Forecasting the Effects of Climate Change on Biodiversity: Visualizing Change to Inspire Public Action

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Abstract

Climate change impacts to the species and ecosystems upon which human economic and ecological well-being depends receive relatively little attention from the media and the general public. Ecological forecasts of future climate impacts on the geographic ranges of iconic species produce models depicting alternative scenarios that vary dramatically in their degree of projected changes. Using the IPCC's latest climate model outputs and greenhouse gas emissions scenarios, scientists and science visualization specialists from the California Academy of Sciences are creating multimedia presentations that convey two different trajectories for Earth (and our) future, told through the lens of wildlife icons such as the jaguar and wolverine. These science-based results translate into educational 'global change vignettes' that introduce the public to alternative potential futures for the species and landscapes to which they are connected. In this way, the diffuse issue of global climate change becomes more personal, and the viewer may be motivated to become part of the solution that creates the more positive outcome.

Introduction

The majority of media and public attention regarding potential climate change impacts is focused on extreme weather events such as droughts, floods, and fires, and public health consequences such as disease and food security. While acknowledged, relatively less awareness surrounds potential climate impacts to biological diversity and ecosystem function. This reflects a general under-appreciation by the media and the public of the critical role intact natural systems play as the economic and ecological foundation to human well being. Despite the fact that climate change is becoming a more popularized issue, many people perceive it as a distant problem in both time and space (Maibach et al., 2009). In order to engage a wide ranging public from diverse backgrounds and with disparate value systems, scientists are challenged to translate the global impacts of climate change on Earth's ecological systems into a more familiar, personal, and regional context. Here, we propose that compelling educational media about climate impacts to biodiversity can be derived from research approaches that use downscaled global climate models to forecast climate impacts at the scale at which plants and animals experience and respond to climate. Ecological forecasts based on downscaled climate models under alternative greenhouse gas emissions scenarios can establish a deeply immediate impact on personal awareness of climate change.

This essay will briefly discuss examples of ecological forecasting with downscaled climate models for two iconic conservation target species, the Jaguar (*Pantera onca*) and the Wolverine (*Gulo gulo*), being conducted at the Center for Applied Biodiversity Informatics of the California Academy of Sciences. We will discuss the challenges and opportunities of visualizing these research results as climate change educational media for our diverse public audiences. By demonstrating the impacts of climate change on the future distribution of

plants, animals and ecosystems that people are familiar with, the effects of global climate change are conveyed at a personal level, and may inspire people to think creatively and actively about solutions.

Biodiversity, Climate Change and Natural History Museums

Natural history museums maintain specimen collections which represent the most extensive and verified record of what life was like on the planet when the climate was considered "normal". The result of several hundred years of research and exploration, biological specimen collections contain essential information about the past and present distribution of species. Recent advances in biodiversity informatics and collaborative digitization efforts have "unlocked" specimen data and made them freely available online through initiatives like the Global Biodiversity Information Facility (www.gbif.org). Researchers can access GBIF integrated databases and apply these collections data to analyses of patterns of biodiversity under alternative climate scenarios. Museums require continued investment in digitizing and georeferencing their historic collections, as much of their legacy data are not yet available for climate change research applications. Natural history museums play complementary roles as both sources of biodiversity research as well as sources of biodiversity education that present interesting opportunities for the visualization community. At the Academy, the opportunity exists to explore research results with advanced science visualization techniques in collaboration with the Morrison Planetarium. (see Figure 1). Through cross-cutting programming, exhibits, and research, the Academy is both a place for innovation and education.

Figure 1. California Academy of Sciences in Golden Gate Park, San Francisco, California. Newly re-designed, the Academy contains a natural history museum, aquarium, planetarium, 23 million biological specimen collections, research and education programs under a living roof.

The Center for Applied Biodiversity Informatics (CABI) focuses on developing strategies for forecasting target species geographic range shifts under a large ensemble of downscaled climate models run under alternative greenhouse gas emissions scenarios. The results of these research efforts produce bioclimactic range maps (see Figure 2) for a target species decade by decade through 2100 under optimistic and pessimistic scenarios of future greenhouse gas emissions (SRES B1 and A2 scenarios, respectively).
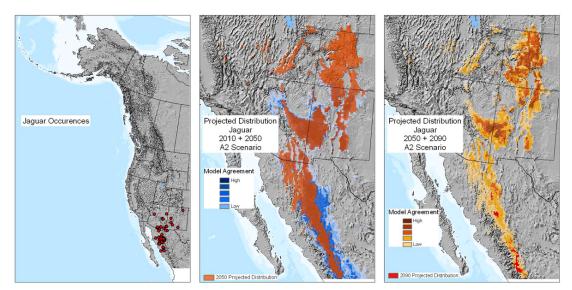
Figure 2a. Current distribution of Jaguar (*Panthera onca*) based on occurrence data from museum collections and field observations and future projected distribution of Jaguar for 2010, 2050, and 2090 under A2 emission scenario. Figures represent preliminary results and are for demonstration purposes only.
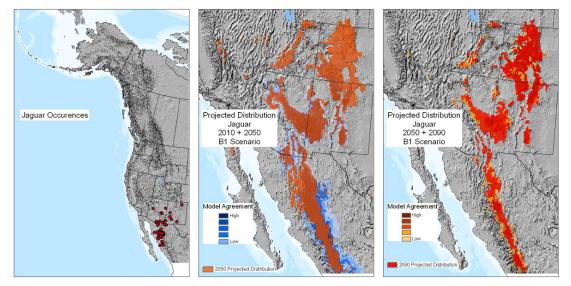

Figure 2b. Current distribution of Jaguar (*Panthera onca*) based on occurrence data from museum collections and field observations and future projected distribution of Jaguar for 2010, 2050, and 2090 under B2 emission scenario. Figures represent preliminary results and are for demonstration purposes only.

Recently, CABI is partnering with the production and outreach teams from the Morrison Planetarium to visualize original research results in multiple media productions for exhibits on the public floor and in the digital dome. The planetarium visualization staff produces feature productions and interactive presentations that are displayed in exhibits on the public floor, online, and in the planetarium. The opportunity to use immersive environments and associated visualization technologies to tell biodiversity and climate change stories is a unique opportunity for natural history museums to explore. By integrating research with visual productions, museums are placed in an active role in the dialogue for finding solutions to climate change and developing approaches that may motivate diverse audiences into action.

Ecological Forecasting Eexamples, The Jaguar (Panthera onca) and the Wolverine (Gulo gulo)

Working with the visualization experts, CABI is translating climate model downscaling and ecological forecasting results into animations of projected range shifts, contractions, and expansions for species to which many people may experience emotional attachment. For example, the Jaguar (*Panthera onca*) is a charismatic top predator with a distribution that spans South and Central America and extends, though tenuously, to the southwest United States. It is considered a keystone species that plays a significant ecological role but with declining populations, the fate of this powerful feline is uncertain.

In a preliminary exercise, we integrated species distribution data from museum collections and observation data to model the future distribution of Jaguar under two emissions scenarios for the years 2010, 2050, and 2090 (see Figures 2.a. & 2.b.). Using an ensemble approach that combines the downscaled climate outputs of 17 GCM's and 5 different species distribution modeling algorithms, we can begin to see trends in the models that identify regions in the Jaguar's range where the species' suitable climate is projected to occur in the future.
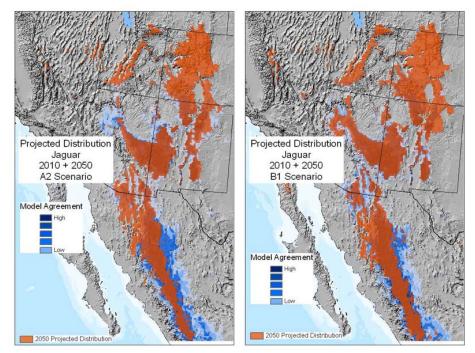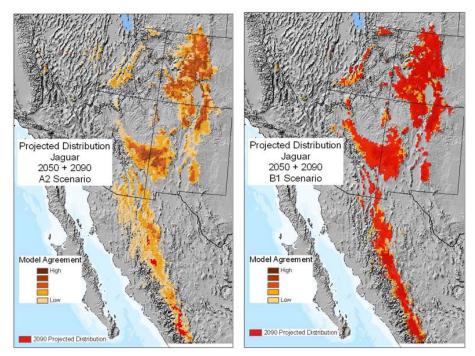

Figure 3. Projected distribution of Jaguar (*Panthera onca*) under the A2 (pessimistic) compared to the B1 (optimistic) emission scenario for 2010 (blue) and 2050 (orange). Figures represent preliminary results and are for demonstration purposes only.

In 2050 (see Figure 3), one can see a significant difference between the A2 (pessimistic) and the B1 (optimistic) emissions scenarios whereby Jaguar's range begins to contract. By 2090 (see Figure 4), the differences between emissions scenarios are drastic. The Jaguar is completely extirpated from the United States in the A2 scenario (if greenhouse gas emissions continue to rise near current rates), whereas in the B2 scenario the projected range of Jaguar remains in the United States and contracts to semi-contiguous, high elevation regions. In a similar exercise with Wolverine (*Gulo gulo*), another charismatic but highly threatened predator, our models demonstrate a stark contrast between the projected future ranges under the two opposing emissions scenarios (see Figure 5).

Figure 4. Projected distribution of Jaguar (*Panthera onca*) under the A2 (pessimistic) compared to the B1 (optimistic) emission scenario for 2050 (yellow) and 2090 (red). Figures represent preliminary results and are for demonstration purposes only.
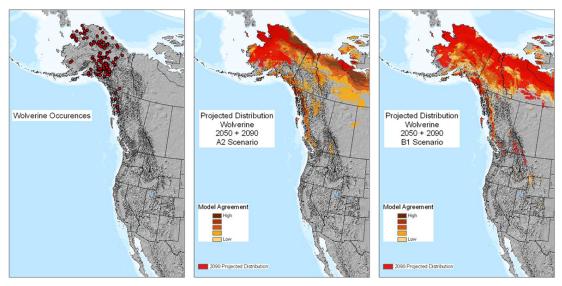

Figure 5. Current distribution of Wolverine (*Gulo gulo*) based on occurrence data from museum collections and field observations and future projected distribution of Wolverine for 2050 and 2090 under A2 compared to B1 emissions scenarios. Figures represent preliminary results and are for demonstration purposes only.

Visualization Challenges and Opportunities

Current climate change visualization efforts at the Academy stemmed from research results that revealed two very stark but consistent alternative future scenarios across modeled species and our desire to share these results with the public. In both the Jaguar and Wolverine modeling exercises, species ranges contracted and became more fragmented as emissions levels continued to accumulate throughout our projected future time slices. By 2090 in the A2 (pessimistic) scenario, Jaguar species are projected to disappear from their historic ranges in the United States altogether. We are compelled by the idea that these contrasting results

connect the behaviors of individuals and societies today to future alternative outcomes for the species and landscapes to which we have personal attachment, providing a motivation to be part of the more optimistic outcome. A recent study conducted across the United States by the Yale School of Forestry found that none of the Americans surveyed are very confident that humans both can and will successfully reduce global warming (Maibach et al., 2009). It is our hope these powerful visualizations will inspire the public to get involved in the solutions that will lead to a more sustainable future, to choose the "optimistic" scenario.

The challenge will be to find the most effective way to visualize this data and develop approaches to evaluate audience responses. Interoperability issues between transferring geospatial and biodiversity data from Geographic Information Systems (GIS) to display platforms like UniView, Google Earth and others are significant stumbling blocks. Visualizing complicated ecological relationships and model results in clear ways is another challenge in terms of balancing data integrity with keeping the human dimension of the message. Opportunities to share these climate change visualizations across institutions and facilities are becoming more widespread due to simulcast web technologies and protocols like web map service (wms) keyhole markup language (kml). Establishing a network of professionals to share data, test programming, and evaluate audience responses are already underway and are further encouraged through symposia like the *Visualizing Climate Change* workshop.

Conclusion

Although the data, models, and computational tools used in these preliminary analyses include significant uncertainties that must be continually evaluated and refined, it is already well- established that species are responding both spatially and temporally to the climate change we have already experienced, and further change is certain. Our challenge will be to develop methodologies and approaches of visualizing the outcomes of ecological forecasts that effectively engages diverse audiences about climate change issues and inspires them to change their actions and perceptions. We believe our ecological forecasting approach as briefly described using the Jaguar and the Wolverine as examples will provide a conceptual connection audiences need to think about how their actions today will affect the species and ecosystems they know and care about in the future. Scientists and visualization experts will need to reach beyond disciplinary, institutional, and cultural boundaries and collaborate with artists, designers, First Nations, and others to develop and test visualization and educational strategies. Natural history museums have a unique opportunity to act as creative incubators for fostering the integration of climate change research and visualization techniques while acting as venues of expression through their various public education programs, exhibits, and facilities.

References

Maibach, E, Roser-Renouf, C. and A. Leiserowitz. (2009). "Global Warming's Six Americas 2009: An Audience Segmentation Analysis". Yale Project on Climate Change, Yale School of Forestry and Environmental Studies and George Mason University Center for Climate Change Communication.

Biography

Lindsay Irving manages the Visualization & Outreach program at the Center for Applied Biodiversity Informatics. Her primary role is to integrate Academy research into digital media products and experiences that include maps, websites, multimedia productions, public

programs, and special events that are shared with audiences online and on the public floor. She has conducted natural resource mapping fieldwork in Panama and has curated exhibits and performances that highlight the collaborative works of artists and scientists.

Dr. Healy Hamilton is a biodiversity scientist at the California Academy of Sciences, and an adjunct professor in the Department of Geography at San Francisco State University. She is the founding director of the [Center for Applied Biodiversity Informatics](), a program that integrates biological and geospatial data for biodiversity research, conservation and education. Her lab's focus is on analyzing geographic patterns of biodiversity in the past, present, and future for science-based conservation planning.