Received: 14 November 2021 | Revised: 17 March 2022 | Accepted: 18 March 2022
DOI: 10.1111/fme.12546

NOTE

Fisheries Management and Ecology
WILEY

Developing a resist-accept-direct (RAD) framework for managing freshwater fish species shifting in and out of political jurisdictions

Karen M. Alofs[1] | Kevin E. Wehrly[2]

[1]School for Environment and Sustainability, University of Michigan, Ann Arbor, Michigan, USA

[2]Michigan Department of Natural Resources, Institute for Fisheries Research, Ann Arbor, Michigan, USA

Correspondence
Karen M. Alofs, University of Michigan, School for Environment and Sustainability, Ann Arbor, MI, 48109, USA.
Email: kmalofs@umich.edu

Abstract

Factors including human dispersal, climate change and varied environmental stressors are altering fish species distributions. Range expansions are producing new records of freshwater species which were rare or previously absent from regional jurisdictions (states, provinces and territories). Simultaneously, species are facing declines and local extirpations in some areas of their distribution. The Resist-Accept-Direct (RAD) framework can provide guiding principles for how declining, newly arrived, or range expanding freshwater fishes should be managed and how range-wide trends can be considered in local management and conservation decisions. We examine the principles of the framework and provide an example decision tree which is applied to examples ranging from *resisting* the establishment of potentially harmful non-native fishes, to *accepting* and providing refuge to those species threatened in other parts of their ranges, to *directing* the migration of fishes which improve ecosystem services. Applying this framework may improve coordination between agencies aiming to improve the resilience of freshwater ecosystems.

KEYWORDS
climate, endangered, migration, range expansion, threatened

Freshwater fisheries management and conservation decisions are often made within local jurisdictions (states, provinces or territories) rather than at regional or federal levels. Local agency responsibilities include monitoring and assessment, the regulation and management of common species and invasive species, and the designation of jurisdictional conservation status for rare species. Conservation status is often inconsistent across jurisdictions (e.g. Mandrak & Cudmore, 2010). Inconsistencies in designated status can be due to real differences in populations and threats or due to differences in the criteria or data used for local designations (Faucheux, 2019) and lead to differences in management approaches across a species range. Additionally, North American freshwater ecoregions, watersheds and species distributions cross state, provincial and territorial boundaries raising the question of whether local-scale management addresses challenges at biologically relevant scales for species (Jelks et al., 2008).

Local-scale decision making has not historically addressed regional-scale changes in species distributions (Paukert et al., 2021). But many interacting factors have and will alter freshwater fish species distributions during the Anthropocene (Myers et al., 2017; Reid et al., 2019; Trushenski et al., 2020). These factors range from direct human impacts such as overfishing, stocking and intentional or unintentional translocation, to indirect human impacts through ecological changes including the impacts of invasive species, habitat degradation and changing water quality and flows. In particular, understanding the impacts of climate change on fish populations and distributions will become increasingly important for managing species in the coming decades (Paukert et al., 2021). Predictions of the impacts of climate change on continental or global distributions are not yet available for more than a limited set of freshwater fishes but should be pursued given the impacts of climate on fish distributions (Myers et al., 2017) and the limits to connectivity imposed by extensive barriers and dams (Cooper et al., 2017). Such predictions in other taxa suggest that under a high-emission scenario, 35% of mammal and 29% of bird species will have over half of their 2070 climatic niche in countries in which they do not currently occur, and many international range expansions of these species could be hampered by barriers to movement along borders (Titely et al., 2021). Models predicting the distribution of suitable habitat under future climate change across species could allow managers to identify local areas where additional protection or improved connectivity would best support freshwater fish biodiversity (Hamilton et al., 2022).

As species ranges change, managers need to prioritise where to allocate limited resources to facilitate species moving to reach suitable climate conditions, anticipate potentially harmful invasions and manage species declines. For example, as species face declines, managers can protect and restore habitat, adjust stocking practices and alter fishing regulations. In contrast, as fish species expand their distributions across borders, jurisdictions must decide how to manage novel species and whether there are cases in which such species may warrant protected status or should be controlled. Given the complexity of managing across a species range, a decision framework could help to consistently evaluate local conservation and management alternatives in a regional context.

The Resist-Accept-Direct (RAD) framework has been developed as a decision-making tool for helping managers facing ecosystem transformation which allows them to intentionally consider management alternatives and decide on target ecosystem conditions (e.g. ecosystem composition, structure, processes or function; Lynch et al., 2021; Schuurman et al., 2022; Thompson et al., 2021). In the RAD framework, *resisting* represents working to maintain or restore historical or "natural" conditions; *accepting* allows changes towards new ecosystem conditions to occur autonomously; and *directing* actively shapes ecosystem change towards a new desirable condition. *Accepting* and *directing* options produce the greatest deviation from historical conditions, while *resisting* and *directing* options require the most effort to implement.

The RAD framework can also be applied to single species management rather than ecosystem scale management. In the framework, rare and common species may require different consideration as management responses may be different across these general groups. Jurisdictions are often mandated to protect rare species while common species, including fisheries species, can hold societal benefit and be important to stakeholders. Examples of *resisting*, *accepting* or *directing* rare and common freshwater fishes, which are drawn mostly from cases in Michigan and the Laurentian Great Lakes Region, are presented below, but this framework is broadly applicable to local and regional management decisions. In addition, a decision tree is outlined which focuses on incorporating climate-related drivers of range shifts, considering species status broadly and weighing societal and ecological benefits to illustrate how the RAD framework can be used to evaluate the management of novel species in a jurisdiction (Figure 1).

1 | EXAMPLES OF RESISTING, ACCEPTING AND DIRECTING RARE SPECIES

Considerable effort has been dedicated to *resisting extirpations* of some species, both at local and national levels. Arctic grayling *Thymallus arcticus* Pallas was extirpated from Michigan by the 1930s because of habitat destruction, harvest and competition from non-native trout species (Goble et al., 2021). There have been repeated failed efforts to reintroduce this coldwater-adapted species prompted by its cultural and recreational fishing value. The Michigan Arctic Grayling Initiative, a state-wide partnership between the Department of Natural Resources, several tribes and numerous stakeholders is now working to refine reintroduction methods, evaluate potential reintroduction sites and establish self-sustaining populations in the state (Goble et al., 2021). If populations of Arctic grayling are re-established in Michigan, this species could immediately qualify as state-endangered. In contrast to grayling, weed shiner *Notropis texanus* (Girard) and bigeye chub *Hybopsis amblops* (Rafinesque) were presumed extirpated in Michigan during the 20th century, but these species were on the periphery of their range in the state and with limited conservation resources and less societal value the extirpations of these species were *accepted*.

Accepting range expansions from neighbouring jurisdictions may be appropriate where species are tracking climate change or are threatened in other portions of their range, and when there is no evidence that they will have negative impacts on native species and ecosystems. As an example, in 2013, two populations of dusky darter *Percina sciera* (Swain) were identified in the Michigan portion of the Maumee watershed; new species records for the state (Muller, 2015). In Michigan, guidelines used for ranking species of conservation concern do not limit consideration to only species native to the state in contrast to, for example, the California Methods for Status Evaluation of Fishes which is only applied to species native to that state (Leidy & Moyle, 2021). Considering the conservation status of non-native species can allow states the discretion to enact protections for species that may be threatened in other portions of their range. Dusky darter, however, is a widespread species, ranked as Least Concern by IUCN criteria (Natureserve, 2013). Natural dispersal within the Maumee watershed likely supported this species range expansion across the Michigan-Ohio border (Muller, 2015). Given the small populations and limited distribution of dusky darter in Michigan and its coexistence with Michigan stream fish fauna elsewhere in its range, this species may be *accepted* by managers,

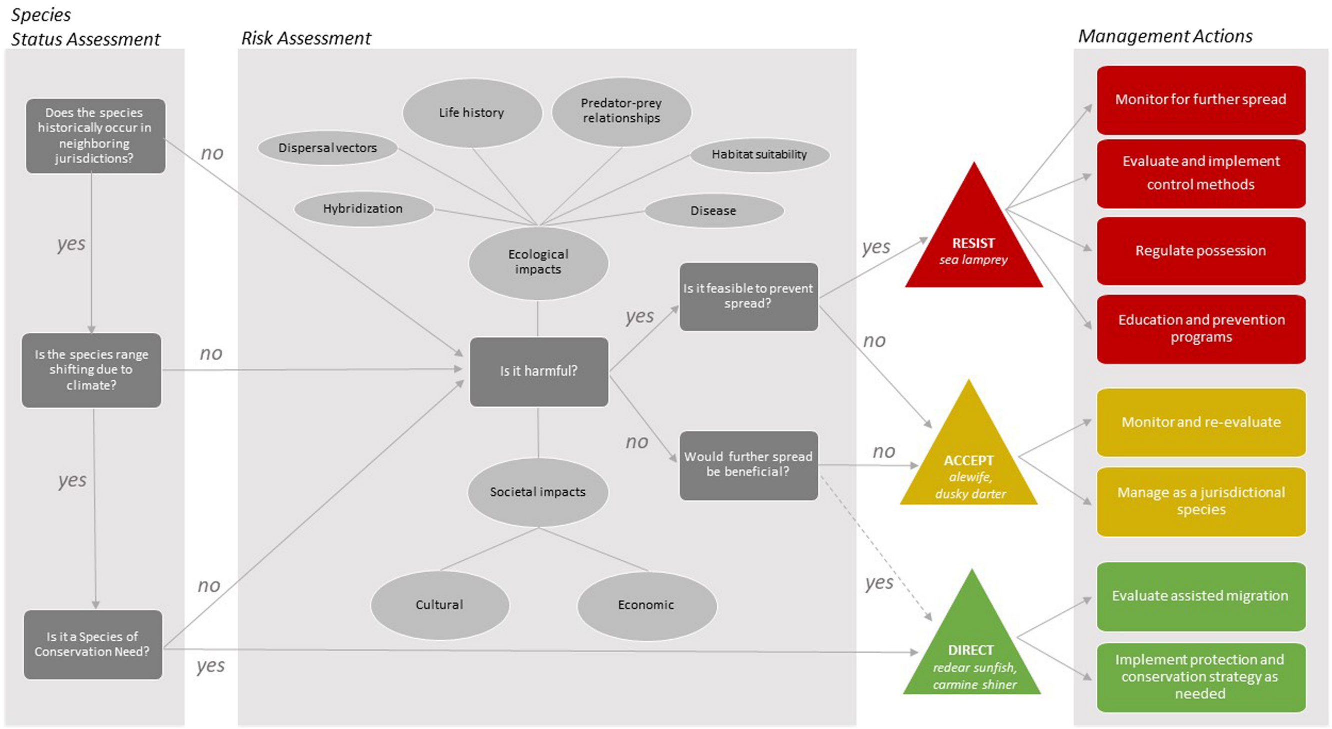

FIGURE 1 Example of a decision tree outlining questions which should be addressed (grey rectangles) in evaluating *resisting*, *accepting*, or *directing* novel species movement into a jurisdiction and what management actions (coloured rectangles) can be associated with each approach. Species listed are examples elaborated in the text. Light grey ovals represent potential considerations to inform risk assessment. The dashed line represents historical management decisions to stock species once perceived as beneficial, like redear sunfish, which might be re-evaluated given greater understanding of ecological impacts

without protections or regulations to limit its spread, but this decision would not prevent revisiting the treatment of this species if conditions change in the future.

Directing the migration of species threatened by climate change may become an increasingly necessary management action. As an example where such action may be necessary, the thermally suitable habitat for carmine shiner *Notropis percobromus* (Cope), an endangered species under COSEWIC (2018), is predicted to shift northward by 78–110 km/decade over the next 40 years and the species may face unsuitable local conditions and challenges to migration that prevent it from reaching new habitat (Pandit et al., 2017). Assisted migration, the translocation of species outside of their native range to overcome migration barriers or time limitations to reaching locations where they are predicted to occur with climate change (as define by Hällfors et al., 2014), has been recommended in cases such as carmine shiner (Butt et al., 2021). While there is a long history of translocating fish species outside of their native ranges to support recreation or provisioning, assisted migration to overcome threats related to climate has been met with hesitancy founded by legal, ethical, ecological and socio-political concerns (Bonebrake et al., 2018; Butt et al., 2021; Ricciardi & Simberloff, 2009). Given the velocity of climate change and the limited connectivity of freshwater habitats fragmented by dams and culverts (Woolway & Maberly, 2020), now is the time to draw on our knowledge of risk assessment, invasion biology, population viability and population genetics to evaluate and implement assisted migration where it is most appropriate. Cooperation between agencies at a regional scale might, for example, lead to redirecting efforts away from *resisting* local extirpations in jurisdictions at the warmer edges of a species range in favour of *directing* the establishment populations in another jurisdiction at higher latitudes or elevations where habitat is predicted to be more suitable in the future.

2 | EXAMPLES OF RESISTING, ACCEPTING AND DIRECTING COMMON SPECIES

Range expansions by common species are often related to human activities (whether intentional or unintentional) and their management can be evaluated by weighing the services they may provide against their ecological and societal impacts. *Resisting invasion* by sea lamprey *Petromyzon marinus* Linnaeus through lampricide application has been underway throughout the Great Lakes Basin for more than six decades. International cooperation in this effort, through the formation of the Great Lakes Fisheries Commission has led to the sole known example of successful control of an aquatic vertebrate non-native species at an ecosystem scale (Wingfield et al., 2021). The cooperative effort in this case was precipitated by the devastating impacts of sea lamprey on native commercial and recreational fisheries and the communities and economies which relied upon these industries (Wingfield et al., 2021).

In contrast to sea lamprey, alewife *Alosa pseudoharengus* (Wilson) stands as an example of managers *accepting species beyond their historical range*. Alewife entered the Great Lakes through connecting canals and became super abundant by the 1960s. Alewife played a key role in building an economically important recreational fishery in the Great Lakes by providing forage for non-native Pacific salmonid predators (Claramunt & Clapp, 2014; Dettmers et al., 2012). Stocking of salmonids has even been adjusted in recent years in an effort to prevent the collapse of alewife in Lake Michigan (Tsehaye et al., 2014).

The stocking of Pacific salmonids in the Great Lakes, including Chinook salmon *Oncorhynchus tshawytscha* (Walbaum) and Coho salmon *O. kisutch* (Walbaum), is one of many examples of *directing translocation of service providing species*. Redear sunfish *Lepomis microlophus* (Günther) is another case of *directing* the translocation of species. Redear sunfish were historically introduced to some Michigan lakes to support recreational fishing of trophy size panfish (Towns, 2003). It is difficult to advocate for such historical management decisions, with common species, as the negative ecological impacts of species introductions on native species are extensive (Gallardo et al., 2016). As a highly molluscivorous species, redear sunfish can compete with native fishes like pumpkinseed *Lepomis gibbosus* (Linnaeus) and impact native snails (Fisher Huckins et al., 2000) but could reduce densities of invasive dreissenid mussels (Wong et al., 2013).

3 | WHAT IS NEEDED TO APPLY THE RAD FRAMEWORK TO FUTURE MANAGEMENT DECISIONS ABOUT SPECIES WHICH CROSS POLITICAL BORDERS?

Decision tree approaches (such as Figure 1) can outline what considerations should be taken into account to decide between *resisting*, *accepting* or *directing* species and what management actions are associated with each approach. For example, with novel species spreading into jurisdictions there are two stages of consideration: species status assessment and risk assessment. Starting with species status assessment, it is important to consider whether a species historically occurs in a neighbouring jurisdiction or may be an introduced non-native species. Non-native species would immediately undergo risk assessment. Risk assessments must consider both ecological and societal impacts simultaneously to determine, overall, whether the spread of these species is harmful and warrants *resistance*. For harmful species, the choice of resistance or acceptance, however, may depend on the feasibility of control. For species where risk of harm is low enough relative to control costs, *acceptance* may be appropriate, with periodic re-evaluation. In the past non-native species have been stocked, *directing* spread (as indicated by dashed arrow in Figure 1). However, in many cases re-evaluating the impacts of such practices has revealed unanticipated and no longer acceptable consequences, and species once perceived as beneficial are now *accepted* or *resisted* rather than *directed*.

For species historically found in neighbouring jurisdictions, it is important to next consider the factors driving shifting distributions. Range expansions not related to climate should be evaluated to examine their cause and undergo risk assessment to determine whether their spread into a jurisdiction should be *resisted* or *accepted*, given the balance of ecological and social costs and benefits (Lynch et al. this issue). Climate change is likely to produce more frequent shifts in species ranges, and it is necessary to consider the status of and threats to these species across their ranges when choosing among management alternatives (Moyle et al., 2013). Species of conservation concern may warrant *directing* with additional protections or assisted migration. As species of concern often hold high intrinsic value, have small populations and have vulnerable life history characteristics, they are assumed to not require risk assessment. However, common species whose ranges are shifting due to climate should be evaluated by risk assessment as they are more likely to have ecological costs or social benefits.

As presented, the decision tree in Figure 1 represents a starting point for managers to consider RAD alternatives and can be modified and expanded upon. Additional decision frameworks would be required for considering management alternatives in reintroducing species, like Arctic grayling, or addressing predicted species losses for edge of range and endemic species. Such decisions would need to consider the availability of suitable habitats, potential threats, genetic and disease concerns, and socio-economic costs and benefits.

ACKNOWLEDGEMENTS

We thank Jay Peterson, Abigail Lynch, Mark Porath who organised the "Managing for a RADical Future: Resisting, Accepting and Directing Ecosystem Transformation" symposium at the annual meeting of the American Fisheries Society. We also thank the members of the Michigan Technical Advisory Committee for Fishes and particularly Matt Herbert for starting conversations on this topic. Finally, feedback from two reviewers and the associate editor have substantially improved our manuscript.

CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

ETHICAL STATEMENT

All the research meets the ethical guidelines, including adherence to the legal requirements of the study country.

DATA AVAILABILITY STATEMENT

There is no data used in this manuscript.

ORCID

Karen M. Alofs https://orcid.org/0000-0002-4161-3554

REFERENCES

Bonebrake, T.C., Brown, C.J., Bell, J.D., Blanchard, J.L., Chauvenet, A., Champion, C. et al. (2018) Managing consequences of climate-driven species redistribution requires integration of ecology, conservation and social science. *Biological Reviews*, *93*, 284–305.

Butt, N., Chauvenet, A.L.M., Adams, V.M., Beger, M., Gallagher, R.V., Shanahan, D.F. et al. (2021) Importance of species translocations under rapid climate change. *Conservation Biology*, *35*, 775–783.

Claramunt, R.M. & Clapp, D.F. (2014) Response to Dettmers et al. (2012): Great Lakes fisheries managers are pursuing appropriate goals. *Fisheries*, *39*, 123–125.

Cooper, A.R., Infante, D.M., Daniel, W.M., Wehrly, K.E., Wang, L. & Brenden, T.O. (2017) Assessment of dam effects on streams and fish assemblages of the conterminous USA. *Science of the Total Environment*, *586*, 879–889.

COSEWIC (2018) *COSEWIC assessment and status report on the Carmine Shiner Notropis percobromus in Canada*. Committee on the Status of Endangered Wildlife in Canada. Ottawa. x + 42 pp.

Dettmers, J.M., Goddard, C.I. & Smith, K.D. (2012) Management of alewife using Pacific salmon in the Great Lakes: whether to manage for economics or the ecosystem? *Fisheries*, *37*(11), 495–501.

Faucheux, N.M.H., Craig, C.A. & Bonner, T.H. (2019) Rapid assessment for identifying species of greatest conservation need: towards a unified approach. *Fisheries*, *44*, 488–497.

Fisher Huckins, C.J., Osenberg, C.W. & Mittelbach, G.G. (2000) Species introductions and their ecological consequences: An example with congeneric sunfish. *Ecological Applications*, *10*, 612–625.

Gallardo, B., Clavero, M., Sánchez, M.I. & Vilà, M. (2016) Global ecological impacts of invasive species in aquatic ecosystems. *Global Change Biology*, *22*, 151–163.

Goble, C.W., Zorn, T.G., Auer, N.A., Holtgren, J.M., Mays, D.W. & Martell, A.W. (2021) Rating the potential suitability of habitat in Michigan stream reaches for Arctic Grayling. *Journal of Fish and Wildlife Management*, *12*(2), 540–553. e1944–687X. https://doi.org/10.3996/JFWM-20-050

Hällfors, M.H., Vaara, E.M., Hyvärinen, M., Oksanen, M., Schulman, L.E., Siipi, H. et al. (2014) Coming to terms with the concept of moving species threatened by climate change–a systematic review of the terminology and definitions. *PLoS One*, *9*(7), e102979.

Hamilton, H., Smyth, R.L., Young, B.E., Howard, T.G., Tracey, C., Breyer, S. et al. (2022) Increasing taxonomic diversity and spatial resolution clarifies opportunities for protecting imperiled species in the US. *Ecological Applications*, e2534.

Jelks, H.L., Walsh, S.J., Burkhead, N.M.S., Contreras-Balderas, E., Diaz-Pardo, D.A., Hendrickson, J. et al. (2008) Conservation status of imperiled North American freshwater and diadromous fishes. *Fisheries*, *33*, 372–407.

Leidy, R.A. & Moyle, P.B. (2021) Keeping up with the status of freshwater fishes: A California (USA) perspective. *Conservation Science and Practice*, *3*, 1–10.

Lynch, A.J., Thompson, L.M., Beever, E.A., Cole, D.N., Engman, A.C., Hawkins Hoffman, C. et al. (2021) Managing for RADical ecosystem change: applying the Resist-Accept-Direct (RAD) framework. *Frontiers in Ecology and the Environment*, *19*, 461–469.

Mandrak, N.E. & Cudmore, B. (2010) The fall of Native Fishes and the rise of Non-native Fishes in the Great Lakes Basin. *Aquatic Ecosystem Health & Management*, *13*, 255–268.

Moyle, P.B., Kiernan, J.D., Crain, P.K. & Quiñones, R.M. (2013) Climate change vulnerability of native and alien freshwater fishes of California: a systematic assessment approach. *PLoS One*, *8*, e63883.

Muller, R. (2015) Dusky darters: a North American native fish new to Michigan. *American Currents*, *Winter*, 26–28.

Myers, B.J.E., Lynch, A.J., Bunnell, D.B., Chu, C., Falke, J.A., Kovach, R. et al. (2017) Global synthesis of the projected and documented effects of climate change on inland fishes. *Reviews in Fish Biology and Fisheries*, *27*, 339–361.

NatureServe, (2013) *Percina sciera*. The IUCN Red List of Threatened Species 2013: e.T202592A18231811. https://doi.org/10.2305/IUCN.UK.2013-1.RLTS.T202592A18231811.en. Downloaded on 10 November 2021.

Pandit, S.N., Maitland, B.M., Pandit, L.K., Poesch, M.S. & Enders, E.C. (2017) Climate change risks, extinction debt, and conservation implications for a threatened freshwater fish: carmine shiner (*Notropis percobromus*). *Science of the Total Environment*, *598*, 1–11.

Paukert, C., Olden, J.D., Lynch, A.J., Breshears, D.D., Christopher Chambers, R., Chu, C. et al. (2021) Climate change effects on North American fish and fisheries to inform adaptation strategies. *Fisheries*, *46*, 449–464.

Reid, A.J., Carlson, A.K., Creed, I.F., Eliason, E.J., Gell, P.A., Johnson, P.T.J. et al. (2019) Emerging threats and persistent conservation challenges for freshwater biodiversity. *Biological Reviews*, *94*, 849–873.

Ricciardi, A. & Simberloff, D. (2009) Assisted colonization is not a viable conservation strategy. *Trends in Ecology and Evolution*, *24*, 248–253.

Schuurman, G.W., Cole, D.N., Cravens, A.E., Covington, S., Crausbay, S.D., Hoffman, C.H. et al. (2022) Navigating ecological transformation: resist–accept–direct as a path to a new resource management paradigm. *BioScience*, *72*, 16–29.

Thompson, L.M., Lynch, A.J., Beever, E.A., Engman, A.C., Falke, J.A., Jackson, S.T. et al. (2021) Responding to ecosystem transformation: resist, accept, or direct? *Fisheries*, *46*, 8–21.

Titley, M.A., Butchart, S.H.M., Jones, V.R., Whittingham, M.J. & Willis, S.G. (2021) Global inequities and political borders challenge nature conservation under climate change. *Proceedings of the National Academy of Sciences of the United States of America*, *118*(7), 1–8.

Towns, G.L. (2003). *Redear Sunfish Management in Michigan. Michigan Department of Natural*. Resources, Fisheries Division Technical Report Number 2003-3.

Trushenski, J.T., Bowker, J.D., Whelan, G.E. & Heindel, J.A. (2020) From johnny fish-seed to hatchery-bashing to shaping the shoal of aquaculture stakeholders. *Fisheries*, *45*, 475–483.

Tsehaye, I., Jones, M.L., Brenden, T.O., Bence, J.R. & Claramunt, R.M. (2014) Changes in the salmonine community of Lake Michigan and their implications for predator–prey balance. *Transactions of the American Fisheries Society*, *143*(2), 420–437.

Wingfield, J., Brant, C., Eshenroder, R., Gaden, M., Miehls, A. & Siefkes, M. (2021) 100 years of sea lampreys above Niagara Falls: A reflection on what happened and what we learned. *Journal of Great Lakes Research*, *47*, 1844–1848.

Wong, W.H., Gerstenberger, S.L., Hatcher, M.D., Thompson, D.R. & Schrimsher, D. (2013) Invasive quagga mussels can be attenuated by redear sunfish (*Lepomis microlophus*) in the Southwestern United States. *Biological Control*, *64*(3), 276–282.

Woolway, R.I. & Maberly, S.C. (2020) Climate velocity in inland standing waters. *Nature Climate Change*, *10*, 1124–1129.

How to cite this article: Alofs, K.M. & Wehrly, K.E. (2022) Developing a resist-accept-direct (RAD) framework for managing freshwater fish species shifting in and out of political jurisdictions. *Fisheries Management and Ecology*, *29*, 486–490. Available from: https://doi.org/10.1111/fme.12546