COMMENTARY:

A blind spot in climate change vulnerability assessments

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Climate change vulnerability assessments are becoming mainstream decision support tools for conservation in the US, but they may be doing migratory species a disservice.

Recent predictions suggest that one in ten species could go extinct by the end of this century as a result of anthropogenic climate change[1]. In response, conservation professionals are scrambling to understand how a changing global climate will influence species persistence, and to develop risk management strategies — even as droughts, wildfires, floods, heat waves and violent storms play out around the world[2].

To proactively manage climate risks, the US government and collaborators have developed a National Fish, Wildlife and Plants Climate Adaptation Strategy[3], to be released early in 2013, which outlines goals for conserving biodiversity in the context of a changing climate. Goals 4 and 5 of the draft plan call for improved support tools to facilitate conservation decisions, along with observation and monitoring to increase empirical knowledge about climate change impacts. Climate change vulnerability assessment (CCVA) frameworks are increasingly popular tools designed to advance understanding of species climate change vulnerability and guide adaptive management. A robust CCVA will examine climate exposure (for example, precipitation and temperature scenarios), climate sensitivity factors (such as population size, range and habitat association) and adaptive capacity (genetic bottlenecks or demographic parameters, for example)[4], ultimately providing insight into potential causes of vulnerability. They can also be used to systematically develop testable hypotheses to generate new knowledge and identify appropriate conservation responses[5].

Standardized CCVA frameworks provide conservation planners with the ability to assess relative climate change vulnerability for many species; at least five frameworks are in use across the US[6–10]. We believe that the methods available now, although insightful for assessing the relative vulnerability of resident species, fall short and may even be misleading in predicting the vulnerability of migratory species to climate change. Because CCVAs are growing in popularity among North American conservation decision-makers, now is the time to address shortcomings that might otherwise misdirect conservation efforts.

We reviewed how five multi-species frameworks used to assess climate change vulnerability in North America treat migratory species, and found their approaches to be varied and incomplete. So far, only three of the frameworks consider a species' migratory status[7,9,10], and three consider factors on non-breeding grounds[8–10]. No assessment explicitly incorporates migratory connectivity — the specific links among breeding, wintering and migrating populations[11] — which would allow for the examination of climate exposure throughout the year for the same populations, or even acknowledges the value of full-life cycle assessments.

Assessments that overlook much of the annual cycle for such a large proportion of species or fail to consider specific linkages between breeding and wintering grounds neglect key aspects of migratory species biology, and should not be considered adequate for guiding conservation policy and management. Conservation decision-makers are regularly faced with trade-offs between certainty and a compelling need for action, and sometimes decisions need to be made with incomplete information. It is nevertheless necessary to identify critical missing data where they exist, as this is the first step in filling such gaps to better inform the decision-making process. In this case, misdirected conservation for migratory species is a significant issue, as many

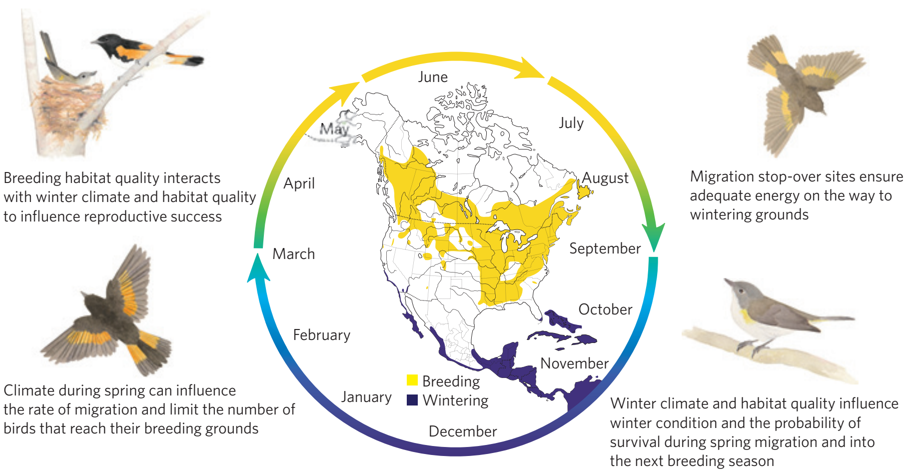

Figure 1 | The annual cycle of a long-distance migratory bird, the American Redstart, involves a round-trip migration between breeding and non-breeding grounds. Climate change impacts in one phase of the annual cycle can carry over to the next, making it necessary to consider climate change sensitivity, exposure and adaptive capacity across seasons and in several locations for linked populations. Figure by Megan Gnekow © 2010 Cornell Laboratory of Ornithology.

vertebrates in temperate regions are indeed migratory; for example, 80% of bird species occurring in North America migrate. We believe this to be addressable in the short term — a matter of several years — given adequate funding.

Below, we outline several areas for improvement in future CCVAs to make them more robust in their accounting for migratory species.

Examine the full annual cycle

Assessing the vulnerability of migratory species to climate change will require examination of factors throughout the year. This type of full life-cycle approach to evaluating climate sensitivity has been demonstrated in research pertaining to a European butterfly species[12], but so far many North American multi-species vulnerability assessments solely consider factors pertaining to the breeding season. Predicting climate change impacts for migratory species that span wide geographies and varied habitats requires better knowledge of migratory connectivity. CCVA frameworks that ignore migratory connectivity of populations, as well as climate exposure and sensitivity during most of the annual cycle, risk yielding oversimplified scenarios that could misrepresent vulnerability.

Evaluation of climate change vulnerability in long-distance migrants (for example, many species of birds, insects, fish, reptiles and mammals) poses a unique set of challenges for ecologists, because in many cases these species spend parts of their annual cycle in different habitats, at different latitudes, or even on different continents. For example, the American Redstart (*Setophaga ruticilla*), a small migratory songbird, spends approximately two months of the year engaged in nesting activities on its northern breeding grounds across the US and Canada (Fig. 1), one to two months of the year on migration between wintering and breeding grounds, and the rest of the year over-wintering in several habitat types in the Caribbean, Central America, and as far south as Ecuador and Peru. Evidence is accumulating that climate on the wintering grounds partly determines breeding-ground arrival times, reproductive success, and population dynamics for this and other migratory bird species[13–15]. Similar seasonal interactions with climate have been documented for monarch butterflies[16]. This demonstrates that for wide-ranging species, obtaining information on migratory connectivity will be crucial for evaluating seasonal exposure and climate impacts within and between all phases of the annual cycle.

Connectivity information has historically been missing for many long-distance migrants, especially small-bodied species like songbirds. However, technological advances in tracking small animals throughout the year — such as light-level geolocation devices, next generation sequencing and stable isotope ratios — combined with long-term mark-recapture data sets are rapidly improving our knowledge of migratory connectivity, including migration routes and where known breeding populations spend the non-breeding season.

Consider key life-history traits

CCVAs should incorporate information on species life-history traits that provide insight into year-round habitat specialization, physiological or behavioural limitations, or potential adaptive flexibility. For example, in the case of birds, factors pertaining to breeding and wintering events suggest direct links between climate and ecology[17–19]. These connections may inform management actions to mitigate negative effects or promote positive wildlife responses. Assessment or modelling efforts that examine only one or a few key resources (such as food) to the exclusion of others (for example, breeding habitat or migration corridors) may miss important parts of the story[20]. Demographic parameters that drive population dynamics — such as reproductive rate and age to maturity — should be incorporated as sensitivity factors, as these parameters directly influence species adaptive capacity and resilience to extreme environmental events[9,17,18].

Geographic variation in ecological conditions and natural history makes it difficult to predict how climate factors will affect a species, or how factors may interact across its range. Migration itself is an adaptive response to geographic and seasonal variation in resources, but recent climate change coupled with widespread land-use changes over the past century may seriously disrupt long-established, intricately timed ecological relationships of migratory species with their environments. Most vulnerability indices apply only to areas within specified management boundaries and not to broader species distribution, yet it is unclear if risk on a regional scale will translate to risk across a species range. This problem is greatly amplified in long-distance migratory species that, in many cases, cross geopolitical boundaries. Ultimately, incorporating spatial and temporal variation of measureable traits will yield a more accurate picture of overall climate vulnerability for a species[5]. An incorporation of variability is also key to estimating uncertainty inherent in a species CCVA — a crucial component of sound management decision-making.

Incorporate conservation status

Extinction risk calculations use previous time-series data on population abundance and dynamics (declining, stable or increasing trends) to inform the future, and are useful for predicting future dynamics in response to perturbations. To isolate climate change impacts from other, non-climate risk factors, most climate vulnerability assessments deliberately do not incorporate individual species extinction risk[6,7,10]. In practice, however, a species' climate change vulnerability may be so heavily influenced by other anthropogenic stressors that we can only meaningfully evaluate it by considering climate and non-climate factors in combination[9]. Species face both types of stressor, and it is the synergistic interaction between them that will ultimately determine vulnerability.

In conclusion, generalized, multi-taxa CCVAs are vital for setting conservation targets in light of a changing climate, and convenient for assessing and comparing many species simultaneously. Unfortunately, available assessment frameworks oversimplify the ecology of migratory species to the extent that they may fail to detect climate change risk for these species or populations when risk truly exists. Oversimplified scenarios could provide erroneous results that mislead habitat managers and affect the allocation of scarce conservation dollars. Therefore, a concentrated effort should be made to rapidly advance the study of migratory connectivity while simultaneously updating recent CCVAs and the standardized methods behind them, to better capture migratory species biology or at least explicitly acknowledge where they fail to do so. Until the critical issues we outline above are addressed, we urge extreme caution in interpreting results for migratory species derived from available CCVA frameworks that do not consider the full annual cycle. We commend efforts to efficiently assess species climate change vulnerability, especially in the absence of easily obtainable data on migratory connectivity. However, we fear that getting it wrong will have enormous costs — the foremost being missed opportunities to take conservation action at the right times and places for those species most likely to be vulnerable. ❐

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