Commentary

Commentary: Osland et al. (2021): Tropicalization of temperate ecosystems in North America: The northward range expansion of tropical organisms in response to warming winter temperatures

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Tropicalization is, "the transformation of temperate ecosystems by poleward-moving tropical organisms in response to warming temperatures" (Osland et al. 2021). In their newly published Research Review article in Global Change Biology, Osland and colleagues provide important context, diverse examples, and discuss critical knowledge gaps on tropicalization for the lower latitudes of North America where species assemblages are changing via range expansions or invasions. Their extensive collaboration documents patterns of tropicalization across varying ecosystems and climates, and points to an underrepresented, yet vitally important, factor of climate change. This article suggests that extreme minimum temperatures are the driving force behind the current and future range limits of most species in North America, regardless of the ecosystem. This may spark some healthy debate as mean, and not extreme, temperatures have traditionally been used when analyzing climate change impacts (e.g., Thompson et al., 2013). We hope these conversations occur, as debate is always good for advancing science.

Climate change impacts, including sea level rise, rising average temperatures, increasing prevalence of extreme high temperatures, and more frequent and intense severe events (storms, forest fires, droughts, etc.) are altering many diverse ecosystems on our planet (e.g., Wernberg et al., 2016; Weiskopf et al. 2020). Osland and colleagues provide multiple lines of evidence supporting the premise that shifting extreme cold temperatures are responsible for the rapidly changing North American landscape. They suggest, and we agree, that prior research may have overlooked the importance of a reduction in the occurrence of extreme minimum temperatures because decades can pass between extreme cold events in temperature ecotone regions. Many scientists and residents currently living and working in areas undergoing tropicalization may never actually experience an extreme cold event to make it “real”. The February 2021 freeze event in Texas made international media headlines with a focus on human suffering associated with loss of power grids, water shortages, and grocery stores unable to open. Equally important losses to endangered species (sea turtles), economically important animals (fish kills) and species providing important ecosystem services (e.g., mangroves) were subsequently reported in the media. It is vital that future research considers the consequences of less frequent but intense extreme temperature minimums in modeling potential species shifts and what this means for the receiving ecosystems.

The article focuses on three essential aspects of tropicalization. First, it provides documentation of climate change-induced decreases in the frequency and intensity of extreme cold events over the past approximately 75 years, with a focus on four locations where subtropical and temperate conditions converge (San Francisco, Tucson, New Orleans, Tampa). Second, there is a wealth of information on physiological constraints, range expansions, and dispersal mechanisms for a wide variety of terrestrial and aquatic taxa. It includes some charismatic favorites (sea turtles, manatees, giant cacti), species that are economically important (finfish, disease-carrying mosquitos, pythons), plus foundational species that have dramatically changed landscapes in recent decades (mangroves overtaking saltmarshes). Third, the scientific team provides a list of knowledge gaps and understudied topics related to tropicalization that should push organized research forward in numerous critical directions. This new publication by Osland et al. should be of broad appeal to many groups of readers, including scientists, resource managers, media specialists, teachers, and students.

This article sets the groundwork for tropicalization research in North America for years to come. In addition to the topics outlined in the publication, we encourage scientists to expand their focus from individual species to include impacted species complexes (including hybridization) and ecosystems; this will provide additional information on the adaptive capacity of our diverse ecosystems. Future research topics should include:

1) Increasing the focus on species complexes that include new arrivals and organisms impacted in the recipient location. For example, the global loss of pollinators is an important conservation

concern. Vasiliev and Greenwood (2021) found that warming winters significantly contributed to the resulting homogenization of pollinator assemblages at all levels (genetic, species, community) in the Northern Hemisphere, making them less resilient. Likewise, McClenachan et al. (2020) reported a 198% increase in mangrove numbers on intertidal oyster reefs in central Florida over the past 74 years due to a lack of extreme freeze events. Interesting ecological, biogeochemical, and physiological questions now need to be addressed to understand interactions between these two foundational species. Additionally, resource managers and restoration practitioners should consider these interactions relative to the goals of their agencies or projects.

2) Broadening the research scope to understand how an entire ecosystem responds to extreme cold events or the lack of such events. Whether it is a single species or species complex, what are the interacting ripple effects for the entire ecosystem? Do flora and fauna acclimate to the lack of freezes in the same way that humans become less prepared for local hurricanes as the duration between storms increases? Laboratory, field observations, manipulations, and historical GIS analyses should enable us to time travel both forward and backwards and model ecosystem interactions and changes. These studies would be especially key for vulnerable conservation areas, such as national parks and wildlife refuges (McClenachan et al. 2020). An interesting ecosystem-level example by Zarco-Perello et al. (2020) reported that tropicalization is occurring faster in marine systems than in terrestrial habitats.

3) Focusing on multiple stressors that accelerate tropicalization and promote range expansions when conducting invasion and vulnerability assessments (e.g., Wallingford et al., 2020). Osland et al.'s article provides some great examples of dispersal of non-native organisms through shipping, and via pet and horticultural trades. Many species are moved globally by humans at alarming rates, and warming winters may allow species to thrive in locations deemed inhospitable even a few years earlier, accelerating the rate of species invasions into new regions (e.g., Hulme 2009; Walters et al., 2006).

4) Hybridization, rather than solely species shifts resulting from tropicalization, needs to be further explored across all ecosystems. Articles that focus on tropicalization and hybridization include species ranging from alpine plants (Charles and Stehlik 2020) to sea urchin larvae (Lamare et al. 2018). If viable, will these hybrids shake up the system more or less than their tropicalized

parents? If there are no obvious ways to distinguish hybrids, how long will it be before we even realize hybridization has occurred?

The most important take-home message from this review is that tropicalization is already happening in numerous locations and varied ecosystems. This article articulates this message with writing that is understandable to a broad audience. We plan to share it with our university students and encourage colleagues teaching classes in environmental studies, climate change, invasive species, and a wide range of biology courses to do likewise to spur conversation on the state of our planet and its future.

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