

Regional variation in the risk of the live bait trade as an invasive species pathway

Hannah Mulligan¹, Mark Kaemingk², and Alison Coulter¹

¹Department of Natural Resource Management, South Dakota State University, McFadden Biostress Laboratory 138, Box 2140B, Brookings, South Dakota 57007; phone: (605)-688-6121; email: hannah.mulligan@jacks.sdstate.edu

²Department of Biology, University of North Dakota, Grand Forks, ND

Recreational fishing is a major pathway for the secondary spread of aquatic invasive species (AIS) including vertebrates, invertebrates, and pathogens in freshwater.³ Nested within the recreational fishing pathway is the live bait trade, a human-mediated pathway whereby AIS are released by anglers, resulting in ecological and economic impacts.¹² Preventative actions, including the implementation of regulations, educational programs, or inspections, can assist in preventing the introduction of AIS via the live bait pathway. However, these actions may ultimately fall short due to inconsistencies in wholistic actions contributing to weak-link scenarios, where the wholistic benefit is only as strong as the weakest preventative action approach. Accordingly, the lack of proactive invasive species prevention worldwide has resulted in an additional management cost of \$1.2 billion USD.² For each preventative action, we sought to 1) examine US geopolitical variations and emphasis on preventative actions, and 2) offer potential recommendations to minimize AIS spread via the live bait trade given constraints (e.g., funding).

Aquatic invasive species coordinators for each US state (or the equivalent position within each state agency) were contacted via email and asked to participate in an exercise where they modified a conceptual map of the live bait trade based on the three preventative actions commonly used for the live bait trade: regulation, education, and inspection. For regulations, experts were asked to review and delete all sources, actors, and vectors that were illegal in their respective state. Sources can include where the baitfish originated from (i.e., hatched or farm-raised). Actors transport baitfish from one location to another, hold them, or sell them and include wholesalers, retailers, and anglers. Vectors entail the pathway by which baitfish are transported from sources and actors. Experts were then asked to review all sources and actors and place a symbol on each component where education or inspections occurred. For each preventative action, the number of sources, actors, or waterbody that received that respective component were summarized and then divided by the number of states that responded to the survey within regions. These values were then compared among regions to determine how much or little each region relatively invested in each type of preventative action. We received completed conceptual maps between March 2023 and July 2023. Regions consisted of the Great Basin (n = 3 states; 3 states ban baitfish entirely), Great Lakes (n = 5), Mississippi (n = 4), Missouri (n = 4), North Atlantic (n = 4), and South Atlantic (n = 3) for the conceptual map analysis.

The Great Basin region of the US exhibited a strong focus on regulation of live baitfish use based on our survey results, and multiple states within this region have banned the use of live baitfish entirely for recreational fishing (Figure 1). Restrictions in this region are often implemented to conserve regionally valuable species, such as trout, from hooking mortality associated with the use of live baitfish.¹³ The South Atlantic-Gulf region had few regulations targeting the live bait pathway (Figure 1). Multiple states in this region also had less regulation of AIS in general compared to states further east in a recent legislation review.⁹ Southern and coastal states contain rivers with limited hydrological connectivity between basins⁵ which reduces the potential for invasive species to spread among jurisdictions and therefore reduces AIS risk. Increased political pressure for lenient regulations due to the economic importance of aquaculture may have also contributed to fewer regulations in our survey results.⁸

The Great Lakes region was the most focused on education based on our survey results and could serve as an example to other jurisdictions as this region uses education for many actors in the live bait pathway. Multiple states have made the Stop Aquatic Hitchhikers! campaign a priority (Figure 1).¹⁰ Due to the economic and ecological importance of the Great Lakes, the US Congress established the Great Lakes Restoration Initiative in 2010, which has contributed to sustaining education and outreach efforts in this

region through grant funding.⁴ The Mississippi region placed the least focus on educational programs based on our survey, which could correlate with a lack of funding or personnel needed to implement such programs (Figure 1).¹ Collaborations among jurisdictions can reduce costs and time commitments for individual states, which could lead to more consistent messaging and receptivity among anglers regarding invasive species.⁴

The Great Lakes region placed the highest focus on inspections, while the South Atlantic-Gulf region placed the least focus on inspections in our survey (Figure 1). Live baitfish are inspected for pathogens and parasites within multiple Great Lakes states regardless of whether they are sourced in-state or out-of-state.⁶ As previously discussed, dedicated AIS funding and the economic and ecological importance of the Great Lakes allow managers the means to invest in inspections and education. Additionally, emphasis has been placed on research regarding inspections within bait retailers.⁶ The South Atlantic-Gulf's lack of focus on inspections could correlate with a lack of resources (e.g., financial, personnel) needed to ensure that invasive species are not present or increased political pressure for more lenient regulations leading to less frequent or nonexistent inspections.^{14,8}

Our survey results revealed spatial weak-link scenarios, and therefore, additional investment is needed to reduce AIS risk. We recommend an approach that capitalizes on interconnections and feedback among preventative actions when resources are limited which should result in a synergistic outcome that optimizes resources and prevents weak-links. Education and inspections often reflect regulations set forth by management agencies and are used to increase awareness of invasive species and regulations within each state. After regulations are in place, education can be used to increase personal responsibility to self-inspect bait and reinforce the interconnectedness among preventative actions. Additionally, inspections will reinforce regulations already in place, but will also allow for opportunities to educate on preventing AIS spread. Therefore, investing heavily in a particular preventative action where feasible instead of spreading limited resources throughout the pathway and across all three preventative actions can reduce AIS risk and overcome barriers to implementation. For jurisdictions with complex live bait pathways and limited funding resources available, focusing efforts on inspecting wholesalers may be the most cost and time effective way to prioritize resources as there are fewer wholesalers than bait retailers or anglers. Contrastingly, jurisdictions with simple live bait pathways could implement harvest restrictions or require online AIS training which may be more straightforward than inspecting bait retailers or predicting individual behaviors of anglers.

Limited resources, lack of information, and uncertainty on how to manage aspects of the live bait trade have promoted reactive or inconsistent spatial approaches to AIS management and an increased risk of AIS spread. One of the greatest barriers to invasive species management is funding, but increased information and resource sharing among regions could overcome this constraint.¹¹ While most management approaches stop at political boundaries, the movement of anglers and AIS does not.⁷ We believe the capacity of jurisdictions to prevent AIS introductions is dependent on an approach that supersedes political boundaries and evaluates the efficacy of preventative actions at a broad scale.

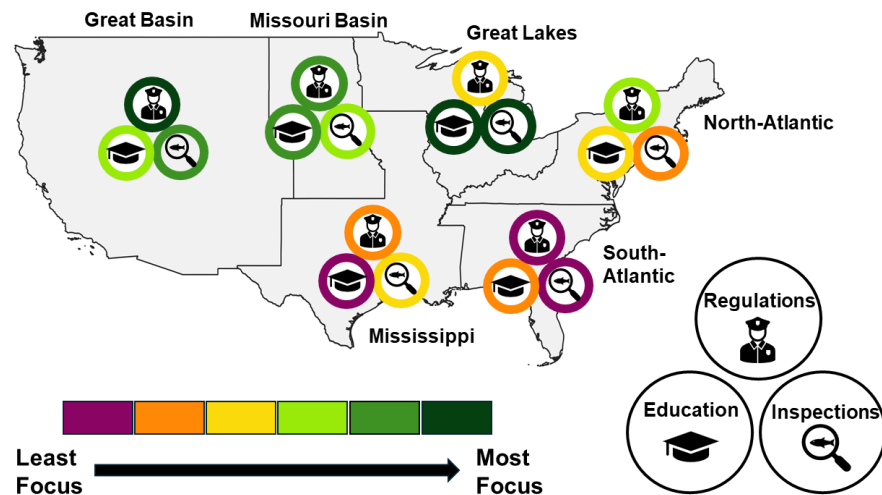


Figure 1. Focus placed on regulations, education, and inspections for the freshwater live bait trade from regions of the US including the Great Basin (3 states ban baitfish entirely), Missouri Basin, Great Lakes, North-Atlantic, Mississippi, and South-Atlantic in 2022.

Information sharing among jurisdictions can alleviate funding constraints by providing a baseline for the creation of effective regulations, education, and inspections. Resource sharing through the creation of regional live baitfish guides and educational programs that can be disseminated broadly can also reduce political and economic barriers to implementation. Prioritizing the live bait trade in management and identifying, implementing, and sharing cost effective approaches should lead to greater spatial coverage and impact to reduce AIS spread via the live bait trade.

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