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Siting and application criteria for push configuration open-water trapping of sea lamprey in rivers

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ABSTRACT:

Continued success in managing invasive sea lamprey (*Petromyzon marinus*) requires the development of innovative new control tactics that leverage natural behaviors. We investigated methods to enhance the effectiveness of a natural chemical deterrent (alarm cue) for use as a repellent to drive migrating sea lamprey toward traps or other fishing devices. First, we sought to identify places in rivers where sea lamprey migratory paths naturally converge, revealing opportune locations to place a trap or net. Hydrodynamic flow models coupled with bathymetric mapping and fine-scale acoustic telemetry confirmed our hypothesis that migrating sea lampreys move through the deeper thalweg scour channels in shallow coastal rivers. These paths allow rapid and efficient upstream migration while avoiding the risk of predation. Notably, when the thalweg is distinct and located near the riverbank, the migratory paths converged at the ideal place to install fishing gear. We hypothesize sea lampreys use a novel orientation technique - hydrostatic pressure-guided rheotaxis - to achieve this navigation. Because movement in the thalweg is necessary to maintain safety, it exposes migrating sea lampreys to faster more energetically costly flows. In a second project we demonstrated that migrating sea lampreys modulate their swim effort to maintain a near-constant ground speed (~1 body length per second), despite varying head current velocities, consistent with minimizing cost-of-transport. Ground speeds also slightly increased in the shallow areas of the stream waters, reflecting the trade-off between energy efficiency and predator avoidance. These findings provide field-based support for theoretical models of energy optimization and underscore how migratory fish adaptively adjust behavior to local hydrodynamic conditions. Next, we investigated how migrating sea lampreys respond to spatially localized predation risk by examining how they navigate around alarm cue plumes in a river. As sea lampreys approached the source of the odor, they exhibited reduced ground speed and increased turning rates typical of odor-conditioned rheotaxis. However, when choosing a route around the alarm cue source, lampreys did not prioritize use of the deeper, safer side of the channel. Rather, they executed contralateral turns away from the center of the plume, showcasing a flexible yet risk-response strategy without compromising migratory objectives. Finally, previous research has established that application of alarm cue to drive migrants toward traps may result in habituation to the cue, diminishing its effectiveness. We tested application practices that mitigate habituation to alarm cues. In our fourth experiment, we found that continuous exposure to alarm cues led to a decline in swim activity, indicating habituation. However, modulating the cue through intermittent on/off exposure partially prevented this decline, while varying the concentration fully maintained behavioral responses. Interestingly, we did not observe habituation of spatial avoidance behavior, possibly due to the small-scale laboratory testing environment. Our fifth experiment further examined how altering concentration and temporal exposure affected behavior. Exposure to alarm cues induced rapid upstream movements, but no habituation was detected. However, when the animals made quick decisions, they were poor ones. That is, they were less likely to successfully avoid the odor source. These findings suggest that varying cue intensity and incorporating dishabituating stimuli could sustain the efficacy of alarm-based repellents in management contexts. Overall, our studies suggest that modulating alarm cue delivery and considering river geomorphology can substantially improve our ability to capture migrating sea lampreys in open river channels and have furthered our ecological understanding of migratory behavior.