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Temperature and Salinity Tolerances of Delta Smelt

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In 1992, we began a study of the environmental tolerances and habitat requirements of the delta smelt, *Hypomesus transpacificus*, at that time a candidate species for listing under the State and Federal Endangered Species Acts. The objective of our research was to provide information useful for defining delta smelt critical habitat and developing management guidelines for the species. In this report we describe results of our studies on temperature and salinity tolerances of the delta smelt and implications of these results for management and protection of this fish.

Delta smelt spawn seasonally and complete their life cycle in a single year; life history stages tend to be strongly correlated with seasonal temperature regimes. Therefore, we conducted our experiments using juvenile (<4.5 cm standard length), subadult (4.5-6.0 cm SL), and adult fish (>6.0 cm SL) acclimated to seasonally appropriate ranges of temperatures that represented, for each life history stage, a low and high temperature level (juveniles and subadults in summer and fall, 17 and 21°C; subadults and adults in winter and spring, 12 and 17°C). Delta smelt may also exhibit seasonal preferences in salinity. Juveniles and subadults are most abundant in the brackish entrapment zone; adults move upstream to fresh water prior to spawning. Therefore, we measured temperature tolerances in fish acclimated to both fresh (0 ppt) and brackish (4 ppt) water.

Temperature Tolerance

Temperature tolerance limits were measured in terms of critical thermal maxima (CT_{max}) and minima (CT_{min}), a protocol in which the fish were subjected to relatively rapid change in temperature (6°C/h increase or 5°C/h decrease). The tolerance limit was defined by a sublethal response, loss of equilibrium, although in the wild such a response would probably be lethal.

Delta smelt tolerated moderate acute changes in temperature (Figure 1). CT_{max} was significantly affected by acclimation temperature; fish acclimated to warmer temperatures tolerated higher temperatures. However, the magnitude of the tolerated temperature increase was similar (5-7°C) for all three acclimation groups. An increase in salinity to 4 ppt significantly increased the delta smelt's tolerance to temperature increases. CT_{min} was less dependent on acclimation temperature and independent of salinity. Fish size (or life history stage) did not affect either CT_{max} or CT_{min}. These results show that delta smelt are

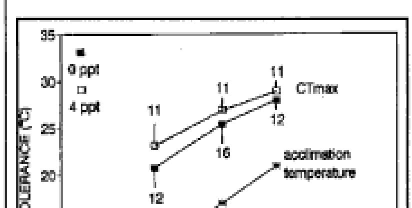

Figure 1
MEAN (±SD) CRITICAL THERMAL MAXIMA (CT_{max}) AND MINIMA (CT_{min}) OF DELTA SMELT ACCLIMATED TO 12, 17, and 21°C IN 0 AND 4 PPT

Sample sizes for each temperature/salinity combination are above or below the points. CT_{min} in 12°C was only measured in 0 ppt.

eurythermal; they acclimated successfully to a relatively wide range of temperatures (12-21°C) and generally survived short-term exposure to acute temperature increases and decreases that are probably greater than the fish would normally encounter in the wild. However, in some areas within their range, delta smelt may be exposed to heated effluents and/or entrained in power plant cooling system water diversions where temperatures may reach 30°C (R. Pine, FWS, pers. comm.); our results strongly suggest that such exposure would be lethal to delta smelt. Furthermore, compared to a number of other delta fishes, delta smelt are more sensitive to acute temperature increases. Table 1 compares the CT_{max} of delta smelt to values measured for other fishes using the same methods and similar rates of temperature change. Splittail and inland silverside tolerated substantially greater increases in temperature. Even chinook salmon smolts acclimated to a slightly lower temperature had higher CT_{max}.

Table 1
COMPARISON OF CT_{max} OF
DELTA SMELT AND OTHER DELTA FISHES

Species	Acclimation Temperature (°C)	CT_{max} (°C)	Source
Delta smelt	12	21	Swanson & Cech (1995)
	17	25	
	21	28	
Inland silverside	17	31	Swanson & Cech (1995)
Chinook salmon	16.5	26-27	Swanson & Cech (1995)
Splittail			
Young-of-Year	17	31	Cech & Young (1995)
	20	32-33	
Juvenile	12	21	
	17	29	
Subadult	12	22	
	17	29	

Table 2
CHRONIC UPPER
SALINITY TOLERANCE LIMITS
OF DELTA SMELT
(Mean ± SD)

Temperature (°C)	Life History Stage SL (cm)	Upper Salinity Limit (ppt)
17	Juvenile 3.7 ± 0.3	18.7 ± 1.8 (n=15)
17	Subadult/Adult 5.9 ± 0.3	19.1 ± 2.1 (n=14)
21	Juvenile 3.7 ± 0.4	19.2 ± 1.9 (n=10)

Salinity Tolerance

Chronic salinity tolerance of delta smelt was measured for juveniles, subadults, and adults in 17°C and for juveniles in 21°C. In these experiments, individual fish were subjected to a gradual increase in salinity (2 ppt/12 h), and the tolerance limit was defined as the maximum salinity the fish survived for 12 hours. The slow increase in salinity allowed the fish to physiologically adapt to the changing osmoregulatory demands; therefore the tolerance limit represents the maximum osmoregulatory capacity of the fish for salinity increase.

Delta smelt tolerated chronic exposure to salinity from 0 ppt (fresh water) to 19 ppt (about 55% sea water) (Table 2). Neither acclimation temperature (17 and 21°C) nor fish size affected salinity tolerance.

The results show that delta smelt are euryhaline and that their osmoregulatory capacity is fully developed by 3 months post-hatch when the juveniles were tested. Furthermore, delta smelt are able to tolerate higher salinities than those in which they have been collected to date, suggesting that salinity is not the factor that limits their distribution to fresh and slightly brackish waters. The chronic salinity tolerances of delta smelt measured in these studies were similar to those measured for young-of-the-year and juvenile splittail (Cech and Young 1995).

Implications for Management

Moyle *et al* (1992) reported that delta smelt are apparently extremely sensitive to estuarine conditions, but the relationships between specific environmental conditions in the estuary and delta smelt abundance have not been well defined. The results of these and other ongoing studies in our laboratory can be used to define how temperature and salinity may limit delta smelt distribution and how, within the fish's range, these factors affect survival, physiology, and behavior. As an example, results of the CT_{max} experiments show how anthropogenic temperature fluctuations may adversely and disproportionately impact delta smelt. This type of information contributes to definition and management of dellta smelt critical habitat and improved protection of this threatened fish.

Acknowledgments

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