

# INLAND FISHES OF CALIFORNIA

Revised and Expanded



**PETER B. MOYLE**

Illustrations by Chris Mari van Dyck and Joe Tomelleri

northwestern Delta in the channel of the Sacramento River. During years of average to high outflow they may concentrate anywhere from the Sacramento River around Decker Island to Suisun Bay prior to spawning movements.

*Life History* Delta smelt are euryhaline fish that typically rear in shallow (<3m), open waters of the estuary. They are mostly found within the salinity range of 2–7 ppt, but they can be found at salinities ranging from 0 to 18.4 ppt (6) and can tolerate salinities up to 19 ppt (7). In general delta smelt prefer to rear in or just above the region of the estuary where fresh water and brackish water mix and hydrodynamics are complex as a result of the meeting of tidal and riverine currents. This region is typically in Suisun Bay. During the 1987–1992 drought, the smelt were concentrated in deep areas in the lower Sacramento River around Decker Island, where the bottom salinity hovered around 2 ppt much of the year (8), apparently because the salt water–fresh water mixing zone was located in this region. However, smelt may also be common in this region during nondrought years, a finding that suggests they are attracted to favorable hydraulic conditions that allow them to maintain position. The idea that smelt do not consistently rely on the mixing zone for location is suggested by observations in such years as 1993, when the smelt continued to be common in Suisun Bay during the summer, even after the 2-ppt isohaline had retreated upstream (9). Smelt survival rates are generally highest in years when the area with salinities of 2 ppt or less includes shallow water in upper Suisun Bay during April–June, but the relationship is not consistent. Temperatures seem to have little effect on smelt distribution, because the smelt are found at temperatures ranging from 6 to 28°C, although 28°C is close to their lethal limit of 29°C (6, 7). Overall their behavior suggests a preference for low-salinity areas with tidal currents. The smelt are relatively poor swimmers (maximum swimming velocities of around 28 cm/sec). They tend to select portions of the water column that have relatively low velocities and to swim in short bursts (strokes) followed by a period of rest (glides) (21). This stroke-and-glide swimming behavior, combined with diel shifts in position in the water column (in response to tidal currents), presumably allows them to stay within relatively limited regions, where planktonic food organisms are also concentrated. These regions include main channels of the Delta and Suisun Marsh and open waters of Suisun Bay, where the waters are well oxygenated and temperatures are relatively cool (usually <20–22°C in summer).

Although nonbreeding delta smelt are usually aggregated together in limited areas, perhaps largely as a result of estuarine hydrodynamics, they do not appear to be strongly shoaling. Indeed the stroke-and-glide swimming behavior likely makes maintenance of coordinated schools difficult. Instead individual fish apparently hang out in the water col-

umn and rely on their small size and transparency to hide them from predators in turbid water. The fact that they are rarely found in the stomachs of such predatory fish as striped bass, white catfish, and black crappie, even when they are abundant (10, 11), is a good indication that this strategy is successful.

Delta smelt feed primarily on planktonic copepods, cladocerans, amphipods, and, to a lesser extent, insect larvae. Smelt measuring less than 12 mm FL feed almost exclusively on immature stages (copepodids and nauplii) of calanoid copepods, with adult copepods gradually becoming an important component of the diet with increasing size (12, 26). Larger fish may also feed on the opossum shrimp *Neomysis mercedis* or *Acanthomysis* sp., as well as other larger zooplankters (12, 25). Historically the most important food organism for all sizes was the euryhaline copepod *Eurytemora affinis*, although in recent years immature stages of the species, *Pseudodiaptomus* spp. (mainly *P. forbesi*) have become a major part of the diet, especially in summer, when *P. forbesi* largely replaces *E. affinis* in the plankton (12, 25). However, *P. forbesi* is a somewhat larger species than *E. affinis*, and larval delta smelt show a strong preference for *E. affinis* as a consequence. The decreased abundance of *E. affinis*, both in absolute terms and relative to the abundance of other copepods, may be reducing the survival of larval smelt (25, 26).

Growth of delta smelt is rapid, and juvenile fish reach 40–50 mm FL by early August (12, 13, 14, 15). The period of most rapid growth occurs after they reach 30 mm and a greater variety of food becomes available to them (27). At this time young-of-year dominate the population, and adults become increasingly scarce. The smelt reach their typical adult length of 55–70 mm SL in 7–9 months (usually by September). Growth during the next 3 months slows down considerably (only 3–9 mm total), presumably because most of the available energy is channeled toward gonad development (14, 15). Growth is apparently strongly limited by food supply. In recent years delta smelt have averaged 10 mm smaller at a given age than previously (16), an observation that is most likely the result of depletion of plankton in Suisun Bay by the invading overbite clam, *Morobula amurensis*. The abrupt change from a population dominated by single-age adults during spawning in summer to a population dominated by juveniles in summer indicates that most adults die after they spawn. A small number either do not spawn in their first year or spawn a second time, some reaching lengths of 90–120 mm SL in their second year.

In September or October delta smelt begin a gradual upstream migration toward spawning areas in the upper Delta. It may take several months for an individual to reach a spawning site. Spawning takes place between February and July, as inferred from collections of larvae