

fecundity ranged from 24,753 to 72,314 eggs per female, which agrees with Caywood's (1974) observations.

Although primarily a freshwater species, splittail can tolerate salinities as high as 10 to 18 parts per thousand (ppt) (Moyle 1976; Moyle and Yoshiyama 1992). Salinity tolerance in splittail increases in proportion to length; adults can tolerate salinities as high as 29 ppt for short periods (Young and Cech 1996). Splittail populations fluctuate annually, depending on spawning success, which is well correlated with freshwater outflow and the availability of shallow water habitat with submerged vegetation (Daniels and Moyle 1983; Sommer *et al.* 1997). Fish typically reach sexual maturity by the end of their second year. The onset of spawning is associated with rising water levels, increasing water temperatures, and increasing day length. Peak spawning occurs from February through May, although records of spawning exist for late January to early July (Wang 1986). In some years, most spawning may take place within a limited period of time. For instance, in 1995, a year of high spawning activity, most splittail spawned over a short period in April, even though larval splittail were captured from February through early July (Moyle *et al.* 2001). Within each spawning season older fish reproduce first, followed by younger individuals (Caywood 1974).

Splittail spawning occurs over flooded vegetation in tidal freshwater and brackish water habitats of estuarine marshes and sloughs and slow-moving, shallow reaches of large rivers. Observations of splittail spawning have indicated spawning at depths of less than 1.5 meters (m) (4.9 feet (ft)) in the Cosumnes River floodplain (Moyle *et al.* 2001), and at depths of less than 2 m (6.6 ft) in Sutter Bypass (Moyle *et al.* 2001). Sommer and Harrell (1999) postulated that individual splittail may not spawn in the year following a successful effort.

Splittail larvae remain in shallow, weedy areas close to spawning sites for 10 to 14 days and move into deeper water as they mature and swimming ability increases (Wang 1986; Sommer *et al.* 1997). Bailey (1994) has documented that splittail eggs hatch in 3 to 5 days at 18.5 degrees centigrade (°C), (65.3 degrees Fahrenheit (°F)). Bailey (1994) also found that at 5 to 7 days after hatching, the yolk sac is absorbed and the diet begins to include small rotifers. Moyle *et al.* (2001) states that splittail of 20 to 25 mm (0.8 to 1.0 in) total length (TL) “\* \* \* are essentially small juveniles, capable of fairly active swimming” and that 4 to 5 weeks post-

hatch are required to reach this size class.

It is speculated that Suisun Marsh is the likely late stage rearing area for juvenile splittail hatched and reared in the extensive spawning habitat found within the Yolo Bypass, as a hydrologic connection apparently exists between these waters (N. Monsen, unpubl. data referenced in Moyle *et al.* 2001). Splittail use of Suisun Marsh varies with outflow (Baxter 1999a).

Splittail are benthic foragers. In Suisun Marsh, adults feed primarily on opossum shrimp (*Neomysis mercedis*, and presumably, non-native shrimp species of the genus *Acanthomysis* as well), benthic amphipods (*Corophium* spp.), and other small crustaceans, although detrital material makes up a large percentage of their stomach contents (Daniels and Moyle 1983). In the Delta, clams, crustaceans, insect larvae, and other invertebrates also are found in the adult diet. More recently, research has indicated a shift in adult splittail diet towards the non-native Asiatic clam (*Potamocorbula amurensis*) in Suisun Marsh.

Historically, *Eurytemora affinis*, the native euryhaline copepod, has been the most important food for larval fishes in the Estuary. Three non-native species of euryhaline copepods (*Sinocalanus doerrii*, *Pseudodiaptomus forbesi*, and *Pseudodiaptomus marinus*) became established in the Delta between 1978 and 1987 (Carlton *et al.* 1990), while native *E. affinis* populations have declined since 1980. It is not known if the non-native species have displaced *E. affinis* or whether changes in the estuarine ecosystem now favor *S. doerrii* and the two *Pseudodiaptomus* species. Meng and Orsi (1991) reported that *S. doerrii* is more difficult for larval striped bass to catch than native copepods because it is fast swimming and has an effective escape response. It is not known if this difference in copepod swimming and escape behavior has affected the feeding success of young splittail. Zeug *et al.* (2002) and Hieb (2002) reported a high abundance of an introduced, predatory Palaemonid shrimp (*Exopalaemon modestus*) in the Yolo Bypass and Delta. It is not known what effect(s) this invasive species will have on the trophic (food) pyramid of the estuary, though Moyle (2002b) speculates it is likely to prey on mysid shrimp and thus, may compete with splittail for food. Juvenile feed mainly on plankton composed of small animals (zooplankton), and then small crustaceans and insect larvae as body size increases.

Predators of splittail include striped bass (*Morone saxatilis*), largemouth bass

(*Micropterus salmoides*) and other centrarchids, and other native and non-native piscivores (Moyle 1976, Moyle 2002a). Introduced, non-native benthic foragers such as shokihaze goby (*Tridentiger barbatus*), chameleon goby (*T. trigonocephalus*), and yellowfin goby (*Acanthogobius flavimanus*), may feed on splittail eggs. Introduced planktivorous, threadfin shad (*Dorosoma petenense*) and inland silverside (*Menidia beryllina*), compete directly with larval and juvenile splittail for food. Other non-native cyprinids, such as golden shiner (*Notemigonus crysoleucas*), red shiner (*Notropis lutrensis*), and fathead minnow (*Pimephales promelas*) are also likely to compete with splittail. In recent years, splittail have been found most often in slow moving sections of rivers, sloughs, and in dead end sloughs (Moyle 1976, Daniels and Moyle 1983). Reports from the 1950's, however, mention Sacramento River spawning migrations and catches of splittail during fast tides in Suisun Bay (Caywood 1974). Current accounts place splittail as far upstream as the Red Bluff Diversion Dam on the Sacramento River (Baxter 1999a). Splittail have been recorded in recent times from within Salt Slough and at the Merced River confluence on the San Joaquin River, and within the Napa and Petaluma Rivers (Baxter 1999a, 1999b; USACE 2002a, 2002b).

Splittail are frequently found in areas subject to flooding because they require flooded vegetation for spawning and rearing. Historically, the major flood basins (*e.g.*, Colusa, Sutter, American, and Yolo basins; Tulare, Buena Vista, and Kern lakes) distributed throughout the Sacramento and San Joaquin valleys provided spawning and rearing habitat. These flood basins have all been reclaimed or modified for flood control purposes (*i.e.* as bypasses), and much of the floodplain area adjacent to the rivers is now inaccessible behind levees. The Yolo Bypass may approximate some of the Yolo Basin's former role, and the Butte Creek, Butte Sink, Sutter Bypass system remains somewhat intact. Meng and Moyle (1995) reported that the core distribution of splittail extends from Suisun Bay and Marsh through the western Delta.

The Yolo and Sutter bypasses and the Cosumnes River floodplain serve as important splittail spawning and early rearing habitat (Sommer *et al.* 1997), as they approximate the large, open, shallow water areas which have been extensively reduced. The Yolo and Sutter bypasses provide good habitat for fish, particularly splittail, when flooded for several weeks in March and April. To provide the best spawning