Conservation Biology

Diversity

Conservation triage at the trailing edge of climate envelopes

Sophie L. Gilbert,[1] Kate Broadley,[2] Darcy Doran-Myers,[2] Amanda Droghini,[2] Jessica A. Haines,[2] Anni Hämäläinen,[3] Clayton T. Lamb,[2] Eric W. Neilson,[2] and Stan Boutin[2]

[1]Department of Fish & Wildlife Sciences, University of Idaho, Moscow, ID, 83844, U.S.A., email sophiegilbert@uidaho.edu
[2]Department of Biological Sciences, University of Alberta, Edmonton, AB, T6G0C5, Canada
[3]School of Optometry, Université de Montréal, Montréal, QC CAN, H3T1P1, Canada

Introduction

Species protection via geographically fixed conservation actions is a primary tool for maintenance of biodiversity worldwide (Pimm et al. 2014). Yet, for many species, the assumption that currently suitable sites will remain so is undermined by climate change (Urban 2015; Wiens 2016). Climate-change-associated range shifts (Chen et al. 2011), a process driven by populations at the trailing edge of the climate envelope going extinct or moving and those at the leading edge becoming established, are becoming widespread around the world (Wiens 2016). We argue that conservation of populations of at-risk species should be prioritized across each species' range based on future climatic suitability of an area with the goal of maintaining or increasing the number of viable populations range wide. Such range-wide prioritization could help conserve species in a changing climate when resources are limited; effort would be reallocated to viable populations (Oliver et al. 2012; Alagador & Cerdeira 2016). Promisingly, resistance to this approach (Oliver et al. 2016) may be waning. Many nongovernment organizations (e.g., International Panel on Climate Change, World Wildlife Fund) now use climate-informed range-wide approaches, as do some national and state agencies (e.g., Association of Fish & Wildlife Agencies 2018; Cornwall 2018). We aimed to advance discussion and implementation of climate-informed prioritization across species' ranges and considered when populations behind the trailing edge of climate change should be deprioritized.

An Urgently Needed Approach

Deprioritizing populations that are no longer viable under climate change is critical but remains rarely discussed. Most decision tools and conservation plans focus on enhancements within and on the leading edge of climate envelopes (connectivity, habitat improvement, refugia protection, and assisted migration [Jones et al. 2016]), whereas decisions for trailing-edge populations are rarely discussed. As climate conditions worsen at the trailing edge, affected populations will near extinction despite conservation actions (e.g., threat mitigation, protection of habitat). Nevertheless, species-specific, geographically static conservation actions are status quo and common. One-fifth of protected areas worldwide aim to protect specific species (IUCN 2008; Supporting Information). For example, protection and restoration designed to stop declines of woodland caribou (*Rangifer tarandus caribou*) do not consider that these populations may already be outside their climate envelope (Murray et al. 2015); likewise, sea-level rise will eventually drive Florida key deer (*Odocoileus virginianus clavium*) to extinction, yet in situ conservation actions continue (Maschinski et al. 2011).

Principles of conservation prioritization could be used to reallocate resources from climate-change unviable to climate-change viable populations within each at-risk species' shifting climate envelopes, which we term trailing-edge triage. Unlike multispecies conservation triage, in which resources are reallocated among species

Article impact statement: Resources should target leading edges of species' climate envelopes rather than populations at the trailing edge of climate change.

Paper submitted November 25, 2017; revised manuscript accepted June 22, 2019.

Conservation Biology, Volume 0, No. 0, 1–4

DOI: 10.1111/cobi.13401

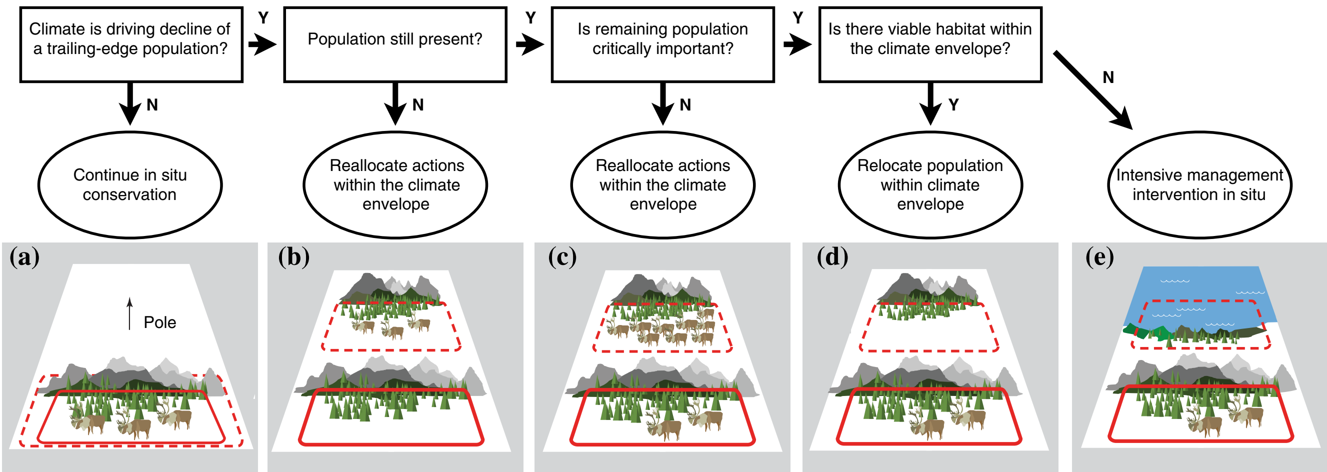

Figure 1. Conceptual diagram of 4 primary scenarios (rectangles) and actions (ovals) resulting from the difference between a protected-area (PA) designated for a population of a target species (solid-line polygon) and the PA designed to encompass the species' climate envelope (dashed-line polygon). Shown as an example are a population of woodland caribou and their northward-shifting climate envelope. Scenarios are (a) no range shift; (b) population shifts range, leaving unoccupied, but protected habitat; (c) population does not shift range, but is not essential for species persistence; (d) protected population does not shift range, is essential, and viable habitat exists elsewhere; and (e) protected population does not shift range, is critical, and no habitat exists elsewhere.

(Hobbs & Kristjanson 2003; Bottrill et al. 2008; Gerber 2016), trailing-edge triage allocates resources within the range of a target species toward populations likely to remain viable under future climate change and away from those at the trailing edge, where efforts are least likely to be effective (Oliver et al. 2012; Alagador et al. 2014). Such an approach should maximize the preservation of biodiversity with limited resources in a changing climate. Four primary scenarios could occur for populations behind the trailing edge (Fig. 1). These scenarios and potential triage actions do not encompass all the social, economic, and political complexities inherent in conservation decision making (Wintle et al. 2011; Hagerman & Satterfield 2014), which are beyond the scope of this article but are critical to resolve if trailing-edge triage is to succeed in the long term (Sinclair et al. 2018). Further, our arguments also apply to species assemblages of conservation concern (e.g., coral reefs, short-grass prairie).

Reprioritization

Determining which populations to deprioritize requires species-specific, range-wide analysis of climate vulnerability to identify climate-change unviable and viable populations so that resources can be reallocated. Range-wide vulnerability analysis currently encompasses several approaches (e.g., correlative, mechanistic, or trait-based [Pacifici 2015]), and recent advances show promise for integrating these approaches (Razgour et al. 2018). The potential for in situ evolutionary adaptation to climate change should simultaneously be facilitated and thresholds for decline agreed on by decision makers prior to prioritization (Doak & Morris 2010; Boutin & Lane 2014). Careful analysis and decision making should be used to disentangle interactive effects, reduce attribution uncertainty, and make robust, adaptive decisions (Oliver & Morecroft 2014).

Several frameworks exist that can inform decisions about how to address climate-change unviable populations. They offer practical, detailed guidance (e.g., Oliver et al. 2012; Alagador & Cerdeira 2016); therefore, we only highlight the general process (Fig. 1). First, if a population shifts range to keep pace with its climate envelope, then what remains behind the trailing edge is a remnant population and potentially a relict, species-specific protected or management area (Fig. 1b). In this situation, conservation actions, including continued habitat protection, would likely cease (but not in multispecies protected areas such as national parks) (Schneider et al. 2010; Alagador et al. 2014).

If a population cannot track the climate envelope and is not critical to the persistence of the species (Fig. 1c), then active management of that population would likewise cease, although considerations such as maintenance of genetic diversity must be taken into account. In contrast, populations unable to follow their moving climate envelope but deemed critical and with viable habitat (i.e., areas with suitable environmental and socioeconomic conditions [Schneider et al. 2010; Corlett 2016]) elsewhere (Fig. 1d) would require ex situ management, such as assisted migration or captive breeding (Dawson et al. 2011). Finally, some populations deemed critical to the persistence of a species would become stranded outside their climate envelopes and would lack viable habitat elsewhere (Fig. 1e). In this case, drastic and ongoing interventions would be required (e.g., maintenance of a conservation-reliant population [Shoo et al. 2013]).

Seizing the Opportunity

Unless geographically static conservation policies are adapted to include trailing-edge triage, increasing conservation failures and economic costs are likely as populations fall behind the trailing edge of climate envelopes and the cost of conserving them escalates. Yet, deprioritizing trailing-edge populations that are no longer climate-change viable is so far a rarely adopted strategy.

We see a number of barriers to adoption, foremost among which may be trepidation and loss aversion within the conservation community. We acknowledge that triaging trailing-edge populations is unsettling and therefore suggest that further research into understanding and mitigating resistance to prioritization and triage is key to further progress. There is a growing recognition of the joint need to both increase and better allocate total conservation resources within the conservation community (Hagerman & Satterfield 2014), which has sparked a subsequent resurgence in discussions of conservation triage (Cornwall 2018). Yet, some level of uncertainty will always remain when determining whether a population is climate-change unviable, which points to the need for involvement of social scientists (e.g., decision science, behavioral economics, etc.) in the conservation prioritization process. Further, we see the evaluation of these populations and their responses to climate change as an ongoing process to be incorporated into an adaptive-management framework. Regular monitoring and adaptive management will increase the chance of success.

Another key challenge to adoption of trailing-edge triage is the multijurisdictional nature of prioritization decisions. Inevitably, some target species will shift range across intra- and international boundaries, challenging resource-reallocation efforts, although existing multinational agreements could be adapted or serve as a productive starting point (e.g., The Migratory Bird Treaty Act, UN Convention on Migratory Species, Convention on Biological Diversity, and the Convention on International Trade in Endangered Species).

Adoption of trailing-edge triage is urgent. Range shifts are occurring faster than anticipated (Chen et al. 2011), and protective policies that are spatially static could erode public support due to real or perceived conservation failure behind the trailing edge (Tam & McDaniels 2013). As the no-analog climate future unfolds, novel tools such as trailing-edge triage could increase conservation success for at-risk species and provide a mechanism for funding conservation efforts elsewhere in species' ranges. Given the increasing interest in climate-informed prioritization and the escalating costs of continued investment in trailing-edge populations, we suggest that now is the time for rapid investment into all aspects of trailing-edge triage and subsequent widespread adoption.

Acknowledgments

We thank, R. Serrouya, C. DeMars, M. Dickie, M. Peers, Y. Majchrzak, and R. Schneider for productive discussions of these ideas.

Supporting Information

Calculations regarding species-specific protected areas (Appendix S1) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

Literature cited

Alagador D, Cerdeira JO. 2016. Climate change, species range shifts and dispersal corridors: an evaluation of spatial conservation models. Methods in Ecology and Evolution **7:**853–866.

Alagador D, Cerdeira JO, Araújo MB. 2014. Shifting protected areas: scheduling spatial priorities under climate change. Journal of Applied Ecology **51:**703–713.

Association of Fish & Wildlife Agencies (AFWA). 2018. State wildlife action plans. AFWA, Washington, D.C.

Bottrill MC, et al. 2008. Is conservation triage just smart decision making? Trends in Ecology & Evolution **23:**649–654.

Boutin S, Lane JE. 2014. Climate change and mammals: evolutionary versus plastic responses. Evolutionary Applications **7:**29–41.

Chen I-C, Hill JK, Ohlemuller R, Roy DB, Thomas CD. 2011. Rapid range shifts of species associated with high levels of climate warming. Science **333:**1024–1026.

Corlett RT. 2016. Restoration, reintroduction, and rewilding in a changing world. Trends in Ecology & Evolution **31:**453–462.

Cornwall W. 2018. Should it be saved? Science **361:**962–965.

Dawson TP, Jackson ST, House JI, Prentice IC, Mace GM. 2011. Beyond predictions: biodiversity conservation in a changing climate. Science **332:**53–58.

Doak DF, Morris WF. 2010. Demographic compensation and tipping points in climate-induced range shifts. Nature **467:**959–962.

Gerber LR. 2016. Conservation triage or injurious neglect in endangered species recovery. Proceedings of the National Academy of Science **113:**3563–3566.

Hagerman SM, Satterfield T. 2014. Agreed but not preferred: expert views on taboo options for biodiversity conservation, given climate change. Ecological Applications **24:**548–559.

Hobbs BRJ, Kristjanson LJ. 2003. Triage: How do we prioritize health care for landscapes? Ecological Management & Restoration **4:**39–45.

IUCN (International Union for Conservation of Nature). 2008. Guidelines for applying protected area management categories. IUCN, Gland, Switzerland.

Jones KR, Watson JEM, Possingham HP, Klein CJ. 2016. Incorporating climate change into spatial conservation prioritisation: a review. Biological Conservation **194:**121–130.

Maschinski J, Ross MS, Liu H, O'Brien J, von Wettberg EJ, Haskins KE. 2011. Sinking ships: conservation options for endemic taxa threatened by sea level rise. Climatic Change **107:**147–167.

Murray DL, Majchrzak YN, Peers MJL, Wehtje M, Ferreira C, Pickles RSA, Row JR, Thornton DH. 2015. Potential pitfalls of private initiatives in conservation planning: a case study from Canada's boreal forest. Biological Conservation **192:**174–180.

Oliver TH, Morecroft MD. 2014. Interactions between climate change and land use change on biodiversity: attribution problems, risks, and opportunities. Wiley Interdisciplinary Reviews: Climate Change **5:**317–335.

Oliver TH, Smithers RJ, Bailey S, Walmsley CA, Watts K. 2012. A decision framework for considering climate change adaptation in biodiversity conservation planning. Journal of Applied Ecology **49:**1247–1255.

Oliver TH, Smithers RJ, Beale CM, Watts K. 2016. Are existing biodiversity conservation strategies appropriate in a changing climate? Biological Conservation **193:**17–26.

Pacifici M. 2015. Assessing species vulnerability to climate change. Nature Climate Change **5:**215–225.

Pimm S, Jenkins CN, Abell R, Brooks TM, Gittleman JL, Joppa LN, Raven PH, Reberts CM, Sexton JO. 2014. The biodiversity of species and their rates of extinction, distribution, and protection. Science **344:**987.

Razgour O, Taggart JB, Manel S, Juste J, Ibáñez C, Rebelo H, Alberdi A, Jones G, Park K. 2018. An integrated framework to identify wildlife populations under threat from climate change. Molecular Ecology Resources **18:**18–31.

Schneider RR, Hauer G, Adamowicz WL, Boutin S. 2010. Triage for conserving populations of threatened species: the case of woodland caribou in Alberta. Biological Conservation **143:**1603–1611.

Shoo LP, et al. 2013. Making decisions to conserve species under climate change. Climatic Change **119:**239–246.

Sinclair SP, Milner-Gulland EJ, Smith RJ, Mcintosh EJ, Possingham HP, Vercammen A, Knight AT. 2018. The use, and usefulness, of spatial conservation prioritizations. Conservation Letters **11:** e12459.

Tam J, McDaniels TL. 2013. Understanding individual risk perceptions and preferences for climate change adaptations in biological conservation. Environmental Science & Policy **27:**114–123.

Urban MC. 2015. Accelerating extinction risk from climate change. Science **348:**571–573.

Wiens JJ. 2016. Climate-related local extinctions are already widespread among plant and animal species. PLoS Biology **14:**e2001104.

Wintle BA, et al. 2011. Ecological–economic optimization of biodiversity conservation under climate change. Nature Climate Change **1:**355–359.