



Interagency Ecological Program

Newsletter - Fall 1995

CONTENTS

- [Interagency Program Highlights](#)
- [Modeling and Predicting Intertidal Variations of the Salinity Field in the Bay/Delta](#)
- [Petition to List Spring Chinook](#)
- [Delta Smelt October Midwater Trawl Survey Results](#)
- [Preliminary Results from the Hydrodynamic Element of the 1994 Entrapment Zone Study](#)
- [Sacramento Coordinated Water Quality Program Includes Interagency Program Representative](#)
- [Sacramento Perch, Wakasagi, Splittail, Sacramento Blackfish, and Shimofuri Goby in San Luis Reservoir and O Neill Forebay](#)
- [Delta Flows](#)
- [Laboratory Culture of Delta Smelt](#)
- [Continuous Flow Measurements Using Ultrasonic Velocity Meters: An Update](#)
- [Feather River Fisheries Studies](#)
- [Critical Dissolved Oxygen Minima in Splittail](#)
- [Temperature and Salinity Tolerances of Delta Smelt](#)
- [Suisun Marsh Diversion Screening Program](#)
- [New Interagency Program Home Page](#)
- [Science Advisory Group Lauds Interagency Monitoring](#)
- [Winter-Run Chinook Salmon Captive Broodstock Program 1995 Progress Report](#)

Literature

- Becker, C.D., and R.G. Genoway. 1979. Evaluation of critical thermal maxima for determining thermal tolerance of freshwater fish. *Environmental Biology of Fishes* 4:245-256.
- Caywood, M.L. 1974. *Contributions to the Life History of the Splittail Pogonichthys macrolepidotus (Ayres)*. M.S. Thesis, California State University, Sacramento.
- Cox, D.K. 1974. Effects of three heating rates on the critical thermal maximum of bluegill. Pages 158-163 in J.W. Gibbons and R.R. Sharitz, editors. *Thermal Ecology*. AEC Symposium Series (CONF-730505), National Technical Information Service, Springfield, VA.
- Daniels, R.A., and P.B. Moyle. 1983. Life history of splittail (Cyprinidae: *Pogonichthys macrolepidotus*) in the Sacramento-San Joaquin Estuary. *Fishery Bulletin* 81:647-654.
- Davis, J.C. 1975. Minimal dissolved oxygen requirements of aquatic life with emphasis on Canadian species: a review. *Journal of Fisheries Research Board of Canada* 32: 2295-2332.
- Department of Water Resources. 1992. *Water Quality Monitoring Program Report, Decision 1485*. State of California, Sacramento.
- Fry, F.E.J. 1970. Effect of environmental factors. Pages 1-98 in W.S. Hoar and D.J. Randall, editors. *Fish Physiology*. Vol VI. Academic Press Inc. New York.
- Herbold, B., A.D. Jassby, and P. Moyle. 1992. *Status and Trends Report on Aquatic Resources in the San Francisco Estuary*. San Francisco Estuary Project.
- International Joint Commission. 1979. *Report of the Review Committee for the Dissolved Oxygen Objective for the Great Lakes*. Great Lakes Science Advisory Board. Windsor, Ontario.
- Meng, L., and P.B. Moyle. 1995. Status of splittail in the Sacramento-San Joaquin estuary. *Transactions of the American Fisheries Society* 124:538-549.
- Moyle, P.B., and R.M. Yoshiyama. 1992. *Fishes, Aquatic Diversity Management Areas, and Endangered Species: A Plan to Protect California's Native Aquatic Biota*. The California Policy Seminar, University of California.
- Rahel, F.J., and J.W. Nutzman. 1994. Foraging in a lethal environment: fish predation in hypoxic waters of a stratified lake. *Ecology* 75: 1246-1253.
- U.S. Environmental Protection Agency. 1986. *Ambient Water Quality Criteria for Dissolved Oxygen*. Criteria and Standards Division. Washington, DC. EPA 440/5-86-003.

Temperature and Salinity Tolerances of Delta Smelt

Christina Swanson and Joseph J. Cech, Jr., University of California, Davis

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 entrainment 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

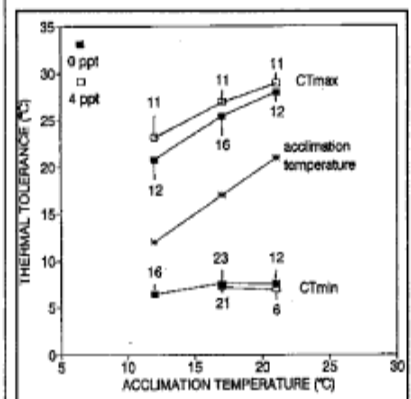


Figure 1
MEAN (\pm SD) CRITICAL THERMAL MAXIMA (CT_{max}) AND MINIMA (CT_{min}) OF DELTA SMELT ACCLIMATED TO 12, 17, AND 21°C IN 0 AND 4 PPT
Sample sizes for each temperature/salinity combination are above or below the points.
 CT_{min} in 12°C was only measured in 0 ppt.

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} .

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.

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	Cech & Young (1995)
Juvenile	20	32-33	
	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	18.7 ± 1.8 (n=15)
	Subadult/Adult	3.7 ± 0.3
17	Subadult/Adult	19.1 ± 2.1 (n=14)
	Juvenile	5.9 ± 0.3
21	Juvenile	19.2 ± 1.9 (n=10)
	Juvenile	3.7 ± 0.4

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 anthro-

pogenic temperature fluctuations may adversely and disproportionately impact delta smelt. This type of information contributes to definition and management of delta smelt critical habitat and improved protection of this threatened fish.

Acknowledgments

This study was funded by the California Department of Water Resources (contracts B-59449 and B-58959). We thank R. Mager and S.I. Doroshov (Department of Animal Science, UC Davis) for their help developing techniques for collection of delta smelt. We also thank the California Department of Fish and Game, particularly D. Sweetnam, G. Aasen, J. Lott, and the Bay/Delta boat crew, for their invaluable cooperation and assistance collecting delta smelt. P. Young (Department of Wildlife, Fish, and Conservation Biology, UC Davis), a number of undergraduate student assistants, including D. Shigematsu, C. Porter, S. Cummings, D. Irwin, M. Thibodeau, and NSF Young Scholars, S. Tannen, S. Aren, and J. Khoo, helped with fish collection, fish care, and data collection.

Literature Cited

- Cech, J.J. Jr, and P.S. Young. 1995. Environmental tolerances and requirements of the Sacramento splittail, *Pogonichthys macrolepidotus* (Ayres). Final Report, Interagency Ecological Program for the San Francisco Bay/Delta. 56 pp.
- Moyle, P.B., B. Herbold, D.E. Stevens, and L.W. Miller. 1992. Life history and status of the delta smelt in the Sacramento-San Joaquin Estuary, California. *Trans. Am. Fish. Soc.* 121:67-77.
- Swanson, C., and J.J. Cech, Jr. 1995. Environmental tolerances and requirements of the delta smelt, *Hypomesus transpacificus*. Final Report, California Department of Water Resources. 77 pp.