Winni Wang

Professor Jensen

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Project Proposal: The Effect of Urbanization on Migratory Birds

My final term project for MSWI-270C Ecology, Environment, & the Anthropocene will focus on the dire effects of human urbanization on migratory birds. I aim to highlight and elaborate how anthropogenic changes brought about by human urbanization can serve as threats towards migratory bird species and how it has impacted them in population and evolutionarily.

Scientists often refer to the current geological age as the Anthropocene, where human activity stands at the forefront of climate and environmental issues as its dominant driving factor. None is this more apparent than the 20th century, in which Earth's human population increased from 1.5 to 6 billion, the world's economy increased fifteenfold, energy use thirteen to fourteen fold, freshwater use ninefold, and use of irrigated area fivefold (Goudie et al.). Another characteristic of the Anthropocene and the accelerating growth of human influence, is the increase in concentration of urban settlements, otherwise known as global urbanization (Elmqvist et al.). Rapid urbanization at a global scale, while a testament to the growing technological advancements of human civilization, is one amongst many contributing factors that is negatively impacting the biophysical condition of Earth's natural environment (Elmqvist et al.).

Amongst many harmful environmental impacts, global urbanization is largely responsible for obstruction and loss of biodiversity. A group of species that is particularly impacted by the threats proposed by urbanization are migratory birds, who encounter many of these anthropogenic difficulties during the migratory journey.

Scientists have defined migration to be the “most dangerous period of the annual cycle for migratory birds” (Nemes et al.). These journeys often span for several months, in which many traverse across continents and varying environmental conditions. While migratory birds have evolutionarily adapted to “overcome the challenges of migration,” human activity has “increasingly modified the environments birds encounter en route, especially in the decades since the advent of the industrial revolution” (Nemes et al.). The unfamiliar landscapes brought upon by human urbanization, unlike the terrestrial and aerial environments they were adapted to navigate, pose various threats lethal to the mortality of migratory birds. While some of these threats are direct sources of mortality, many indirectly result in the failed survival of migrants by interacting “synergistically” with other threats to reduce the physical fitness of the birds.

The success of the migratory journey and the lifetime fitness of the birds define the two factors crucial for the survival of migratory birds. Circumstances that directly impact the success of the migratory journey and lifetime fitness of the migrants are the migration timing, physiological condition of the birds, and their orientation and navigation.

Migration timing is defined as the “appropriate timing of arrival to breeding, stopover, and stationary non breeding sites” to “secure high-quality territories and mates, maximize reproductive potential, secure food resources for refueling, and avoid adverse weather” conditions (Nemes et al.). Changes to the migratory route or the physical condition of a migrant can cause delays. Migratory birds that are delayed in arriving to their destination can “hinder its reproductive potential” while “delayed arrival to nonbreeding areas in autumn can mean an individual spends the season in poor-quality habitat” thus “delaying [their] departure in spring” (Nemes et al.).

Physiological condition refers to the “health and energetic condition” of the migrants during and at the end of their journey, which are powerful influencers of their “subsequent survival and reproduction” (Nemes et al.). After arriving at a destination, they must actively begin foraging for food, seeking mates, and be alert against potential predators. Challenges encountered caused by anthropogenic threats can “change a bird’s condition by reducing its energy stores through an impaired ability or motivation to forage; by causing injury, illness or exhaustion; or by increasing disturbance and stress” (Nemes et al.).

The stability of a migrant’s orientation and ability to navigate are crucial to ensure proper migration timing and a healthy physiological state. Migratory birds utilize an “internal clock and compass mechanism coupled with a variety of external cues to orient themselves and navigate to their destinations” (Nemes et al.). Although a birds’ navigational system is rather adaptable against the rapidly changing conditions present during the journey, anthropogenic threats brought upon by the unfamiliar scapes of urbanization can easily interfere with a migrant’s ability to accurately perceive and interpret environmental cues for maneuvering, orientation, and navigation. Birds that are disoriented may result in the depletion of their “energy reserves in flight, imposing fitness costs through reduced condition, delayed timing, or failure to reach the destination” (Nemes et al.).

Anthropogenic threats brought about by the rapid globalization of urbanization significantly influence migration timing, physiological condition, and orientation and navigation, all of which are crucial for the success of the migratory journey and lifetime fitness. These threats include human-made structures and sensory pollutants; artificial light at night, also known as ALAN, and noise pollution.

Anthropogenic structures such as skyscrapers and wind turbines and other “human-made elements in the airspace have become an increasingly common barrier to migratory movements” as “birds [are colliding] with anthropogenic structures throughout the world’s migration systems” (Nemes et al.). While some collisions are a source of instant mortality, many collisions result in nonlethal effects that instead contribute towards the reduction of the migrant’s physical fitness. Traumatic brain injuries that emerge as a result of survival against collisions can lead to cognitive impairments in “slowed reaction times, amnesia, balance impairment, and sleep [and wake cycles” (Nemes et al.). Intracranial hemorrhaging, a medical condition in which there is internal bleeding in the skull, is a common injury in birds that survive window strikes. Another common collision-related injury, ocular trauma, can “lead to infection or necrosis, causing vision impairments that leave birds vulnerable to predation and less efficient at foraging” (Nemes et al.). Collision survivors that manage to reach breeding grounds experience lowered reproductive success due to decreased physical fitness and broken or dislocated bones compared to birds that are uninjured.

Artificial light at night, also known as ALAN, is a threat induced by global urbanization that alters the nocturnal landscape for migratory birds during air travel. ALAN is capable of influencing the future survival and reproductive success of migrants by impacting their migration timing, physical condition, and orientation and navigation. ALAN is capable of increasing “migrating birds’ risk of collisions with human-made structures, increasing the risk of immediate mortality” (Nemes et al.). As a nonlethal source, artificial light at night has the ability to “attract birds in flight (affecting orientation), which causes them to change direction and lengthen the distance traveled (affecting route), which leads to increased energy expenditure in flight (effecting condition)” (Nemes et al.). Artificial or natural, nocturnal migratory birds are

evolutionarily attracted to light despite its source. Bright floodlights pointing upwards are capable of attracting nocturnal migrants and influencing them to “fall to their death from exhaustion” as they are unable to escape the light’s influence on their orientation and navigation (Nemes et al.). Flares and artificial lights from oil and gas drilling platforms are similarly capable of attracting and disorienting birds until they “die of exhaustion” or from “inhalation of toxic compounds, [and] incineration” (Nemes et al.). Migratory birds that manage to escape entrapment or burning ultimately still suffer injury and exhaustion, which reduces their flight performance and their ability to safely reach a stopover site for recovery (Nemes et al.).

A rising concern for migratory birds, similarly emerging amidst rapid urbanization, is sensory pollution in the form of noise. Increased human development and activity in urbanized regions is “accompanied by noise from [various] sources such as transportation, construction, and energy production” (Nemes et al.). Although noise pollution has been studied to be one of the least mortality causing anthropogenic threats, it is capable of affecting “birds nonlethally by interesting with inter- and intraspecies communication” which “induces stress” and causes “birds to alter their behavior and habitat use” (Nemes et al.). Thus, many birds avoid regions and areas with high levels of noise, causing the lengthening of their migratory journey. Noise pollution can also “mask acoustic cues that birds use to detect predators or prey, “ therefore “ hindering their ability to escape or find food” (Nemes et al.). Birds in noisy urban environments must expend more energy to remain vigilant as a form of protection, therefore allotting less time and energy for the foraging of food.

The threats that urbanization imposes on migratory bird species is slowly leading to the decline in population of specialist bird species as they are slowly being replaced by generalist species, increasing monogamous phylogenetic traits to appear within bird communities.

Scientists studying the large-scale negative impact of urban environments on the evolutionary uniqueness of birds found evidence that “bird communities in urban environments have lower average evolutionary distinctiveness [across] all countries” compared to bird communities present in predominantly rural regions (Morelli et al.).

Migratory birds with phylogenetic traits attributed to “larger clutch size, more generalist diets, and passage birds or species with more than one migration type” were found to be the most tolerant of urban spaces (Yang et al.). The terminology, clutch size, refers to the total amount of eggs laid by female birds in a single nesting attempt. Birds living in constantly changing environments have been studied to have larger clutch sizes, as the faster and increased reproduction rate is capable of overcoming the potential hazards of living in urban environments (Yang et al.).

In addition to larger clutch sizes, migratory birds with more generalist diets experience increased levels of survival traveling across urbanized regions. Generalist diets with less specialized restrictions help aid in the improvement of a migrant’s performance when foraging for food and facing decreased options for nourishment due to human disturbance (Yang et al.). Omnivores, who eat a wider range of plant and meat-based foods, were advantaged in city settings. Birds with specialized feeding strategies” such as insectivores and granivores however, “were negatively associated with urbanization” (Callaghan et al.).

The method in which migrants acquired and foraged for food played an important role in the survival of the birds. Compared to waterside or canopy foragers, ground-foraging species were found to be at a disadvantage as human activity and disturbance were greatest at the ground level (Yang et al.). Increased human presence at the ground level increased chances of trampling as direct sources of mortality and obstruction of proper food when foraging.

As I slowly transition into working on my creative project, I would like to aim to incorporate scientific concepts regarding how global urbanization poses a threat to migratory bird species. The main talking points I plan to highlight in my creative work involves how man-made structures, light pollution, and noise pollution negatively affect the migration timing, physiological condition, and the orientation and navigation of migratory birds.

My first creative proposal is to demonstrate these scientific concepts in the form of a video game mockup. While time constraints cause limitations for fully developing a video game, I plan to create mockups and conceptual drawings of a game that portrays how anthropogenic threats related to urbanization negatively impacts migratory birds' success of the migratory journey and lifetime fitness for survival. In the character design department, I plan on conducting research on a few bird species and creating stat charts each highlighting their specialized abilities and flaws. A concept drawing will be created, depicting the stage of the video game. I envision this stage, or video game setting, to be industrialized and placed in an urban environment. The game's level design, in which I brainstorm and create the mechanics, challenges, and interactions of the video game will prove to be the most difficult. Threat of man-made structures is displayed in the stage creation of the developmental process. However, characters are able to actively collide against these structures, causing their hit points or health bar to decrease. Sensory pollutants such as night lights at night and noise pollution present themselves as stage debuffs that can actively hinder the player's ability to safely navigate across the urban setting. Sketches and assets for these stage debuffs will be created in the mock up process. I envision my potential audience to be individuals who are less likely to seek out information regarding active threats against Earth's environment in the form of books and articles, and find it easier to engage with online interactive forms of media to help seek awareness and aid in informing their views.

Another potential direction for my creative proposal is to carefully create a curation of an exhibition showcasing how global urbanization poses a threat to migratory bird species. Due to time constraints acting as a limitation to fully curating a potential exhibition, I instead plan to create several infographics that would be placed in such an exhibition. Through the use of infographics, I would be able to directly communicate my scientific concepts regarding how man-made structures, light pollution, and noise pollution negatively affect the migration timing, physiological condition, and the orientation and navigation of migratory birds. I would create three infographic pages, one focusing on the threat of man-made structures, one focusing on the threat of light pollution, and one focusing on noise pollution. Through the use of graphic design to combine picture and text, I hope to create infographics that are easy to read and understand. I envision my potential audience to be individuals who find learning and extracting information easier in a colorful spread of imagery and text, rather than a long article, report, or book.

Works Cited

Callaghan, C.T., Major, R.E., Wilshire, J.H., Martin, J.M., Kingsford, R.T. and Cornwell, W.K. (2019), Generalists are the most urban-tolerant of birds: a phylogenetically controlled analysis of ecological and life history traits using a novel continuous measure of bird responses to urbanization. Oikos, 128: 845-858. https://doi.org/10.1111/oik.06158

Factual

- Migratory birds with more generalized, phylogenetically controlled patterns such as larger clutch size were most urban-tolerant.
- Specialized feeding strategies, such as insectivores and granivores, displayed lower survival rates.

Elmqvist, T., Andersson, E., McPhearson, T. *et al.* Urbanization in and for the Anthropocene. *npj Urban Sustain* 1, 6 (2021). https://doi.org/10.1038/s42949-021-00018-w

Factual

- The Anthropocene is defined by rapid changes in the current biophysical conditions of the Earth, largely driven by the predominance and accelerating growth of human activity.
- Urbanization acts as a constant accelerating aspect of the Anthropocene.

Goudie, Andrew S. *Human Impact on the Natural Environment: Past, Present and Future*. 7th ed., Blackwell Publishing, 2018. Google Scholar, https://books.google.com/books?hl=en&lr=&id=YZVdDwAAQBAJ&oi=fnd&pg=PR11&dq=human+actions+on+the+environment&ots=i2dld3vnzs&sig=P4Xh7R_ag1U8ZrDFg-jd5Edotok#v=onepage&q=human%20actions%20on%20the%20environment&f=false

Factual

- The 20th century is defined as a time of extraordinary change as the human population increased from 1.5 to 6 billion, the world's economy increased fifteenfold, the world's energy consumption thirteen to fourteen fold, freshwater use ninefold, and utilization of irrigated area fivefold.

Morelli, Federico, et al. "Evidence of Evolutionary Homogenization of Bird Communities in Urban Environments Across Europe." *Global Ecology and Biogeography*, vol. 25, no. 11, 2025, pp. 1284-1293. Wiley Online Library, https://doi.org/10.1111/geb.12486.

Factual

- Global urbanization is leading towards the culling of specialist species, and their replacement by generalist species, slowly increasing monogamy and similarity in traits amongst bird communities.
- Urban environments pose as a large-scale source negatively contributing to the evolutionary uniqueness of birds.
- Bird communities in urban environments display lower average evolutionary distinctiveness across all countries in comparison to bird communities that reside in rural areas.

Nemes, Claire E., et al. "More than Mortality: Consequences of Human Activity on Migrating Birds Extend Beyond Direct Mortality." *Ornithological Applications*, vol. 125, no. 3, 7 Aug. 2023, duad020, https://doi.org/10.1093/ornithapp/duad020.

Factual

- Urbanization has caused the most drastic transformation to the landscape to date.

- Consequences of threats do not always materialize immediately at the source.
- The repeated combination and interaction of minor nonlethal threats can synergistically lower chances of survival.
- Anthropogenic threat types emerging from global urbanization include but are not limited to human-made structures, and sensory pollutants such as artificial light at night and noise pollution.
- Migration Timing
    - Appropriate timing of arrival to breeding, stopover, and nonbreeding sites are crucial for securing food resources, avoiding difficult weather, increasing reproductive ability, and seeking high-quality mates and territories.
- Physiological Condition
    - Migrants must find food, avoid predators, and seek potential mates upon arrival at their destination.
    - The health and energetic condition of migratory birds influences their subsequent survival and reproductive success.
- Orientation & Navigation
    - Migratory birds utilize an internal clock and compass mechanism combined with alertness to external cues to aid in orienting themselves when navigating to destinations.
- Anthropogenic Structures

    - Human-made structures obstructing the airspace acts as a barrier to migratory movements, as birds are increasingly colliding against various anthropogenic structures throughout the world.
    - Collisions are responsible for delayed mortality and the creation of nonlethal effects that impose fitness costs on migratory birds.
    - Intracranial hemorrhaging is the most frequent injury in birds that survive collisions.
    - Collision survivors that manage to reach breeding grounds with broken and dislocated bones experience lower reproductive success compared to their uninjured counterparts.
- Artificial Light
    - Artificial light at night influences future survival and the reproductive success of migratory birds.
    - Artificial light at night greatly alters the nocturnal landscape.
    - Artificial light at night increases risk of collision against human-made structures, increasing risk of immediate death.
    - Nocturnal migratory birds are attracted to light regardless if it is emitted by an artificial or natural source.
- Noise Pollution
    - Areas of high human activity and development create various sources for noise such as construction, transportation, and production of energy.
    - Noise pollution is amongst very few anthropogenic threats that are cause for immediate sources of direct mortality.

    - Many migratory birds actively avoid noisy regions and habitats.

Conceptual

- Migration is the most dangerous period of the annual cycle for migratory birds as journeys are capable of spanning across several months and across various continents while navigating difficult, unfamiliar terrain.
- Migratory birds are adapted to overcome challenges posed by migration with ease, but human activity has greatly modified the environments birds must traverse en route.
- Direct and indirect anthropogenic sources of mortality can produce nonlethal effects in the form of delayed fitness costs, reducing migratory birds' probability for survival and ability to reproduce.
- Migration Timing
    - Anthropogenic threats encountered by migratory birds en route may delay their arrival to breeding sites, hindering reproductive ability and potential.
    - Delayed arrival to non breeding sites result in migratory birds spending the season in lower-quality habitats, and eventually delaying their departure in spring.
- Physiological Condition
    - Anthropogenic threats are capable of altering the physiological condition of migratory birds by reducing their energy level through an impairment to their ability to forage due to injury, illness, exhaustion, disturbance, and stress.

    - Anthropogenic threats can reduce the fat stores of migratory birds, leading to potential costs in fitness through the delayed timing or hampering reproductive abilities upon arrival to areas for breeding.
- Orientation & Navigation
    - Although migratory birds have evolutionarily evolved to navigate with ease in the face of changing conditions en route, anthropogenic threats are capable of interfering with their ability to accurately perceive and interpret environmental cues for orientation and navigation purposes.
    - Disoriented migrants deplete their energy reserves quicker during flight, imposing harsh fitness costs due to reduced physiological condition, delayed migration timing, or complete failure to reach the destination.
- Anthropogenic Structures
    - Traumatic brain injuries resulting from collisions and window strikes cognitively impairs reaction time, balance, sleep wake disturbance, and causes amnesia.
    - Ocular trauma, a common collision-related injury, can result in infection and necrosis, eventually causing vision impairments that leave migratory birds vulnerable to predatory threats and decreased efficiency in foraging for food.
- Artificial Light
    - Artificial light affects the survival and reproductive success of migratory birds by altering their migration timing, physiological condition, and orientation and navigation.

        - Artificial light affects the orientation or migratory birds by attracting their attention during flight, affects their route by causing changes in direction and length of flight, and affects condition by increasing the amount of energy expended.
        - Flares and artificial lights from oil and gas drilling platforms are capable of attracting and disorienting birds before they die of exhaustion, inhalation of toxic compounds, or death by incineration.
        - Birds that escape entrapment or burning often suffer exhaustion and injury, reducing their flight performance and hindering migratory birds' ability to successfully recover at an appropriate stopover site.
    - Noise Pollution
        - Noise pollution affects migratory birds by interfering with inter- and intraspecies communication, causing birds to alter behavior and habitat use, and inducing stress.
        - Noise pollution is capable of masking acoustic cues that migratory birds utilize to aid in the detection of potential predators and prey, therefore hindering their ability to escape or forage for food.
        - Noise pollution in urban environments causes migratory birds to expend more energy to maintain vigilance against predators, leaving less time and energy for foraging for food.

Yang, Mengxia, Corey T. Callaghan, and Jiayu Wu. "How Do Birds with Different Traits Respond to Urbanization? A Phylogenetically Controlled Analysis Based on Citizen Science Data and a Diverse Urbanization Measurement." *Landscape and Urban*

Planning, vol. 237, 2023, Article 104702. *ScienceDirect*, https://www.sciencedirect.com/science/article/pii/S0169204623001202.

Factual

- Birds with larger clutch sizes and more diverse, generalist diets were found to be the most tolerant of urban environments and spaces.
- Omnivores displayed higher urban tolerance.
- Passage migrants with multiple migration types, larger clutch sizes, and more generalist diets were the most commonly found in urban environments and spaces.

Conceptual

- Birds living in increasingly differing environments displayed larger clutch sizes, their fast and increased reproduction enabling them to overcome the hazards of living in urban spaces.
- Migratory birds with generalist diest display increased performance of foraging for food in the face of human disturbances.
- Unlike fast reproducing migratory bird species, migratory birds that reproduce slower and require specific resource requirements display decreased chances of survival and increased need for special protection strategies set in place by humans.
- Ground-foraging species are disadvantaged in urban spaces in comparison with waterside and canopy foragers, as increased human activity and disturbance at the

ground level are capable of trampling, destruction, and obstruction of potential sources of food and nourishment.