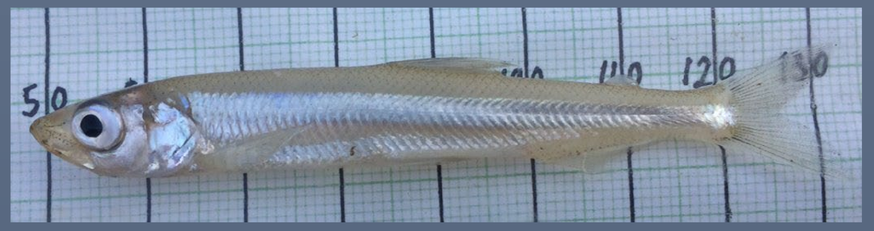
Wakasagi in the San Francisco Bay Delta: Comparative trends in distribution and life-history traits with native Delta Smelt



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Background

- Wakasagi (*Hypomesus nipponensis*) are an introduced forage fish native to Japan that were previously separated from their endangered congener the Delta Smelt (*Hypomesus transpacificus*) until they were introduced into CA reservoirs in the 20th century as bait fish.
- Wakasagi have since expanded their range downstream to the San Francisco Estuary (hereon 'estuary') but current knowledge of Wakasagi distribution status and biology in the estuary and negative influences on Delta Smelt is limited.
- Our study used a comparative approach, synthesizing long-term field monitoring surveys, modeling environmental associations, and quantifying phenology, growth, and diets of Wakasagi and Delta Smelt to describe abundance and range, trends of co-occurrence, and shared ecological roles between smelt species.

Methodology

- Distribution and catch summaries
  - Wakasagi catch, spatial range and size distributions (Fig. 1)
    - Regional delineated catch per unit effort (CPUE) for trawl, rotary screw trap, seine and salvage data
- Comparative life-history traits of Wakasagi and Delta Smelt
  - Occupancy modeling
  - Growth and phenology (otolith analyses)
  - Diet composition

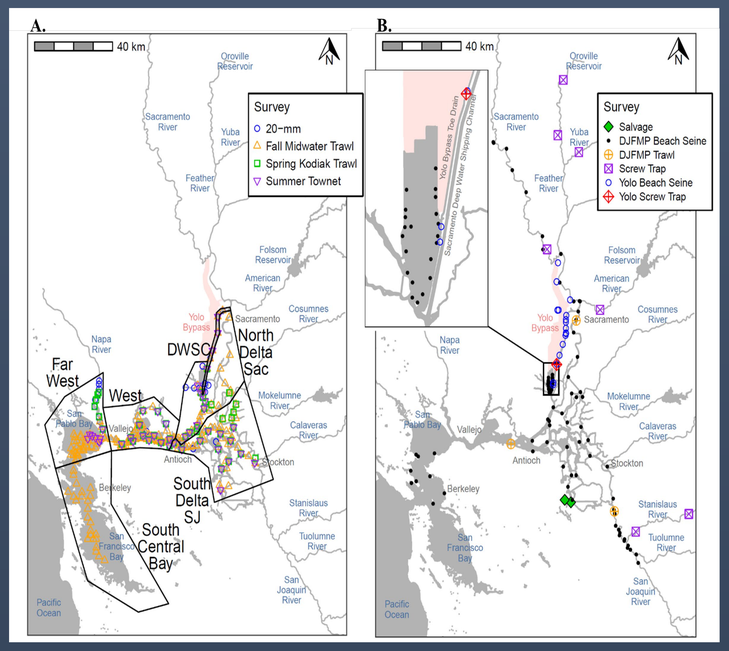

Figure 1. Maps of the San Francisco Bay-Delta Estuary. Long-term CDFW monitoring surveys, sampling locations, and region assignments used for comparative Delta Smelt and Wakasagi analysis are shown in A, whereas non-CDFW surveys assessed for Wakasagi catch are displayed in B. Yolo Bypass surveys for life-history traits including growth, phenology, and diets are shown in B

Results

- Wakasagi are detected in all gear types across life stages (Fig. 2).
- Wakasagi abundance was higher in northern regions of the estuary, where most co-occurrence with Delta Smelt was found (Fig. 3), and below source reservoirs (screw trap data not shown)
- Evidence of an established Wakasagi population in the estuary and increasing abundance in the Sacramento Deep Water Ship Channel (SDWSC), Fig. 3.
- Extent of Wakasagi range appears to extend to western regions of the estuary (Figs. 3 & 5)
- Similar ecological roles noted for both smelt species, demonstrated by overlapping habitat use (Figs. 3,5), growth and phenology (Fig. 4), and diets (data not shown)

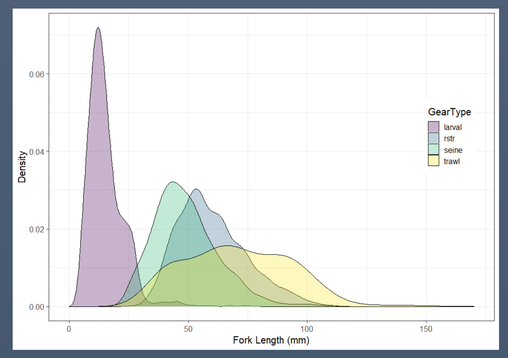

Figure 2. Density plot showing frequency of Wakasagi fork length in millimeters for different gear types: larval trawls (larval), rotary screw traps (rstr), beach seines (seine), and non-larval trawls (trawl).

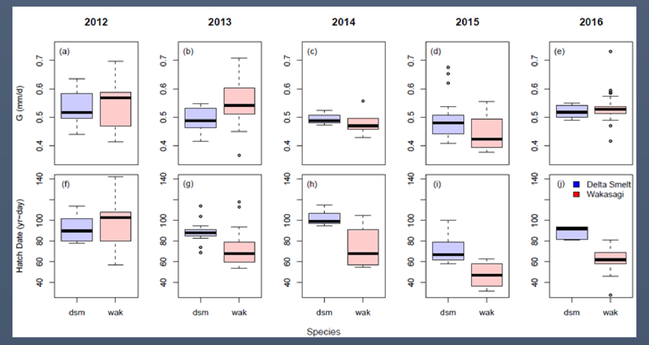

Figure 4. Variation in growth rates (a-e) and hatch dates (f-j) between species (Delta Smelt -dsm, Wakasagi-wak) and among years (2012-2016).

Figure 3. Delta Smelt and Wakasagi annual mean catch per tow for Bay-Delta regions. Note the difference in scale between Wakasagi and Delta Smelt plots, thus for reference, the top of the Y-axis scale for Wakasagi catch per tow is shown as a dotted line on the Y-axis for Delta Smelt catch per tow. Grey shading shows start of sampling in the Deepwater Ship Channel for each survey. (A) 20mm Survey; (B) Spring Kodiak Trawl; (C) Summer Townet Survey; (D) Fall Midwater Trawl.

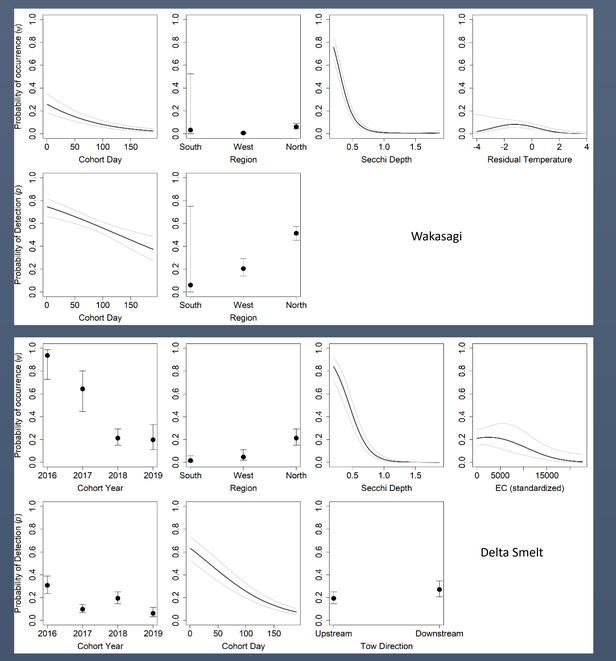

Figure 5. Model prediction results from the final Wakasagi (above) Delta Smelt (below) occupancy models, with occupancy submodel plots in the top and detection submodel plots in the bottom. Grey lines and error bars indicate 95% confidence intervals. Each prediction plot was constructed using median value for other covariates that are continuous and the following level for categorical dummy variable (when applicable): 2018 cohort year and North region.

Conclusion

- Earlier hatching and rearing of Wakasagi during cooler months and reduced growth during warmer drought years suggest this species is unlike typical non-natives (e.g., Centrarchids) in the estuary, and may exhibit similar sensitivity to environmental variability as Delta Smelt.
- Wakasagi also appear to favor similar habitat and food as Delta Smelt, with high turbidity and food availability in Suisun Marsh and the SDWSC resulting in these regions being relative "hot spots" for both species.
- The limited abundance and patchy distribution of Wakasagi in the estuary, despite relatively large numbers upstream, suggest that severe negative interactions with Delta Smelt have been limited or infrequent.