., 2011). Male blackbirds also show flexibility when they try to time their dawn songs to periods of less noise in response to traffic. Inevitably, they will awaken several hours before people (Helmholtz Centre for Environmental Research, 2012). When there is a lot of daytime noise, the European Robin (Erithacus rubecula) will sing at night to drown it out (Fuller et al., 2007). British robins have been seen to stop singing during the morning rush hour (Francis et al., 2009) and instead switch to singing at night. It's possible that the singing of birds that are active during the day helps drown out the sounds of the city at night. While this may boost energy expenditure, it may come at the expense of quality sleep (Fuller et al., 2007).

In the presence of background noise, birds will adjust the pitch and volume of their songs accordingly. The Lombard effect (Lombard 1911) describes the behaviour of the signaler, who raises the volume of his or her calls when subjected to an increase in background noise. Male nightingales (Luscinia megarhynchos) that forage independently are more likely to raise their voices in noisy environments, displaying their territory. The increased volume of the German nightingale's songs (95 dB) poses a risk to human hearing (Francis et al., 2009). The volume of anthropogenic noise is positively correlated with the lowest frequency of male song in urban song sparrows (Melospiza melodia) (Wood and Yezerinac, 2006). To avoid being drowned out, many bird species change the pitch of their calls, including the great tit, the house finch (Carpodacus mexicanus), and the oscine. It's possible, though, that the acoustic signal will be less effective if high-frequency sounds don't go far. The volume of a bird's call may rise in some species. The magnitude of this progress is proportional to both body mass and the amount of energy expended. Here, the value of pitch modification may be diminished due to rising energy prices (Patricelli and Blickley, 2006). There is some evidence to suggest that singing in noisy environments can impair one's ability to pay attention, increasing the danger of the scenario (Diaz et al., 2011).

Rapid progress has been made by humanity. Increased auditory interference with animal communication can have significant behavioural repercussions (Fuller et al., 2007). The calls of larger birds tend to have a lower frequency. Larger birds are more likely to be injured in noisy environments than smaller species because they use a higher frequency to communicate. Tolerance can be affected by parameters such as body size, vocal amplitude, and frequency (Francis et al., 2011). Some tiny animals that communicate via radio waves may be able to make it through loud settings. In addition, the lower risk of predation in these places could assist these as well. This advantage, however, comes at the expense of male-female interaction, successful mating, and successful reproduction in the absence of predators (Francis et al., 2011).

IMPACTS ON HEALTH AND PHYSIOLOGY

Young birds in the nest are especially vulnerable to disturbances since they are unable to leave the nest. Immediate effects include possible stunting of growth and impaired immunological function (Crino et al., 2012). Consequences to health, appearance, and behaviour over the long term are possible. Potentially permanent and intergenerational repercussions on reproductive health and viability could result from such actions. Even brief exposure to stress, such as noise, during development may have far-reaching consequences (Crino et al., 2012). Traffic noise has been shown to have negative phenotypic impacts on the offspring of white-crowned sparrows (Zonotrichia leucophrys) (Crino et al., 2012). There may be a variety of tactics birds employ to counteract the impacts of noise. Short-term adjustments or long-term evolutionary shifts in signal properties may result from this (Herrera-Montes and Aide, 2010).

Ecological impacts

Reduced bird populations, sightings, and diversity are all the result of traffic noise near highways. High-traffic areas saw the greatest decreases (Summers et al., 2011). The same things happen close to airports. Only a handful of species, those with flexible enough behaviours to avoid extinction, can survive in close proximity to airports. However, this still has an impact on the ecology by reducing the number of birds in it (Gil et al., 2011). Especially in secondary lowland forest settings, noise has been shown to diminish the diversity of bird groups (Francis et al., 2009; Herrera-Montes and Aide, 2010). The Western Scrub Jay (Aphelocoma californica) is an egg-eating predator, however sometimes noise helps smaller birds if it is too loud for the Jay to bear. Nonetheless, this can potentially have serious ecological repercussions, as Scrub Jays play a crucial role in pollination (Francis et al., 2009). However, Francis et al. (2012) found that noise indirectly encourages hummingbirds to pollinate flowers.

LIGHT POLLUTION

Light as a problem

Several ecological implications (including shifts in animal behaviour and community make-up) can be traced back to the development in artificial lighting, which has had a significant impact on natural light regimes. The potential effects include an increase in the amount of time spent feeding, an increase in the amount of time spent in sexual competition between diurnal and crepuscular animals, an increase in the ability to identify prey and escape predators, a shift in navigational abilities, and a change in the ability of pollinators to locate nectar sources. Because this is a relatively new environmental concern, research on these topics is scant (Davies et al., 2012). Light's modest effects haven't gotten the attention they deserve (Poot et al., 2008; Kempenaers et al., 2010). Although several aspects of light have the potential to affect ecological and evolutionary processes (Navara and Nelson 2007; van Langevelde et al. 2011), these factors are still under investigation. Artificial light interferes with the natural day-night rhythm that has shaped plant and animal evolution (Cinzano et al., 2001). In fact, light has been an ecological problem for quite some time, and it's only going to get worse as lighting technology improves (Gaston et al., 2012). Some of the many potential ramifications that need further investigation are addressed below (Gaston et al., 2012).

Impact of light on birds

Natural behaviour

According to research by Mahr et al. (2012), light has a crucial role in the circadian rhythm of birds, which in turn controls when they mate, breed, forage, and migrate. Thus, changes in activity patterns occur when exposed to light (Mahr et al., 2012). Thus, natural behaviour patterns may be disrupted when artificial light interferes with the body's circadian clock (Mahr et al., 2012). Since birds rely heavily on indications provided by appropriately scheduled seasonal cycles, artificial light can either hasten or slow down the migration process. Because of this, birds may not be able to take advantage of prime times for nesting, foraging, and other activities (International Dark Sky Association). Greater flamingos (Phoenicopterus roseus) and Peahens (Pavo cristatus) increase their vigilance behaviour at night under decreased light levels (Yorzinski et al., 2011), demonstrating the influence of light on behaviour. Some species of birds, when exposed to artificial light, can forage for longer periods of time. Late at night, when there is more light pollution, mockingbirds (Minimus sp.) feed their young. When European blackbirds are exposed to artificial night lighting, they forage later into the evening and rise sooner in the morning. Yorzinski et al. (2011) found that light can significantly affect bird fitness by causing behavioural changes.

The effects of light on bird nesting habits are substantial. It has a lot of unexplored repercussions (Kempenaers et al., 2010). The Florida Fish and Wildlife Conservation Commission reports that birds start mating earlier when the days become longer. It has been observed that in urban blackbirds, exposure to artificial light can hasten the onset of breeding by nearly a month. Light may also cause these birds to moult up to three months earlier than birds in rural settings (Helm et al. 2012; Partecke et al. 2005). The Blue Tit (Cyanistes caeruleus) is another species of bird whose reproductive behaviour is altered by artificial light (Mahr et al., 2012). Males in these situations are more likely to find mates if they are located near light sources at woodland borders. This means that they frequently produce offspring with secondary females (Kempenaers et al., 2010). Since males and females may have different preferences for light (Mahr et al., 2012), nocturnal light may affect how birds select mates. Global warming is projected to raise spring temperatures, which will have a multiplier impact on the effects of night lighting on breeding birds (Kempenaers et al., 2010).

Traffic noise may amplify the negative effects of nighttime lighting. When added together, these factors may cause birds to become active as much as five hours earlier in the morning than they would be under natural light conditions (Helmholtz Centre for Environmental Research, 2012). The natural cycles and habits of city blackbirds provide a good reflection of these interconnected effects (Helmholtz Centre for Environmental Research, 2012). Given the expected growth in both road infrastructure and traffic loads, this is an issue with contemporary relevance. When combined with other influences, such as noise and artificial light, roads can have significant negative ecological consequences (Kociolek et al., 2011). However, the effect of artificial night lighting on natural cycles is contingent on a number of anthropogenic causes. Even less is known about how these shifts in seasonal timing of behaviour affect fitness (Da Silva et al., 2011).

Disorientation

Birds can be easily entangled in artificial light because it serves as a powerful misleading orientation cue (Verheijen 1985). Nighttime migrants are especially susceptible to this problem since light interferes with their ability to find their way (Gauthreaux and Belser 2006; Watson et al. 2011). Artificial light can wash out the colour vision of migrating birds. As a result, they might easily lose track of the horizon and end up circling aimlessly within a narrow beam of illumination. According to the Florida Fish and Wildlife Conservation Commission, this can cause the animals to become overheated or even run into the light itself. Birds may be lured away from safe migration routes by artificial light, which illuminates cityscapes at night. Evidence for this can be seen in the high annual mortality rate of birds caused by accidents with artificially lit structures (International Dark Sky Association). For instance, every year in North America alone, between 99 and a hundred million birds are killed when they collide with buildings (Chepesiuk, 2009). When meeting artificial light sources like offshore platforms, many nocturnally migrating birds either perish or suffer significant energy loss (Poot et al., 2008). There is a lack of knowledge on why birds are drawn to man-made light sources (Poot et al., 2008). Light can cause birds to shift their migration patterns, fly at lower altitudes, call more frequently, and spend more time over illuminated regions than they would otherwise (Watson et al., 2011).

The Balearic Shearwater (Puffinus mauretanicus), Scopoli's Shearwater (Calonectris diomedea), and the European Storm-petrel (Hydrobates pelagicus) are all at risk of extinction because to light pollution. During their first nighttime flights from the nest to the ocean, fledglings are drawn to artificial lighting. Because of this, they are vulnerable to being grounded and subject to a variety of dangers. High mortality rates may result from this (Rodrguez et al., 2011). Since seabirds are nocturnal predators, they have trouble locating their prey when the light levels at their feeding grounds are low (Florida Fish and Wildlife Conservation Commission). But nighttime lighting can help certain shorebirds switch to visual foraging rather than tactile foraging when it's dark outside (Rojas et al., 1999). Birds' reactions to any type of illumination are most pronounced during moonless and starless evenings (Poot et al., 2008).

Mating calls

Some birds begin singing before sunrise when exposed to artificial light, according to a 2012 study by the Helmholtz Centre for Environmental Research. Many songbirds are found to sing earlier in the morning, later in the evening, and even at night when exposed to artificial light (Da Silva et al., 2011). Male birds lose sleep from singing too early (Kempenaers et al., 2010) and are thus more vulnerable to predators. According to the Florida Fish and Wildlife Conservation Commission, night lights can extend the day for diurnal songbirds, making them easier prey because their songs travel farther. Some species of birds' males start their morning songs sooner because of streetlights. Egg laying is accelerated in females of the same species (Kempenaers et al., 2010). Some bird species' females may have multiple sexual encounters with the best available males in an effort to produce offspring of the highest possible quality. These might use the quality of the male voice as an early indicator of dawn (because of the light). In this way, light has the potential to break the association between early singing and male quality, leading to lower-quality male offspring for females (Kempenaers et al., 2010).

Additional effects of light

Some species' nesting densities are influenced by the amount of light cast from roads (Longcore and Rich, 2004). Certain species, however, show a preference for alternating between dark and light phases (McClure et al., 2012). Exposure to artificial light at night may also cause melatonin synthesis disturbance in birds. Negative physiological effects of melatonin deficiency have been reported (Gaston et al., 2012).

There are direct and indirect consequences. Many types of artificial lighting, for instance, can be lethal to insects by distracting them from food sources. Thousands upon thousands of insects perish every summer in Germany because they are drawn to artificial lights. This has a knock-on effect of killing off insect populations, which is bad news for birds that rely on them for food (International Dark Sky Association; Eisenbeis, 2006).

GLOBAL WARMING

Global warming as a problem

Human activity is responsible for the vast majority of the recent increase in global temperature, which has occurred at a rate not seen in the preceding 1300 years (Whelan et al., 2008). The global average temperature has risen by 0.83 °C in the last century, and it is projected to rise by another 0.28 °C to 4.78 °C in the next. Since 1880, the average yearly increase in global temperature is 0.07 °C, whereas the rate has accelerated to 0.17 °C per decade since 1970. In 2011, land and ocean temperatures around the world were 0.94 degrees Celsius warmer than the average for the entire twentieth century. It was 0.04 degrees warmer than the previous record, set in 2011. It was the fifth occasion in the twenty-first century that an annual high temperature record was broken (the others being in 2005, 2010, and 2011) (Global Climate Report-Annual 2011).

An increase in greenhouse gases such as carbon dioxide, methane, nitrous oxide, and chlorofluorocarbons is to blame for this warming (US EPA, 2011). Remarkable climate shifts are being triggered by global warming in turn (Sahu et al., 2011). Grace (2004) estimates that carbon dioxide is responsible for about 60% of global warming. Since the beginning of the industrial revolution, this greenhouse gas's concentration in the atmosphere has increased dramatically (World Meteorological Organisation website; British Geological Society website). Deforestation, fossil fuel consumption, and cement manufacture are three of the biggest sources of manmade carbon dioxide emissions (World Meteorological Organisation; British Geological Society). Between 1750 and 2011, over half of all human-caused CO2 emissions happened in just the last 40 years. The ocean will warm and become more acidic, and heat waves and extreme precipitation events will become more often as a result (IPCC, 2011).

Landfills and the agriculture and livestock industries also contribute to methane emissions (World Meteorological Organisation; British Geological Society). Nitrification and denitrification in agricultural soils are the primary sources of nitrous oxide. About 10–50 kg of nitrous oxide gas is produced for every 1 tonne of reactive nitrogen (mostly fertiliser) in such soils. This is a major problem because there will likely be a substantial expansion in farmland in the not-too-distant future (Tilman et al. 2001; IPCC 2007; Singh et al. Chlorofluorocarbons are synthetic substances used mostly in refrigeration and air conditioning. These compounds are regulated by the Montreal Protocol. Increases in the emission of these greenhouse gases (a tenfold increase since the turn of the twentieth century) are strongly correlated with the expansion of industrialization (World Meteorological Organisation Website).

Because of climate change, certain climatic extremes are projected to become more common, which can have severe consequences for biodiversity (Jentsch et al., 2007; Seneviratne et al., 2011; US EPA, 2011). The crossing of meteorological thresholds that result in population collapses makes this a very real possibility (Oliver et al., 2011). Climate change's most visible environmental characteristics have consequences for biodiversity, including temperature, solar radiation, humidity, cloud cover, and precipitation (Bickford et al., 2010). As a result, climate change is already having an effect on biodiversity, and many species are at risk of decline or extinction as a result (Foden et al., 2012). Bird Life International (2012) notes that the impacts will vary according to the species' sensitivity, adaptability, and degree of exposure to climate change. Wildfires, which can become more common as a result of climate change (Silvestrini et al., 2011), have their own set of ecological repercussions. Changes in precipitation and, thus, decreased water availability for animals, poleward and altitudinal range shifts (seen in some butterflies), complex responses for migratory species (seen in birds by the fact that Red Knot Calidris canutus are becoming smaller, with smaller bills, resulting in decreased survival rates in Africa), and changes in phenology and community composition and abundance are all notable biotic effects of global warming. Benning et al. (2002) found that many bird species became extinct due to a combination of climate change, changes in land use, and biological invaders.

Combating climate change and its repercussions has been included by UNEP as one of its sustainable development goals (Goal 13) (UNEP 2011), and immediate action is needed to adequately safeguard animals from global warming.

IMPACT OF GLOBAL WARMING ON BIRDS

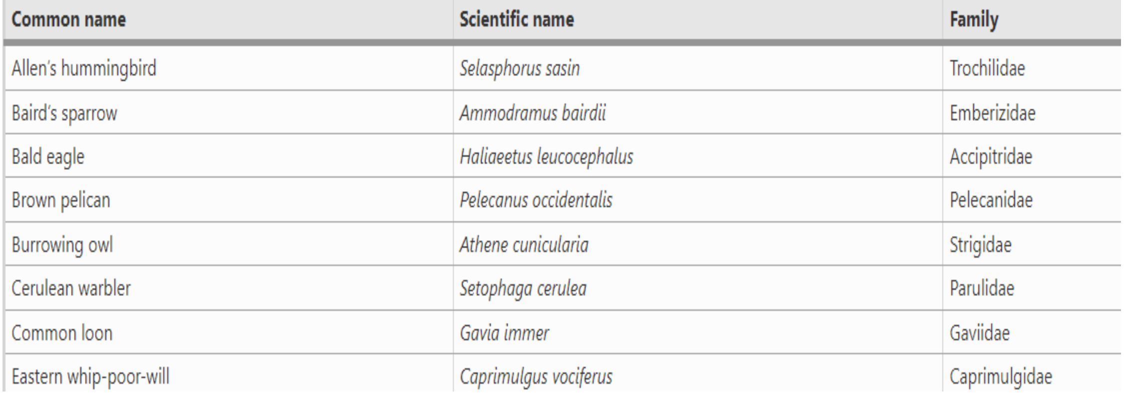
Extinction

Bird extinction rates are increasing at an alarming rate due to climate change (Foden et al., 2012). Twenty to thirty percent of species worldwide are predicted to be at high danger of extinction within this century if global mean temperatures exceed two to three degrees Celsius over pre-industrial levels (Barnosky et al., 2011). This is according to the Intergovernmental Panel on Climate Change (IPCC). Indeed, climate change has already led to a 90% reduction in some bird populations (WWF, 2011). Mid-range climate change is predicted to cause a 33-40% extinction rate in South Africa if birds are unable to relocate to new, suitable habitats (Thomas et al., 2004). If global warming exceeds 2 °C above pre-industrial levels (it is currently 0.8 °C above), WWF predicts that 38 bird species in Europe and 72 in north-east Australia will become extinct. If global temperatures rise by 3.5 °C, it is estimated that 600-900 species of terrestrial birds will go extinct by the year 2100. Furthermore, for every 1° increase in temperature above this amount, 100-500 bird species may become extinct (Sekerciolu et al., 2012). Species of birds with particularly small suitable habitat ranges are especially vulnerable to extinction. Global warming may aid invading species in their quest to displace native species (WWF, 2011). The problem is especially severe for migratory, mountain, island, wetland, Arctic, Antarctic, and marine birds (WWF, 2011). on spite of this, up to 83% of all birds that are very vulnerable to climate change are not included on the current IUCN Red List of Threatened Species (Foden et al., 2012). Important factors in determining the likelihood of extinction can be found in the range limitations put on species by the climatic, ecological, and physiological impacts of elevation (Sekercioglu et al., 2008).

Habitat and distribution

Many bird species have had their distributions predicted to shrink or expand as a result of climate change. The specific habitat needs of a certain species play a significant role in this context due to their importance in the species' natural history. Grey vireos (Vireo vicinior) and black-throated sparrows (Amphispiza bilineata) may be able to expand their breeding ranges. However, sage thrashers, Williamson sapsuckers, and pygmy nuthatches (Sitta pygmaea, Oreoscoptes montanus, and Sphyrapicus thyroideus) are all expected to suffer severe declines. Future population decreases may be triggered by such losses. Such shifts may have far-reaching consequences for the survival and dispersal of many species (US Geological Survey, 2011). The website for the National Audubon Society (2011) reports that 314 bird species may be at danger from climate change owing to the loss of habitat. Table 1 is a list of some of the most probable affected bird species.

Table 1 Birds at risk due to habitat and range shrinkage occurring under the influence of global warming.



Common name	Scientific name	Family
Allen's hummingbird	*Selasphorus sasin*	Trochilidae
Baird's sparrow	*Ammodramus bairdii*	Emberizidae
Bald eagle	*Haliaeetus leucocephalus*	Accipitridae
Brown pelican	*Pelecanus occidentalis*	Pelecanidae
Burrowing owl	*Athene cunicularia*	Strigidae
Cerulean warbler	*Setophaga cerulea*	Parulidae
Common loon	*Gavia immer*	Gaviidae
Eastern whip-poor-will	*Caprimulgus vociferus*	Caprimulgidae

By the end of this century, the probable distribution of bird species in Europe could shift north-east by around 550 kilometres due to climate change. Due to climate change, it is predicted that the typical range of European breeding birds will decline by a fifth and eventually overlap the current range by only 40%. It is estimated that 75% of all such species will see their ranges decrease. If this happens, certain species in Europe would have very little suitable habitat left (RSPB, 2008). Sea level rise is another threat to coastal ecosystems and the wildlife that calls them home. Waterbird nesting habitat in the Arctic tundra is anticipated to be impacted by climate change (Bird Life International, 2012).

Because of climate change, the ranges of many North American bird species are shifting northward in latitude and altitude (King and Finch, 2012). Interspecific competition could be triggered by space and resource limitations at higher elevations, posing a threat to locals there (Jankowski et al., 2010). Species that migrate south could potentially outcompete and wipe out their upland relatives if certain conditions are met (Jankowski et al., 2010). Landscapes that have been fractured or degraded as a result of human activity may also make it more difficult for birds to relocate to more favourable climates. Birds of islands and mountains are especially at risk because their habitats are fragmented and difficult to protect (WWF, 2006). Also, if climate shifts happen too quickly for vegetation to adapt, or if they happen outside of viable plant ranges, then bird populations may be pushed to relocate to inappropriate habitats. As a result, they might not be able to reproduce as well or live as long (Crick, 2004). Alterations in the rate at which species shift their ranges may potentially cause changes in community composition as a result of climate change. The movement of species along divergent paths can further alter communities (Gillings et al., 2011). Sea level rise, changes in fire regimes, vegetation, and land use are all indirect effects of climate change that will have an impact on birds in the future (WWF, 2006). Wildfires, which can be exacerbated by the dry circumstances brought on by climate change, have the potential to negatively damage birds by destroying nests and altering their habitats. There are signs of this in the American West right now (King and Finch, 2012).

Droughts have become more frequent as a result of climate change. There is a high degree of avian diversity on river reaches that are characterised by open water, a high biomass of flora, and native over-story trees. Drought reduces river water flow, which in turn reduces all three elements. Important vulnerable species suffer as a result. One place in Mexico where this is clearly visible is the Colorado River Delta (Hinojosa-Huert et al., 2012). In addition, when soil is dry, birds like blackbirds, robins, thrushes, and starlings have a harder time digging for food. Vegetation growth is also stunted as water sources dry up. As a result, wading birds become more vulnerable to predators (The Wildlife Trusts Website). Changes in salinity brought on by droughts can wipe out insect populations, including those of avian food staples like brine flies (Ephydridae sp.). Due to lower hatching rates, insect populations can decline when water is scarce (Frost, 2011). Bird community shifts, along with amphibian and reptile extinctions, have all been connected to drought (Pounds et al., 2006). Water flow and water quality are just two of the ecosystem services protected areas assist to preserve, along with other ecosystems (World Bank, 2003). They prevent local climate from drying out and help preserve ecosystems (Stolton et al., 2008). Therefore, vulnerable places are more likely to feel the effects of drought.

Reproduction

Climate change is already causing widespread problems for birds, including reproductive failure and population decline (Sekerciolu et al., 2012). As a matter of fact, climate change has led to an unparalleled collapse in bird reproduction (WWF, 2011). This is due to the fact that breeding success is influenced by climatic change (Crick, 2004). Birds' metabolisms and behaviours, especially their ability to breed, are impacted by climate change (Crick, 2004). The optimal song choice, the variation in mating success, and the interactions between predators and prey can all be affected by climate change (Moller, 2010).

Extreme weather (frozen spills and droughts) brought on by climate change can also kill or starve young birds, reducing their reproductive success (Crick, 2004). Wading birds' nesting success decreases when there is a drought, as was shown in England in the spring of 2011. If breeding success drops for more than two years in a row, endangered wading birds like the Redshank (Tringa totanus) could be in danger. It is also impossible for these birds to get food in solid, dry ground, according to The Wildlife Trusts. Furthermore, climate-induced alterations to the timing of the breeding cycle might cause damaging interspecific competition (Ahola et al., 2007).

Timeliness of arrival at breeding and overwintering grounds is the most important factor in reproductive success, survival, and fitness in migratory birds (Cotton, 2003). This is because it is extremely important for the needs of young to coincide with the availability of food (Visser et al., 2004). As a result of climate change, growing seasons are getting longer, flowering phenology is shifting, and distribution patterns are getting jumbled up (Cotton, 2003). Plant phenology has been disrupted by the rise in spring temperatures. This means that in some bird species, reproductive conduct is not coordinated with the provisioning of food for young. Some birds, like the great tit in the UK, have experienced reproductive failure as a result of this (Visser et al., 1998). The same factors led to a precipitous decline in seabird nesting in the North Sea surrounding the United Kingdom in 2004. This happened because there wasn't enough food available due to changes in ocean temperatures and species composition (WWF-India, 2006). As a result of climate change, many bird species have moved up their breeding seasons. Species that don't breed quickly enough will eventually become out of sync with the food supply and die out. Population declines are predicted to be proportional to the severity of this mismatch (Moller et al., 2008).

However, various species react differently to climatic change. Two types of Siberian seabirds make this clear: planktivorous (Aethia cristatella and Cyclorhynchus psittacula) and piscivorous (Fratercula corniculata and Lunda cirrhata) auklets and puffins, respectively. Macro-zooplanktons, which thrive in colder waters, are the primary food source for the former. The latter are dependent on the fish populations that thrive in warmer seas (fish devour mesoplankton, which thrives in warmer water). As a result, the reproductive success of these two groups responds differentially to variations in sea surface temperatures (Crick, 2004).

Similarly to humans, birds can have unique reactions. As temperatures rise, the pied flycatcher moves up the timing of its egg-laying and hatching processes (Visser et al., 2004). This species' egg and clutch sizes have increased in Germany and Finland as a result of warmer springs (Crick, 2004). Some species, however, instead of laying eggs at an earlier age, will try to raise a second brood (Visser et al., 2004).

Incidence of disease

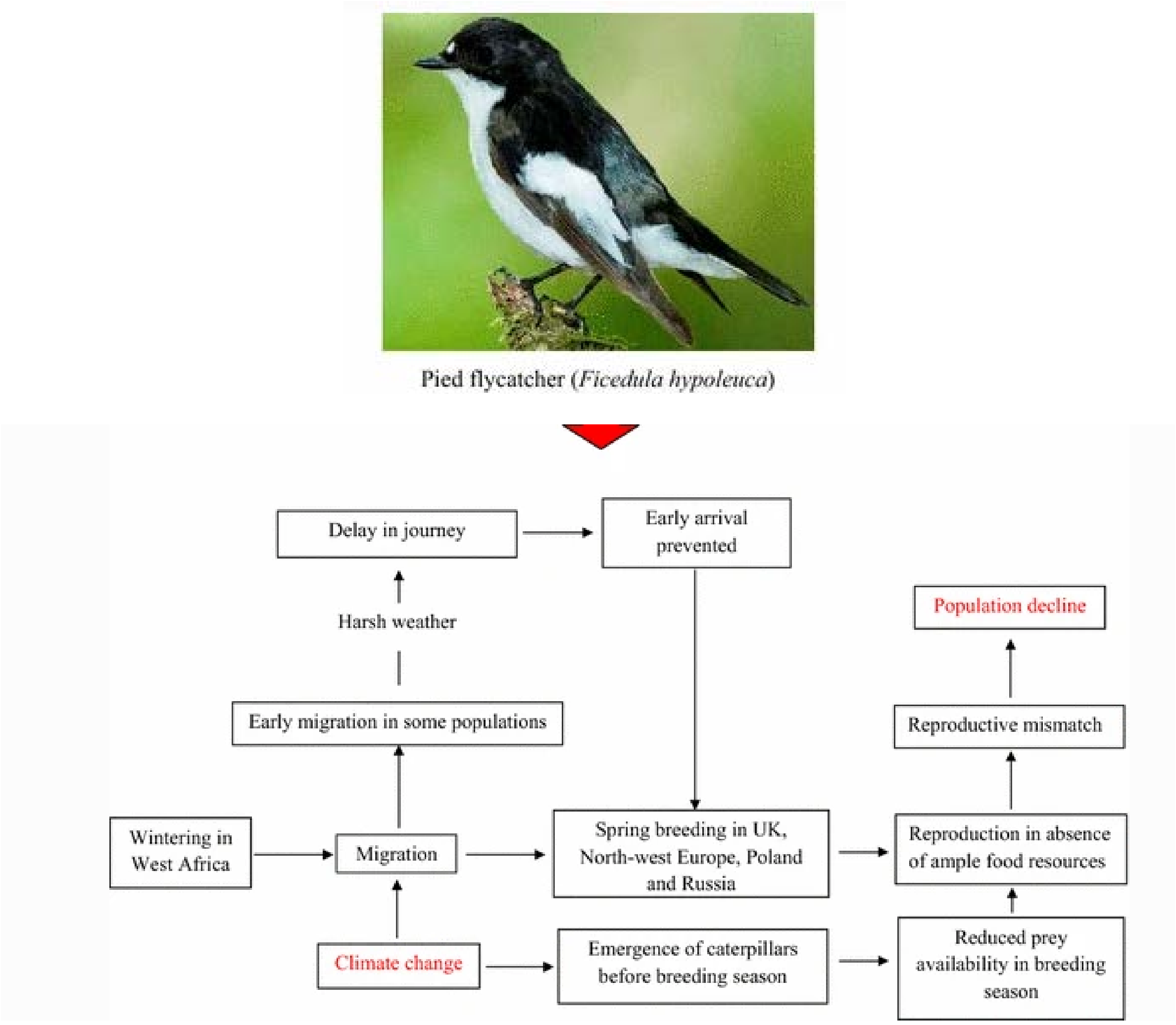
King and Finch (2012) point to the expansion of West Nile virus as evidence that climate change can increase the prevalence of some bird diseases and parasites. Because of climate change, avian malaria may spread further north, away from its traditional tropical and temperate habitats. It is predicted that this illness will spread to new locations by the year 2080, posing a threat to bird populations in places where it has not yet made an appearance (Loiseau et al., 2012). As another illustration, due to climate change, mosquito populations in Hudson Bay, Canada have reached their peak earlier in the spring. On the other hand, breeding seabirds have not adjusted their habits. Therefore, significant egg losses and adult mortality have resulted from heat and mosquitoes (Gaston et al., 2002). Hawaii is especially vulnerable to the effects of climate change because temperature and rainfall swings have a role in the spread of diseases like avian pox and malaria. A two-degree increase in temperature is associated with a significant increase in the chance of these diseases occurring (Atkinson and LaPointe, 2009). As the world warms, the mosquitoes that spread avian malaria may find their way to new habitats in cooler, higher altitude woods. As a result, Hawaiian honeycreepers (Drepanidinae sp.) would be in risk of extinction should the disease spread to them (Benning et al., 2002). The effects of pathogen and vector range expansions are evident in the cases of avian pox and influenza (Atkinson and LaPointe, 2009). In addition, climate change can impact how various local species interact with one another. As a result, avian flu can recirculate among various demographics, species, and migration routes (Sehgal, 2010).

Physical effects of rising temperatures

Finlayson (1932), Keast (1960), and Miller (1963) all report high avian mortality rates after extreme heat. It's important to note that rising temperatures pose a serious threat to desert bird populations. This is due to the fact that a number of these species are found in regions with excessive summer temperatures and limited, unreliable water supplies (African Climate and Development Initiative, 2011). The widespread death of birds in hot desert habitats has been linked to heat waves, which climate change models predict will become more intense, frequent, and long-lasting in the future. Midsummer is when desert bird populations are most at risk of dying out by the 2080s (McKechnie and Wolf, 2010). As global temperatures rise, birds will need more water to maintain their internal temperature. Smaller birds are more susceptible to acute dehydration because their mass-specific evaporative water loss rates are higher (McKechnie and Wolf, 2010). Birds are typically modest in stature and active during the day. They also require fewer micro-sites with thermal buffers. All of these factors contribute to their heightened susceptibility to heat waves. Evaporative water loss in tiny species can surpass 5% of body mass per hour, even in shaded micro-sites and under sedentary conditions. In such conditions, birds may rapidly lose too much water to survive (Wolf and Walsberg 1996). Therefore, the smaller the bird, the more at risk it is during heat waves.

Migration

Some bird species have been seen to begin their annual migration earlier and this trend has been linked to climate change-induced earlier nesting and hatching. Species that fail to migrate in time usually see their numbers diminish. Long-distance migratory birds rarely move up their migration start dates. Consequently, numbers of these have been falling sharply (Gill et al., 2011). Many species that used to migrate between Europe and North America are now extinct. Due of their inability to adapt, these birds have been starved during migration. Because of this, several species are unable to get to their spring breeding areas early enough (WWF, 2006). Some long-distance migrants have endogenous rhythms that dictate when they begin their journey. Climate change hastens the phenology of their breeding habitats, but this may not be enough to prompt them to migrate any earlier. This prevents these species from reaching their mating grounds at the right time. The pied flycatcher is a good example of this phenomenon (Both and Visser, 2001). A member of the family Muscicapidae, the insectivorous pied flycatcher spends the winter in tropical West Africa and returns to Europe in the spring to nest. A long-distance migrant across the Sahara Desert, as confirmed by multiple sources (Wormworth and Mallon 2006; Harnos et al. During its annual migration through Europe, the bird chooses South West France, North West Spain, and North Portugal as refuelling stops (Jones, 2002). The pied flycatcher has not been able to successfully reproduce recently despite an abundance of food. This is due to the fact that climate change is hastening the pupation process, causing caterpillars to emerge before the bird can reproduce (Wormworth and Mallon, 2006). As a result of climate change's effects, the bird population is in decline (Both et al., 2006). Some communities have tried to benefit from early migration, but they have been thwarted by extreme weather that has prolonged their voyage. This suggests the bird's ability to adapt to climate change, but it also shows the precarious nature of migration in the face of shifting environmental conditions (Both 2010; Fig. 2).



Pied flycatchers, a species of migratory bird that eats insects, have seen their numbers drop as a result of climate change.

The take-off phase of a bird's migration is especially vulnerable to weather changes. Climate change, on the other hand, has been shown to have far-reaching consequences for migratory patterns, including the timing and location of foraging and resting stops. Birds use many wetlands as rest stops on their journeys and as breeding places once they arrive. Due to climate change, these are drying up, making it impossible for many migratory birds to rest throughout their journey. They will be confined to smaller spaces, which increases the likelihood of disease transmission (Frost, 2011).

It is the length of day that determines when migrating birds leave their wintering grounds. However, plant phenology, a factor that advances as a result of climatic shifts, affects the accessibility of food sources. That's why certain migratory birds shift when they breed based on the availability of food (Both and Visser, 2001). Some Arctic-breeding species don't have to venture as far south in search of milder climates and food sources because of global warming. Because of this, conservation efforts could be hampered because fewer birds would visit designated bird sanctuaries (Lehikoinen et al., 2012). However, at some locations at higher elevations, the start of the growth season is defined by the melting of snowpack that has been undisturbed by the rising spring temperatures. Problems arise for altitudinal migrants as a result of the disjuncture between changed bird phenology (as a result of mild spring temperatures) at low altitude and high altitude environments (Inouye et al., 2000).

II. CONCLUSION

The assessment rounded up the bad things that humans have done to the environment, focusing on how it has affected birds in particular. The repercussions are bound to be far-reaching and varied. These days, it's not uncommon for multiple environmental issues to arise at once. Since the consequences of the four main issues have a synergistic effect on one another, it is preferable to tackle all four at once rather than individually. This is due to the fact that the effects of one issue may compound when another is present. Future investigations should include additional animal groups besides birds to better understand the state of the biosphere as a whole, which was not considered in this work. Particularly abundant in this sense are the world's herpetofauna. Finally, our results highlight the importance of planning development with an eye towards protecting animals from major anthropogenic challenges, such as industrial expansion and road construction.

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