



INFORMATION ITEM

Lead Scientist Report

Summary

The Resist-Accept-Direct (RAD) framework was developed to help environmental managers decide how to respond to species invasion in a changing ecosystem, and where best to marshal their resources. In a recent article, Keller et al. (2025) use mathematical approaches to determine when managers should shift from resisting change caused by invasive species to accepting and possibly directing it. The authors found that the shift from resistance to acceptance depends on factors such as invasive species population size, colonization intensity, habitat connectivity, and the way these factors evolve in response to climate change. However, the decision also depends on considerations like the cost of species removal versus environmental harm. As such, the shift from resist to accept involves a value judgement. The framework developed by the authors can inform decision-making in an uncertain and changing world, and could be a useful approach for tackling Delta management challenges such as the golden mussel invasion.

A decision-making framework for managing species invasions in changing ecosystems

Keller, A. G., Counihan, T. D., Grosholz, E. D., & Boettiger, C. (2025). The transition from resistance to acceptance: Managing a marine invasive species in a changing world. *Journal of Applied Ecology*, 62, 715–725.
<https://doi.org/10.1111/1365-2664.14881>

Conservation goals for ecosystems have historically focused on how to maintain or preserve environmental conditions. However, global change is challenging this paradigm and forcing decision-makers to consider how to manage for change. The resist-accept-direct (RAD) decision framework was developed for situations where

ecosystem transformation is underway and maintaining historical or current conditions is no longer possible without management action (<https://www.usgs.gov/programs/climate-adaptation-science-centers/science/resist-accept-direct-rad-framework>). In this framework, decisions can involve: 1) **resisting change**, and focusing on management actions that maintain or restore conditions to historical or acceptable levels; 2) **accepting change**, and managing the system in a way that recognizes its new ecological trajectory and conditions; or 3) **directing change**, where management actions are intended to actively shape conditions in a direction that might be preferable to allowing the change to happen without management input. In this framework, resources should be prioritized for areas where resistance is feasible. But when does the shift between decision alternatives happen?

In a recent article from Keller et al. (2025), the authors used mathematical approaches to address the question of when a manager should stop resisting change and accept a new ecological course. The study used the invasive European green crab, a marine invader with no documented examples of eradication from areas it has invaded throughout the world. The species is becoming more abundant in estuaries of the Northeast Pacific, a trend attributed to increased dispersal of the species across large distances in the ocean associated with El Niño events. To strategically manage this invasion, managers must prioritize resources where they will be most effective; in other words, managers must understand where resisting change is feasible versus when they should instead accept that they are now managing the system in its new condition.

The study found that a decision-maker's actions are not likely to shape an invasion trajectory when there are large source populations and/or high colonization intensities. In those cases, resistance (control efforts) are not optimal. Furthermore, the authors found that the cost of removal played a larger role in determining the optimal level of control than the ecological impact of the control actions. The resistance/acceptance boundary is therefore a question of decision-maker values: the relative importance of the cost of removal compared to environmental harm. Another important consideration for the resistance/acceptance boundary is how the connectivity of a region to an invasive population changes with climate change (e.g., ocean currents, temperature-driven growth or survival rates).

The results of the study highlight the importance of developing proactive and anticipatory management strategies that account for changes to how basic ecosystem processes or functions occur over time, referred to as **non-stationary dynamics**. With non-stationary dynamics, processes are not constant over time, so past relationships can no longer be used to accurately predict the future. The decision framework developed by the authors can facilitate proactive and strategic decisions given uncertainty and a changing world. This approach could be a useful way to tackle Delta management challenges such as the golden mussel invasion.

Delta Science Program Activities

Delta Science Plan update

The Delta Science Plan update is well underway, and we aim to release a draft for public comment this fall and a final version in spring 2026. This update is structured around four “grand challenges” facing the Delta. To receive community feedback, the Delta Science Program hosted a two-day workshop in February 2025. Ninety-nine participants attended the workshop, resulting in 533 individual comments, which were considered for the update. Additionally, nine of the appendices from the 2019 update are undergoing revisions to better reflect current practices. We have also added two new appendix resources: *Data Governance, Portals, and Online Resources*; and *Social Science Integration to Natural Science Workflows*. These new additions reflect emerging needs identified through the workshop and broader engagement efforts.

Healthy Rivers and Landscapes peer review completed

The Healthy Rivers and Landscapes (HRL) Science Plan peer review ended in late June. The review's purpose was to provide the HRL program's Science Committee with recommendations to improve the Science Plan. The review considered how the HRL Science Plan could support the development of individual science plans and reports that would be required as part of the HRL program, including triennial progress reports and a final Ecological Outcomes Analysis Report.

The final document consists of three independent letters from the reviewers, who are subject matter experts in fisheries, structured decision-making, and monitoring evaluations. Overall, the reviewers found the HRL Science Plan to be a comprehensive and carefully conceived guide. They provided recommendations

related to monitoring protocols, adaptive management, high-priority uncertainties to address (e.g. improved understanding of habitat suitability), and hypotheses that could be included (e.g. marine survival rates, the effects of hatchery practices).

The final document is available on the Council's website (<https://deltacouncil.ca.gov/delta-science-program/scientific-peer-review>) and any additional questions can be directed to ReviewAdvice@deltacouncil.ca.gov.

On Your Radar

[Adaptive Management Forum save the date: October 14–15](#)

The Delta Science Program hosts the Adaptive Management Forum every two years to increase adaptive management capacity in the Sacramento-San Joaquin Delta for ecosystem restoration, water management, and beyond. The next forum will be on **October 14–15** and will feature presentations, panel discussions, a poster session, and activities connecting participants across sectors and disciplines. Presenters and panelists will share lessons and insights from all stages of the adaptive management cycle to showcase successes, gaps, and future needs. We hope you will join us for these important conversations. The forum will be a hybrid event, with the in-person component hosted at the California Natural Resources Agency Headquarters in Sacramento and the online component on Zoom. You can attend Day 1 in-person or virtually, but Day 2 attendance is in-person only and space is limited. Register to attend the forum using this link:

<https://www.eventbrite.com/e/2025-delta-adaptive-management-forum-tickets-1520571332789>. Additionally, if you have a research, management, or implementation project to share, submit your poster abstract by September 26 via the link in the attendance registration form above.

[Delta Invasive Species Symposium save the date: December 4](#)

The sixth biennial Delta Invasive Species Symposium will take place on **December 4** at the California Natural Resources Agency building in Sacramento. This year's theme is "Modeling and Managing Invasive Species for Tomorrow's Delta". Organized by the Delta Interagency Invasive Species Coordination (DIISC) Team, the Symposium is a forum for managers, researchers, and decision-makers to share and synthesize information, best practices, and lessons learned. It is free

to attend and open to anyone interested in the impacts of invasive species in the Sacramento-San Joaquin Delta region. Council staff are part of the organizing team for the Symposium. The Symposium will be held in person with a virtual attendance option. Additional details and registration information will be available this fall.

Golden mussels update

Monitoring for golden mussel adults and larvae is ongoing in the Delta and across the state for the detection of additional populations. The results are available on the California Department of Fish and Wildlife (CDFW) golden mussel webpage: <https://wildlife.ca.gov/Conservation/Invasives/Species/Golden-Mussel>. To support these efforts, research is underway on high-priority questions identified by a team of researchers and agency personnel. The results will help to pinpoint locations vulnerable to invasion by golden mussels, methods that will prevent their spread, and methods to protect water infrastructure. Furthermore, outreach materials on how to prevent mussels' spread are being distributed in English and Spanish targeting boaters and other recreational users. CDFW is also offering \$1 million in grant funding to boating facility operators to enhance efforts against invasive mussels (funding is provided by the federal Sportfish Restoration Act). Finally, recent media attention has included stories on CalMatters (<https://calmatters.org/environment/water/2025/07/golden-mussel-california-water-supplies-spread-inspections/>) and KCRA (<https://www.kcra.com/article/davis-scientist-invasive-golden-mussels/65556782>).

Social Science Extension Specialist update

The Delta Stewardship Council and California Sea Grant are excited to welcome Tara Pozzi as the new Social Scientist Extension Specialist, starting August 1. She will be a familiar face to some, as she was part of the 2022 Delta Science Fellow cohort. In her new role, Tara will be based out of UC Davis and will conduct research, education, and outreach projects that address the human dimensions of Delta water and ecosystem management.

Invasive Species Presentation

Dr. Richelle Tanner of Chapman University and Dr. Christine Whitcraft of California State University-Long Beach will describe the results of invasive species research

recently funded by the Council with an emphasis on collaboration and recommendations to improve future invasive species response.

By the Numbers

Science Program staff will summarize current numbers related to Delta water and environmental management. The summary (Attachment 2) will inform the Council of recent counts, measurements, and monitoring figures driving water and environmental management issues.

List of Attachments

Attachment 1: Visual Summary of Article

Attachment 2: By the Numbers

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