frontiers in Climate

POLICY BRIEF
published: 22 November 2021
doi: 10.3389/fclim.2021.735608

Regulatory Fragmentation: An Unexamined Barrier to Species Conservation Under Climate Change

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Requirements for the protection or restriction of species are based on regulatory classifications such as "native" or "invasive," which become anachronistic when climate change drives species outside of their historical geographic range. Furthermore, such regulatory classifications are inconsistent across the patchwork of land ownership that species must traverse as they move between jurisdictions or when transported by humans, which obstructs effective regional management. We surveyed the U.S. laws and regulations relevant to species movement and found that the immigration of species to new jurisdictions makes paradoxical existing regulatory language that sets the categories of species deserving protection or removal. Climate change is universal and progressing rapidly, which provides a shrinking window to reconcile regulatory language originally developed for a static environment.

Keywords: regulatory fragmentation, climate change, conservation, natural resources law, Anthropocene, endangered species, invasive species, public lands

OPEN ACCESS

Edited by:
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Specialty section:
This article was submitted to Climate Law and Policy, a section of the journal Frontiers in Climate

Received: 02 July 2021
Accepted: 06 October 2021
Published: 22 November 2021

Citation:
Camacho AE and McLachlan JS (2021) Regulatory Fragmentation: An Unexamined Barrier to Species Conservation Under Climate Change. Front. Clim. 3:735608. doi: 10.3389/fclim.2021.735608

INTRODUCTION

Species migrations of hundreds to thousands of kilometers were a common response to past periods of rapid climate change (Davis and Shaw, 2001), and, because movement was not coherent across species, the species composition of ecological communities changed substantially with these climate disruptions (Blois et al., 2013). Contemporary climate change is already driving species shifts and community realignment (Blois et al., 2013; Moritz and Aguda, 2013). Since the rates and magnitude of contemporary climate change are projected to be as high or higher than those past analogs (Raftery et al., 2017), it is virtually certain that species range shifts will grow larger and more ubiquitous this century.

Species displaced long distances by climate change will thus increasingly have to traverse a patchwork of jurisdictional boundaries to survive. However, the regulatory status of species that disperse beyond their historical ranges varies from jurisdiction to jurisdiction and often hinges on whether they are considered "native," an ambiguous designation for species undergoing range shifts. Like habitat fragmentation, which can impede the capacity of migrating species to keep up with shifting climates (Warren et al., 2001), such "regulatory fragmentation" can compromise management strategies under climate change (Craig, 2008). Although regulatory programs are emerging at local, state, and national scales that attempt to address some of the impacts of climate change on species conservation (National Academies of Sciences, 2016), there has been no systematic effort to address the mismatch between a body of regulatory language designed for a static environment and a future context of extensive and ubiquitous species movement (Scheffers and Pecl, 2019).

The management and conservation of species is presently built on regulatory classification schemes that focus on the historical and/or existing ranges of species (e.g., "native" or "non-native"), consideration of the extent of past human instigation ("invasive," "introduced"), and the prevalence of the current population opaquely combined with cultural determinations of a species' significance (e.g., "invasive," "endangered"), (Executive Office of the President, 1999). Such retrospectively oriented classifications may become anachronistic when species ranges shift. Making matters worse, these regulations differ between jurisdictions, and jurisdictional boundaries matter because natural resources law is generally grounded in treating different types of lands as distinct from and largely unconnected to others. As a result, in many areas throughout the U.S., federal, state, local, and private entities own parcels of land arranged in checkerboard or more chaotic patterns, with concomitant differences in regulations (Camacho, 2011).

This "regulatory fragmentation" poses unprecedented challenges to coherent management across geographical regions and governmental scales. because, under a changing climate, the ranges of many species will shift far beyond where they are currently considered "native" or "protected," potentially across many administrative, state, and international borders (Dawson et al., 2011). Other species will move slowly or not at all, creating a landscape where ecological communities contain mixtures of "old native" species, "old invasive" species, and new species recently arrived via self-propelled, ostensibly "natural" dispersal or via direct (intentional or unintentional) human introduction. Experience from past natural and anthropogenic species introductions suggests that the ecological impact of new combinations of species is difficult to predict. Immigrant species that are rare in their current habitat might become common as they expand into new regions under novel future climates, or vice versa (Ricciardi and Simberloff, 2009). Newly arrived species might outcompete, prey upon, or otherwise harm "old native" species, or vice versa.

Here, we use illustrative scenarios to show how current regulatory language can become problematic, even paradoxical, when climate drives species out of their historical ranges. Our goal is to make regulatory fragmentation as visible to conservation biologists and strategists as habitat fragmentation, which is routinely used in the assessment and planning of species conservation (Dickson et al., 2017). Our approach is to use simple "climate envelope" projections of species range shifts, developed by us and others, not as predictions but as plausible scenarios, illustrating how far, and by which route, species might move under climate change this century. We then collate and interpret the set of laws and regulations that apply to species movement in the jurisdictions that the species crossed in our "migration" scenarios. This approach allows us to identify a set of likely unforeseen consequences of the current regulatory landscape. We believe that the types of regulatory paradoxes illustrated by our scenarios are likely to pose general problems in the near future, but we emphasize, for clarity, that the specific migratory pathways we delineate in this paper are only realistic scenarios. Actual migratory pathways will depend on the realized trajectory of greenhouse gas emissions, the actual climate response to those emissions, and many details missing from our model, like species interactions, dispersal barriers, etc., (Moritz and Aguda, 2013). Our analyses focus on the United States, but the broad issues of regulatory fragmentation under climate change apply in the regulatory context of most other countries and in trans-global governance as well (Trouwborst et al., 2015; Scheffers and Pecl, 2019; Somsen and Trouwborst, 2020).

POLICY IMPLICATIONS OF REGULATORY FRAGMENTATION

Regulatory Fragmentation Might Endanger Beneficial Taxa

Some current management rules might inhibit the movement of species considered by policymakers to be "beneficial," such as rare or vulnerable taxa. Harwood's woolly star (*Eriastrum harwoodii*), for instance, is a rare plant endemic to 31 populations in the Mojave Desert of California. Harwood's woolly star is protected on both state land and by federal agencies, such as the US Bureau of Land Management (BLM) in its historical range, thanks to its classification (rank 1B) by the California Native Plant Society (see **Supplementary Table 1** for details). The future geographic range of Harwood's woolly star will depend on the trajectory of regional climate; the details of the woolly star's physiology, demography, dispersal, etc.; and its interaction with other species, each of which is largely unknown. To illustrate the regulatory challenges faced by migrating species, however, we applied a simple but plausible range shift model to Harwood's woolly star under a moderate climate change scenario as a heuristic example (**Supplementary Document 1**). Under this scenario, the most likely 21st century migration route takes the species 240 km southeast into southern Arizona, where local habitat is projected to be similar that of its current range (**Figure 1**). Southward migrations under climate change can occur when the combination of local climate factors favoring species habitat outweigh the general tendency of warming to move habitat polewards (Rapacciuolo et al., 2014). The biological challenges of this range displacement will be augmented by the uneven standards of protection that result from regulatory fragmentation. Our estimation of its most likely migration route crosses 41 legal boundaries involving over a dozen state and federal entities (**Supplementary Table 1**), including a daunting shift into Arizona, which does not provide protections for rare species not listed under the US Endangered Species Act (ESA). Once it crosses state lines, this species has no protected status, even if it were to again settle on BLM land in Arizona (Bureau of Land Management, 2008; **Supplementary Table 1**).

While our modeled migration pathway is unlikely to be the exact route Harwood's woolly star takes this century, the fragmented landscape crossed by the woolly star in this example is typical of the piecemeal mixture of rules alternately protecting or obstructing newly arriving species that derives from varying definitions of terms like "native" across jurisdictions. In another example, the USFWS actively promotes reintroductions of native

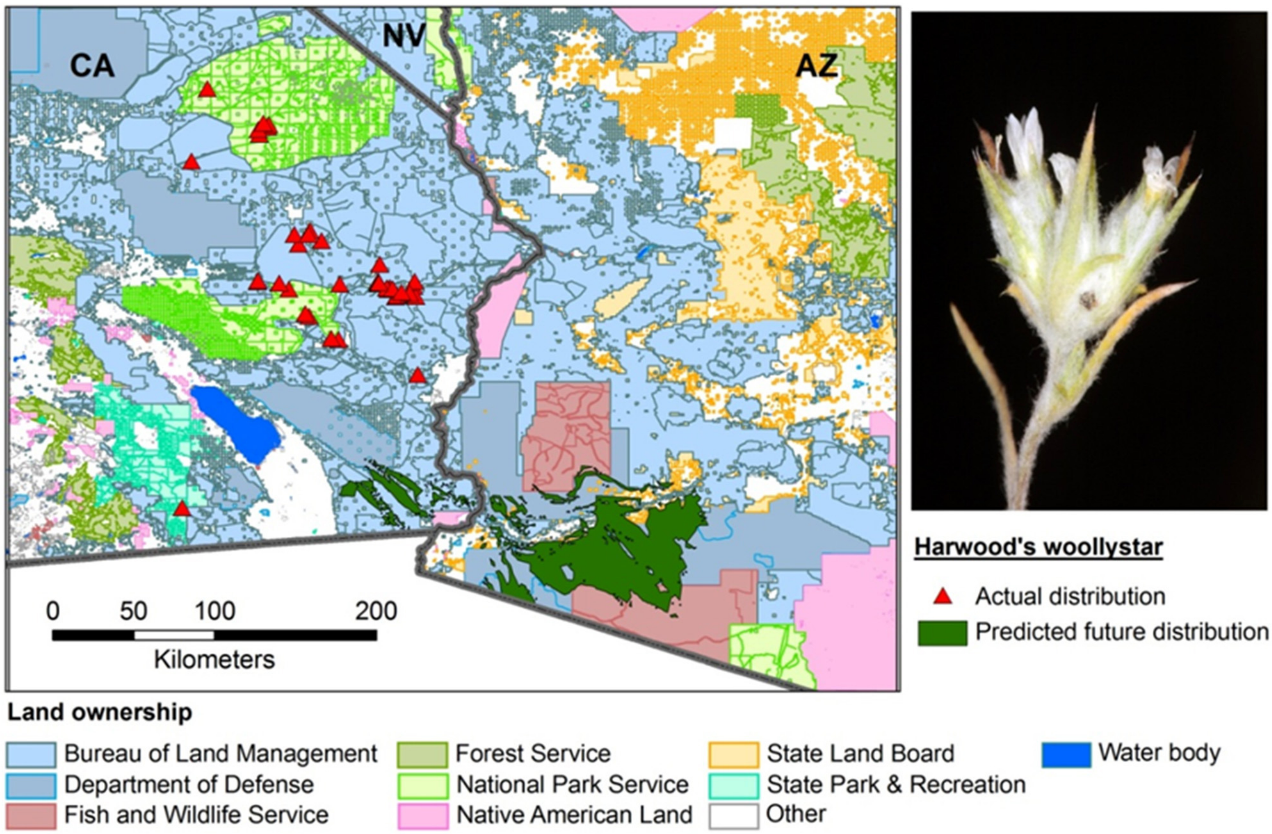

FIGURE 1 | Harwood's woolly star is currently endemic to California and protected on state and federal land. Under a moderate warming scenario, suitable habitat for this plant might shift to the southeast, forcing it to traverse a fragmented regulatory landscape. Populations arriving in Arizona might lose state and federal protection (see text).

species in US National Wildlife Refuges as long as they were not "naturally" extirpated, but it discourages such introductions for vulnerable non-native species unless essential and prescribed in an endangered species recovery plan (USFWS, 2021). This makes the status of "new natives," particularly those that are not listed as endangered, problematic. Even species listed under the ESA, often considered the highest level of protection in the US, face changing levels of protection as they traverse the fragmented regulatory landscape. For example, some protections against damage to a federally listed plant established on federal land disappear if the plant disperses to non-federal land (United States, 1983), making non-federal land a greater barrier to climate change-induced species movement. Finally, though wide-scale shifts in climatic conditions are likely to impose significant stress across taxonomic groups, such regulatory barriers do not apply equally across taxa: The legal barriers to movement under the Endangered Species Act for federally listed endangered plants on non-federal land, for example, are less than for federally-listed endangered animals (United States, 1983). It is possible of course, that such regulatory inconsistencies could be addressed by discretionary enforcement of contradictory rules, though that leads to additional complications, which we explore later.

Because active adaptation strategies, such as managed relocation, are already being discussed and used as a component of species conservation under climate change (Richardson et al., 2009), it is also important to consider the impact of direct human assistance on the regulatory status of spreading species. In most jurisdictions, if the governing authority determines that species moved by humans to minimize or mitigate the impact of climate change are "introduced," such species receive less regulatory protection and more regulatory resistance than if their arrival was not facilitated by direct human intervention. The National Parks Service, for example, defines and manages "exotic species" as "those species that occupy or could occupy park lands directly or indirectly as the result of deliberate or accidental human activities," while native species include "all species that have occurred, now occur, or may occur as a result of natural processes on lands designated as units of the national park system," (U.S. National Park Service, 2006). Thus, active management intended to preserve a species might paradoxically lead to lowered protective status for that species. Laws favoring purportedly "natural" migration over conservation-oriented human introduction are increasingly untenable in the context of a rapidly changing patchwork landscape that subjects wildlife to substantial physical and regulatory dispersal barriers.

Short of deliberately relocating taxa, some conservation biologists have advocated expanding the potential habitat for protective species to include either environments believed to have supported these species in the past, or environments deemed potentially suitable for species based on other inferences (Hiers et al., 2012). The regulatory complications identified above for managed relocation might also apply to efforts to expand conservation decision space by including habitats not currently occupied by the target species.

Regulatory Fragmentation Might Protect Harmful Taxa

Climate change also complicates regulations meant to inhibit harmful species movement. In many U.S. jurisdictions, only non-native species can be deemed "invasive" [e.g., Executive Office of the President (1999)], meaning that the ambiguous and inconsistent process of determining native status described above could result either in a policy of control or eradication of newly arrived climate refugees, or at the other extreme: in active protection. The existing paradigm for invasive species management focuses on prohibiting only certain blacklisted species. In the novel ecological communities created when "new natives" mix with "old natives," the difficulty of establishing such lists will be compounded by ambiguity about the status of "new natives" combined with the difficulty of assessing the acceptable impact of "new natives" in the context of novel ecological communities. These problematic aspects of determining "invasive" status in a dynamic biological setting thus raise the risk both of inhibiting the movement of species deemed beneficial and of facilitating the movement of species that may cause considerable harm. Making matters more troublesome for big-picture conservation and resource management policy, these contrary treatments could occur simultaneously in different jurisdictions depending on the laws, policies, and interpretations of different agencies or landowners.

Black locust (*Robinia pseudoacacia*), a native tree in the Ozarks and southern Appalachians, is identified as an ecological threat in the Upper Midwest, due primarily to its habit of establishing dense groves that exclude native vegetation (Hoffman and Kearns, 1997). Eight states in the eastern US consequently have laws or regulations limiting the movement of black locust, or encouraging its eradication (see **Supplementary Document 1**). In Wisconsin, black locust is listed as a "restricted" invasive species, mandating a statewide plan for controlling the species, including prohibitions on the transport, possession, transfer, or introduction of the species (**Supplementary Document 1**).

Ironically, in projections of the habitat range of black locust under a high greenhouse gas emissions scenario, black locust is projected to become rare or extinct in the western range of its native habitat by 2,100, shifting its primary habitat to Northeastern and Midwestern states, including states where it is currently considered invasive (**Figure 2**; Peters et al., 2020). Given this possibility, and the logic of the Harwood's woolly star example in the previous section, it might be reasonable to ask whether such states might wish to have a mechanism for reclassifying former invasive as "new" native species.

Alternatively, a tempting argument for continuing efforts to curtail migration of black locust in the Northeast and Midwest, even should a scenario like that depicted in **Figure 2** unfold, might be that it has a proven record of negative impact on "old native" species. Such an argument, handily distinguishing a "good" new native like Harwood's woolly star, from a "bad" new native like black locust, ignores the fact that climate change of the magnitude predicted for this century has historically disrupted "old native" communities and shifted biomes (Williams et al., 2004). Might a policy of continued black locust eradication in Wisconsin look as non-sensual to future generations as it would for us to consider black spruce to be "invasive" in formerly glaciated Canada, and "native" in the Southeastern US, where it thrived in glacial times (Williams et al., 2004)? And what if black locust were to become in danger of extinction in parts of its historical range, as it does in the southern Ozarks in the scenario depicted in **Figure 2**? In fact, USFWS might be required to list black locust if it were likely to become at risk of extinction in the foreseeable future in any significant portion of its range. Fundamentally, the regulatory context for species shifting geographically under climate change should play a larger role in discussions about the conservation challenges posed by the Anthropocene (Corlett, 2015).

"Soft" Language Allows Flexibility, With the Potential for Mixed Consequences

We looked closely at the suite of regulations relevant to the projected movement of Harwood's woolly star and determined that management action is often contingent on soft language potentially allowing management flexibility (**Supplementary Table 1**). For example, the Department of Defense monitors and controls invasive species "whenever feasible" (Department of Defense, 2011), and the United States Forest Service strives to prevent, control, and/or manage invasive species in National Forests "as appropriate" (USDA, 2004). In our projected displacement of Harwood's woolly star, the most protective interpretation of existing regulations would mean that the species would remain under either proactive or, at least, passive protection by land managers for 55% of its route, leaving over 100 km of its journey transiting across land where it is neither protected or actively discouraged (**Figure 3**). Under the least protective interpretation of regulatory language, where state or federal agencies determine that Harwood's woolly star is non-native and is determined to cause harm to existing taxa, managers could decide to actively control or eradicate species like Harwood's woolly star along half of its projected migration route.

Such soft language *could* work to the benefit of regional management. In some cases, such discretion might allow

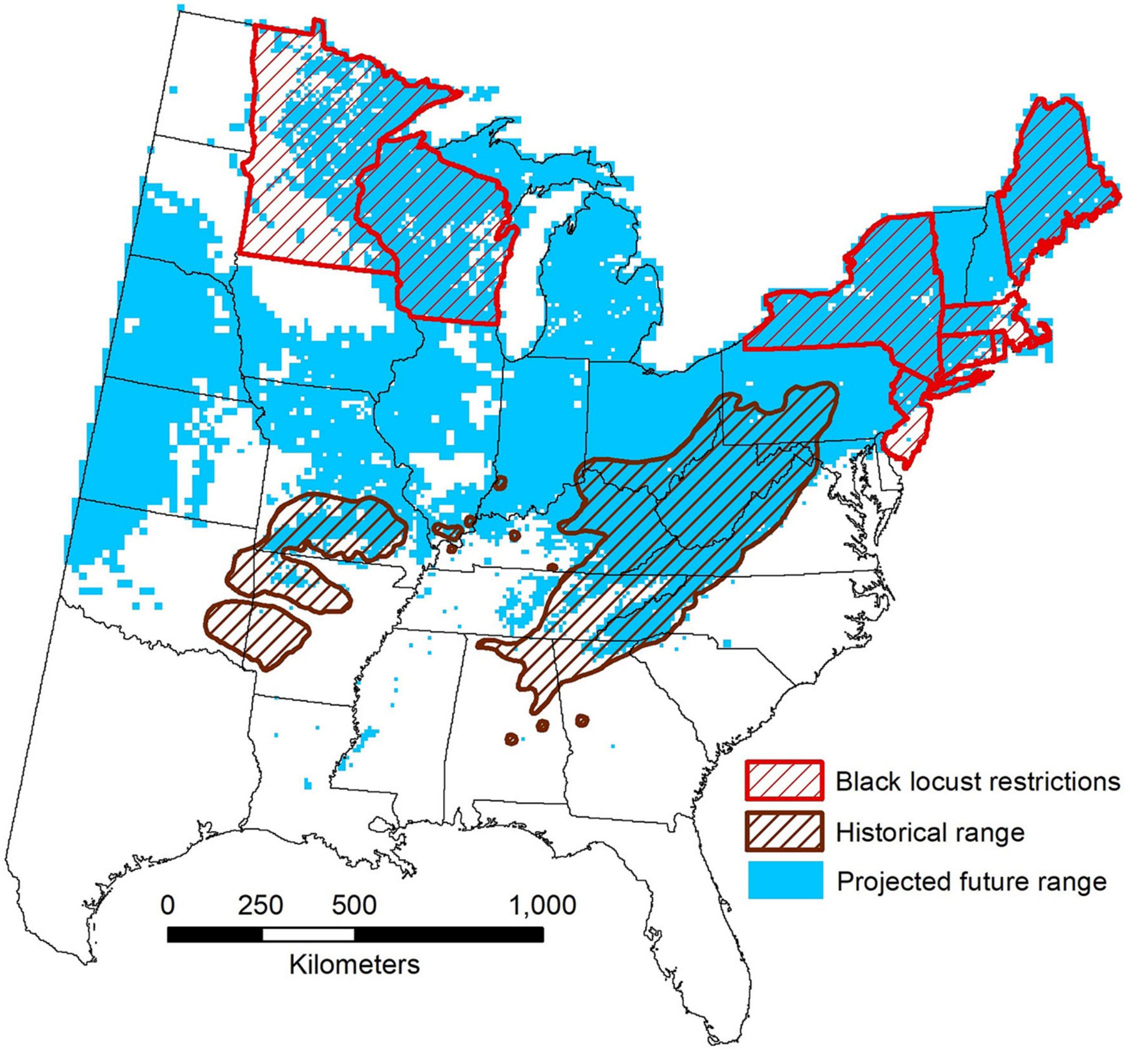

FIGURE 2 | Historical native range (brown polygon) of black locust and its projected future range under a high greenhouse gas emission scenario (blue polygons, Peters et al., 2020). Each state highlighted in red has laws or regulations that require active eradication measures or otherwise restrict the movement of the species (see **Supplementary Document 1**).

administrators to avoid inconsistencies and paradoxes associated with a strict interpretation of laws regulating species movement. For instance, this soft language allows breathing room for new efforts fostering greater collaboration between jurisdictions, such as the Landscape Conservation Cooperatives and large-scale multi-species Habitat Conservation Plans (Wilhere, 2002; National Academies of Sciences, 2016). However, reliance on vague regulatory language—originally developed largely to arrest movement rather than to facilitate it—will only provide temporary reprieve. Concrete legislative or regulatory guidance rooted in the dynamic nature of species conservation would ultimately create greater consistency and long-term viability of conservation under changing climate. While providing land managers discretion may allow for the adjustment of management to account for changing conditions and new information in localized contexts, placing the burden of controversial normative decision making on local managers who are often under-resourced, constrained by strict performance targets, and subject to local pressures is unwise.

ACTIONABLE RECOMMENDATIONS AND CONCLUSIONS

Existing regulatory language, processes, and structures meant to protect beneficial species and deter harmful species will become increasingly problematic as climate changes this century. A new regulatory infrastructure is required to promote long-term ecological function and biodiversity in the face of wide-scale pressure from climate change. Not only the substantive

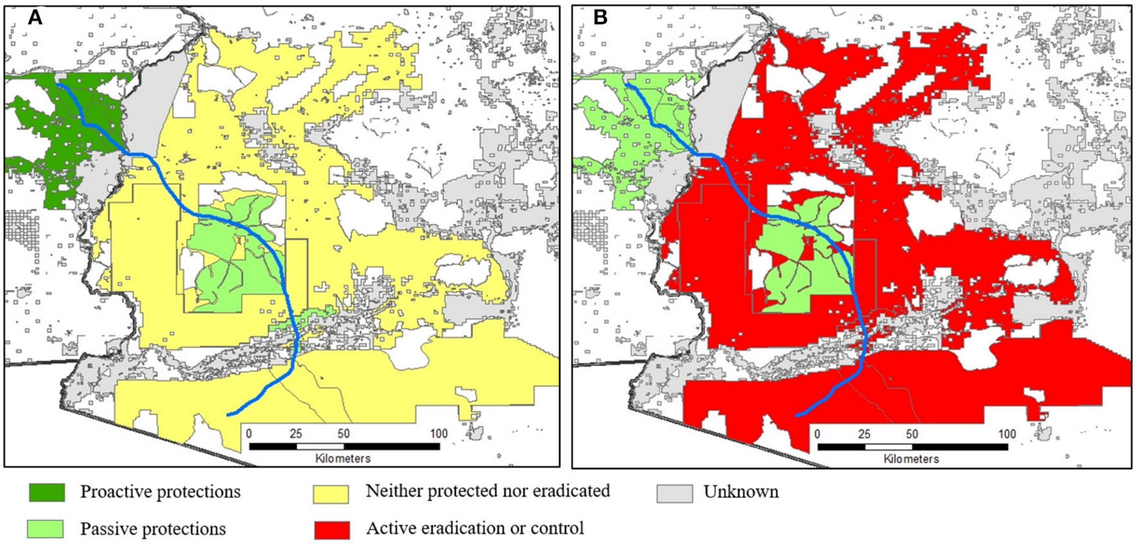

FIGURE 3 | Regulatory status of Harwood's woolly star in jurisdictions along a plausible climate-driven migration route (blue line): **(A)** Under the most protective interpretation of relevant regulatory language; **(B)** Under the most restrictive interpretation of relevant regulatory language (see **Supplementary Table 1**).

strategies, but also the processes and institutional structure of ecosystem governance, must be reshaped—recognizing that such changes will undoubtedly pose fundamental ethical questions for conservation governance.

First, the *substantive* standards governing species movement need to be reframed away from categorical dualisms like native/non-native and introduced/natural that dominate the law and policy. Classifications like "native" and "invasive" have long provided simple, though occasionally controversial (Somsen and Trouwborst, 2020), guidelines for normative decisions about which species are and should be locally promoted or impeded. The current regulatory paradigm emphasizes the preservation of historical conditions and the minimization of human intervention, but these goals are becoming increasingly at odds with each other. Moreover, these standards will be increasingly untenable as species make essentially permanent range shifts accompanying climate change.

Accordingly, it is important to immediately begin the difficult task of establishing new standards. Rather than a myopic focus on promoting native species and minimizing active management, laws and policies should be reoriented to promote beneficial and discourage harmful movement. This necessarily means increased emphasis on ecological health over historical and wildness preservation objectives in conventional conservation strategies like ecosystem-based and landscape-level conservation planning, species recovery planning, or even private land management incentives to increase or decrease permeability (Kostyack et al., 2011). Yet advancing ecological health in the face of landscape-level climatic change will likely require employment of active interventions such as assisted migration, biotechnological strategies (Camacho, 2020), and reconsideration of invasive management strategies.

For instance, the President might update Executive Order 13,112 and 13,751 to define "invasive species" to remove the requirements of being both non-native and introduced. Static regulatory designations of species as native or non-native will primarily be useful as rebuttable presumptions in cautious risk assessment of species movement in increasingly non-static natural environments (Camacho, 2015). In other words, active translocation strategies like assisted migration under laws like section 10(j) the ESA as well as in Federal land agency regulatory guidance might rely on risk assessments that include rebuttable presumptions that (1) the movement of an ecological unit is appropriate in locations where it already exists or existed, and (2) immigration or intentional translocations to areas outside a species' historical or current range is not appropriate. In some contexts, policymakers might instead remove distinctions between, for example, "introduced" and "natural" movement completely when such a distinction provides little guidance for when species movement might be beneficial or harmful.

We unequivocally acknowledge, however, that determinations of what are beneficial or harmful movements are value laden and contextual. Science and management expertise alone cannot solve the problem. To be sure, policymakers will need to work closely with scientists and local managers to develop and implement measurable criteria that balance the increasingly competing goals of preservation and biodiversity in the broader framework of promoting ecological function at broad scales. Ongoing efforts by biologists, climate scientists, and social scientists to improve forecasts of the species composition of future ecological communities will, of course, be vital (Blois et al., 2013; Bonebrake et al., 2018) as will continued scientific progress defining and analyzing the ecological targets of conservation, like "biodiversity" and "ecosystem health," which remain contestable and elusive. General principles of invasion biology, like the set of biological traits linked to "weediness" will be worth considering in establishing rules and priorities for managing novel communities. Conservation scientists and managers must increasingly direct their efforts toward characterizing the value of ecological phenomena and the metrics of operationalizing values of ecological constituents, processes, and systems in the context of the tradeoffs raised by resisting, allowing, or assisting species movement (Camacho, 2020).

Yet even a vast reduction in scientific uncertainty will not clarify the difficult ethical and ultimately political questions raised by climate change's effects on biodiversity. Under the scenario posed in **Figure 2**, for instance, current regulations would prioritize "old native" species over "new natives" in an increasingly untenable way. Improved scientific understanding (of climate trajectories, of the demography and ecology of "new natives," etc.) cannot by itself resolve this problem. Laws must address if and how species that move into new jurisdictions under climate change will be encouraged or controlled, and they must address the likely scenario that "native" communities will be different in the future. If legislators determine that humans should take an active hand in protecting species from the ravages of climate change by introducing them to new habitats, it will no longer make sense to deem such "introduced" species less worthy of protection in their new homes. Such decisions are fundamental value choices that raise tradeoffs that not only require the input of the resource management and scientific communities. More importantly, they necessitate thoughtful and inclusive public deliberation through the democratic process.

Accordingly, ensuring robust conservation governance *processes* is at least as important an endeavor for conservation law in the Anthropocene. Federal and state legislatures in the U.S. must reevaluate not only the ends but also the means of species management policy under climate change. New dynamic and adaptive processes and institutional authority are needed for managing species as they move across jurisdictional boundaries (Camacho, 2020). This includes integration of adaptive species movement management in, for example, ESA recovery planning and habitat conservation planning for listed species, federal land management planning, and state wildlife action plans for other vulnerable species.

Climate change also raises deep *structural* and institutional concerns about the continued efficacy of fragmented species management institutions in the United States. But it also provides an opportunity to reimagine species conservation in ways that recognize and mediate linkages between artificially disparate jurisdictions through tailored reallocations or coordination of authority (Ruhl and Salzman, 2009; Craig, 2010; Camacho and Glicksman, 2019). Coordinating institutions particularly over information dissemination and generation, planning, and implementation may help reconcile disparate regulations among the many local, state, and federal jurisdictions. Yet an increased federal presence over funding and standard setting over wildlife movement may increasingly be necessary to minimize transboundary harms, promote harmonization, and leverage economies of scale while maintaining the expertise, diversity, and experimentation advantages of still primarily decentralized authority (Camacho, 2020). More fundamentally, a meaningful democratic dialogue about the goals, procedures, and structures of species management in a changing world is needed to foster regulatory species management policies that are as complex and dynamic as the threats to ecological function and diversity presented by a rapidly changing climate.

AUTHOR CONTRIBUTIONS

AC and JM contributed equally to the conceptualization and writing of the manuscript. JM designed the geographic analyses. AC led the collation and analysis of the laws and regulations. Both authors contributed to the article and approved the submitted version.

FUNDING

This research was funded by NSF CDI-1029584.

ACKNOWLEDGMENTS

We thank Jishan Liao and William Tintor for assistance with the geographic analysis, and Christopher Dalbey, Christopher Glueck, Duncan Justice, and Dexter Rappleye for assistance with the legal analysis. We thank Jody Peters for managing this project and producing the figures.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2021.735608/full#supplementary-material

Supplementary Table 1 | Regulatory classification for Harwood's woolly star under climate-driven migration scenario.

Supplementary Document 1 | Details of climate shift scenarios and regulations restricting black locust in U.S. eastern states.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer JM declared a past co-authorship with one of the authors AC to the handling editor.

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