Title:
Prey Selection of Larval and Juvenile Planktivorous Fish in the San Francisco Estuary

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Abstract:
This project examined the effects of the introduced Asian copepod Limnoithona tetraspina, the dominant zooplankton species in brackish waters of the San Francisco Estuary, on the diets of larval and juvenile delta smelt (Hypomesus transpacificus) and striped bass (Morone saxatilis).

Prey Selection of Larval and Juvenile Planktivorous Fish in the San Francisco Estuary

Lindsay J. Sullivan, San Francisco State University

SUMMARY

This project examined the effects of the introduced Asian copepod *Limnoithona tetraspina*, the dominant zooplankton species in brackish waters of the San Francisco Estuary, on the diets of larval and juvenile delta smelt (*Hypomesus transpacificus*) and striped bass (*Morone saxatilis*).

L. Sullivan/SFSU

Intern Sean Rohtla of Marin Catholic High School collecting plankton for feeding experiments.

Likely introduced via ships' ballast water, *L. tetraspina* outnumbers all other copepod species by as much as a factor of 10 in the estuary and is far smaller than historically dominant copepod prey species (i.e., calanoid species such as *Eurytemora affinis* and *Pseudodiaptomus forbesi*).

The hypothesis explored during this project was that larval and juvenile fishes might avoid eating the introduced copepod and/or that the copepod's small size might reduce the total amount of food available to them. If true, the shift in the zooplankton community might be a contributing factor in the pelagic organism decline, which more broadly has been linked to water diversions.

Somewhat surprisingly, laboratory experiments showed that larval delta smelt and striped bass both eat the introduced *L. tetrapina* in proportion to its presence in the water column. As the fish grow larger, however, they seek out larger copepods for nourishment; fish with bigger mouths want to eat bigger things. In the absence of the preferred larger zooplankton, juvenile fishes may end up eating fewer calories than they need. In essence, the foraging fishes ignore *L. tetrapina* while searching for larger prey species.

PROJECT

The Delta Science Fellow quantified the relative consumption of different copepods by larval delta smelt and striped bass via laboratory feeding experiments. She then videotaped fish as they hunted for zooplankton to characterize predatory-prey interactions.

In the feeding experiments, larval and juvenile fishes were incubated with known concentrations of the copepod species *E. affinis*, *P. forbesi, L. tetraspina, Acartiella sinensis* and *Acanthocyclops vernalis*.

Combinations of the five species were varied depending on their temporal and spatial overlap with the early life-history stages of smelt and bass. Both larval (naupliar) and juvenile (copepodid) copepods were included in the feeding study. Thirty-seven incubation experiments were conducted with smelt, 18 with bass.

RESULTS

Both larval and juvenile delta smelt and striped bass fed selectively on copepods, with fishes consuming higher proportions of copepodite (juvenile) stages and lower proportions of naupliar (larval) stages for all five copepod species examined.

L. Sullivan/SFSU

Intern Sean Rohtla of Marin Catholic High School counting larval delta smelt for use in feeding experiments.

T. Ignoffo/SFSU

Postdoctoral fellow Lindsay Sullivan of the Romberg Tiburon Center measuring larval delta smelt.

Larval delta smelt (15 to 30 days post-hatching) consumed copepodid *L. tetraspina* in higher proportions than naupliar *E. affinis* or *P. forbesi*. The scientist reports that this observation was surprising because, at these stages, all three species are similar in size, suggesting that prey morphology and/or behavior, in part, controls selection.

Larval delta smelt (15 to 30 days post-hatching) consumed *E. affinis*, *P. forbesi* and *L. tetraspina* copepodites in proportion to their abundance in the assemblage. In other words, they showed no selection among the three species. Based on fish gape (mouth size) and copepod lengths, the early copepodid stages of *E. affinis* and *P. forbesi* and the late copepodid stages of *L. tetraspina* are of optimal size for larval delta smelt. Larval striped bass showed similar patterns.

Juvenile smelt and bass (60 to 120 days post-hatching), however, selected for the larger calanoid copepod species (*E. affinis* and *P. forbesi*) and avoided eating the small, introduced *L. tetraspina*.

Unfortunately for the delta smelt, which is protected by both state and federal endangered species acts, *L. tetraspina* is most abundant at times of the year when delta smelt are larger and seeking larger prey.

The amount of available prey calories has not changed, the scientist reports—the prey is just in smaller pieces. It's like offering fish a baked potato, or one potato cut into French fries. The juvenile fish prefer a baked potato, but they're not getting enough of them. Because of this, the introduced copepod could be contributing to an observed decline in growth rates of wild delta smelt.

Following the feeding experiments, the scientist videotaped feeding behaviors of larval delta smelt (15 days post-hatching) on *E. affinis, P. forbesi* and *L. tetraspina* and found that, at similar prey concentrations (i.e., encounter rates), larval delta smelt had high attack rates on the copepodite stages of the calanoid copepods (*E. affinis* and *P. forbesi*), as compared to those for the copepodite stages of *L. tetraspina*; however, larval delta smelt were more efficient at capturing *L. tetraspina*, compared to *E. affinis* and *P. forbesi.* The contrasting patterns of attack rate and capture efficiency negate each other, resulting in the appearance that larval fish are not selectively feeding on prey.

Results demonstrate that larval delta smelt and striped bass consume the copepodite stages of *E. affinis, P. forbesi* and *L. tetraspina* in approximately the same proportion to their abundance in the prey assemblage. This contradicts prevailing views that *L. tetraspina* avoids predation by planktivorous fish because of its small size, and suggests that *L. tetraspina* may be an important food source for larval planktivorous fish in the San Francisco Estuary. The same cannot be said for juvenile smelt and bass, which have been shown to favor larger calanoid species, now relatively scarce in the estuary.

APPLICATIONS

The fish species studied for this project, as well as others in the Bay-Delta, are in decline. To understand why, managers need basic information on their ecology. Numerous studies have shown that many fishes in the Bay-Delta are likely undernourished. Information on what they eat at different life stages is of critical importance for restoring fish populations, and for predicting future stressors on fish populations associated with changing copepod communities. Simply put, if there is not appropriate food, there will be no recovery.

The project's findings also underscore the importance of preventing species' invasions, even for tiny copepods.

COLLABORATORS

Fish Conservation and Culture Laboratory; Department of Biological and Agricultural Engineering; and Department of Civil and Environmental Engineering, all at UC Davis.

PRESENTATIONS

Sullivan, L.J. and W.J. Kimmerer. Feeding, growth and survival of larval planktivorous fish in the San Francisco Estuary: impacts of introduced prey. Coastal and Estuarine Research Federation 20th Biennial Conference, Portland, Ore., 2009.

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Sullivan, L.J., W.J. Kimmerer, B. Baskerville-Bridges and T.R. Ignoffo. Prey selection of larval delta smelt and striped bass: Impacts of an introduced species. CALFED Science Conference, Sacramento, 2008.

Sullivan, L.J., W.J. Kimmerer, B. Baskerville-Bridges and T.R. Ignoffo. Prey selection of larval planktivorous fish in the San Francisco Estuary: Impacts of an introduced species. Larval Biology Symposium, Lisboa, Portugal, 2008.

Sullivan, L.J., W.J. Kimmerer and B. Baskerville-Bridges. Prey selection of larval delta smelt: baked potato or French fry? Interagency Ecological Program Annual Workshop, Pacific Grove, 2008.

MENTORS

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Community: Senior Environmental Scientist Ted Sommer, California Department of Water Resources

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Postdoctoral fellow Lindsay Sullivan of the Romberg Tiburon Center videoing larval delta smelt feeding on copepods at the Fish Conservation and Culture Laboratory in Byron.

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