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Short Communication

Effects of Temperature on Hatching and Growth Performance of Embryos and Yolk-Sac Larvae of a Threatened Estuarine Fish: Longfin Smelt (*Spirinchus thaleichthys*)

Nann A. Fangue* **and Yuzo R Yanagitsuru**

Department of Wildlife, Fish, and Conservation Biology, University of California, Davis, CA, USA

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Abstract: The longfin smelt (Spirinchus thaleichthys) population in the San Francisco Estuary has declined to less than 1% of historic numbers. It is crucial to identify the mechanisms that are driving the decline in order to implement species conservation plans. However, the low abundance and ever-declining population of longfin smelt limits access to research specimens. Developing a captive culture of longfin smelt would solve this issue while simultaneously gathering knowledge that could be used by conservation managers. To improve culture methods, we focused on the early life stages because it is the first major bottleneck in culturing the species. We measured the hatching and growth performance of longfin smelt embryos (ca. 15-28 days post-fertilization) and larvae (ca. 3-5 days post-hatch) and found that temperatures of 9°C and 12°C are appropriate culturing temperatures. These results demonstrate that the early life stages of longfin smelt require cooler water than delta smelt, another species of conservation concern that many California water management policies center around. While our study is useful for informing conservation efforts, the complexities surrounding the distribution of water resources in California may delay efforts to implement this knowledge into conservation plans.

Keywords: Endangered species; Temperature; Conservation

***Correspondence to:** **Fangue NA,** Department of Wildlife, Fish and Conservation Biology, University of California, Davis, USA, E-mail: nafangue@ucdavis.edu

Description

Longfin smelt (*Spirinchus thaleichthys*) is an anadromous forage fish species, distributed from the Aleutian Islands to the San Francisco Estuary (SFE), and was once among the most abundant fish species in California. However, over the last two decades, the SFE population, which is considered the largest self-sustaining population of the species in the world has been reduced to less than 1% of historical abundances and are now listed as "threatened" under the California Endangered Species Act. Their decline in the SFE is likely due to a combination of anthropogenically induced environmental disturbances that require a multipronged management effort. To make informed conservation management decisions, it is crucial to mechanistically determine the factors contributing to longfin smelt decline. Such an effort requires many live research specimens though, which for a species in decline poses the challenge of acquiring enough specimens and the dilemma of applying further pressure to the wild stock. Developing a captive culture for longfin smelt would solve this issue and the studies necessary to develop the culture could also be used to inform conservation management plans. To date, efforts to culture longfin smelt have been thwarted by >90% mortality at the larval stage. To begin systematically addressing issues with culture methods for the early life stages of longfin smelt, we compared the hatching and growth performance of embryos and yolk-sac larvae at three different temperatures that they may be exposed to in the SFE: 9, 12, and 15℃. We tested a range of environmentally-relevant temperatures because of the profound effects that temperature can have on fish physiology and behavior, which translates to changes in growth and survival. Averaged across all clutches, we found that longfin smeltembryos had 32-50% higher hatching success and larvae grew to 16%-19% larger sizes at 9 and 12℃ than those reared at 15℃, suggesting an optimal range of temperatures for culture of 9℃-12℃. However, there was high interclutch variation in hatching and growth performance across all test temperatures. Interestingly, the incomplete yolk and oil resorption of most larvae at all temperatures suggest that there may be issues with culture methods unrelated to temperature. Clearly there is much work to be done to close the life cycle of longfin smelt in captivity. Nevertheless, we reported the first systematic study to determine a potential cause of culture failure and because on average the early life stages performed best at the cooler temperatures, we suggest that the embryos and yolk-sac larvae should be reared at 9 or 12℃ [1-11].

Conclusion

Our study primarily sought to identify appropriate culturing temperatures for longfin smelt embryos and larvae, but we also found that longfin smelt require relatively cool water at their early life stages compared to other California native fish species. This is alarming because water management policies currently center around other native species such as delta smelt, which have a considerably higher thermal tolerance and an optimal temperature of 16℃ that would lead to suboptimal physiological performance for longfin smelt larvae. While these data suggest that water management policies should accommodate longfin smelt as well, water demand from the urban sector and multi-billion dollars agriculture industry of the Central Valley makes further improvements to conservation efforts difficult. Many of the water management policies currently center around delta smelt and require the release of water from freshwater reservoirs to cool down estuary temperatures and push back intruding saltwater. These measures are heavily criticized by farmers who feel that water that could be used to grow crops is wasted on "four buckets of minnows," in reference to the delta smelt. This discontent in environmental water use has resulted in a vilification of delta smelt. Considering the similarities in nomenclature and morphology to delta smelt, the poor reputation of this species among farmers may transfer to longfin smelt as well. Conservation management of the SFE remains a major challenge due to limited water resources and a deep political divide in water management ideologies. While research is essential for determining how to protect a species, it is important to be mindful that political and regulatory complexities can often significantly delay or preclude the implementation of the newfound knowledge to conservation plans.

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