



Allometric Growth in Delta Smelt and Implications for Determination of Condition

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Introduction

The California Department of Fish and Game (DFG) Long-Term Monitoring Unit (LTM) has collected length and weight measurements from preserved fishes to calculate length-weight (l-w) relationships to evaluate the "body condition" of fishes in the estuary for management purposes.

The objective of this study was to determine a suitable index to evaluate the "body condition" of delta smelt (*Hypomesus transpacificus*) among different time periods in the upper San Francisco Estuary.



Methods

- Age-0 delta smelt were collected by several DFG LTM surveys sampling from San Pablo Bay upstream through the Delta in 2005-2008.

- Fish were placed in 10% buffered formalin upon collection, returned to the DFG laboratory (Stockton, CA), and measured fork length (FL) in millimeters (mm) and weighed wet (W) in grams (g).

- Log₁₀ transformed length and weight (l-w) data were used to generate least squares linear regression relationships.

- Evaluation of the regression residuals revealed a non-linear trend for the pooled log₁₀ transformed l-w data. Two inflection points in the l-w data were identified that distinguished 3 separate allometric growth phases (FL <12.0 mm, 12.0-27.9 mm, >27.9 mm); allometry being growth in weight not in proportion to growth in length resulting in varying body shapes.

- The slope (b) of the l-w regression for each growth phase was checked for isometry (b = 3.0), negative allometric growth (b <3.0), or positive allometric growth (b >3.0) in wet weight (van Snik et al. 1997).

- Multiple condition indices (Fulton's, Ricker's, and Relative condition factors) were calculated for each fish (Table 1) to evaluate presence of length bias.

Table 1. List of condition indices.

Fulton's condition factor (K)	Ricker's condition factor (Kb)	Relative condition factor (Kn)
$K = (W / FL^3) * 100,000$	$Kb = (W / FL^b) * 100,000$	$Kn = (W / W') / (a' / a)$

Where W is wet weight (g) of the individual, b is the slope of the pooled data, and a and the intercept and n is the slope calculated from the regression of separate growth phases based on fork length (FL, mm).

Results

- A total of 781 delta smelt were processed (Table 2).

- The plot of the pooled log₁₀ transformed l-w data and residuals revealed a non-linear relationship (Figure 1).

- Further examination revealed three allometric growth phases in weight, resulting in three l-w regressions, associated with the morphological changes that occur between larval, post larval, and juvenile life stages (Figure 2).

Table 2. Summary of sample number and fork lengths (mm) of delta smelt.

	Year				Grand Total
	2005	2006	2007	2008	
Count	324	263	68	126	781
Average FL	22.8	25.7	40.6	32.8	26.9
Min FL	4.3	7.0	5.5	8.1	4.3
Max FL	67.2	55.7	65.1	63.1	67.2

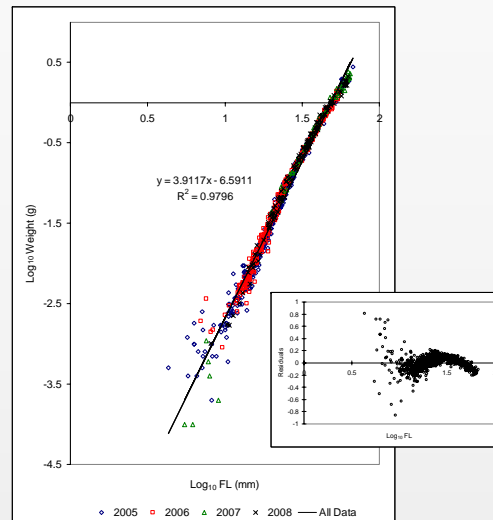


Figure 1. Log₁₀ transformed length-weight data of age-0 delta smelt collected in 2005-2008. Inset plot of regression residuals in relation to fork length.

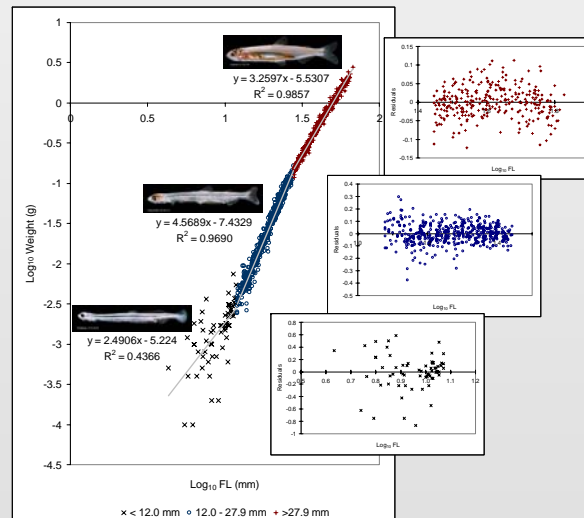


Figure 2. Log₁₀ transformed length-weight regressions of age-0 delta smelt by growth phase (4.3-11.9 mm, 12.0-27.9 mm, and 28.0-67.2 mm FL) collected 2005-2008. Inset plots of regression residuals in relation to length per growth phase. Photographs of delta smelt at 11.8 mm, 20 mm, and 31 mm FL by Rene Reyes, from USBR Tracy Reports Vol 38.

Results cont.

- Delta smelt larvae (hatch-11.9 mm FL) exhibited negative allometric growth: b = 2.49. Post-larval and pre-juvenile fish (12.0-27.9 mm FL) displayed strong positive allometric growth at b = 4.57, and juvenile and sub-adult fish (>27.9 mm FL) exhibited only slightly positive allometric growth at b = 3.26.

- The existence of multiple growth phases -- differing rates of body volume gain at length -- resulted in Fulton's (K) and Ricker's (Kb) condition factors having a length bias (Figure 3A).

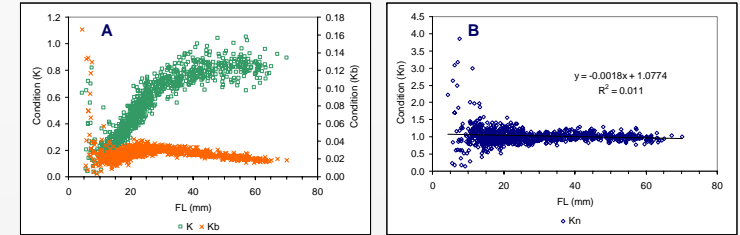


Figure 3. Comparison of delta smelt individual index values by fork length (mm) using A) Fulton's (K) and Ricker's (Kb) and B) relative (Kn) condition factor indices.

Results cont.

- Use of the relative condition factor (Kn) incorporating the regression results of the three growth phases removed the length bias from the analysis (Figure 3B).

- The seasonal pattern of mean monthly Kn was similar among years with condition highest in spring or early summer followed by a slight decrease through fall. This pattern was consistent with the exception of very high condition in spring of 2006 and very low condition in spring of 2007 (Figure 4).

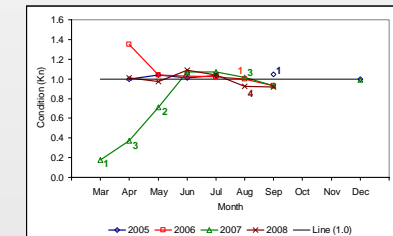


Figure 4. Mean monthly relative condition factor (Kn) indices of delta smelt collected in 2005-2008. Monthly means with contributing samples n<5 noted with sample size next to data point.

Discussion

- A single length-weight relationship for delta smelt is not an accurate predictor of weight at length due to consistent, sequential changes in body shape (volume), and thus weight, at length that occurred at transitions between life stages.

- Delta smelt exhibited three phases of allometric growth in weight over the length range examined, with the 12 mm FL inflection point near the ontogenetic shift point in length-otolith growth found by Hobbs et al. (2007).

- Delta smelt did not grow isometrically, so an unbiased condition index must include parameters from the l-w regressions for each different life stage.

- The large variation in weights at length of small larval fish was likely due to difficulty in obtaining weights near the lower measurement limit and also from handling error, specifically removing exterior moisture consistently.

- Comparison of condition temporally (and regionally) is possible for delta smelt when estimates are from the same pooled data, but should not be compared to estimates generated outside the pooled data.

Acknowledgements

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References

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