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Network of Conservation Educators and Practitioners

# LESSONS IN CONSERVATION

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## The Network Issue

***Lessons in Conservation*** is the official journal of the Network of Conservation Educators and Practitioners (NCEP)—a collaborative project of the Center for Biodiversity and Conservation (CBC) at the American Museum of Natural History—and is published as issues become available. Teaching and learning modules presented here in *Lessons in Conservation* are available in modifiable form for teachers on the NCEP website (ncep.amnh.org). All materials are distributed free of charge. Any opinions, findings, and conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the American Museum of Natural History or the funders of this project. All components of a module (e.g., Syntheses, Exercises, and Case Studies) have been peer-reviewed and approved for publication by NCEP.



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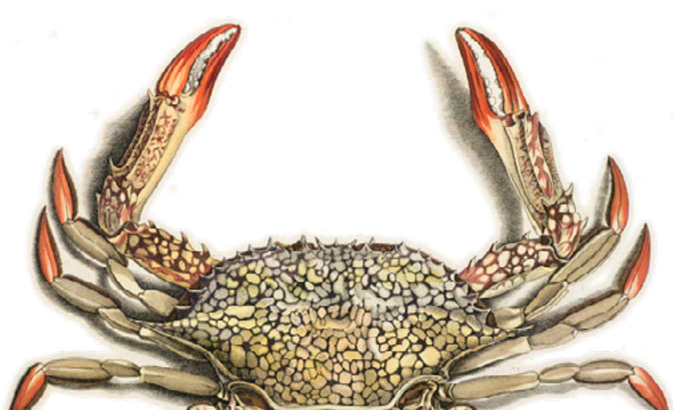



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# Letter from the Editors

Dear Reader,

Welcome to *Lessons in Conservation*, the official journal of the Network of Conservation Educators and Practitioners (NCEP). This journal aims to introduce NCEP teaching and learning resources, or "modules," to a broad audience. Our modules are designed to support undergraduate and professional level education on a variety of conservation topics and are freely available for download at our website (ncep.amnh.org).

Since 2015, NCEP has hosted an annual Conservation Teaching and Learning Studio where participants learn about evidence-based teaching and learning approaches, practice new techniques, and exchange strategies for (mainly) college-level conservation education. Studios are also launching pads for writing (or re-writing) educational materials, redesigning curriculum, and establishing new collaborations (for more, see our Studio Issue: amnh.org/research/center-for-biodiversity-conservation/resources-and-publications/lessons-in-conservation/volume-9). In this issue of *Lessons in Conservation*, we are pleased to present a suite of materials by participants of NCEP Studios, including case studies on the impacts of climate change on biodiversity and exercises engaging with issues of human-wildlife coexistence through mapping and stakeholder role-play. Indicative of the times, these materials include recommendations for implementation in both in-person and online classroom settings, and instructor guidance, solutions, and notes are available for download by registered educators on our website (ncep.amnh.org).

The last three years have been unprecedented for everyone, including NCEP, and these challenges—and opportunities—have been reflected in our Studios (see Perspective, *Exchange for Change: Learning from Our Network to Expand Our Teaching Practice*). We recently asked Studio alumni to reflect on questions such as: "how has the professional field or your teaching practice changed?" and "what will you focus on going forward?" Their responses are interlaced throughout this issue in three Perspective themes: *Lessons in Inclusive Conservation, Lessons in Remote Learning – The Classroom Experience*, and *Lessons in Remote Learning – Collaboration and Connection*. These Perspectives—which cover topics from equity in the classroom and the field to challenges and possibilities with remote learning—provide thoughtful and thought-provoking vignettes from our Network. Perspectives are an exciting new format we are launching with this issue, so stay tuned for future opportunities to contribute your own!

We hope you enjoy this issue of *Lessons in Conservation*. We invite you to visit our website to start using NCEP resources in your classroom, and we welcome your feedback. If you are interested in being further involved in the Network, we hope to hear from you! Finally, we wish to extend our sincere gratitude to the authors and reviewers who made the work we present here possible.

Suzanne K. Macey & Nadav Gazit

Visit us at: ncep.amnh.org. Contact us at ncep@amnh.org.

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# Decolonizing Primate Conservation in Africa: BIPOCs' Perspective

Reiko Matsuda Goodwin[i] and Edem A. Eniang[ii,iii]
[i]*Department of Sociology and Anthropology, Fordham University, NY, USA;* [ii]*Department of Forestry & Wildlife, University of Uyo, Akwa Ibom, Nigeria;* [iii]*Biodiversity Preservation Center, Akwa Ibom, Nigeria*

How has our field changed in the last several years? Unfortunately, the pace of decolonization in primate conservation in Africa has been slower than we wish it would be. While there are many definitions of decolonization (e.g., Tuck and Yang 2012), we consider it "a movement to eliminate, or at least mitigate, the disproportionate legacy of white European thought and culture in education" (Nordling 2018). Although there are some encouraging signs, many of these seem superficial. For instance, some Western primatologists now advocate that the colonialist term, "Old World," must be abolished and instead use the term "Afro-Eurasian." But if they, for example, continue to operate with colonialist attitudes in their interactions with Black, Indigenous, and People of Color (BIPOC), then they are not decolonizing the field.

The leadership positions of most primate conservation projects in Africa are often exclusively guarded by Western scientists and conservationists even when local collaborators are more knowledgeable. The project leaders' approach to local partners is often blatantly paternalistic. They frequently engage in a centralized decision-making system, othering competent BIPOC scientists, thereby proliferating parachute science (e.g., Fernández et al. 2019). This stark reality gives undue advantages to those in the West with structural privilege.

RMG is a Japanese immigrant and primate conservationist living in the USA who conducts conservation research in Africa. She has encountered numerous episodes of discrimination, microaggression, and colonialist attitudes in her career. EAE is a black Nigerian conservationist who witnessed many colonialist conservation practices in the last two decades. When he publicly criticized some white academics' colonialist attitudes, his career almost stalled. We both identify ourselves as BIPOC, who share similar negative experiences in primate conservation projects in Africa. Although our positionalities differ, our shared experiences give us a unique perspective allowing us to offer advice to conservationists in Western countries and BIPOC conservationists. The frequent thread among those with colonialist attitudes is a lack of sociocultural-psychological sensitivity and knowledge. We acknowledge the enormity of this issue but offer some practical and meaningful suggestions.

To conservationists in Western countries: Conscientiously create a team with people who do not look or speak like you in raising funds for a project, decentralize decision-making, and strive toward transparency. In your daily life, practice reflexivity or critically self-reflect on your positionality and recognize your privileges, cultural biases, and assumptions about racial stereotypes, and consider how these may influence your interactions with collaborators and community members. Stop forcing your own culture and manners from your geopolitical centers as normal upon us. Stop invalidating our feelings; instead, start treating us with respect and listening to different views.

To BIPOC conservationists: When we encounter colonialist attitudes that marginalize us, our experiences often solidify as trauma, but our internal struggles are invisible if we keep silent. We must voice against such attitudes, but with empathy for Western conservationists' obliviousness. This is far from easy—or fair—because we fear repercussions and wish not to be recognized for our colors and accents. Nonetheless, we must be brave and speak up!

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## Rethinking a Class: on Mushrooms, Molds, and Society

Natalie Howe
*Department of Environmental Science and Policy, George Mason University, VA, USA*

Inspired by the Black Lives Matter Movement, I changed my teaching to try to center equity; this involved centering the students and centering climate change. So, while the class I'm teaching is still Mycology, now I'm also teaching about history and culture, colonialism and agriculture, reindeer and termites, climate change and interdependence, entrepreneurship and listening.

I am still on a wobbly path of centering equity in the class. To do that, I focus more on student interests, student perspectives, and student ways of interacting with information. In that effort, I have made time to meet students one-on-one outside of class and ask them what they're interested in. Some students told me they wanted to learn more about fungal medicines, which led me to discover so many intriguing fungal stories to share, especially with recent research on fungal effects on brains and uses of fungi in mental health treatment.[i] I am also trying to be a teacher who meets people where they are; I realize that I was being too judgmental about content that I'd thought was hokey but that actually resonated with student interests and imagination, like the fungal metaphors in the Avatar movie. So, when I introduce fabulous research about mycorrhizal networks that helps reframe our view of the world as a highly cooperative space, I facilitate a discussion about how that metaphor applies in other contexts.

Following the students' lead has also helped me integrate more types of sources in the class; students have a diversity of things they hope to learn in the class, so a diversity of sources makes sense. Being more responsive to student requests on what the class covers leads me to include some content that is outside of my expertise, and in turn leads to my being more imaginative in class design. For example, since climate is so important for how fungi grow, climate change can easily pop into the center of conversations in our mycology class. So, I made more space for climate change discussion in my class, which made way for making space for discussing equity since colonialism, capitalism, and racism have shaped the inequitable patterns in wealth, access, and infrastructure that underly many drivers and responses to climate change. When I talk about fungal ecology, I now link those roles to climate resilience (e.g., holding soils and water during extreme events) or climate chaos (e.g., crop failures, animal diseases). Plus, I make more time for lively discussions about mushrooms as climate solutions: as alternatives to meat to reduce the land, water, and carbon footprint of our diets; as alternatives to plastic; and as waste management solutions. When one student was leading a climate action event, I encouraged the others to join, and, in the next class, we talked about student reactions to the event and the connections between campus activism and fungi in ecosystems.

So far, my attempts to center equity by centering students and climate change has made the class more open-ended, more hopeful, and more fun to teach, and I have really appreciated the opportunity to talk over my changes with friends, mentors, and colleagues in the Network of Conservation Educators and Practitioners!

[i] Goodwin, G.M. et al. 2022. Single-dose psilocybin for a treatment-resistant episode of major depression. New England Journal of Medicine 387:1637–1648.

# Observed Impacts of Climate Change on Biodiversity

Richard G. Pearson[i] and Stefanie J. Siller[i,ii]
[i]*Center for Biodiversity and Conservation, American Museum of Natural History, New York, USA;* [ii]*Department of Ecology, Evolution and Environmental Biology, Columbia University, Columbia University, New York, USA*

## ABSTRACT

There is strong scientific evidence that climate change is already impacting plant and animal populations, and model projections indicate that the current trends are likely to continue over the coming century. This synthesis reviews the observed effects of climate change on biodiversity, drawing on key findings from the primary scientific literature. Case studies covering a broad taxonomic and geographical range have been selected to provide examples of recent studies on these impacts including poleward and upslope shifts in distribution, changes in disease risk, phenological responses, coral bleaching, and regional and global impacts across taxa.

## INTRODUCTION

Evidence from the fossil record (Mayhew et al. 2008; Edie et al. 2018; Nogués-Bravo et al. 2018) demonstrate that changes in climate can have a profound influence on the myriad of species that comprise Earth's biodiversity. Predicted climate change over the coming century is therefore likely to have a significant influence on biodiversity (Rinawati et al. 2013; Bellard et al. 2014). Through this synthesis, students will review some of the main ways that climate change affects natural systems. Case studies have been selected to provide examples of observed impacts from the recent past, including poleward and upslope shifts in distribution, changes in disease risk, phenological responses, and coral bleaching.

The physical science of climate change is covered in the NCEP module *The Global Carbon Cycle and Climate Change* (available from https://ncep.amnh.org). The focus of this module is on the impacts of climate change on biological systems (see Box 1 for an overview). The scope of the module is to deal with responses of wild biological species and ecosystems, but not impacts on agricultural systems (see Wheeler and von Braun 2013; Kumar 2016) or human health (see Franchini and Mannucci 2015; Kreslake et al. 2016). There are a number of excellent extensive reviews of climate change impacts on biodiversity, notably Pecl et al. 2017, Bellard et al. 2012, Foden et al. 2013, and a book-length treatment by Pearson (2011). Rather than try to duplicate these reviews, this synthesis distills key findings from the primary literature into easily understandable summaries of a selection of case studies. Case studies were selected to give a fairly broad range of taxonomic (e.g., birds, insects, fish, and plants) and geographical (e.g., North and Central America, and Australia) examples.

## POLEWARD DISTRIBUTION SHIFTS

One of the expected impacts of climate change on biodiversity is a shift in species' distributions toward the poles (i.e., northward shifts in the northern hemisphere, and southward shifts in the southern hemisphere). This is because climates generally get cooler moving away from the equator, so particular climate regimes will be expected to move toward higher latitudes under climate change. Hitch and Leberg (2007) provide a good example showing northward shifts in the breeding distributions of North American birds as a result of climate change. Birds provide especially good subjects for investigating shifts in species distributions because: 1) birds distributions are generally well-known (especially in North America), with observations having commonly been made over a long

**Box 1. Climate change: impacts on nature**

At its 7th Plenary session in 2019, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) developed a critical assessment report on the condition and direction of the natural world and the implications of these trends. Notably, this assessment incorporated evidence from a wide range of sources and perspectives, including Indigenous and local knowledge, and therefore represents a more global and comprehensive synthesis. The following list summarizes some of the main conclusions of the IPBES plenary report regarding impacts of climate change on biodiversity:

- Climate change is a direct and substantial driver of changes in nature that also interacts with and magnifies the impacts of other drivers, such as land use change, overexploitation, pollution, and invasive species.
- Human activity has led to an increase in global temperature by 1.0°C compared to pre-industrial levels, an increase in frequency and intensity of extreme weather events in the past 50 years, and an increase in sea level by over 3 mm a year for the last 20 years. These changes have altered species distributions, population and community structure and dynamics, and ecosystem functioning.
- The impacts of climate change are predicted to accelerate in coming years, with exponentially worsening effects on biodiversity and ecosystem functioning. Effects will vary regionally, with tropical ecosystems facing particularly large declines in biodiversity due to the combination of climate change with land-use change and exploitation of fisheries.
- A global warming estimate of 1.5°C to 2°C is projected to cause a decline in range size for the majority of terrestrial species, which in turn will heighten the risk of global extinctions. Studies indicate that at 2°C warming, 5% of species will be at risk of extinction due to climate change. Local population extinctions are already well established and widespread.
- Nearly half of threatened land mammals (other than bats) and a quarter of threatened birds have potentially already been negatively impacted by climate change in some part of their range. The number of threatened species is predicted to increase due to climate change.
- The ability for species to respond to climate change will depend on their abilities to disperse, move to favorable conditions, or evolve.

time period, meaning that temporal dynamics can be studied; 2) bird ranges are known to be strongly associated with temperature (e.g., Root 1988); and 3) most birds have good dispersal capacity, enabling them to move around the landscape to track suitable climate conditions.

For their assessment, Hitch and Leberg (2007) used data from the U.S. Geological Survey's North American Breeding Bird Survey (BBS). The BBS is a very large initiative whereby trained observers annually record birds present along 3,500 roadside survey routes in the continental United States, southern Canada, and northern Mexico. The researchers tested for shifts in distributions using data recorded during the periods 1967–1971 and 1998–2002. To exclude possible confounding effects from large elevation gradients that would be expected to show upslope distribution shifts (see next section), Hitch and Leberg (2007) restricted their evaluation to central and east North America, thus leaving out the Rocky Mountains in the west. They also chose to exclude game birds, because their distributions have been greatly influenced by direct human interference, and to also exclude species dependent on aquatic habitats, since these were unlikely to be well sampled by the roadside surveys.

An important part of the study was to ensure that the analyses distinguished between general range expansions and true northward range shifts. Only assessing the northern range margins of species could result in the appearance of a northward range shift, when in fact the species is generally expanding, resulting in both a northward shift at the northern margin and a southward shift at the southern margin. While a true northward range shift in the northern hemisphere is most likely to have been caused by climate change, a general range expansion could be caused by other factors, such as changes in land use or increased supplemental feeding. An apparent general expansion could also result from increased survey effort in the later years. To get around these potential problems, Hitch and Leberg (2007) asked whether northern range margins were moving north, and/or if southern range margins were moving south. Because few species have both their northern and southern range margins included within the geographical scope of the BBS, the researchers divided bird species into those whose northern range margin was included and those whose southern margin was included. The authors also required that range margins were at least 200 km from the edge of the area sampled by the BBS to ensure that any shift in range would have been detected by the survey.

The results of the analysis showed that northern range margins had moved northward by a statistically significant average of 2.3 km per year. However, results for the southern range margins did not show a statistically significant shift to the south. Hitch and Leberg (2007) thus concluded that their results show a northward shift in sampled bird distributions over recent decades. The results are similar to those from a comparable study undertaken in Britain, which showed that the northern (but not southern) range margins of many species of birds had moved north by an average of 18.9 km over a 20-year period (Thomas and Lennon 1999). Since it is very difficult to identify other factors that could have caused northward range shifts consistent across many species and two continents, climate change is implicated as the most likely explanation.

An interesting question raised by this case study is why are southern range boundaries not also moving north? A response concerns the way that analyses of range shifts utilize presence and absence data: a small population colonizing a new area will be recorded as a ‘presence’, but ‘absence’ will not be recorded until population density has dropped to a level whereby the species is no longer detected. In effect, a single individual moving into a new area may be recorded as a range expansion and can be more readily detected over a short time span, but all individuals have to move out of an area in order for a contraction to be recorded, a much longer process. Thus, it is much easier to detect a range shift at the leading edge, as opposed to trailing edge, of the distribution (Thomas et al. 2006). For instance, a similar study by Brommer et al. (2012) looking at the range shifts of 148 bird species in Finland also found a poleward shift in the northern range margins by 1.1–1.3 km/year. However, despite using repeated surveys over multiple decades, the change in southern range margins was not significant (Brommer et al. 2012). In order to observe range contractions, it is therefore preferable to study abundance data, as opposed to presences and absences (see, for example, Foden et al. 2007; Howard et al. 2014).

## MARINE POLEWARD DISTRIBUTION SHIFTS

Terrestrial poleward distribution shifts have been well documented in a wide range of taxa (Hickling et al. 2006; Mason et al. 2015). However, poleward distribution shifts as a result of climate change are happening even faster in marine species, with an estimated range expansion of 72 km/decade (Poloczanska et al. 2013). Marine species are both more sensitive to climatic changes and more adept at colonizing new regions than terrestrial species, enabling them to expand their ranges on a wider spatial scale (Pinsky et al. 2020).

The ability for marine species to shift and/or expand their ranges can depend on a number of intrinsic factors, including rates of reproduction and dispersal abilities (O’Connor et al. 2011). For many marine species with a sedentary adult life stage, range shifts occur during the mobile larval stage. These larvae can disperse over great distances, producing juvenile “vagrants” that have moved beyond their typical range boundaries (Cowen and Sponaugle 2009). Many vagrants fail to survive because they are faced with temperatures outside their normal range; however, with ocean temperatures increasing, more vagrants may be able to survive beyond their typical boundaries.

Ocean currents also play a critical role in shifting distributions, particularly when combined with changing ocean temperatures (see Ling et al. 2008; Beaugrand 2009; Johnson et al. 2011). The East Australian Current, for example, moves southward along the coast of Australia, carrying warm water as well as larval organisms (Booth et al. 2007). Effects of climate change have driven an increase in both the temperature and flow rate of this current (Ridgway 2007), driving warmer water temperatures further south. This has provided potential opportunity for vagrants to expand their ranges poleward.

Fowler et al. (2018) used a long-term monitoring study to show how distributions of tropical reef fishes in southeastern Australia are responding to changes in the East Australian Current. From 2006 to 2016, Fowler et al. (2018) monitored tropical reef fishes in three southeastern monitoring locations in Australia: Jervis Bay, Narooma, and Merimbula. They conducted multiple underwater surveys per year at each site and recorded and identified observed reef fish species. These survey results were then compared to those conducted by Booth et al. (2007) from 2003 to 2005. Fowler et al. (2018) found that 30 tropical reef fish species had vagrants present in regions beyond the southern poleward boundary of their last reported location. This indicates that warmer temperatures are enabling vagrants to increase overwinter survival beyond their normal boundaries and may lead to established populations of adults in new southern regions.

This will be important to monitor, as tropical fish can have various impacts on ecosystems. For instance, 20% of the reported species are herbivores, including the three species with the most observed number of vagrants, and a poleward shift of these species presents a potential threat to kelp habitats. This study points to the potential impact that poleward shifts in marine species distributions can have on species interactions and communities, as a result of changing ocean temperatures and currents.

## UPSLOPE DISTRIBUTION SHIFTS AND EXTINCTION

Because temperature decreases with increased elevation, warming in a mountainous region causes conditions previously found at lower elevations to move upslope toward higher elevations. This is the reason why many glaciers on high tropical mountains are rapidly melting, as warmer temperatures usually found at lower elevations are now found upslope (IPCC 2014; IPCC 2019). While climate-driven latitudinal and elevational shifts have been reported for numerous species in temperate regions, empirical evidence for such distributional changes are more rare for tropical species (Pecl et al. 2017). Yet, tropical species are considered more sensitive to temperature changes than temperate ones due to narrower climate niches (Perez et al. 2016). Furthermore, because tropical species' distributions are impacted more by elevational temperature gradients than by latitudinal gradients, it is likely that tropical species will shift uphill in response to warming (Colwell et al. 2008). Molina-Martínez et al. (2016) provide the first empirical study on the effects of climate change on Neotropical butterfly elevational distributions.

From 2010 to 2011, Molina-Martínez et al. (2016) surveyed eight sites in the Sierra de Juárez mountain range in Oaxaca, Mexico. These sites, previously surveyed in 1988, ranged in elevation from 117 m to 3000 m. Using fixed transects and traps, the researchers sampled from April to October, when adult butterflies are most active. In addition, they used historical temperature data collected from three meteorological stations to estimate temperature for each specific sampling site in 1988 and compared this to data obtained using data loggers during the sampling transects. The data showed that temperatures had increased significantly across the entire area by an average of 1.3°C since 1988. This increase was even higher at sites below 1000 m, with an average increase of 1.8°C.

The authors found that since 1988, butterflies had increased their average elevational distribution across the entire gradient by an average of 145 m, with 65% of species showing an uphill shift. Species above 1000 m showed an even greater shift, with an average increase in elevational distribution of 308 m. In the latest survey, some species, such as *Pterourus pilumnus* and *Vanessa virginiensis*, were found only at the highest elevations. Because of the sensitivity of Lepidoptera to temperature, the researchers attribute this shift to climate change. If climate warming continues, potential suitable habitat may disappear, and these high elevation species could face extinction.

Below 1000 m, species also showed a significant elevational shift of an average 87 m upslope. However, the rate of change for these species did not keep pace with the rate of temperature increase. In addition, the researchers found that overall species richness had declined since 1988, particularly at sites below 2000 m. A number of species recorded in 1988 were not recorded in the 2010–2011 surveys, potentially indicating local population decline or extinction.

The study by Molina-Martínez et al. (2016) thus provides strong evidence that climate change is affecting montane communities. The dominant trend is that of upslope distribution shifts, with the potential for extinction in cases where the population is unable to move to higher elevation or adapt to new climatic conditions. Furthermore, the risks associated with climate change are compounded by other threats such as land-use change. Molina-Martínez et al. (2016) found that below 1000 m, there was a pronounced change in land use with an increase in agriculture and a corresponding decrease in rain forest. These shifts also impacted community structure; the latest survey showed an increase of up to 76% of generalist species in the low elevation area. As these species are well adapted to disturbed and open habitats, the researchers propose that this change in composition is indicative of local population declines and extinctions for species more susceptible to climate and land use changes. Land use changes could further impact species by reducing habitat connectivity, thereby limiting range shift potential.

## DISEASE RISK

There is concern that rising temperatures and changed precipitation regimes may favor certain pathogens, thus triggering disease outbreaks (for review see Altizer et al. 2013 and Wu et al. 2016). Vector-borne diseases are particularly responsive to climate change, as climatic shifts can impact the abundance and distribution of both the pathogen and the vector. For instance, the range of the white-footed mouse, an important reservoir host of the pathogen *B. burgdorferi*, is expanding poleward, thus altering the geographical range of Lyme disease (Roy-Dufresne et al. 2013). The emergence and spread of vector-borne diseases into new areas can have severe consequences for human health and food security (see for instance Ryan et al. 2019 and Anderson et al. 2020) as well as susceptible native species.

Increasing temperatures are also likely to be associated with higher prevalence of malaria, a disease caused by *Plasmodium* parasites (Garamszegi 2010). The arrival of avian malaria (*Plasmodium relictum*) and the mosquito vector *Culex quinquefasciatus* to the Hawaiian Islands has had considerable impact on the distribution and abundance of many native Hawaiian birds over the century, resulting in range contractions and even extinction (Warner 1968; van Riper et al. 1986; Atkinson and Samuel 2010). Indeed, the Hawaiian Islands are already experiencing warming, especially in the higher elevations that currently act as refuge from not only heat but from the transmission of disease as well (Giambelluca et al. 2008; Atkinson and LaPointe 2009). In their study, Atkinson et al. (2014) present empirical evidence for the association between avian malaria transmission and prevalence and changing climatic conditions in the Hawaiian Islands.

Atkinson et al. (2014) focused their study on Kaua'i's Alaka'i Plateau, a region characterized by montane rainforests and numerous endemic bird species. Using mist nets, they collected birds from three locations in the region over three periods: 1994–1997, 2007–2009, and 2012–2013, in both the summer and winter months. Birds were banded, measured, weighed, and blood samples were collected in order to detect the presence of parasites. The researchers then looked for associations and interactions between malaria infection, year, season, location, and native status of the bird, and compared the overall prevalence of malaria in birds from 1994–1997 and 2007–2013. They also determined changes in temperature from 1920–2007, using monthly temperature data from 18 weather stations as well as radiosonde temperature data. Finally, they measured long-term changes in precipitation and streamflow, using data from the National Oceanic and Oceanographic Administration and the United States Geological Survey surface-water data site. Both precipitation and streamflow are important for determining availability of habitat for mosquitoes.

The authors found that from 1994 to 2013, malaria prevalence more than doubled, from 8.6% to 19.6%. Increases were observed in most of the species sampled. The Puaiohi, or Kaua'i thrush (*Myadestes palmeri*), saw the largest increase at 22%, while the 'Anianiau honeycreeper (*Magumma parva*) only increased by 6%. The authors attribute these differences to potential variation in sample size, host defense behavior, host attractiveness, parasite resistance or tolerance, or other life history differences. Analyses of temperature changes showed that there was a 0.199°C increase per decade from 1960 to 2009. Precipitation and streamflow data indicated that the Plateau is becoming drier, but the availability of suitable mosquito breeding habitat has not changed over time. The authors suggest that because of declines in precipitation, high streamflow is occurring less frequently, thereby enabling mosquito larval habitats to persist for longer alongside streams. Persistence of these habitats may lead to increased abundance of mosquitoes on the Plateau, and therefore increased malaria transmission. Thus, the increase in malaria prevalence is associated with both increasing air temperature and shifting precipitation and streamflow patterns.

Atkinson et al. (2014) therefore illustrate that over the past two decades, avian malaria across the Alaka'i Plateau has significantly increased. These results support similar trends found in avian malaria increase at Hakalau Forest National Wildlife Refuge on the Island of Hawai'i (Freed et al. 2005; Freed and Cann 2013), though this study shows a much higher overall presence of malaria. Together, these findings are crucial for directing conservation efforts to protect native forest birds susceptible to the spread of avian malaria in Hawai'i under climate change.

## PHENOLOGICAL CHANGES

Phenology is the study of biological life-cycles throughout the year. Examples of phenological events include egg-laying and migration in birds, flowering and fruiting in plants, and reproductive periods in frogs. Such events are often closely related to climate. For example, warming each spring initiates a flurry of biological activity, related to growth and reproduction for many species. Climate change can thus be expected to have an impact on phenology.

Bradley et al. (1999) analyzed a dataset comprising phenological events recorded over a 61-year period at a site in Fairfield Township, Sauk County, southern Wisconsin in the USA. Phenological data were collected during two time intervals: 1936–1947 and 1976–1998. Interestingly, the first 11 years of data were recorded by famed ecologist and environmentalist Aldo Leopold, while the subsequent years were added by Leopold's daughter, Nina Leopold Bradley. Together they recorded 74 different phenological indicators, focusing especially on arrival dates for migratory birds and dates of first bloom of spring flowers. Examples of indicators recorded include arrival dates for geese (*Branta canadensis*), robin (*Turdus migratorius*), and meadowlark (*Sturnella magna*), and dates of first bloom for wild geranium (*Geranium maculatum*), forest phlox (*Phlox divaricata*), and marsh milkweed (*Asclepias incarnata*). Bradley et al. (1999) omitted 19 of the indicators from their study because there were too few records for statistical analysis, leaving 55 indicators that were investigated for long-term changes in the dates of events. All of these indicators occurred in the springtime (February-June).

Overall, 17 of the 55 indicators showed a statistically significant advance in springtime occurrence; in other words, during the period of study the event tended to occur earlier in the year. The data also showed that the timing of 20 indicators did not appear to change over the period of study, with dates of occurrence tending to stay roughly constant throughout the period of study. The remaining 18 indicators showed small responses, but none were statistically significant so these cases could not be classed as either responders or non-responders. Importantly, there were no cases with a statistically significant delay in springtime occurrence.

The earlier occurrence of spring events is an expected response to climate change: as the climate warms, higher temperatures arrive earlier and trigger life cycle events. The lack of any observed delays in phenology support the assertion that the trends in Wisconsin reflect twentieth century global climate warming. But why don't all indicators show a trend toward earlier occurrence? Many phenological events, such as bird migration and reproductive activity, are not regulated by climatic factors, but are instead related to other cues such as the number of hours of daylight per day (which is termed 'photoperiod'). We would therefore not expect these indicators to respond to changes in temperature and precipitation patterns.

One interesting conclusion of the Bradley et al. (1999) study is that some phenological indicators will respond to climate change, whilst others will not. Furthermore, the data show that species will respond by differing amounts. For example, geese were found to be arriving roughly half a day earlier per year, while forest phlox bloomed a quarter of a day earlier per year. Differing phenological responses can result in disruption of ecosystem interactions, such as birds failing to breed at the time of maximal food abundance (see, for example, Both et al. 2006 and McKinnon et al. 2012). This is called a phenological mismatch.

## PHENOLOGICAL MISMATCHES

The impacts of climate change on phenology are likely to vary substantially among different taxa. As a result, differential phenological changes in species that closely interact, such as plants and pollinators, may cause them to become increasingly mismatched in timing (for review, see Renner and Zohner 2018).

Migratory species in particular are tied to the specific phenological changes of other taxa. Migratory birds, for instance, rely on the availability of resources at their stopover sites to provide fuel for migration, and at their eventual breeding grounds to feed offspring. Birds must match their stopovers, arrival, breeding, egg laying, and egg hatching upon the phenology of plants and insects in order to maximize fitness (Marra et al. 2005). However, increasing temperatures earlier in the spring is driving an advance in the phenology of leaf growth and insect emergence (Renner and Zohner 2018). Many long-distance migrants, on the other hand, use photoperiod cues rather than environmental conditions like temperatures to signal the start of their migration (Dawson et al. 2001). Migratory birds must therefore shift the timing of their migration or else they may face a phenological mismatch with resources upon arrival at their breeding grounds.

Mayor et al. (2017) assessed the extent of phenological mismatch between migratory birds and vegetation in North America. Using citizen science data collected from eBird, they analyzed the arrival date for 48 passerine bird species over a 12-year period (2001–2012). For a proxy of food availability, they assessed "green-up" of vegetation using satellite imagery; green-up of vegetation has been shown to be strongly linked to insect emergence, a primary food source for passerine birds (Visser et al. 2012).

They found that between 2001 and 2012, green-up advanced an average of 0.372 days/year for all species. For 27 species, green-up significantly advanced by an average of 0.952 days/year. Species' arrival dates also accelerated by an average of 0.426 days/years for all species, and significantly moved up for over half of the species by an average 0.669 days/year. The exceptions to this trend were a delay in green-up by 1.52 days/year for four species, and a delay in arrival by 0.370 days/year for a single species (*Contopus sordidulus*). Mayor et al. (2017) note that when green-up advanced in an area, there was often a corresponding change in species' arrival.

The authors also measured phenological interval as the difference between a species' arrival date and the date of green-up. Seven species showed a significantly positive increase in phenological interval, with green-up advancing faster than arrival by an average 0.630 days/year. For two species, there was a significantly negative increase in phenological interval, with green-up occurring progressively later than arrival date by an average 1.60 days/year. For all changes in phenological interval, however, green-up had a greater phenological shift than did arrival. Furthermore, Mayor et al. (2017) found that these trends differed by region, with species in the Eastern Temperate Forest showing a positive change in phenological interval, and species in Western Forests displaying a negative change.

This study shows that many migratory birds do have the capability of adjusting their arrival time to the changing phenology of vegetation. However, for a subset of species, this adjustment is already failing to keep up with changes in green-up. Furthermore, keeping pace with an advancing spring can still produce phenological mismatches for a migratory species. Lameris et al. (2018), for instance, showed that although the migratory barnacle goose has advanced its arrival date to its Arctic breeding grounds, it was unable to similarly advance its egg laying. As a result, it still experienced a phenological mismatch with resource availability, leading to a reduction in offspring survival (Lameris et al. 2018). It is therefore important to consider additional breeding and reproductive phenologies to better understand the impact that climate change will have on producing phenological mismatches.

## CORAL BLEACHING

Coral reefs are one of the most biologically diverse ecosystems on Earth. Reefs support about 25% of all marine life, as well as a number of key ecosystem functions (NOAA 2019). A review by Brandl et al. (2019) highlights eight core ecosystem processes provided by coral reefs, including nutrient cycling, herbivory interactions, and $CaCO_3$ dynamics. In addition, coral reefs provide foods and services that are critical to people's well-being. An estimated six million people depend on coral reef fisheries for their livelihoods (Teh et al. 2013), and coral reefs are also valued for their aesthetics and spiritual importance (Cinner and Aswani 2007; Hicks et al. 2009).

Almost all corals live in a symbiotic relationship with zooxanthellae, a type of single celled algae that lives within the coral's tissues. Zooxanthellae photosynthesize, and in doing so produce compounds that are absorbed as a food source by the coral. Bleaching occurs when this coral-algae relationship breaks down, resulting in the loss of the zooxanthellae from coral tissues, and consequently a loss of color. Although corals can survive bleaching events, mortality tends to occur if the bleaching is prolonged. Bleaching can be caused by changes in salinity, intense solar radiation, exposure to air by low tides or low sea level, sedimentation, or chemical pollutants such as herbicides and oil (Reaser et al. 2000). In addition, the rate of ocean warming has more than doubled since 1993 (IPCC 2019), and observations have shown a significant correlation between bleaching events and high sea surface temperature (see Eakin et al. 2010, Krishnan et al. 2011, and Bindoff et al. 2019).

Large-scale coral bleaching events have increased in frequency in recent decades, and going forward, temperature anomalies capable of triggering severe bleaching events will also rapidly increase (Kleypas et al. 2021). It is predicted that most coral species will not be able to recover quickly enough to survive these changes (Kleypas et al. 2021). Reef resiliency is further impaired by two additional consequences of climate change: an increase in the intensity and frequency of storms and a decrease in the pH of seawater (termed "ocean acidification"). Frequent, intense storms like hurricanes and cyclones damage the physical structure of the reef, and ocean acidification slows coral growth and can weaken the calcium carbonate structure upon which the polyps live (Hoegh-Guldberg et al. 2017; NOAA 2021). In sum, these climate change stressors can cause compounding effects: coral weakened from ocean acidification or recent bleaching events may be more susceptible to the damaging effects of intense storms.

Coral reef ecologists use several techniques to study past bleaching events and model future bleaching scenarios. For example, after the Great Barrier Reef's mass bleaching event in 2015–2016, researchers conducted aerial surveys to assess the extent of bleaching at 1,156 individual reefs along the reef's 2,300 km length—the largest reef ecosystem in the world. Divers conducted detailed belt-transect underwater surveys via SCUBA to verify the accuracy of these aerial survey bleaching scores. The aerial and underwater bleaching data were then compared with satellite-derived sea surface temperature data and bleaching models, which showed a "tight" correlation between the level of local heat exposure and the severity of bleaching on individual reefs (Hughes et al. 2017).

Climate change is the greatest threat to coral reefs worldwide (GBRMPA 2019). At a global warming increase of 1.5°C, coral reefs are projected to decline by up to 30% of their former cover (IPBES 2019). As global warming progresses and sea surface temperatures increase, the potential for climate-driven mass bleaching and coral mortality during hot summers—regardless of El Niño events—is even more likely, and this shorter window of time between bleaching events makes it harder for corals to recover (Hughes et al. 2018). Corals and the ecosystems they support are therefore dependent upon the reduction of global greenhouse gas emissions and the management of local stressors (e.g., sedimentation, pollution) to bolster their resiliency. Maintaining healthy reef ecosystems will be critical for the local human populations that depend upon coral reefs for their food, livelihoods, and well-being (Burke et al. 2011).

## META-ANALYSES

Many studies have described impacts of climate on biological systems. For example, in this synthesis we have seen how climate is affecting birds, butterflies, and plants in North America, reef fish in Australia, and corals around the world. However, most individual case studies such as these are limited to a particular region and/or a limited sample of taxa. Because species may be impacted by many different factors (for example, habitat destruction, introduced species, or nitrogen deposition), it is often difficult to demonstrate a strong influence of climate change in any particular study. Researchers have therefore examined results from a large number of individual studies using an approach called "meta-analysis," which is a type of statistical method for exploring trends across multiple studies.

Pacifici et al. (2017) undertook a meta-analysis to better understand the impact that climate change has already had on birds and mammals, and the life-history traits that make species vulnerable to these changes. Since climate change is a global phenomenon, it is expected that certain traits will be consistent across different regions and taxa. Such traits include distribution, population size, phenology, behavior, genotype or phenotype. The authors conducted a literature search for studies between 1990 and 2015 that showed a change in climate in a specific area, and a corresponding climate-induced change (or lack of change) in a species' trait. They used data from 70 studies on 120 mammal and 569 bird species. A species' response was categorized into one of four types: "negative" if at least 50% of its populations had a decrease in population, range size, survival, reproduction, or body mass; "positive" if there was an increase in these traits or a change in phenology; "unchanged" if there was no response; or "mixed" if opposite responses were shown within a species. Pacifici et al. (2017) then determined the relationship between a species' inherent and spatial traits, and their response to climate change.

The study found that of the 689 species analyzed, 38.3% of mammals and 20.9% of birds had shown a negative response to climate change. Negative responses were associated with a number of spatial traits. For both birds and mammals, species most at risk occurred in regions with large recent changes in temperature and low seasonality of rainfall. Negative responses in birds were also associated with species living at high altitudes, in areas with low seasonality of temperature, and high maximum temperature at breeding sites. Species that inhabit areas with low seasonality of temperature and precipitation generally have a narrower ecological niche, and thus are more vulnerable to climatic changes. In addition, species living at high altitudes are often more restricted in range, with less opportunity to move upslope to escape increasing temperatures.

For intrinsic traits, negative responses were associated with mammals with a narrower diet, and birds with low dispersal, long generation times, and limited altitudinal range. Mammals most at risk were primates, elephants, and marsupials.

Only two mammal orders had positive responses to climate change: rodents and insectivores. These orders include species with fast reproduction time and wide habitat generalization. Interestingly, most of the species in this category were also fossorial, or burrowing, which may allow them to limit exposure to temperature changes. On the other hand, the majority of bird orders did not have a negative response to climate change.

By quantifying the number of species that have been impacted by climate change, this study illustrates the wide-ranging impact that climate change has had over the last century. The authors estimate that 47% of mammals and 23.4% of birds have had at least one population already negatively impacted by climate change. While many assessments of a species' vulnerability to climate change use modeling to project future risk under various climate change scenarios, it is important to consider the recent and current impacts of climate change on biodiversity. The findings demonstrate that climate change is a common force discernable in natural systems all around the world. Although, in individual cases, other threats may have a more overriding impact on species, climate change is an underlying force with the potential to directly (e.g., warmer seas causing coral bleaching) or indirectly (e.g., changing temperature and precipitation patterns promoting disease epidemics in birds) impact biodiversity.

## CONCLUSIONS

Species have survived major climatic changes throughout their evolutionary history (Mayhew et al. 2008). However, the case studies presented in this synthesis suggest that contemporary anthropogenic climate change presents a significant threat to biodiversity. Furthermore, while the case studies provided here highlight the impacts of climate change to particular species or taxa, it is crucial to remember that natural systems comprise a complex web of interactions and feedbacks among species. As we saw in the Phenological Mismatch example, climate change impacts on a single species could have significant knock-on impacts on many other species, resulting in changes to the community as a whole (see Brown et al. 1997 for a case study example). The different ways and degrees to which different species respond to climate change will alter community interactions and ecosystem functioning in numerous and important ways (Pecl et al. 2017).

A key factor that differentiates contemporary climate change from past changes is that the impacts are combined with multiple other stressors, in particular habitat fragmentation. Natural systems in the twenty-first century exist on a planet that is dominated by humans, with over 75% of the ice-free land surface showing evidence of human modification (Ellis and Ramankutty 2008). The combined effects of rapid climate change and unprecedented habitat loss and fragmentation have the potential to greatly reduce global biodiversity (Mantyka-Pringle et al. 2012). Invasive species are another major driver of biodiversity loss. Under climate change, the distribution, abundance, and impact of invasive species are likely to be altered. Invasive species are often suggested to expand under climate change, as they are usually abundant, possess broader physiological niches, and inhabit a wider range of environments than other species (Hellmann et al. 2008). In particular, climate change is expected to impact invasive species by altering the mechanisms of their introduction, changing climatic constraints, varying species distributions, modifying their impact, and shifting management strategies and effectiveness (Hellmann et al. 2008).

Climate change thus presents an important challenge for conservation efforts. Ecosystems, and the biodiversity they hold, are of immense value to human society, providing many essential goods and services, including the recycling of waste, generation of soil fertility, pollination of crops, and regulation of climate (Millennium Ecosystem Assessment 2005; see also the NCEP module *Why is Biodiversity Important?* available from https://ncep.amnh.org). The effect of coral bleaching due to climate change on human populations through impacts on fish stocks and tourism has already been discussed earlier in the synthesis. However, climate change impacts food security in a wide variety of ways, as changes in temperature and rainfall limit crop productivity (Wheeler and von Braun 2013), and changes in weather impact availability, accessibility, and utilization of food systems (Gu et al. 2010). Tripathi et al. (2016) review the numerous ways in which climate change will reduce both the quality and quantity of major food sources across the world.

Predictions of continued rapid climate change over the coming century have prompted many attempts to estimate future impacts on biodiversity. Various methodological approaches have been taken to estimate future impacts, including the use of correlative and mechanistic species distribution models (Bradley et al. 2010; Kearney et al. 2010), dynamic vegetation models (Campbell et al. 2009), species-area relationships (Carnaval et al. 2009), IUCN status methods (Chevin et al. 2010), and dose-response relationships (Barnosky et al. 2011; for review see Bellard et al. 2012; see also the NCEP module *Species Distribution Modeling for Conservation Educators and Practitioners* available from https://ncep.amnh.org). In one high-profile study, Thomas et al. (2004) estimated that, on the basis of a mid-range climate warming scenario for 2050, 15–37% of species in their sample of over 1,000 study species would be on a trajectory toward extinction. Such predictions of extremely high extinction risk due to climate change have generated a great deal of debate among scientists, politicians, and the broader general public. Uncertainties inherent in the predictions, along with debate as to how (if at all) society should manage the threat, make this a controversial debate. Management options revolve around reducing climate change through reductions in atmospheric greenhouse gas concentrations, and developing dynamic approaches to contend with changing conditions, for example by incorporating potential shifts in species' distributions into the planning of new natural reserves (Williams et al. 2008).

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# Exchange for Change: Learning from Our Network to Expand Our Teaching Practice

Kimberley Landrigan, Suzanne K. Macey, Nadav Gazit, Kristin E. Douglas, and Ana L. Porzecanski
*Network of Conservation Educators and Practitioners, Center for Biodiversity and Conservation, American Museum of Natural History, New York, USA*

The global COVID-19 pandemic upended workplaces worldwide and the Network of Conservation Educators and Practitioners (NCEP) was no exception. In Spring of 2020, we were in the initial planning stages of our annual Conservation Teaching and Learned Studio (typically held in June at the American Museum of Natural History in New York). Suddenly we were asking ourselves not only about the logistics of holding the event (*how do we move our training to an online format?*) but also reflecting on the needs of our community (*in a time of considerable change and uncertainty, how can we best support our network of educators?*). We decided to turn to our community directly, in order to better understand their needs, interests, and preferences for information sharing and events before launching our own online Studio. Unbeknownst to us then, this marked a decided shift towards exchange in our professional development endeavors.

Exchange had always been a goal of NCEP Studios, but we found that pandemic realities made it possible in new and important ways. First, being aware that everyone was receiving a flood of online resources and opportunities as the realities of pandemic life unfolded, we surveyed our community before planning our online debut. In place of our customary three-day in-person event, our initial reimagined Studio took place over a four-week period in July 2020 with a total of three hours of synchronous and asynchronous programming each week. Importantly, the online format reduced costs and travel requirements as well as resolved space limitations, enabling us to reach a wider audience than ever before—more than twice as many participants as in 2019. Additionally, given the interest from our network, we held two concurrent events: a traditional training event for educators relatively new to practicing active and evidence-based teaching techniques; and a "Community Exchange" for those educators experienced in active teaching who needed support in their transition to online learning formats, and an opportunity to learn from peers. This latter format would be distinctive for its emphasis on co-creation (for example, we did not know what topics we would delve into beforehand!) and exchange, centering the experiences of our participants, as we all shared our own perspectives, tips, and approaches.

Our online event format would adapt as our community's needs and availability changed in the months and years ahead, but the shift to online training allowed NCEP to hold more events and respond to the needs of our network more than ever before. For instance, in 2021 we saw the need and opportunity for an optional "sharing and work session" for recent Studio alumni to continue building community. Participants could ask the NCEP team or other alumni for advice and connect with other group members to continue making progress preparing their classroom materials. Additionally, our initial Community Exchange generated a list of online teaching resources that is still being updated, refined, and shared among our wider network (please email ncep@amnh.org for more information). We also continued our emphasis on exchange and learning from our community. In Spring 2022, we offered a two-session "Educator Exchange" for Studio alumni and their colleagues focusing on centering equity when teaching conservation, drawing on the experiences of our colleagues at the Center for Biodiversity and Conservation. We continued this topic in our most recent Educator Exchange in October (following our summer Studio), organized in collaboration with the Society for Conservation Biology (SCB). Over 30 educators convened to discuss what competencies and literacies should be fostered in conservation education to meet the broadening scope of conservation practice. Social justice and equity are fundamentally important dimensions of conservation practice, and educators are increasingly seeking to make them a central part of their teaching and conservation competencies. Across the two exchange events this year, participants highlighted the role of social justice and equity, as well as affect, and collaboration, and multiple ways of knowing, as essential for a holistic conservation classroom today.

NCEP's Conservation Teaching and Learning Studios and other professional development events have never been about "right" or "wrong" ways of teaching, but about fostering a critical teaching practice and connecting educators to a wider array of tools for their teaching toolkits. The past three years have offered us new ways of connecting with and learning from each other and our network, further expanding our own toolkit. Moving forward, we intend to keep online training and exchanges as an important part of NCEP's professional development portfolio, even as we re-introduce in-person events at the Museum. We also look forward to new and continuing collaborations with organizations and associations such as SCB-North America. We envision this emphasis on true exchange and learning will lead us to a more effective community of practice and subsequently, a more inclusive conservation community.

## Teaching Ecology and Conservation: Lessons from the COVID-19 Pandemic

Maya M
*Department of Sociology and Social Work, CHRIST (Deemed to be University), Bangalore, India*

As a teacher leading an interdisciplinary course on Social Ecology for undergraduate social science students, the shift to online sessions due to COVID-19 was a challenging experience that nevertheless expanded my teaching and learning canvas. My reflections on that experience are informed by the feedback from my students.

> *"... the prompts in the running whiteboard made me curious and made me reach out to my friends to know what happened during the class which I missed."*

Interrupted internet and power supply and technical glitches often affected the smooth flow of the classes from both ends. In addition to recording the sessions and pre-recorded videos of certain important concepts, as a class, we realized the possibility of having a running whiteboard in the form of a Google document where every student could comment. This was a valuable space for collaborative learning as students used it to comment on related works, visual texts, or case studies.

> *"Online sessions helped me to overcome my fear of discussing openly in the class and I am happy that people were acknowledging the points I raised through Webex whiteboard. I would not have opened my mouth in a regular class."*

I learned to be mindful about students with different learning abilities and other challenges to being an active participant in the class. A sense of anonymity, while using tools like whiteboard in the Webex platform or Mentimeter, gave introverted students an opportunity to voice their opinions and contribute to classroom discussions. This experimental phase has also made me realize the importance of continuous feedback and conversations with students to make each session interesting. The feedback "I think there was much more learning through online classes, the perspectives which we got through discussion forums were enriching…" summarizes the way in which some students reacted to these kinds of exercises.

> *"… the emphasis at each stage for reflection had an impact on the way I connect myself with the environment."*

Reflective weekly essays were a regular mode of engaging students through asynchronous platforms. As a class, we realized the importance of learning in small chunks to help learners stay on track and pausing for a moment to reflect on why it is relevant for each of us. Using pre-recorded videos or related content for self-guided learning provides more space for reflective thinking and discussions in the classroom. Other strategies I now employ include having separate sessions to connect the discussions back to the syllabus and using online gamification tools like Quizziz. These strategies help me and the learners evaluate their learning and the classes become more interesting too.

The stresses of the pandemic and the transition to remote learning (and the associated digital overload) affected the attention span of my students. At the same time, I noticed a positive shift in the way my students related to the resources and the natural environment around them. A shared knowledge that came out through the classroom experiments during the pandemic was a mindful way of locating ourselves as *Homo sapiens* and having a critical way of examining conservation efforts. Discussions and activities during Social Ecology classes were also a search within, both for the teacher as well as the students.

## A Metamorphosis During COVID: a Biodiversity Mapping Exercise

Amadeus DeKastle
*Environmental Sustainability and Climate Science Department, American University of Central Asia, Bishkek, Kyrgyzstan*

Until COVID and the ensuing necessity to transition my classes to online teaching, one of my favorite projects was during the early Fall semester when my students and I would work together to photograph and collect geolocation data on butterflies in and around the city of Bishkek, Kyrgyzstan. Then, using some simple mapping tools, we'd produce a map of various species within the city showing how different butterflies inhabit different places. This outdoor practical experience was always very popular with students, but, as all teachers know, there are always ways to improve and integrate assignments. Even though

I'm always on the lookout for those improvements, I certainly wasn't expecting them to come as a result of a global pandemic.

During quarantine and lockdown, university policy prohibited external meetups thus making it impossible to do any data collection together in the field. As a result, I needed to re-evaluate how to run this project because I didn't want to lose the "hands on" aspect that I knew students enjoyed so much, and it was still possible to get students out of their homes without any trouble. Instead of going as a group to collect data, students were given three easily accessible locations throughout the city and asked to spend time at each of them collecting data on their own. Since the data was localized in those three areas, students could combine their data into a larger dataset and do some simple comparative statistics between the three locations. Best of all, the project steps were simple enough for my students to follow through online instruction and provided self-directed learning in multiple areas: field work, identification, technical integration, data management, statistics, and GIS.

Upon returning to the physical classroom, I realized that I preferred the new format for this project as it offered more autonomy: my students could take learning into their own hands. The original project also missed out on the integration of statistical analysis that the online change had spurred. So, as a result, I've decided not to change back to the pre-COVID format of this project. In this way, being forced into online teaching required me to re-evaluate my assignment. The result is a project that is not only online friendly, but more integrated with the course content and learning while also building stronger, more resilient students through self-directed learning. I think that changing this assignment improved it, and the process encouraged me to breathe new life into old projects by incorporating similar self-directed elements, like conservation journaling and mapping, into other courses I teach.

# Finding a Place for Panthers: Mapping Conservation Issues Related to Florida Panthers

J. Stephen Gosnell[i,ii], David P. Green[iii], Laila Akallal[i], Chelsea Wepy[i], Gregory Laghiti[i], Muspika Akter[i], Noa Heller[i], and Nihal Ozgur[i]
*[i]Department of Natural Sciences, Baruch College CUNY, New York, NY, USA; [ii]The Graduate Center of the City University of New York, New York, NY, USA; [iii]National Center for Science and Civic Engagement, Washington, DC, USA*

## ABSTRACT

Restoring wildlife populations requires locating, protecting, and connecting areas where species can thrive under both ecological and anthropological conditions. Addressing these spatial needs may be difficult, as required habitats may have been lost, fragmented, or altered prior to restoration. Changes in land use may also lead to increased human-animal interactions that impact restoration outcomes. In this exercise, students consider these issues in a case study of Florida panthers (*Puma concolor coryi*), a currently federally protected carnivore that has a growing population in the state of Florida, USA. Students will use Google Earth to view, manipulate, and create maps related to the growth of panther populations and related habitat needs and human interactions from the early 1990s to 2021. In doing so they will explore how stakeholders interact with each other and with panthers regarding both their hopes for species restoration and the areas they represent or occupy. Students will also consider various ways stakeholders may be engaged to provide panthers with increased protection and expanded ranges, including land acquisition, conservation easements and banking, and wildlife corridors.

## LEARNING OBJECTIVES

After completing this exercise, students will be able to:

1. Produce maps by uploading, opening, and manipulating spatial datasets in Google Earth, including adding placemarks and changing display properties.
2. Identify and define methods used to increase habitat and connectivity for endangered species, including land acquisitions, conservation easements, wildlife crossings, and conservation banking, and discuss why stakeholders use these methods.
3. Discuss how the spatial needs of species and stakeholders interact to determine ecologically and socially acceptable management strategies.

## INTRODUCTION

Although efforts to restore native populations—including reintroductions (Taylor et al. 2017) and supplementations (Seddon et al. 2014)—are becoming more prevalent, a common source of tension is determining where and how species ranges should be developed or expanded. The habitats species require to thrive may have been lost due to conversion to other uses, such as agriculture, grazing, and urban development; habitats may also have been degraded due to factors such as pollution and climate change (Kerr and Deguise 2004; Maxwell et al. 2016). Even when patches of optimal habitat still exist, they are often too small to meet species needs (Banks-Leite et al. 2020) and fragmented. Re-establishing ranges for growing populations may thus require using various conservation tools to create a patchwork of connected habitat parcels that may differ in habitat quality and protection status due to their history and land use restrictions.

Along with increases in the population size of restored species, changes in habitat availability and efforts to connect parcels may lead to increased human-animal interactions. These interactions may have direct (via mortality or fitness) or indirect (via public or financial support) positive or negative impacts on restoration outcomes. This is especially true when the focal species are apex predators [e.g., sea otters (Pinkerton et al. 2019), tigers (Doubleday 2018)] since stakeholders[1] may have concerns regarding potential impacts of predator consumption on humans, pets, livestock, and large game (Lopes-Fernandes and Frazão-Moreira 2017; Niemiec et al. 2020; Sakurai et al. 2020) or associated non-consumptive effects (Laporte et al. 2010). These concerns must be balanced with the potential benefits that restoring predator populations and protecting habitats can have for ecological and human communities (Gilbert et al. 2017; Martone et al. 2020).

Attempts to restore the Florida panther (*Puma concolor coryi*) population in Florida exemplify these issues. Beyond its status as a predator, spatial considerations are especially relevant given the large habitat needs of the species. Efforts to recover the existing population through genetic introgression[2] and protecting habitat over the past thirty years have been successful, but now managers must decide how to handle the growing population and range needs of this large felid. In this activity you will follow changes in the panther population and habitat usage from this period and ponder future options for the continued restoration of the species. In doing so you will consider the needs of various stakeholders and learn how mapping species and stakeholder needs can provide a visual context for exploring, valuing, and comparing management options.

## EXERCISE

This exercise is a sequential activity and is designed so you can see the changes in panther protection and restoration in Florida over time. Questions are spread throughout to assess your grasp of skills and concepts. A full list of questions contained in the exercise can be found in Appendix 1. Numbered responses to questions should be aggregated in a short report document for submission.

In this exercise students will use Google Earth, a free geodesign tool, to map the habitat usage and needs of Florida panthers and then relate them to the needs of various stakeholders. Maps allow the spatial aspect of data to be easily visualized and may offer insight on where restoration may be more supported given the needs of panthers and desires of human communities. Reading related media articles will supplement and provide context to GIS-based (geographic information system) activities.

Google Earth (https://www.google.com/earth/) is software produced by Google that offers access to satellite and aerial imagery of different parts of Earth that can be used to produce static or interactive maps. The Google Earth platform has been utilized for conservation research and outreach. For example, scientists have used Google Earth to study deforestation in Gombe National Park, Tanzania (Pusey et al. 2007), and classify different mangrove communities (Calva et al. 2019). Also, the Jane Goodall Institute has produced an interactive Google Earth Voyager story titled Goodall, Gombe and Google (Jane Goodall Institute 2017).

The below instructions focus on using the web-based version of Google Earth, given its ease of access and use across platforms. This also allows the exercise to be easily completed via in-person, remote, or hybrid learning modalities. In all modalities, students will need access to a computer with connection to the internet. Images below were formed using Google Earth version 9.176.0.1. Notes on implementing the exercise, copies of the articles used in this exercise, and information on potential extensions to this activity are available in the Instructor Notes, which can be downloaded from the NCEP module website (https://ncep.amnh.org/).

### Importing panther data into Google Earth

First, launch Google Earth. Visit https://www.google.com/earth/; the application should automatically load, resulting in an image of the earth. Once loaded, note you can move around the globe or zoom in and out for different views using your mouse and/or keyboard. Different types of data, such as names and locations of natural (e.g., lakes), political (e.g., boundaries), and man-made (e.g., roads) features can be displayed using the Map Style menu (Figure 1). **Make sure you can navigate around the globe and select different types of data to display before continuing.** Users can also create their own features (points, lines, and polygons) to overlay on top of these images using tools in the software. You will learn to create these features as part of the exercise.

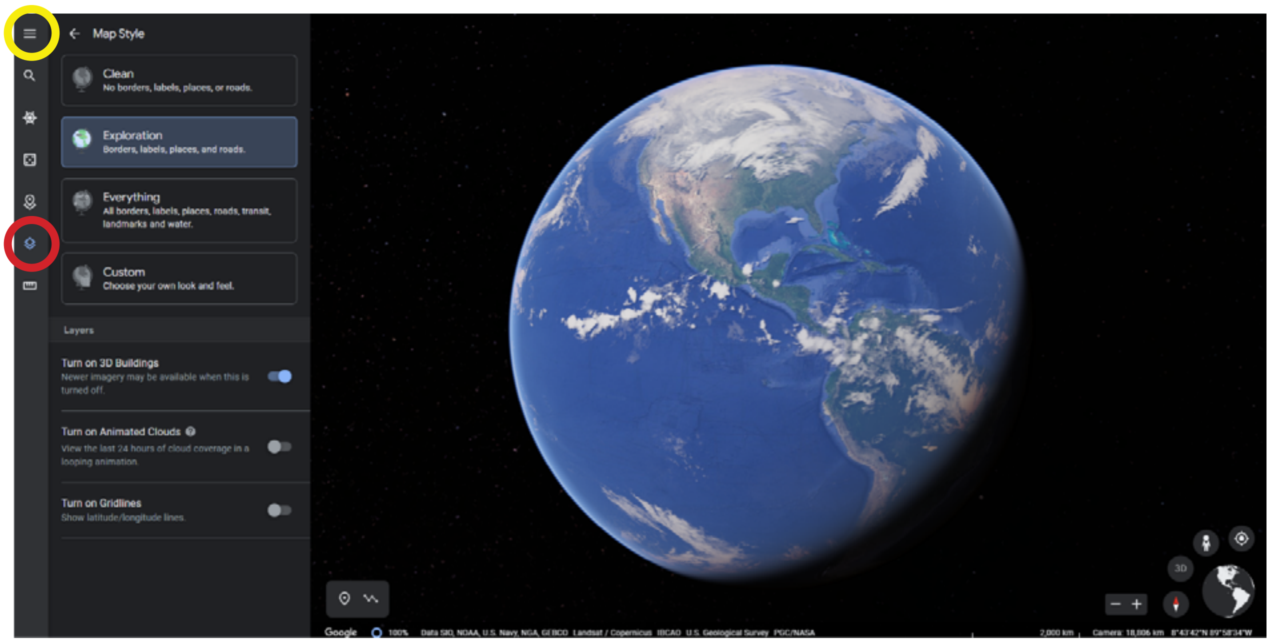


Figure 1. Users can choose the type of data displayed on Google Earth under the Map Style menu (outlined in red). Users can also change settings by selecting the Menu button (outlined in yellow) and then Settings (the gear icon) on the pop-up menu.

Next, download the exercise file (.kml or .xml file extension) that is available as a supplementary file with this module at https://ncep.amnh.org. Then import the file into Google Earth. For the web version of Google Earth, select the **Projects** menu (Figure 2). Then choose **Open** and choose to upload the file from your computer. Once opened, you may see a pop-up asking for permission to store the file (common on Chromebooks); please allow this so you can edit the map as required for later questions.

After you have imported the data, your Project should automatically open and look like the image shown in Figure 3. The loaded file combines data from several datasets previously published and mapped by the Florida Wildlife Commission (FWC). The combination of spatial data and information on how programs should render it are known as layers. The column on the left shows the various layers that are contained in the file.

In the web version of Google Earth, these layers cannot be expanded or collapsed, so you will also see various sub-layers contained in each layer (denoted by a folder icon). These sub-layer folders can be expanded further to show the actual features (polygons and placemarks) that can be displayed on the map (Figure 3, icon outlined in yellow). These features identify areas needed for the continued survival and restoration of Florida panther populations (Logan et al. 1993; Kautz et al. 2006) and document panther interactions with humans.


Figure 2. You can import KML or XML data into the web version of Google Earth by using the Projects menu (outlined in red).

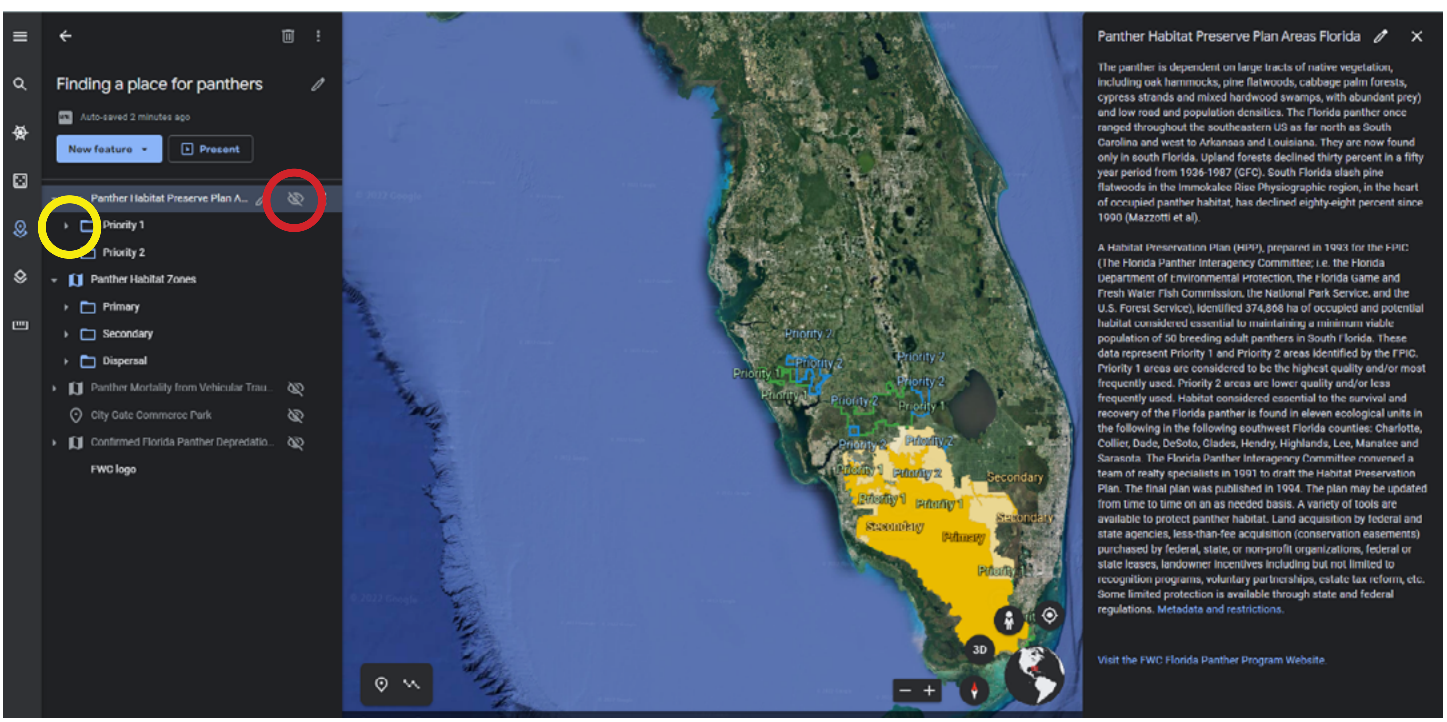


Figure 3. Overview of properly imported data in the web version of Google Earth. Selecting the layer name will open an information box. Selecting the icon outlined in red will stop displaying a layer. Selecting the icon highlighted in yellow will display the features contained in each sub-layer. Note primary layers are expanded to show information contained in sublayers.

You can hide or show layers, sub-layers, or individual features by hovering your mouse over a feature and selecting the **Show/Hide feature** (eye) that appears next to it (Figure 3, icon outlined in red). Although all icons show an eye with a line through it initially, when you hover your mouse over the icon it will continue to display this icon (and note "Hide feature") if the feature is currently displayed. For example, select the **Hide feature** (eye) icon next to the Panther Habitat Preserve Plan Areas Florida layer to see what happens.

If the feature is not currently displayed, hovering over the icon will result in the icon switching to an eye without a line through it (and note "Show feature"). By default, several layers are not displayed when you open the map. For example, re-display the Panther Habitat Preserve Plan Areas Florida layer by selecting the **Show feature** icon. **Note that if the layer or sub-layer (folder) that contains a feature is hidden, the feature or layer will not display on the map even if you select "Show feature" for that specific feature.**

Selecting any layer, sublayer, or feature listed in the Projects menu will open available information boxes. For example, selecting the Panther Habitat Preserve Plan Areas Florida layer will open the information box shown in Figure 3. By default, only data on panther habitat needs are initially displayed. Each of these layers contains multiple features (polygons or points). Double-clicking the layer will also zoom to a default view.

Selecting any of the features (outlined or highlighted regions or placemarks) on the map itself will also display additional information. For example, right-clicking on the polygons displayed by default should cause boxes to appear with information on the parent layer, size, and designation of the focal polygon (Figure 4).

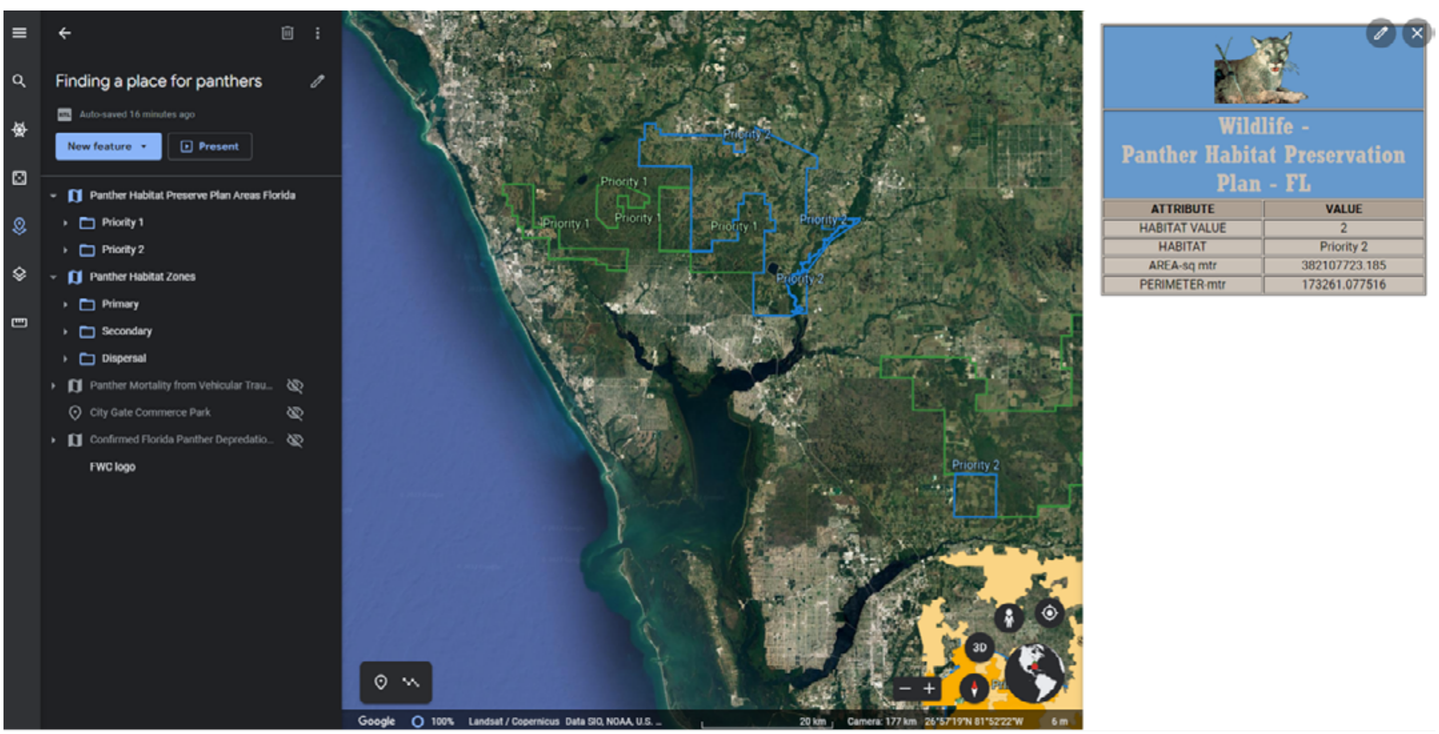


Figure 4. Information box with additional information appears when an area is selected.

## The history of panthers in Florida

Pumas (*Puma concolor*), also known as cougars, catamounts, and mountain lions, are large felid predators that were historically located throughout the Americas (Frakes et al. 2015). Populations in North America commonly interacted through the movement of adults (Culver et al. 2000; Saremi et al. 2019). However, these populations were greatly reduced, and in some cases extirpated, in the 19th and 20th centuries due to habitat loss and intentional hunting (Saremi et al. 2019). In the southeastern United States, these pressures resulted in the local species representative, known as the Florida panther (*Puma concolor coryi*) [Box 1], losing much of its historical range and being restricted to a small, isolated population in southern Florida (van de Kerk et al. 2019).

This population decline led to increasing state-level protections in Florida in the 1950s and eventual federal designation as an endangered subspecies in 1967 by the Department of the Interior. Despite these efforts, by the early 1970s the Florida panther population consisted of approximately 20 independent adult panthers (U.S. Fish and Wildlife Service 2008). The subspecies was further protected under the Endangered Species Act upon its passage in 1973. Under the Endangered Species Act, three distinct populations that each consist of at least 240 adults are required before delisting can be considered (U.S. Fish and Wildlife Service 2008).

Since their listing, groups including the U.S. Department of Fish and Wildlife Service, the Florida Fish and Wildlife Commission, and non-governmental organizations (NGOs) have worked to recover the Florida panther population (U.S. Fish and Wildlife Service 2018).

## Exploring panther habitat needs

Following their designation as a protected species, finding, protecting, and connecting habitat has been identified as a major issue in allowing panther populations to grow and eventually expand (U.S. Fish and Wildlife Service 2008). Many of the preferred habitats of panthers had seen drastic declines over the past century in Florida due to urban development, agriculture, and livestock grazing (Logan

### Box 1: Panther Biology

Adult male panthers typically weigh 100–160 pounds and may reach up to seven feet in length (nose to tip of tail). Females are smaller, weighing 50–115 pounds and reaching six feet in length (U.S. Fish and Wildlife Service 2018). Adults typically have dark reddish-brown fur on their backs. Fur color fades to a gray or white underside, and no spots are present. Juveniles (kittens) have grayish-brown fur with darker spots and a ringed tail. These large carnivores primarily consume white-tailed deer, wild hogs, raccoons, armadillos, and other mammals (U.S. Fish and Wildlife Service 2008).

A mother with three cubs. Photo credit: U.S. Fish and Wildlife Service Southeast Region via Wikimedia Commons (public domain).

et al. 1993). Finding space for these large mammals, however, is difficult given conflicting demands for limited space on the Florida Peninsula. Adult panthers are solitary (apart from breeding), and their hunting and breeding requirements demand large, overlapping home ranges; male ranges can range from 435–978 $km^2$, while females ranges span 193–396 $km^2$ (U.S. Fish and Wildlife Service 2008; Alfano 2013). Male ranges may include the home ranges of several females and their offspring.

To begin the exercise, you will first consider the habitat needs of Florida panthers as noted in 1993. These needs are displayed in the Panther Habitat Preserve Plan Areas Florida layer. To stop displaying features associated with the Panther Habitat Zones layer, hover over the layer and select the "Show feature" (eye) icon to hide all features associated with that layer. Click on the layer name to view information about the layer. The box also provides a link to the metadata for the layer and the Florida Fish and Wildlife Conservation Commission (FWC) website page on the Florida panther.

In 1993, the Florida Panther Interagency Committee presented maps of essential habitat that needed protection to support panther populations in South Florida (Logan et al. 1993). Areas were selected that would support at least the 50 adult panthers that population viability analysis indicated would be required for a self-sustaining population. This was done even though panthers continued to persist at low population numbers into the early 1990s, with many individual panthers suffering from reproductive and developmental issues that were likely due to inbreeding depression due to the lack of gene flow from other populations (Gross 2005; van de Kerk et al. 2019).

1. Why do you think the Committee focused on protecting habitat even when population numbers were low?

The Committee ranked focal areas as Priority 1 or 2 for protection based on current and potential future usage by panthers. As much of the identified habitat was on private lands, the Committee's report also emphasized the importance of using both land acquisitions and strategies that encouraged private landowners to protect panther habitat (Logan et al. 1993; U.S. Fish and Wildlife Service 1999).

2. Ensure all areas are displayed (you should see Priority 1 and Priority 2 zones). Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label it as "Figure 1". In the caption explain what the Panther Habitat Preservation Plan shapes identify.

To address issues related to inbreeding depression, eight females from the nearest geographical subspecies (*Puma concolor stanleyana*, native to Texas) were released in Florida in 1995 in an attempt to increase genetic diversity in the population (Gross 2005; Johnson et al. 2010; Hostetler et al. 2010). This purposeful movement of individuals to restore genetic diversity, or genetic introgression, effectively restored historic connectivity among meta-populations. Genetic restoration was successful, with admixed kittens having increased survival (Hostetler et al. 2012). Panther numbers increased over the following decade, with estimates ranging from ~100–200 adults and sub-adults by 2008 (McBride et al. 2008; Johnson et al. 2010; McClintock et al. 2015).

As the panther population grew, continuing efforts were made to monitor and understand the habitat needs of the growing population. In 2002, the Panther sub-team of the Fish and Wildlife Service's Multi-species/Ecosystem Recovery Implementation Team (MERIT) identified regions that were both of current use to panthers and that might be used in dispersal outside of South Florida (U.S. Fish and

Wildlife Service 2008). These zones are displayed in the Panther Habitat Zones layer. Display the layer and read the provided information box.

As noted in the information box, three types of zones were used to identify areas currently inhabited by Florida panthers (in 2002) or of potential future. You will produce several maps of these zones and collect some information regarding them.

3. Produce a map that only shows the **Primary** Zone of panthers. You can do this by selecting the **Hide feature** icon for the folders that contain the features associated with the Secondary and Dispersal Zones (and for the Panther Habitat Preserve Plan Areas Florida layer). Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label the image "Figure 2". Provide a descriptive caption for what the image shows, including the size of the area (convert to $km^2$). You can find this information by clicking on the Primary Zone in Google Earth; this will cause an information box with information about the selected area to appear (Figure 4). Information provided includes the area's size (in squared meters), type of zone, and link to metadata.

4. Next, add all the **Secondary** and **Dispersal** Zone layers to the previous map by selecting the **Show feature** (eye) icon next to the folder containing those features. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label the image "Figure 3". Provide a descriptive caption for what the image shows, including the size of both the Secondary and Dispersal Zones (convert to $km^2$). Since there are multiple areas that comprise the Secondary Zone, you will need to select each individual area, note their size, and calculate the total area in the zone. Note, we recommend you expand the Secondary zone sub-layer on the left menu and click on individual polygons to display the needed information to make sure you do not miss any areas.

5. Next, produce a map of only the **Dispersal** Zone layer by hiding all other zones and zooming into this area. To see the habitat that comprises the dispersal zone, we will manipulate the transparency of the shape feature. You can select the **Edit feature** (pencil) icon (Figure 5) in the informational box that appears when you click on the dispersal zone. You can also find this icon if you hover your mouse over the Dispersal Zone shape feature (denoted by a polygon icon; Figure 5). Select this and change the fill color saturation level from 100% to 25% in the box that opens. Note you can also change the outline or fill color if you wish.

   Now you should be able to see the habitat cover and shaded area of the dispersal zone simultaneously. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label the image "Figure 4". In the caption, explain why the dispersal zone is essential to the continued success of Florida panther restoration.

6. What major landscape features do you observe in the Dispersal Zone?

The river that runs through this area is the Caloosahatchee River. It marked the northern boundary of the known breeding population following the release of panthers from Texas until 2017 (U.S. Fish and Wildlife Service 2008, 2018; Florida Fish and Wildlife Conservation Commission 2022).

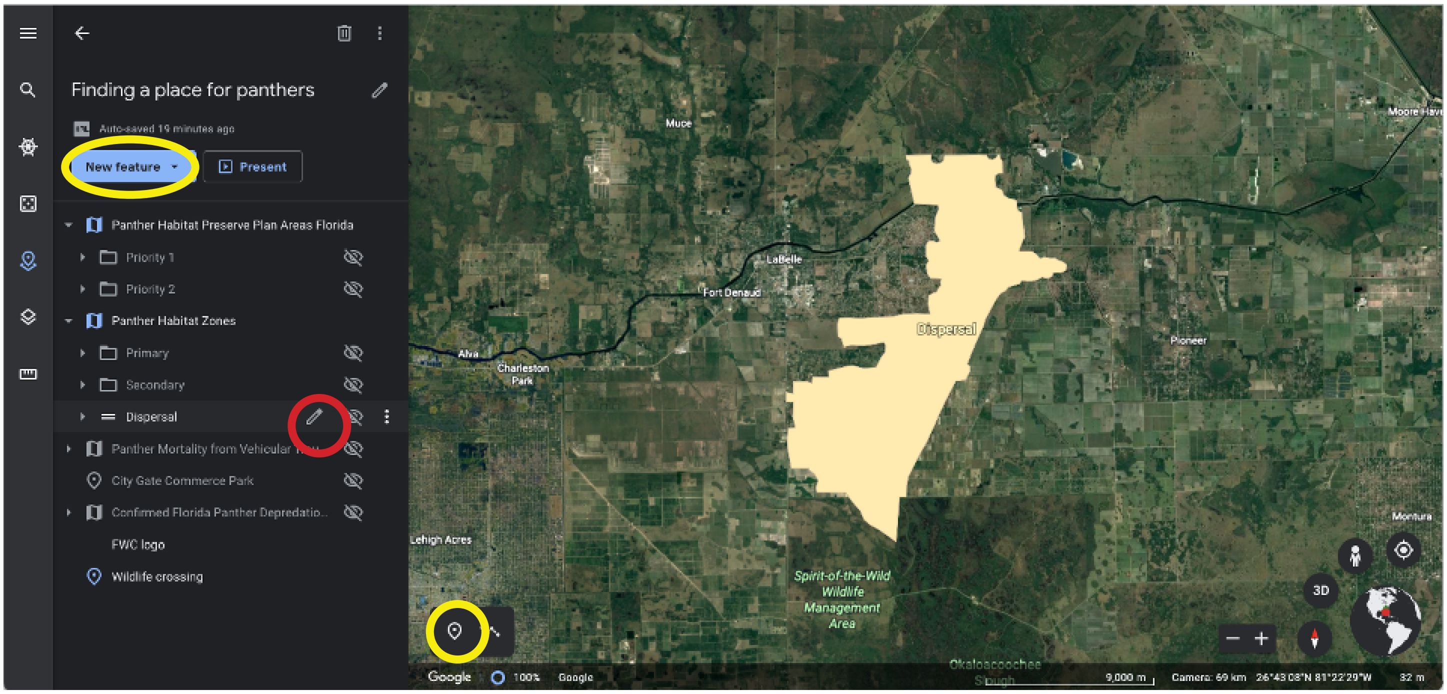


Figure 5. The Edit feature icons (outlined in red) allow you to manipulate feature properties. The Add placemark icon and New feature button (both outlined in yellow) allows you to add new features such as placemarks to your project. The coordinates of your current cursor location are also displayed in the lower right corner of the map (area outlined in blue).

7. Note you can add a placemark on your own to the map by selecting the **Add placemark** icon or button under the New feature menu (Figure 5). Select this icon and add a placemark to the area where the dispersal zone intersects the Caloosahatchee River. Name the placemark *River intersection*. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label the image "Figure 5". Note the importance of the river that runs through the dispersal zone in your caption.

You can also provide the coordinates of the *River intersection* placemark. Coordinates use a system of reference grids to specify the location of a spot on Earth. Although multiple reference grids exist, Google Earth uses a coordinate system known as the World Geodetic System (WGS-84, specifically) to identify the location of a site using latitude, longitude, and elevation. Remember, latitude measures how far north or south a point is from the equator and may be denoted as either N/S or +/-. Longitude indicates how far west or east a point is from the prime meridian and can be denoted as either W/E or -/+. You can find coordinates in Google Earth by hovering your mouse over a point and looking in the bottom right corner of the screen, which displays coordinates in degrees, minutes, seconds format by default (Figure 5); this display can be changed in the Settings menu (Figure 1). Alternatively, if you use the **Edit feature** (pencil) icon next to a placemark you can find the coordinates in the table that appears (which displays coordinates in decimal degrees format but is the same location).

8. What are the coordinates for your *River Intersection* Placemark?

9. What is the benefit of being able to specify exact locations on earth to the management of natural populations? Give at least three clear examples.

One benefit of mapping software is the ability to display multiple layers simultaneously. For now, display the Panther Habitat Preserve Plan Areas Florida layer again. Note that displaying this data layer as "outlines only" allows layers to be easily stacked.

10. Using the PrintScreen function on your computer or a similar screenshot tool, capture an image of your Dispersal Zone layer (it may still be semi-transparent) and your placemark marking the *River intersection* along with the features associated with the Panther Habitat Preserve Plan Florida layer. Label it as "Figure 6". In the caption discuss the relationship between the zones in the two layers.

Much like the Panther Habitat Preserve Plan areas, the zones identified by the MERIT sub-team included many privately held lands. For example, as of April 2001, 27% of the land in the Primary zone was privately held and the Dispersal zone was fully located on private lands. For these reasons, plan authors again discussed the importance of public-private conservation partnerships to panther conservation (Kautz et al. 2006).

For example, agricultural lands (e.g., pastures, citrus groves (see Pienaar et al. 2015) and hunting preserves (or privately-owned areas where customers pay for access to hunting sites while not targeting panthers, which may not be hunted given their protection under the Endangered Species Act) may be useful to panther recovery efforts. These are typically large areas where panther-human interactions may be limited, and they often include panther habitats such as forests and open areas. If managed appropriately, these types of properties can contribute to land protection and range expansion. One method of accomplishing this is to designate a piece of land as a conservation easement[3] (U.S. Fish and Wildlife Service 2019).

A conservation easement occurs when a private landowner voluntarily agrees to limit the use of their land to protect its conservation value. Importantly, landowners may be able to continue to use their land for approved low-impact activities that do not impede panther activity. These easements typically "run with the land," meaning they are permanent and pass on to future owners. Landowners may be paid for entering into these agreements, and they may receive other benefits such as tax relief.

Compensation may be key to encouraging landowners to accept panthers and assist their range expansion, as their presence may come with costs. For example, panthers may prey on livestock and impact the targeted populations that hunting preserves are intending for human harvest. Although these effects may be minimal (for example, estimates suggest calf mortality due to panthers' ranges from 0.5–5% annually (Jacobs and Main 2015), recognizing these potential costs and compensating landowners for providing habitat to panthers may allow for the expansion of panther range via private lands. Landowners may also be compensated for engaging in practices such as the removal of exotic plants that increase the value of habitats for panthers. These efforts may be funded by agencies such as the USDA's National Resource Conservation Service, which administers the Environmental Quality Incentives Program (for more info, see USDA n.d.).

Market-based approaches like these can lead to added value for owners of low-use lands, further encouraging habitat conservation. Conservation easements can also offer ways to connect other protected lands, such as those in state or national parks or owned by groups for the sole purpose of habitat protection, so that organisms like panthers have a corridor to safely reach protected areas. For example, over 1500 acres of the Black Boar Ranch near Labelle, Florida, was entered into a conservation easement in 2015 to aid panthers and other species. The transaction involved payments of 50% of the property's value (USD $2,369,255) by the USDA's Natural Resources Conservation Service and 25% by The Nature Conservancy (NBC2 2015 p. 2). The terms of this easement means this land will remain undeveloped while still being actively used as a game preserve and cattle ranch. You can read (or listen to a podcast session) about this easement and how various stakeholders felt about panther range expansion in media produced by NPR (Allen 2015a, 2015b). Article, podcast, and transcript may be found on NPR's website (https://www.npr.org/2015/07/03/418585657/on-the-rebound-panthers-prowl-expanding-swath-of-land-in-florida) or downloaded by instructors from the NCEP Module collection.

11. In Google Earth, use the search tool to locate the *Black Boar Ranch* (Figure 6). On the resulting screen, select **Add to Project** to add a placemark for the ranch. Manipulate layers as needed to produce a map showing how the ranch relates to habitat and preservation zones. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label it as "Figure 7". In the caption, explain what you displayed and the importance of the Black Boar Ranch in terms of both habitat and panther species range.

This property connects to other conservation easements to the south (Warren 2013) and to the north to better fill in the dispersal zone of the panthers and facilitate their movement across the river. You can read more about these easements in the U.S. Fish and Wildlife article by Warren (download it directly from this module's page at https://ncep.amnh.org or ask your instructor for the pdf version) and in an article from The Nature Conservancy (Seeger 2019). The Nature Conservancy article also has an interactive map that demonstrates connections among the protected lands and land change (visit https://www.nature.org/en-us/magazine/magazine-articles/florida-panther-corridor or ask your instructor for the pdf version).

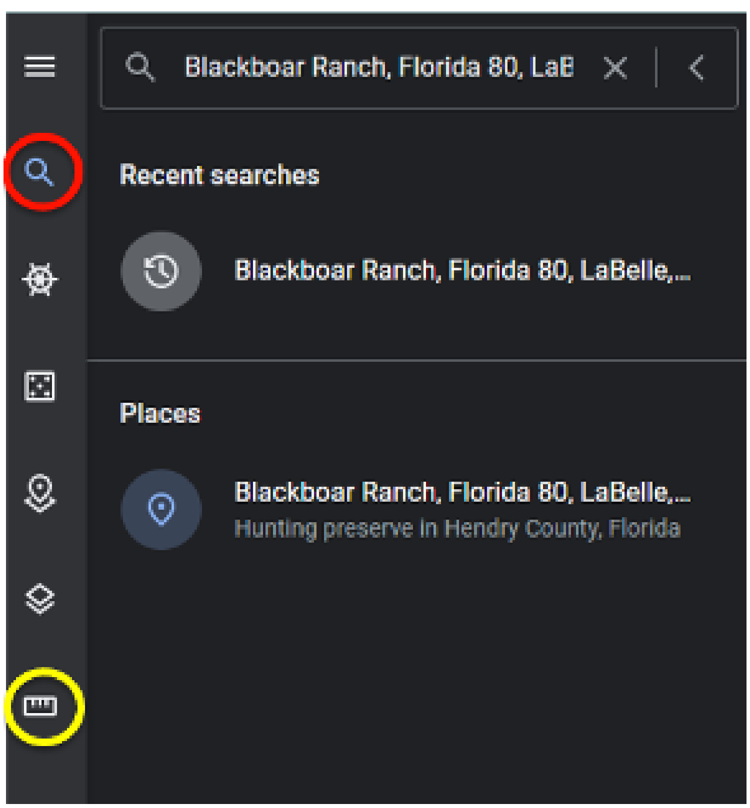


Figure 6. The Search (magnifying glass icon) tool is circled in red. The measuring tool is circled in yellow.

12. Read the articles by Warren and Seeger. Based on these and other readings completed throughout this exercise, name three reasons why choosing a conservation easement may be of value to the owner of a property. Also, name three reasons a property owner may choose not to enter a conservation easement.

These land protection efforts may have already contributed to the range expansion of the Florida panther. Recent (2022) estimates put the number of panther adults and sub-adults at 120–230 (U.S. Fish and Wildlife Service 2018), and evidence of northern range expansion has been documented. A female panther with kittens was confirmed north of the Caloosahatchee River in 2017, and additional female panthers, including a pregnant individual that unfortunately experienced mortality prior to birth, have been documented north of the river since then (U.S. Fish and Wildlife Service 2018; Kelly and Onorato 2020; Florida Fish and Wildlife Conservation Commission 2022).

**Safety and acceptance within existing areas**

Even as panther populations expand, panther conservation still face issues. Despite a population increase, panthers still only inhabit ~5% of their ancestral territory (Frakes et al. 2015). Panthers also continue to encounter threats in established areas. Panther-vehicle collisions, for example, represent a major threat to the species, and roads may also further fragment available habitat.

13. To view the impact of vehicle collision on panther mortality, display the *Panther Mortality from Vehicular Trauma* layer. This layer shows all confirmed deaths due to vehicle collisions collected from February 13, 1972, through January 2, 2021. You can display it with (or without) other layers to make an informative image. Notice the image includes evidence of occurrence north of the Caloosahatchee River. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label it as "Figure 8". In the caption note any patterns or trends you see. Are collisions distributed randomly, or do they occur more in certain areas? Where?

One option to mitigate vehicle mortalities is to create wildlife crossings that allow panthers and other species to safely navigate roadways. Understanding where panther-vehicle collisions commonly occur is necessary to optimally place these crossings, as further explored by Smith et al. (2006) and Downs et al. (2014). You can see how wildlife use these crossings in Collier County, Florida, in a YouTube video (https://www.youtube.com/watch?v=iFJSfOsbcDs&t=3s) from the Florida Department of Transportation (Wildlife Crossing 2018).

Wildlife crossings may be constructed by state agencies. They also may be constructed as part of mitigation plans that may be required when development or other human activities would have negative impacts on protected wildlife. For example, developers of the large City Gate Commerce Park in Collier County, Florida, paid for the construction of a wildlife crossing near Immokalee, Florida (Layden 2010). This site was identified as a high priority area due to usage and panther-vehicle collisions (Swanson et al. 2005; Smith et al. 2006). You can read about this in a press release from Collier County (https://www.colliercountyfl.gov/Home/Components/News/News/18090/18?date=20160506030200&npage=376&arch=1) or downloaded by instructors from the NCEP Module collection (Collier County 2011). Another map of wildlife crossings and panther mortality may be viewed at https://www.arcgis.com/apps/webappviewer/index.html?id=a105b26615f64b19b543eb9ab61fe197.

14. Using information from the Collier County press release, attempt to find the City Gate-funded wildlife crossing. As a hint, click the "Map Style" icon on the left tool bar and choose "Everything" to see road names. Then use the search tool in Google Earth to search for Immolakee, Florida, then follow Country Road (CR) 846 (also known as Immokalee Road) east of town. You may need to make one or more layers from your currently displayed maps transparent or not visible. When you find the intersection of CR-846 and County Line Road, use the measuring tool (Figure 6) to find an area approximately 3 miles before the intersection (note, you can change the units from meters to miles by selecting the down triangle in the measuring tool dialogue box). You should be able to zoom in and locate the crossing. Place a landmark icon here and name it *Wildlife crossing*. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label it as "Figure 9". In the caption explain why the crossing is essential to protecting Florida panthers.

Note that the wildlife crossing the developers paid to have built outside of Immokalee was not actually part of the developed property, which is located in Naples, Florida.

15. View the location of City Gate Commerce Park by turning on the placemark icon for the location in Google Earth. Make sure your image also shows the *Wildlife crossing* placemark. You can add any other layers you need to make an informative image or to offer insight on the placement of the crossing. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label it as "Figure 10". In the caption discuss the benefits of allowing mitigation measures to take place in areas other than where the negative impacts on species actually occur. Are there any negative consequences to this approach to offsetting negative impacts on species?

Other options for mitigating negative impacts on threatened species include protecting lands that are part of a conservation bank[4] (Kreye and Pienaar 2015; U.S. Fish and Wildlife Service 2019). Conservation banks are lands that provide useful and protected habitat to focal species like panthers (U.S. Fish and Wildlife Service 2019). In exchange for protecting and maintaining or improving these areas, the landowners are provided with habitat or species credits that are approved by the United States Fish and Wildlife Service. These credits can be purchased by developers or other groups who need to compensate for the negative impacts (calculated using a published assessment method (U.S. Fish and Wildlife Service 2012) of their proposed activities on protected habitats or species. Conservation banking offers another market-based structure to mitigate negative environmental impacts while still allowing development to occur. Use of this practice may be more practical for developers than restoring small parcels of land and may also result in larger, more appropriate habitats being protected.

16. Read about panther habitat conservation banking in Florida in an article by Sarah Leon-Kilpatrick (download it directly from this module's page at https://ncep.amnh.org or ask your instructor for the pdf version; Leon-Kilpatrick 2015). In which panther zones are the two banks discussed in the article located?

As noted in the article, conservation banks also explicitly value protecting lands for wildlife use. This value can be compared to values associated with development.

17. Do you consider establishing easements or species credits (via conservation banks) to be a payment for ecosystem services[5]? If so, what service are they providing, and do you think it was worth the cost?

In addition to land protection, other programs may also be used to incentivize conservation efforts and increase local support. For example, panthers may prey on pets in addition to domestic livestock (Jacobs and Main 2015), although these are generally rare events. You can view depredation on domesticated species using the *Confirmed Florida Panther Depredations of Domestic Animals* layer in Google Earth (data current through 12/3/2018). To address this issue, programs like the Florida Panther Compensation Program, which is run by the Conservancy of Southwest Florida, may compensate ranchers for free-range livestock lost to panthers or pay for pet and livestock pens. Read about these programs at the Florida FWCC page (https://myfwc.com/wildlifehabitats/wildlife/panther/depredations/) or downloaded by instructors from the NCEP Module collection (Florida Fish and Wildlife Conservation Commission 2022; "Depredations" n.d.).

18. Given that attacks on pets and livestock are rare, why do you think such programs are valued by conservation groups and other stakeholders? List at least three reasons.

### Support beyond a species range

Citizens living outside of the current range of the panther (in Florida and beyond) may also have feelings about panther restoration for various cultural or economic reasons. For instance, the panther plays a key role in the creation stories of the Seminole tribe of Florida, and the panther is one of eight non-human entities that represent a specific Seminole clan. The panther is also the state mammal of Florida and mascot for the state's National Hockey League team, which hosts Conservation Nights and supports conservation efforts financially. Most of the state of Florida's panther research is funded through the voluntary purchase of panther vehicle license plates, indicating a high level of public support (Florida Fish and Wildlife Conservation Commission 2022).

19. What do you think is the value of engaging stakeholders who may not be directly tied to the land used by panthers? Give at least three reasons engaging these stakeholders may be useful to conservation efforts.

20. How do you balance the desires of these stakeholders versus those who are directly impacted by panther restoration (like ranchers and pet owners)?

## CONCLUSION

Although panthers are still restricted to ~5% of their ancestral territory and dispersal opportunities remain an issue, the species shows promise for continued recovery beyond south Florida (Frakes et al. 2015; Frakes and Knight 2021). Areas in the north and Gulf coast portions of the state have been identified that may contain suitable habitat (Frakes and Knight 2021). Continuing to consider the different perspectives and needs of stakeholders, and where they are focused, will be critical to the success of this and other restoration programs, especially given the continued mixture of public and private lands panther populations are likely to need to grow (Pienaar et al. 2015).

## EXTENSIONS: CONSIDERING CHANGES IN PANTHER HABITAT OVER TIME

While we considered changes in habitat needs over time by viewing maps developed throughout the panther restoration program, Timelapse, an extension of Google Earth, allows you to consider temporal issues directly. For example, we can consider how available space has changed over time. You can open Timelapse in a separate tab at https://earthengine.google.com/timelapse/.

Given the importance of the dispersal zone to allowing panther populations to grow, we will focus on how this area has changed as an example of Timelapse. First, we need to enter coordinates into the Google Timelapse application. You can enter the coordinates you obtained from your *River intersection* placemark. You will need to enter coordinates in decimal format. If you select the **Edit feature** (pencil) icon next to the River Intersection placemark, you can find the coordinates in decimal degrees format in the table that appears (Figure 5). Alternatively, you can use the search tool to locate Black Boar Ranch again, given its proximity to the Caloosahatchee River (Figure 6).

21. Once the map is focused on the area corresponding to the dispersal zone, use the scroll bar at the bottom to select the year **1984** (or earlier if possible). Press the **Play** (triangle) icon to begin a slideshow of images showing views of the area over time. Note the slideshow may automatically repeat. For easier comparison, pause the show and select the earliest year possible. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Next use the scroll bar to select the most recent year. Capture this image as well and paste it into your report document. In the caption make sure you note the year that corresponds to each image (and their relative location). Using image marking tools in your document or screenshot tool, mark at least three areas regarding Panther habitat which have changed over time; you can do this by adding shapes over relevant areas.

22. What are the main differences between the two images? What are some possible causes of this?

23. Given the changes that have taken place in the dispersal zone over the past 25 years, what do you predict will happen in the next decade? How does this impact the need to preserve habitat for panthers?

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## GLOSSARY

1. **Stakeholder:** People or groups who will be impacted by a conservation action or regulation.
2. **Genetic introgression:** Genetic introgression occurs when new genetic material is introduced to a population when individuals from another population enter an area and breed with the resident population. Although introgression may occur naturally, individuals may also be moved among populations as a conservation tool focused on improving fitness; this approach may also be called genetic restoration or genetic rescue (Hostetler et al. 2012).
3. **Conservation easement:** Conservation easements are permanent or term-limited legal agreements that limit the use of land to maintain its conservation value. Easements may be part of a conservation bank.
4. **Conservation bank:** Conservation banks are lands that are permanently protected to offer benefits to vulnerable species (e.g., endangered species) and that have been awarded credits for this designation. These credits can be purchased by others whose actions (such as property development) may have negative impacts on the species in other parts of its range, as a mitigation strategy.
5. **Payments for ecosystem services:** Ecosystem services are the benefits people obtain from ecosystems (Millennium Ecosystem Assessment 2005). Stakeholders may be compensated for protecting or increasing these services directly (through monetary payments) or indirectly (e.g., through changes in tax status and liability).

## APPENDIX 1. QUESTIONS FROM THE EXERCISE

1. Why do you think the Committee focused on protecting habitat even when population numbers were low?

2. Ensure all areas are displayed (you should see Priority 1 and Priority 2 zones). Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label it as "Figure 1". In the caption explain what the Panther Habitat Preservation Plan shapes identify.

3. Produce a map that only shows the **Primary** Zone of panthers. You can do this by selecting the **Hide feature** icon for the folders that contain the features associated with the Secondary and Dispersal Zones (and for the Panther Habitat Preserve Plan Areas Florida layer). Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label the image "Figure 2". Provide a descriptive caption for what the image shows, including the size of the area (convert to km$^2$). You can find this information by clicking on the Primary Zone in Google Earth; this will cause an information box with information about the selected area to appear (Figure 4). Information provided includes the area's size, type of zone, and link to metadata.

4. Next, add all the **Secondary** and **Dispersal** Zone layers to the previous map by selecting the **Show feature** (eye) icon next to the folder containing those features. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label the image "Figure 3". Provide a descriptive caption for what the image shows, including the size of both the Secondary and Dispersal Zones (convert to km$^2$). Since there are multiple areas that comprise the Secondary Zone, you will need to select each individual area, note their size, and calculate the total area in the zone. Note you can also expand the Secondary zone sub-layer and click on individual polygons to display the needed information.

5. Next, produce a map of only the **Dispersal** Zone layer by hiding all other zones and zooming

into this area. To see the habitat that comprises the dispersal zone, we will manipulate the transparency of the shape feature. You can select the **Edit feature** (pencil) icon (Figure 5) in the informational box that appears when you click on the dispersal zone. You can also find this icon if you hover your mouse over the Dispersal Zone shape feature (denoted by a polygon icon; Figure 5). Select this and change the fill color saturation level from 100% to 25% in the box that opens. Note you can also change the outline or fill color if you wish.

Now you should be able to see the habitat cover and shaded area of the dispersal zone simultaneously. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label the image "Figure 4". In the caption, explain why the dispersal zone is essential to the continued success of Florida panther restoration.

6. What major landscape features do you observe in the Dispersal Zone?

7. Note you can add a placemark on your own to the map by selecting the **Add placemark** icon or button under the New feature menu (Figure 5). Select this icon and add a placemark to the area where the dispersal zone intersects the Caloosahatchee River. Name the placemark *River intersection*. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label the image "Figure 5". Note the importance of the river that runs through the dispersal zone in your caption.

8. What are the coordinates for your *River Intersection* placemark?

9. What is the benefit of being able to specify exact locations on earth to the management of natural populations? Give at least three clear examples.

10. Using the PrintScreen function on your computer or a similar screenshot tool, capture an image of your Dispersal Zone layer (it may still be semi-transparent) and your placemark marking the *River intersection* along with the features associated with the Panther Habitat Preserve Plan Florida layer. Label it as "Figure 6". In the caption discuss the relationship between the zones in the two layers.

11. In Google Earth, use the search tool to locate the *Black Boar Ranch* (Figure 6). On the resulting screen, select **Add to Project** to add a placemark for the ranch. Manipulate layers as needed to produce a map showing how the ranch relates to habitat and preservation zones. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label it as "Figure 7". In the caption explain what you displayed and the importance of the Black Boar Ranch in terms of both habitat and panther species range.

12. Read the articles by Warren and Seeger. Based on these and other readings, name three reasons why choosing a conservation easement may be of value to the owner of a property. Also, name three reasons a property owner may choose not to enter a conservation easement.

13. To view the impact of vehicle collision on panther mortality, display the Panther Mortality from Vehicular Trauma layer. This layer shows all confirmed deaths due to vehicle collisions

collected from February 13, 1972, through January 2, 2021. You can display it with (or without) other layers to make an informative image. Notice the image includes evidence of occurrence north of the Caloosahatcher River. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label it as "Figure 8". In the caption note any patterns or trends you see. Are collisions distributed randomly, or do they occur more in certain areas? Where?

14. Using information from the article, attempt to find the City Gate-funded wildlife crossing. As a hint, use the search tool to search for Immolakee, Florida, then follow Country Road (CR) 846 (also known as Immokalee Road) east of town. You may need to make one or more layers from your currently displayed maps transparent or not visible. When you find the intersection of CR-846 and County Line Road, use the measuring tool (Figure 6) to find an area approximately 3 miles before the intersection (note, you can change the units from meters to miles by selecting the down triangle in the measuring tool dialogue box). You should be able to zoom in and locate the crossing. Place a landmark icon here and name it *Wildlife crossing*. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label it as "Figure 9". In the caption explain why the crossing is essential to protecting Florida panthers.

15. View the location of City Gate Commerce Park by turning on the placemark icon for the location in Google Earth. Make sure your image also shows the *Wildlife crossing* placemark. You can add any other layers you need to make an informative image or to offer insight on the placement of the crossing. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Label it as "Figure 10". In the caption discuss the benefits of allowing mitigation measures to take place in areas other than where the negative impacts on species actually occur. Are there any negative consequences to this approach to offsetting negative impacts on species?

16. Read about panther habitat conservation banking in Florida in an article by Sarah Leon-Kilpatrick (download it directly from this module's page at https://ncep.amnh.org or ask your instructor for the pdf version; Leon-Kilpatrick 2015). In which panther zones are the two banks discussed in the article located?

17. Do you consider establishing easements or species credits (via conservation banks) to be a payment for ecosystem services? If so, what service are they providing, and do you think it was worth the cost?

18. Given that attacks on pets and livestock are rare, why do you think such programs are valued by conservation groups and other stakeholders? List at least three reasons.

19. What do you think is the value of engaging stakeholders who may not be directly tied to the land used by panthers? Give at least three reasons engaging these stakeholders may be useful to conservation efforts.

20. How do you balance the desires of these stakeholders versus those who are directly impacted by panther restoration (like ranchers and pet owners)?

**Timelapse Extension**

21. Once the map is focused on the area corresponding to the dispersal zone, use the scroll bar at the bottom to select the year **1984** (or earlier if possible). Press the **Play** (triangle) icon to begin a slideshow of images showing views of the area over time. Note the slideshow may automatically repeat. For easier comparison, pause the show and select the earliest year possible. Capture the image by using the PrintScreen function on your computer or a similar screenshot tool and paste it into your report document. Next use the scroll bar to select the most recent year. Capture this image as well and paste it into your report document. In the caption make sure you note the year that corresponds to each image (and their relative location). Using image marking tools in your document or screenshot tool, mark at least three areas regarding Panther habitat which have changed over time; you can do this by adding shapes over relevant areas.

22. What are the main differences between the two images? What are some possible causes of this?

23. Given the changes that have taken place in the dispersal zone over the past 25 years, what do you predict will happen in the next decade? How does this impact the need to preserve habitat for panthers?

# Supporting Biodiversity, Supporting Each Other

Shelby H. Riskin
*Department of Ecology & Evolutionary Biology, University of Toronto, Toronto, Canada*

*"Hope is a muscle that allows us to connect" - Björk*

I've learned many things about teaching during the pandemic, from my students, from my research, and from my family. Some involve the value of community, the need for compassion, and the importance of hope.

For me, even in a home with other people, parts of the pandemic were profoundly lonely. The lack of small social interactions, and especially social affirmations, took a toll. One of my sons, upon the third (or millionth) time he was sent home for remote schooling, came to me in tears, saying that online school made him feel bad about himself. I knew what he meant, and I could see my own (university) students struggling too. During meetings, they seemed nervous, scattered, and often told me they couldn't get any work done. Remote learning options offer opportunities to increase access to learning and build inclusive groups of learners. To me, however, they lack the social interactions and sense of community inherent in in-person learning. In response to these experiences, and to help myself as well as my students, I have made community-building and interaction an even bigger part of what I try to do in my classrooms and ask for as much participation as possible, even online. I now feel like I am meeting learning objectives when I see students ask each other out to lunch or discuss plans to study together.

Due to the lack of community, the uncertainty, disappointment, and true tragedy that many people experienced—and continue to experience—during the pandemic, I have also tried to increase the compassion and flexibility I offer my students. I'm not sure I've gotten this right yet; it feels like a moving target. I worry about developing a reputation for being "soft," for giving easy extensions and the like. I have many colleagues who have begun to take away some supports (such as lecture recordings) as the pandemic eases, arguing that they aren't good for students, but I'm not so sure about that. I'm struggling to tease apart what we do because our pride is involved, what we do because it creates an environment that optimizes learning, and even what we do to make our classrooms positive places to spend time. For now, the students are expressing the need for compassion and extra support, so I'll try to extend it to them.

In teaching about conservation, hope can sometimes seem to be in short supply. In the last few years, my students seem to be feeling almost apocalyptic about the environment and the future of biodiversity, and I don't blame them. But I also think that if I want to foster a sense of biodiversity and ecosystem stewardship in my students, I can't be hopeless. I'm obsessed with how and why people care about biodiversity. My students and I have been running experiments to see what kinds of messaging encourages people to care and act on behalf of endangered species. For example, we've been making videos with positive or negative tones and seeing how viewers respond. One result we've seen repeatedly is the importance of positivity. Our "positive" videos make people more hopeful, and people who are more hopeful trust the information we provide more and are more likely to donate to the featured endangered species. I'm trying to apply these results beyond outreach videos. I am increasingly shifting my tone away from the doom-and-gloom messaging common in conservation and instead focusing on bringing enthusiasm, a sense of wonder, and positivity to my teaching.

Just as adversity and new selection pressures can drive evolutionary innovations, I'm hoping that teaching through the pandemic will ultimately lead me to become a better teacher. These lessons were likely waiting for me already, but I have them in my pocket now. As I move forward, I will keep the need for connection, support, and positivity at the front of my mind.

## Beyond "Zoom Sucks": Environmental Studies and Sciences, Fieldwork, and the COVID-19 Pandemic

Jennifer M. Bernstein
*The Breakthrough Institute, Berkeley, CA, USA; University of Southern California, Los Angeles, CA, USA*

In the discipline of environmental studies and sciences, fieldwork is central. For many educators and researchers, there is a belief that, at the core, one can't deeply understand a place without spending time in and collecting data in the field. So when the COVID-19 pandemic hit, there was rightful widespread lamentation of the inability to conduct fieldwork. Academics argued that undergraduates wouldn't learn data collection techniques or connect with fellow students. Graduate students' academic work was stalled, with vaccine access privileging some and not others. Researchers' long-term projects were interrupted. Further, there was a fear that if faculty taught too effectively remotely, funding for field work would be pulled. While faculty did their best to adapt, there was communal grumbling just below the surface. On social media, a prominent conservation biologist simply stated, "zoom sucks".[i]

There is a robust literature on how to make distance teaching and learning achieve academic objectives and facilitate student success. At its best, distance teaching and learning is a tool for overcoming inequity and access. For many working parents, caregivers, and the differently-abled, days or weeks in the field is a non-starter. Further, there are real risks to particular groups, such as those who identify as women, when in remote locations. Distance teaching and learning can reduce the "friction of distance"[ii] between students and the education they want. Having caregiving responsibilities or being differently-abled should not be barriers to achieving success and furthering progress in environmental fields of study.

Further, we need to challenge the idea that distance teaching and learning inherently inhibits connection, either to a place or one another. During the pandemic some faculty reported feeling more connected with their students and colleagues because of the ease of online interaction, even half-jokingly reporting that they had time to hike (and hence "connect with nature") during what were previously commuting hours (Quay et al. 2020).

[i] Given that this individual's social media platform is private, we have not cited their quote directly.
[ii] The origin of this term is unknown, but it is a core principle in the field of economic geography: "As the distance from a point increases, the interactions with that point decrease, usually because the time and costs involved increase with distance." (Oxford Dictionary of Geography, 2009).

The pandemic necessitated creativity with respect to field data collection. Instead of a single researcher traveling to a number of field sites, individuals already in those locations collected data per the principles of citizen or community science. Some outdoor educators used the pandemic as an opportunity to advocate for the safety and resiliency of fieldwork as a pedagogical tool.

There will always be questions that only fieldwork can answer. But distance teaching and learning and field-based learning have been unnecessarily dichotomized. Scientific research is nothing if not a collaborative effort, and not all work is done in the field. If one isn't able to conduct fieldwork, for whatever reason, there are multiple ways to engage with the scientific process. The broader scientific community can heal this artificial dichotomy by committing to make room at the table for everyone.

Further, it's not that virtual learning platforms are inherently bad. What was bad was the massive disruption the pandemic caused in our lives, academic and otherwise. Individuals respond to teaching and learning mediums differently and being suddenly forced into one or another is uncomfortable. But it doesn't mean that one is inherently superior. We need to acknowledge the difference between hating distance teaching and learning and hating the pandemic. We can use virtual learning as an ongoing tool to facilitate equity and access, rather than treating it as a proxy for the pandemic.

The calls for returning to the field, as well as the classroom, should be tempered with the recognition that distance teaching and learning will always be a part of higher education, and that the ability to participate in fieldwork is not a privilege held by all. For many, the pandemic continues to pose real risks and barriers to participation. Rather than lament the lack of fieldwork during the pandemic, we should think about it more creatively. Uncertainty and dynamism will be an inherent part of educational leadership. Distance teaching and learning will remain a tool in our educational toolbox, and perhaps more importantly, help remove barriers to participation in environmental studies and sciences. We need everyone if we are to address the environmental problems of the present and future.

## REFERENCES

Quay, J., et al. 2020. What future/s for outdoor and environmental education in a world that has contended with COVID-19? Journal of Outdoor and Environmental Education 23:93–117.

# Human-Wildlife Conflict: Assessing the Complexity of Stakeholder Perspectives

Leo Douglas[i], Loraine Cook[ii], and Rose-Ann Smith[ii]
[i]*Center for Biodiversity and Conservation, American Museum of Natural History, New York, USA;* [ii]*University of the West Indies, Mona, Jamaica*

## ABSTRACT

This collection of case study-based exercises presents a fictional case study of a community facing conflict related to living with carnivores. The activities provide an opportunity for students to explore diverse stakeholder perspectives on living with wildlife, predator conservation, and how interests, values, and needs might vary within a community. Also included is a guide to facilitate use of the student activities in a virtual or remote learning setting [to download the adaptation,[i] see this module's page on the NCEP collection (https://ncep.amnh.org)]. Activity 1 asks students to use a brainstorming tool called a spider map to illustrate the disparate perspectives and contributing factors that are involved in a situation of conflict. Activity 2 has students adopt the roles of the various stakeholders and examine their diverse perspectives. Activity 3 asks students to reflect upon and analyze the conflict critically to determine the basic interests, values, and needs that produce conflict.

## INTRODUCTION

Human-wildlife conflicts (HWCs) are widely perceived as unfavorable interactions between people and wild animals, but they also include concurrent disputes between groups of people about wild animals. Because of this, HWCs are inherently complex social phenomena, strongly influenced and contextualized by local culture, identities, local history, values, and politics; and, by extension, they may be difficult to both comprehend and effectively resolve. Even the simplest intergroup conflict about wildlife can have many elements. Therefore, approaches to conflict management that occur within a social and political vacuum can be ineffective and even aggravate, rather than mitigate, conflict. It is important to understand the cultural and social issues surrounding conflicts with wild animals in order to identify the best approaches to improving human-wildlife coexistence.

Here we will examine a fictional case study of a community facing conflict related to living with carnivores (in this case, jaguars; Figure 1). The accompanying collection of case study-based exercises provides an opportunity to understand how local perspectives on predator conservation and disagreement between stakeholders about the place, value, and management of predators can vary within a community. Many stakeholders will have conflicting positions related to the issue, irrespective of what type of predator is involved. Despite this, their interests can frequently overlap and understanding these shared interests is important for consensus or compromise about how to handle predator-related conflict in support of conservation objectives.

Activity 1 asks students to use a brainstorming tool called a spider map to illustrate the disparate perspectives and contributing factors that are involved in a situation of conflict. Then in Activity 2 (a role-play exercise), students delve into the different interests represented in this fictional case and adopt the roles of the various stakeholders. Activity 3 asks students to reflect upon and analyze the conflict critically to determine the basic interests, values, and needs that produce conflict.

[i] Moore, A. 2002. Human-wildlife conflict: assessing the complexity of stakeholder perspectives – Remote learning adaptation. Network of Conservation Educators and Practitioners, Center for Biodiversity and Conservation, American Museum of Natural History, New York, NY. Available from https://ncep.amnh.org.

## LEARNING OBJECTIVES

After completing the various activities, students will be able to:

1. Identify the different dimensions of HWC in a diverse and changing community.
2. Compare and contrast the different potential perspectives of local stakeholders when facing conflict about living with predators.
3. Identify where stakeholder interests overlap and use this information to recommend possible solutions.

## BACKGROUND: UPROAR AT LION'S GATE[ii]

It has been a stress-filled time in Lion's Gate, a town in the northernmost section of Belize (Figure 2). Everyone is still working on repairs after a Category 1 Hurricane hit the region the month before. People have also been talking about the recent name-change of the town. For as long as everyone knew, the name of the town (and entire area) was Corozal, a name of Spanish colonial origin; but recently the town name was changed to "Lion's Gate." This was spurred by the release of a new blockbuster feature film about a pet mountain lion[iii] that rescues tourists in an area that the film calls Lion's Gate. The aim in changing the name was to capitalize on the area's new tourism potential. Soon, the newly refurbished entrance to the town's local zoo and animal rescue center would be unveiled in a grand re-opening ceremony. The new entrance features a visitor's center, a mural (depicting scenes from the feature film), and a pillared gateway crowned by cat faces carved out of stones. Additionally, Lion's Gate is home to a growing community of North American and western European retirees. This morning, the town's local newspaper ran a story based on a press release from the New York Post titled "Jaguar Kills Yank" (see the press release re-printed below).

Figure 1. Jaguars (*Panthera onca*) are the largest cat species in the Americas, and they are categorized as Near Threatened by the International Union for the Conservation of Nature (IUCN Red List 2017; https://dx.doi.org/10.2305/IUCN.UK.2017-3.RLTS.T15953A50658693.en) Image credit: Tambako The Jaguar (CC BY-ND 2.0).


Figure 2. A map of Belize. Belize is an English-speaking country that borders Guatemala and Mexico. The town of Corozal is located in the north, close to the Mexican border. Image credit: CIA World Factbook (public domain).

[ii] Please note that while this case study is intended to illustrate the different dimensions of a human-wildlife conflict (in this case involving predators), this conflict is **imagined** taking place within a **fictionalized** community.
[iii] Both mountain lions (also called pumas or cougars) and jaguars are found in Mesoamerica.

----- PRESS RELEASE ------

BELIZE CITY[iii] — A jaguar that escaped from its cage at a Belize animal rescue center during Hurricane Richard has been blamed in the mauling death of a US citizen whose body was found on Tuesday.

The four-year-old male jaguar, named Max, escaped when a tree fell on his cage during the Category 1 Hurricane Richard that hit the country's Caribbean coast with howling winds and rain.

Authorities found the victim's body near the animal center on Tuesday. It had bite marks on the forearm and neck and had apparently been attacked the day before and dragged for some distance into the bushes.

Kelly McCarthy, a spokeswoman for the US Embassy in Belize, confirmed that "…a US citizen died from a jaguar attack." McCarthy could not provide any information on the man's hometown or name.

The center's operators regularly rescue animals and attempt to return many of them to the wild. But it is unclear whether Max would be allowed to return to the wild if he is recaptured. Jaguars have also been responsible for the killing of livestock throughout the region and human-jaguar conflict appears to be on the rise. As a result, the number of jaguars killed in retaliation for actual or perceived threat to livestock or human lives is to be investigated.

## MAJOR STAKEHOLDERS

You will be assigned to act as one of the following major stakeholders in a town hall meeting. Study the bios for these stakeholders carefully with a focus on the stakeholder group to which you have been assigned. Use the guiding questions to think more critically about the values and perspectives of your assigned group. Later in the exercises you will represent this stakeholder group in class activities.

### Guiding questions

- What are your main goals and values?
- With whom do your goals and values most closely align?
- With whom do you most likely disagree?
- How might members of your stakeholder group agree/disagree with one another?
- What does the jaguar represent to you?
- In what way would this recent event impact your work and objectives?
- What is your biggest concern following this recent event?

### *Mayan Community Heritage Trust (MCHT)*

This group of stakeholders is defined by their collective interest in preserving the traditional ways and customs of the people of the Yucatan Peninsula (Mexico and Belize). As a group they are generally older and led by individuals over 40 years of age. They value jaguars for their sacred importance and spiritual significance. While a majority of Belize's residents are Christians, cultural practices and the worship of the ancestral deities still continue. These traditions have been communicated through the

[iv] Adapted from: Post Staff Report, Oct. 27, 2010. Belize big cat kills yank. New York Post. Available from https://nypost.com/2010/10/27/belize-big-cat-kills-yank/.

retention of several indigenous languages of the area. This group opposes the capture of jaguars and has long advocated for the release of all captive jaguars in the country with the exception of those that have been injured and could not survive in the wild on their own. Furthermore, the Trust has long lobbied for the name of the town to be changed to *Chactemal*—the name that Mayan history suggests the site was called before the area was colonized by European nations.

*National Park Service (NPS)*

The NPS is a government-funded entity whose mandate is to manage issues related to wildlife, national parks, and protected areas in the country. Rank-and-file staff members are citizens of Belize while the management is dominated by American citizens who live in the country and a few Belizeans who have lived and studied at universities in the United States. Overall, the organization has focused on public education, scientific study, captive breeding of jaguars, and the legal export of jaguars to other institutions involved in big cat conservation worldwide. The NPS is in charge of the rescue center. They have been trying to encourage ecotourism as a conservation strategy. Recently they sent a letter to the Mayan Community Heritage Trust requesting a dance performance in native dress for the opening of the new Lion's Gate mural and visitor's center.

*Ministry of Labor and Development (MLD)*

The stated mission of this government ministry is to create an enabling environment for the economic and social development of communities, through the provision of services that help the local workforce gain the right jobs to compete successfully in the marketplace. The MLD oversees projects in agriculture, manufacturing, and commercial tourism. The work plan of the MLD has been driven by the urgency of economic development. Seeing the success of their close partners to the north (in the Cancun area), the MLD has increasingly encouraged the development of tourism ventures. The more recent employees of the MLD have overwhelmingly been individuals with backgrounds in resort development and hospitality management.

*Chactemal Livestock and Youth Development Program (CLYDP)*

This NGO group is dominated by working age individuals involved in the business and tradition of raising livestock and is mostly composed of men between 17–35 years of age. Many of them have at least some high school education and some have obtained a one-year associate degree in Agricultural Practices and Farm Extension Service Training. Over the last two years, their monthly meetings have been dominated by discussions, fundraising, and strategies to appeal to the central government for better support services and for funding to support their efforts to become self-sufficient and profitable. Over the long term, they would like to expand their operations to capture more of the region's unemployed youth. It is an election year and they have heard rumors that, in an effort to stimulate economic development and bolster support, the government may be reallocating funding promised to the CLYDP in the national budget to further tourism developments instead.

While CLYDP members have been influenced by their elders (supporters of the Mayan Community Heritage Trust), they are also concerned about jaguars (who sometimes injure or kill goats among other form of livestock). Protecting livestock from predators, such as jaguars, adds to their costs in time and money. They would like to find ways of eliminating livestock raiding by predators and are divided about jaguar conservation.

*Belize News Network (BNN)*

The local correspondents for BNN have their ears on the ground and occasionally attend meetings of the various groups. They are very interested in the current state of affairs as disputes encourage greater public interest on media items and create more demand for their work. BNN is a private organization, which means that their general positions and values are fluid and determined by those who make up the organization.

## ACTIVITY 1: SPIDER MAP EXERCISE

In this exercise, the class will work in their assigned stakeholder groups to examine each group's inherent values and what factors are contributing to the conflict through a brainstorming activity: a "spider map."

### Instructions

As your assigned stakeholder role, create a spider map that details your group's major concerns, values, and objectives. Refer back to the guiding questions to help you complete this activity.

1. Place your assigned stakeholder group name in the center of the page and list **at least five** factors that influence your stakeholder's perspective in the conflict.
2. For each factor that you identify, add a rank from 1 to 3, with "1" as Most Important, "2" as Somewhat Important, and "3" as Less Important.
3. Additionally, for each factor, provide additional detail exploring how this might impact your role in this HWC, and indicating how this factor may relate to other factors influencing your perspective. See Figure 3 for an example.

## ACTIVITY 2: ROLE PLAY

### Background to town hall meeting

*Grand Opening of New Lion's Gate Zoo/ Rescue Center Mural and Visitor's Center*

When the day for the grand opening of the new mural and visitor's center arrives, a scuffle develops during the ceremony. A fire starts to blaze, and the newly created structures are badly damaged. Participants are injured in the confusion and the police and the crowd clash. The NPS director remarks that they had received threatening communications and she suspects that individuals related to the MCHT were most likely involved. She said that she felt fearful and called on the government to provide protection to her and NPS management as they might be at risk.

As if overnight, the volatility of the situation appears to have escalated and the MLD is very concerned that the negative publicity could spell doom for their massive all-out investment promoting Lion's Gate as a place where tranquil wildlife and welcoming people live in harmony. The MLD calls for a town hall meeting and representatives from all the major stakeholder groups, along with other concerned citizens, attend. The goal of this meeting is for each stakeholder group to have an opportunity to communicate their central concerns, and to voice ideas and opinions.

### Prepare for the Meeting

To prepare for role play in class, read the key definitions below, think back to the guiding questions, then reflect and prepare brief points in response to the questions below. Answering these questions will help you contribute to the class activity (Activity 3). You will have time before the town hall

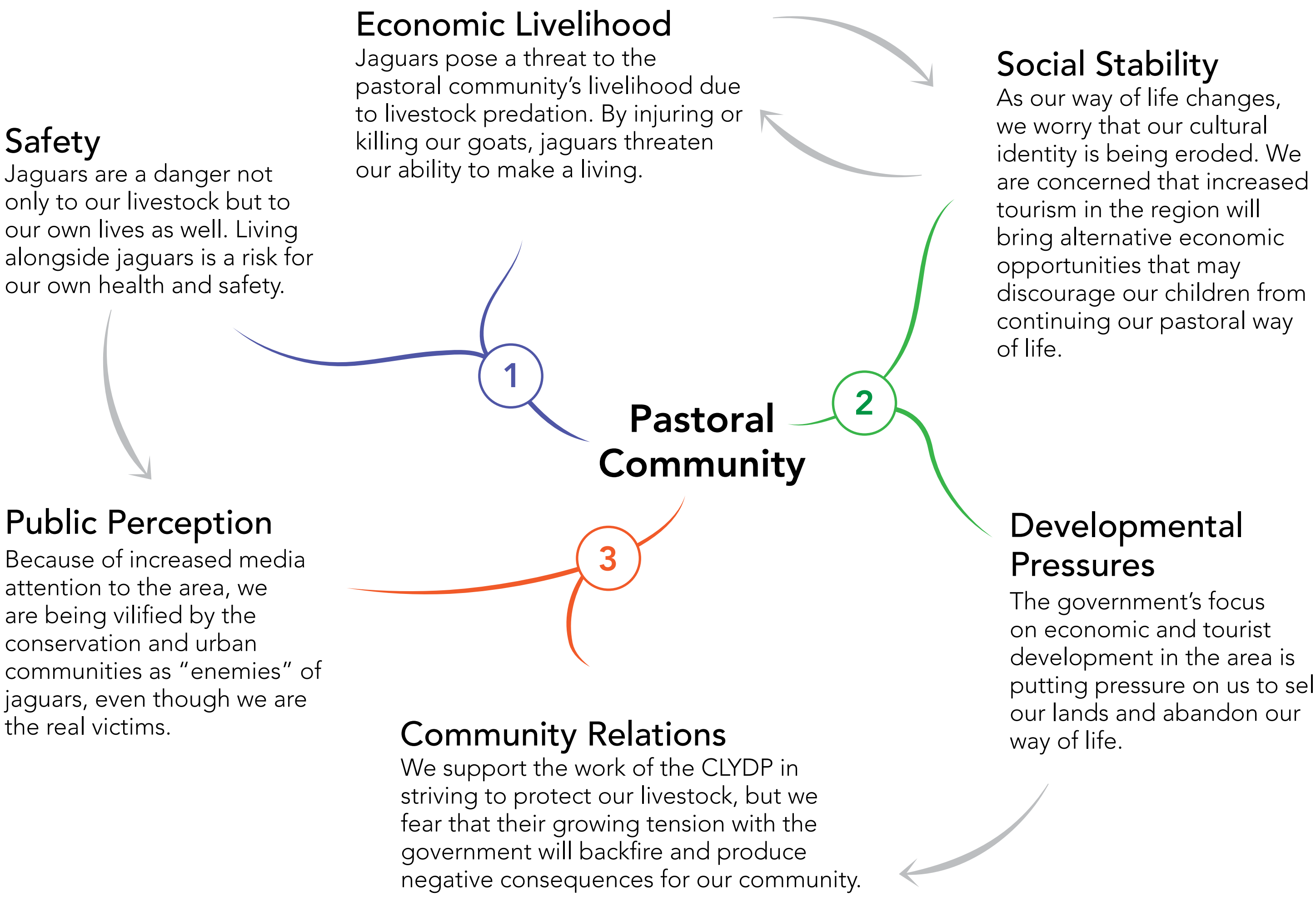


Figure 3. Example spider map for local pastoralists (an additional stakeholder group).

meeting to discuss, agree on, and practice the general points you wish to make with your stakeholder group. Each stakeholder group is also encouraged to investigate what the other groups might be like and the relationships that they might have with one another, using information from the major stakeholder descriptions found earlier in the text.

*Key definitions [from Engel and Korf (2005) unless otherwise indicated]:*

- **Conflict analysis:** the identification and comparison of the positions, values, aims, issues, interests, and needs of conflict parties.
- **Dialogue:** a process for sharing and learning about another party's beliefs, feelings, interests, and/or needs in a non-adversarial, open way, usually with the help of a third-party facilitator. Unlike mediation, in which the goal is usually to reach a resolution or settlement to a dispute, the goal of dialogue is usually simply to improve interpersonal understanding and trust.
- **Interests:** the underlying desires and concerns that motivate people to take a position. While people's *positions* are what they say they want, their *interests* are the reasons why they take a particular position. Parties' interests are often compatible, and hence negotiable, even when their positions seem to be in complete opposition.
- **Identity:** the way in which people see themselves, i.e., the groups that they feel part of, and the significant aspects of themselves that they use to describe themselves to others.

- **Needs:** Psychologist Abraham Maslow suggested that all people are driven to attain certain biological and psychological requirements, which he called "fundamental human needs." Several conflict theorists (e.g., John Burton and Herbert Kelman) have applied this idea to conflict theory, suggesting that the needs for security, identity and recognition underlie most deep-rooted and protracted conflicts. Most ethnic and racial conflicts, they argue, are not interest-based (and hence cannot be negotiated) but are driven by the subordinate group's claiming of fundamental needs. The only way of resolving needs conflicts is to restructure the society so that the fundamental needs of all groups are met (Conflict Research Consortium 1998).
- **Parties:** the people who are involved in the dispute. Most parties are "disputants"—they are the people who are in conflict with each other.
- **Positions:** what people say they want, or the superficial demands they make of their opponents. *Positions* are what people have decided, while their *interests* are what caused them to make that decision. One side's position will often be the opposite of their opponent's, but their interests may actually be compatible.
- **Values:** the ideas that people have about what is good, what is bad, and how things should be. People have values about family relationships (e.g., regarding the role of the husband with respect to the wife), work relationships (e.g., regarding how employers should treat employees), and other personal and relationships issues (e.g., regarding how children should behave towards adults, or how people should follow particular religious beliefs).

*References*

Engel, A., and B. Korf. 2005. Negotiation and mediation techniques for natural resource management (Vol. 3). Rome: Food and Agriculture Organization of the United Nations. Available from https://peacemaker.un.org/sites/peacemaker.un.org/files/NegotiationandMediationTechniquesforNaturalResourceManagement_FAO2005.pdf (accessed December 2, 2022).

Conflict Research Consortium. 1998 "International online training program on intractable conflict." University of Colorado, CO, USA.

*Questions*

1. What demands did you come here to make of the other parties? (These are your **positions.**)
2. What would you hope that this session will achieve for you personally and others in your stakeholder group? In other words, what did you hope to gain out of it? (These are your **interests.**)
3. What are the **values** of your assigned stakeholder group?
4. What can you not live without (physically, culturally)? In particular, what are the things that you feel are threatened directly or indirectly to this dispute? (These are your fundamental **needs.**)

### The town hall meeting

The script below is intended as a **general guide** that you should develop further and adapt based on your own understanding of the situation and your specific stakeholder role. It is deliberately not prepared as a complete script—each group should discuss their current understanding of the conflict and their stakeholders' positions, interests, and values. They should then review their own speaking points for the town hall meeting. This information may then be supplemented, for instance through an online search for similar groups within the same geographic region (i.e., Central America). Each stakeholder group should discuss, agree on, and practice the general points that they wish to make prior to the town hall meeting. During this discussion, revisit and reflect on the various presumed causes and contributing factors of HWC identified through your spider map (Activity 1), and how they might result in grievances or points of contention.

Your instructor will act as the facilitator for the town hall meeting and will explain the basic guidelines or rules of the town hall meeting. By the end of the town hall meeting, each stakeholder group will have had the opportunity to speak freely about the conflict. The groups will be graded based on how well they have represented their respective groups, including communicating their central concerns, delivered their arguments, and researched their case. Remember that this an opportunity for the stakeholder groups to voice ideas and opinions; it is not a court hearing and a resolution is not required.

**Mayan Community Heritage Trust (MCHT) Leaders:**

Why does the MCHT's name get called whenever there are incidents of this nature?

The jaguar does not belong to the park service. We need to be part of what is happening to them and our community.

These meetings are pointless because what we have to say is disregarded even before it comes out of our mouth.

What has happened is your own doing! You brought this on all of us, but our hands are clean!

Further Context:
MCHT stakeholders are frustrated and angry at being implicated or blamed for not doing enough to convince other residents to support the objective of the Ministry of Labor and Development (MLD) and the work of the National Park Service (NPS).

**National Park Service (NPS) Director and Staff:**

We have worked tirelessly for this community, and we are doing our very best to help Belize conserve its globally endangered biodiversity.

These species (jaguar) are critically endangered and if they go extinct, they will be lost forever! Livestock farmers or poachers are killing them in the wild.

This community cannot protect the jaguar alone and your meddling stirs up trouble.

Further Context:
The majority of NPS cash income is from the tourists coming to see the jaguars, who buy NPS goods, such as baskets and carvings.

**Ministry of Labor and Development (MLD) Representatives:**

We are outraged by these acts of vandalism and call on anyone with information that could lead to the arrest of the perpetrator(s) to come forward! The authorities are here to take your information.

We are trying to make life better for the town and build our community, why can you not see that?

We all know that wild predators will eat whatever food they can catch—why do you think that this is our responsibility all the time?

You people have no vision or business experience and we have heard enough of your endless complaints!

We even tried a compensation program, and your greed and dishonesty made the program bankrupt!

Further Context:
The MLD is responsible for receiving complaints of damages caused by wildlife. They send field officers out to farms to assess these claims and compensate farmers in either cash or by replacing crops or livestock that have been damaged or destroyed/ killed.

**Chactemal Livestock and Youth Development Program (CLYDP) Spokespersons:**

The police broke into our meeting once and assaulted several of our members. This was never investigated—why should we help now?

Why is so much money being invested in building a colorful mural, etc., when we cannot get loans to build fences to protect our goat pens?

You all work 9 to 5 in your air-conditioned offices while we have to watch our animals, day and night in the field, often risking our lives!

You bus your tourists through our villages to see wildlife. You secretly encourage these animals to come out of the forest to show to tourists.

If you never come to our community meetings or visit the MCHT, what do you know about how we live?

Further Context:
The youth of the CLYDP are possibly the most disenfranchised of the stakeholder groups. Often there are tensions about whether wild animals are being valued more than people by State and park officials.

**Belize News Network (BNN):**

The local correspondents for BNN have their ears on the ground and occasionally attend meetings of the various groups. They are very interested in the current state of affairs as disputes encourage greater public interest in media items and create more demand for their work. BNN is a private organization.

Note:
The media group will determine their own position and interests. At the end of the town hall meeting there will be approximately 10 minutes where the media can ask questions of the different stakeholders.

After the town hall, you will write a report reflecting on the meeting. In order to capture the key components of the discussion, use the following Conflict Matrix to note the various positions, interests, values, and fundamental needs that are part of this conflict. A Conflict Matrix can be used to map the conflict's elements. By using this tool, all parties can better understand the current state of the conflict and later exchange ideas on how to best achieve the alternatives for amicable management. This matrix is for your own use and will not be turned in, unless requested by your instructor.

**Conflict matrix**

| | MCHT Leader | NPS | MLD | CLYDP |
|---|---|---|---|---|
| Values | | | | |
| Positions | | | | |
| Interests | | | | |
| Needs | | | | |

## ACTIVITY 3: ANALYZING THE CONFLICT

### Conflict report

At home, write a report (one-page minimum) describing the role play activity that was completed in class. Be sure to address the following questions, and use evidence from the role play to support your explanations:

- What are the different parts of the conflict? What were the different issues that were discussed?
- What are the values, positions, interests, and needs of each stakeholder group? How do these influence their individual context and assumptions?
- How did the values, positions, interests, and needs of the stakeholder groups overlap? Which groups were most aligned, and which groups were most opposed?
- What was your role like in the activity? What would you do differently, if anything? What do you wish you knew about your stakeholder or other stakeholders?
- How did this activity influence your perceptions of the different stakeholders and the conflict itself?

## ACKNOWLEDGMENTS

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We welcome your comments and feedback. To write to NCEP or for more information, contact the Network of Conservation Educators and Practitioners at:

American Museum of Natural History
Center for Biodiversity and Conservation
200 Central Park West
New York, New York 10024
ncep@amnh.org

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