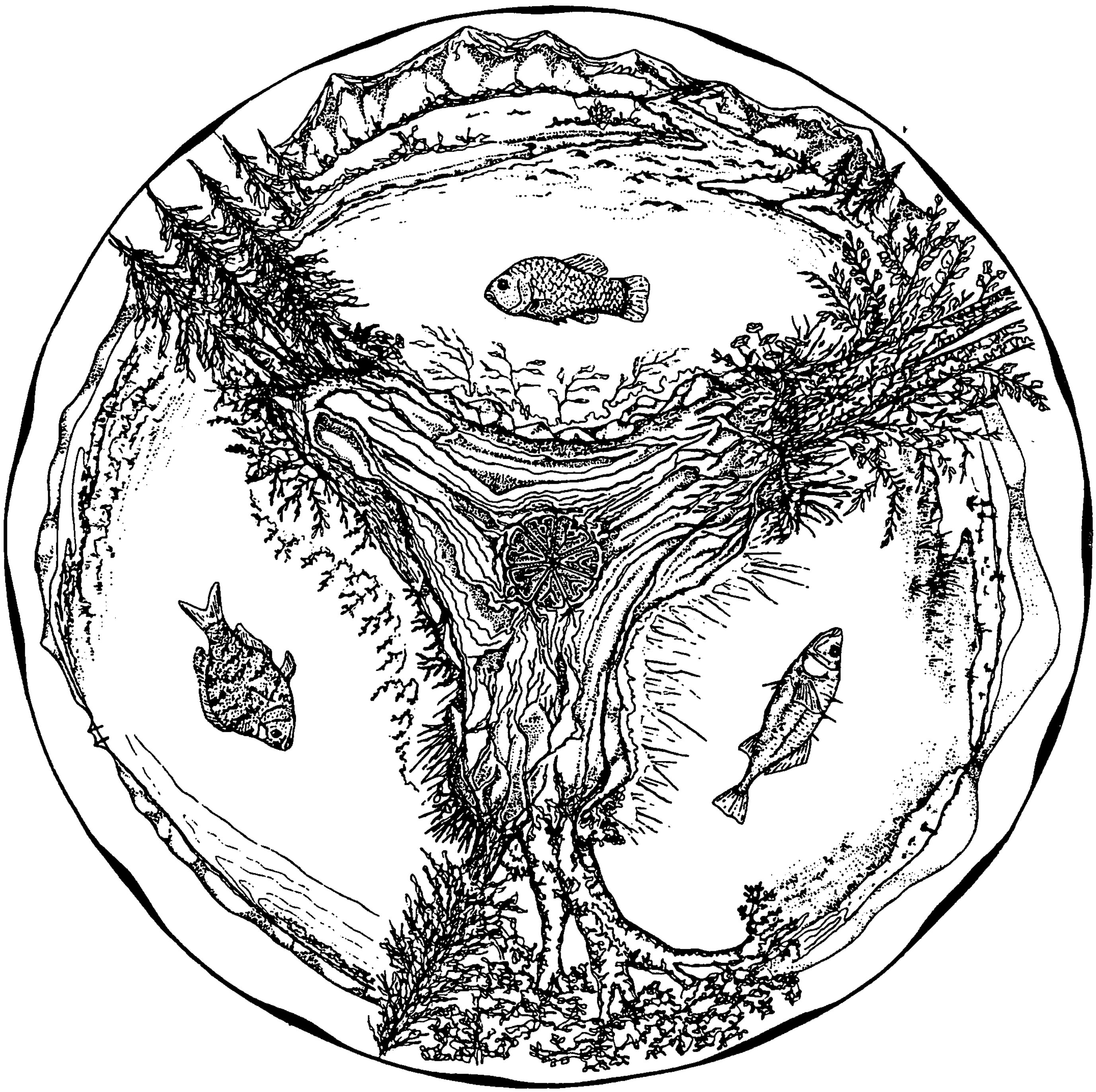
FISH SPECIES OF SPECIAL CONCERN OF CALIFORNIA



CALIFORNIA DEPARTMENT OF FISH AND GAME

FISH SPECIES OF SPECIAL CONCERN OF CALIFORNIA

by

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DELTA SMELT
Hypomesus transpacificus (McAllister)

Description: Delta smelt (*Hypomesus transpacificus*) are slender-bodied fish that typically reach 60-70 mm SL, although a few may reach 120 mm SL. The mouth is small, with a maxilla that does not extend past the mid-point of the eye. The eyes are relatively large, with the orbit width contained approximately 3.5-4 times in the head length. Small, pointed teeth are present on the upper and lower jaws. The first gill arch has 27-33 gill rakers and there are 7 branchiostegal rays. The pectoral fins reach less than two-thirds of the way to the bases of the pelvic fins. There are 9-10 dorsal fin rays, 8 pelvic fin rays, 10-12 pectoral fin rays, and 15-17 anal fin rays. The lateral line is incomplete and has 53-60 scales along it. There are 4-5 pyloric caeca.

Live fish are nearly translucent and have a steely-blue sheen to their sides. Occasionally there may be one chromatophore between the mandibles, but usually there is none.

Taxonomic Status: The confusing taxonomic history of this species is detailed in Moyle (1976). Delta smelt was first considered to be a population of the widely distributed pond smelt, *Hypomesus olidus*. Hamada (1961) recognized pond smelt and delta smelt as being different species and renamed the pond smelt *H. sakhalinus*, retaining the name *H. olidus* for the Delta smelt. In 1983 McAllister redescribed the Delta smelt as *H. transpacificus*, but with Japanese and California subspecies, *H. t. nipponensis* and *H. t. transpacificus*, respectively. Subsequent studies have shown that the two widely separated subspecies should be recognized as species, with Delta smelt being *H. transpacificus* and Japanese species (wagasaki) being *H. nipponensis* (Moyle 1980). Unfortunately, wagasaki were introduced into California reservoirs on the assumption that they were the same species (*H. olidus*!) as the Delta smelt (Moyle 1976).

Distribution: Delta smelt are endemic to the upper Sacramento-San Joaquin estuary (Fig. 16). They occur primarily below Isleton on the Sacramento River side, below Mossdale on the San Joaquin River side, and in Suisun Bay. When outflows from the Sacramento and San Joaquin rivers are high (mainly during March-mid June), the smelt congregate in upper Suisun Bay and Montezuma slough. During high outflow periods, they may be washed into San Pablo Bay, but they do not establish permanent populations there. Since 1982, the center of Delta smelt abundance has been the northwestern Delta in the channel of the Sacramento River. It has become rare in Suisun Bay and is virtually absent from Suisun Marsh where it was once seasonally common.

Habitat Requirements: Delta smelt are euryhaline fish that rarely occur in water with more than 10-12 ppt salinity (about 1/3 sea water). Spawning takes place in freshwater at temperatures of about 7-15°C (Wang 1986). All sizes are found in the main channels of the Delta and Suisun Marsh and the open waters of Suisun Bay where the waters are well oxygenated and temperatures relatively cool (usually less than 20-22°C in summer). When not spawning, they tend to be concentrated near the null zone where incoming salt water and outflowing freshwater mix. This area has the highest primary productivity and is where zooplankton populations (on which they feed) are most dense.

Life History: Delta smelt inhabit the open, surface waters of the Delta and Suisun Bay, where they presumably school. Spawning takes place between February and June, as inferred from larvae collected during this period (Wang 1986). Apparently, most spawning occurs in dead end sloughs and shallow edge-waters of the channels in the upper Delta and in the Sacramento River above Rio Vista, although it has been recorded in Montezuma Slough near Suisun Bay (Radtke 1966, Wang 1986). Delta smelt eggs are demersal and adhesive, sticking to hard substrates such as rock, gravel, tree roots or submerged branches, and perhaps submerged vegetation (Moyle 1976, Wang 1986). Hatching occurs in 12-14 days, assuming development rates of the embryos are similar to those of the closely related wagasaki (Wales 1962).

After hatching, the buoyant larvae rise to the surface and are washed downstream until they reach the mixing zone. Here currents keep them suspended and circulating with the abundant zooplankton that also occur in this zone. Growth is rapid and the juvenile fish are 40-50 mm long by early August (Erkkila et al. 1950; Ganssle 1966; Radtke 1966). By this time, the young-of-year fish dominate trawl catches of smelt, and adults become increasingly scarce. Adult smelt reach 55-70 mm SL in 7-9 months (Moyle 1976). Growth during the next 3 months slows down considerably (only 3-9 mm total), presumably because most of the energy ingested is being channeled towards gonadal development (Erkkila et al. 1950, Radtke 1966). There is no correlation between size and fecundity, and females between 64-80 mm lay 1400 to 2800 eggs (Moyle 1976). The abrupt change from a single-age, adult cohort during the spawning runs in spring to a population dominated by juveniles in the summer suggests strongly that most adults die after they spawn (Radtke 1966).

Delta smelt feed primarily on planktonic copepods, cladocerans, amphipods and, to a lesser extent, on insect larvae (Moyle 1976) although larger fish may also feed on the opossum shrimp, *Neomysis mercedis* (Moyle, 1976). The most important food organism for all sizes seems to be the euryhaline copepod, *Eurytemora affinis* (Moyle, unpubl. data).

Status: Class 1.

Delta smelt was once one of the most common pelagic fish in the upper Sacramento-San Joaquin estuary, as indicated by its abundance in CDFG trawl catches (Erikkila et al. 1950, Radtke 1966, Stevens and Miller 1983). Smelt populations have fluctuated greatly in the past, but since 1982 their populations have consistently been very low. The decline became precipitous starting in 1982 (Fig. 18). The numbers of Delta smelt are now (1989) at their lowest levels recorded and there is no sign of recovery. This is shown most dramatically by using the annual index of abundance calculated by the CDFG based on an annual midwater trawl survey (Lee Miller, pers. comm.). Details on how the index is calculated are presented in Stevens and Miller (1983). The number of Delta smelt is not known; however, their pelagic life style, short life span, broad-cast spawning habits, and relatively low fecundity indicate that a large population is probably necessary to keep the species from becoming extinct.

The causes of the decline of Delta smelt are probably multiple and synergistic, but seem to be in the following order of importance:

1. <u>Reduction in outflows</u>. Increased diversion of water from the Sacramento and San Joaquin Rivers and tributaries has reduced fresh water available to flush through the estuary. In particular, spring (March-June) outflows created by snow melt from the Sierras are usually diminished, so the total amount of outflow is reduced, as is the number of weeks of high spring outflows. Diversion also creates reverse flows up the San Joaquin River, making

Delta smelt more vulnerable to entrainment (see #3 in this section). The overall effect is particularly severe in years when the total water available from runoff is low. For fishes and most other Delta organisms, moderately high spring outflows are important because they cause the mixing zone (entrapment zone) of the estuary where outflowing freshwater meets incoming tidal water to be located in Suisun Bay. The mixing effect allows phytoplankton, zooplankton, and larval fish to remain in the mixing area rather than being flushed out to sea. Suisun Bay is broad and shallow, so when the entrapment zone is located there nutrients and algae can circulate in sunlit waters, allowing algae to grow and reproduce rapidly. This provides plenty of food for zooplankton, which are food for plankton-feeding fish such as Delta smelt and their larvae. Low outflows place the mixing zone in the deep, narrow channels of the Delta and Sacramento River where productivity is lower because much of the water is beyond the reach of sunlight so fewer fish can be supported.

A strong relationship between the abundance of striped bass, American shad, chinook salmon, longfin smelt, splittail and outflows was demonstrated by Stevens (1977), Stevens and Miller (1983), and Daniels and Moyle (1980). Stevens and Miller (1983) failed to find this same relationship for Delta smelt. Nevertheless, there is a positive relationship between outflows and smelt abundance, but it is more complex than the one for the other species because outflows not only affect abundance but also distribution patterns and, perhaps, spawning times of the smelt. Moyle and Herbold (1989) found that lowest smelt numbers occurred either in years of low outflow or of extremely high outflow, but outflow and smelt numbers showed no relationship at intermediate outflows.

The analysis of environmental factors correlated with Delta smelt abundance shows that the strongest associate of their abundance is high productivity (as reflected in phytoplankton and zooplankton abundances) in late spring (April-June). This high productivity is associated with establishment of the entrapment zone in the shallow waters of Suisun Bay. When this zone is located there, the abundance of zooplankton fed upon by larval smelt is higher than when the zone is located in the deeper channels of the Delta. Presumably, most of the larval smelt starve to death if the food supply is inadequate, as it seems to have been in recent years.

2. High outflows. Years of the major smelt decline have been characterized not only by unusually dry years with exceptionally low outflows (1987, 1988) but also by unusually wet years with exceptionally high outflows (1982, 1986). High outflows have much the same effect biologically as low outflows: they put the entrapment zone in a location (Carquinez Straits, the deeper parts of San Pablo Bay, or San Francisco Bay) where phytoplankton grow and reproduce slowly, disrupting food chains of which smelt larvae are part. High outflows may have the additional effect of flushing adult smelt out of the system along with much of the zooplankton. This means that not only is potential spawning stock of smelt reduced, but its food supply as well. Furthermore, the depletion of the established populations of invertebrates and fish may have made it easier for exotic species of copepods, clams, and fish to colonize the estuary (see #4), which may be detrimental to smelt.

3. Entrainment losses to water diversions. This factor is closely tied to the first factor because as diversions increase, there is less fresh water available to establish the entrapment zone

in Suisun Bay. Water is pumped out of the system through numerous small diversions for the farms of the Delta and, especially, the large diversions of the federal Central Valley Project (CVP) and the State Water Project (SWP). Water is also pumped through several power plants to cool the water for the fish. Recent analyses by CDFG (1987) indicate that the entrainment of larvae in these diversions, coupled with the loss of food organisms entrained as well, has been a major cause of the ongoing decline of striped bass. Turner (1987) indicates the diversions are the major cause of striped bass declines. It is likely that this entrainment loss is also a major factor limiting Delta smelt populations, as Delta smelt are ecologically similar to larval and juvenile striped bass. Large numbers of smelt larvae are pumped through the CVP and SWP plants just as striped bass larvae are. Delta smelt are vulnerable to diversions throughout their life cycle because smelt usually occur in the channels of the Delta from which water is diverted. In recent years, the more upstream location of the entrapment zone may have increased the likelihood of entrainment. Efforts are made to rescue larger fish being entrained at the CVP and SWP plants by trapping them and trucking them back to the Delta. The effectiveness of this procedure has not been well evaluated, but it is unlikely that many Delta smelt survive the handling it involves. Our experience in capturing and handling the fishes of the estuary indicates that Delta smelt are one of the most delicate fish in the Delta and most likely to die from handling.

4. Changes in food organisms. In recent years, two exotic copepods (*Sinocalanus doerrii* and two species of the genus *Pseudodiatomous* sp.) have invaded the estuary and increased in numbers while the dominant native euryhaline copepod, *Eurytemora affinis*, has declined. Whether or not this is caused by competition between the native and introduced species, by selective predation on the native copepod, or by changes in estuarine conditions that favor the introduced species is not known. However, CDFG (1987) studies show that larval striped bass do not feed on the introduced species as much as its abundance would indicate they should. Apparently, *Sinocalanus* can swim faster and therefore avoid predation more easily than *Eurytemora* (J. Orsi, pers. comm.). Feeding, by Delta smelt, especially larvae, is probably affected in ways similar to that of striped bass larvae by this change in zooplankton species, so the decreased abundance of native copepods may increase the likelihood of larval starvation.

Another potential indirect cause of larval starvation is the recent invasion (1986-87) of the euryhaline clam, *Potamocorbula*, which is now abundant in Suisun Bay. This clam may reduce phytoplankton populations in the bay with its high filtration rates and dense populations (D. Ball, USBR, pers. comm. to L. Meng). This clam has obviously not been responsible for the smelt declines, but it may help keep smelt populations at low levels by reducing availability of phytoplankton for larvae.

Yet another complicating factor is the rise in abundance of the diatom *Melosira* to the point where it is often the most abundant species of phytoplankton. This diatom grows in long chains and is very hard for zooplankton to graze on; thus the change in composition and/or abundance of zooplankton may also be tied to the increased importance of this diatom. The causes of the increase in *Melosira* are not known, but it may be related to the increase in water clarity experienced in recent years.

5. Toxic substances. The waters of the estuary receive a variety of toxic substances, including agricultural pesticides, heavy metals, and other products of our urbanized society. The effects of these toxic compounds on larval fishes and their food supply are poorly known (CDFG 1987). Although there is no indication so far that larval fishes are suffering direct mortality or additional stress from low concentrations of toxic substances, this factor has not been studied extensively so cannot be eliminated as a possible factor affecting Delta smelt populations.

6. Loss of genetic integrity. The closely related wagasaki, or Japanese smelt, was introduced successfully into Almanor Reservoir in the Sacramento drainage and has subsequently been collected from downstream areas. Wagasaki are also present in Folsom Reservoir, a relatively short distance from the Delta. It is highly likely that the wagasaki can hybridize with Delta smelt, but whether they have is not known, nor is it known if such hybridization could have a negative effect on the fitness of the Delta smelt. Loss of genetic integrity is nevertheless a possible contributing factor to the decline of Delta smelt. It is also possible the wagasaki could displace the Delta smelt completely through introgression and/or direct competition.

The Delta smelt clearly fits the definition of an endangered species under state laws and under the federal Endangered Species Act because it is in danger of extinction throughout its entire limited range. According to the Endangered Species Act, there are five general reasons for a species to be endangered: "(A) the present, or threatened destruction, modification, or curtailment of its habitat or range, (B) overutilization for commercial, recreational, scientific, or educational purposes, (C) disease or predation, (D) the inadequacy of existing regulatory mechanisms or (E) other natural or manmade factors affecting its continued existence." Reasons can be found in all areas except (B), as Delta smelt have never been harvested for any reason except scientific study.

Destruction of habitat. The principal habitat of Delta smelt is the open water of the Delta and Suisun Bay. To provide sufficient food for these fish, the water must contain dense populations of zooplankton. This means it is critical to have the entrapment zone located in Suisun Bay from March to mid-June when larval smelt are present. Present outflow regimes usually place the entrapment zone upstream from Suisun Bay for at least part of this period in Delta channels. Prior to the reduction of Delta outflows, the null zone also may have been located well above Suisun Bay at times, but presumably there was then adequate shallow water habitat in the Delta to create the conditions needed by larval smelt. This habitat is now gone, as the Delta today consists of a complex of islands separated by dredged channels. Thus the long-term survival of Delta smelt requires that conditions in Suisun Bay in the spring months meet the smelt's ecological requirements.

Disease, competition, and predation. There is no evidence that disease, competition, or predation has caused Delta smelt populations to decline, despite the abundance of introduced species in the estuary. However, the diseases and parasites of Delta smelt have never been studied. The effects of predation by fishes like introduced striped bass or of competition from introduced planktivores like threadfin shad (*Dorosoma petenense*) and inland silverside (*Menidia beryllina*) have likewise not been deeply studied. Although smelt has managed to coexist with these species in the past, it is quite possible that under low population levels interactions with them could prevent recovery. However, populations of other fish species, including striped bass, appear to be depressed in the upper estuary as well (Moyle et al. 1985; Moyle and Herbold, unpubl. data). A particular problem could be the proposed effort to enhance striped bass populations by producing large numbers of juveniles in hatcheries. The enhanced predator populations, without a concomitant enhancement of prey populations such as Delta smelt, could result in excessive predation pressure on Delta smelt.

Inadequacy of regulatory mechanisms. The regulation of Delta outflows, Delta water quality, and flow patterns through the Delta is complex and under the jurisdiction of a number of agencies, but the primary regulating agency is the State Water Resources Control Board. The present regulatory system primarily benefits water users at the cost of the fish. Even valuable gamefishes like striped bass and chinook salmon have suffered severe declines in recent years, despite major efforts to sustain them. For example, large numbers of all pelagic species and species with pelagic larvae are entrained in CVP and SWP facilities and current rescue/mitigation efforts do not seem to compensate for the losses. This is particularly true of Delta smelt which have received little attention from the management agencies, are exposed to entrainment for many months of the year, and are unlikely to survive any rescue attempts that involve handling. In short, the present mechanisms that regulate freshwater flows through the Delta have been inadequate to protect Delta smelt.

Other factors. There are a number of other factors that may affect abundance of Delta smelt; four mentioned previously are the invasions of exotic copepods, the invasion of the exotic clam, the blooms of the diatom *Melosira*, and the presence upstream of populations of a closely related Japanese smelt. A number of other exotic species are also invading the estuary at this time and may directly or indirectly affect the Delta smelt. The current series of invasions of exotic species only may be possible because of altered environmental conditions in the Delta and the depressed populations of fishes. The combination of altered conditions and invasions of exotic species, however, may extirpate Delta smelt.

Management: Delta smelt should be declared an endangered species by both state and federal governments so that efforts will be made to restore it to its former abundance. The long-term survival of this species depends on an adequate food supply for its larvae and on reducing entrainment losses. The key to solving both of these problems is to provide enough outflows so that the entrapment zone is located in Suisun Bay during March, April, and May during all but severe drought years. Plus it should not be located outside Suisun Bay for more than two years in a row. This flow regime would also benefit other species, including striped bass.

As a back-up measure, fish culture techniques and facilities should be developed, as the Japanese have done for other smelts. However, if hatchery propagation is to be successful, the fish must be released into an environment which provides ample food, low levels of toxic compounds, and low entrainment losses. Thus water management for the Delta will always be a key factor for smelt survival.

If steps are not taken to restore this species, California will lose its only endemic smelt and the only true native estuarine species found in the Sacramento-San Joaquin estuary.

SACRAMENTO SPLITTAIL
Pogonichthys macrolepidotus (Ayres)

Description: Splittail are large cyprinids, growing in excess of 300 mm SL, and are distinctive in having the upper lobe of the caudal fin larger than the lower lobe. The body shape is elongate with a blunt head. Small barbels may be present on either side of the subterminal mouth. They possess 14 to 18 gill rakers, and their pharyngeal teeth are hooked and have narrow grinding surfaces. Dorsal rays number from 9-10, pectoral rays 16-19, pelvic rays 8-9, and anal rays 7-9. The lateral line usually has 60-62 scales, but ranges from 57-64. The fish are silver on the sides and olive grey dorsally. Adults develop a nuchal hump. During the breeding season, the caudal, pectoral, and pelvic fins take on a red-orange hue and males develop small white nuptial tubercles in the head region.

Taxonomic Relationships: This species was first described by Ayres (1854) as *Leuciscus macrolepidotus*. It has now been reassigned to the genus *Pogonichthys* that is considered by some taxonomists to be allied to cyprinids of Asia (Howes 1984). The genus *Pogonichthys* is comprised of two species, *P. ciscoides* Hopkirk and *P. macrolepidotus* (Hopkirk 1973). The former species from Clear Lake, Lake County, became extinct in the early 1970's.

Distribution: *Pogonichthys macrolepidotus* is a California Central Valley endemic and was once distributed in lakes and rivers throughout the Central Valley (Fig. 25). Although a complete record of splittail distribution before water development and reclamation is unavailable, Caywood (1974) presented the following compilation of past records. Splittail were found as far north as Redding by Rutter (1908) who collected them at the Battle Creek Fish Hatchery in Shasta County. Splittail are no longer found at this location and are limited by the Red Bluff Diversion Dam in Tehama County to the downstream reaches of the Sacramento River. They also enter the lower reaches of the Feather River on occasion, but records indicate that Rutter (1908) had collected them as far upstream as Oroville. Splittail are also known from the American River and have been collected at the Highway 160 bridge in Sacramento, although in the past Rutter (1908) collected them as far upstream as Folsom. He also collected them from the Merced River at Livingston and from the San Joaquin River at Fort Miller. Snyder (1905) reported catches of splittail from southern San Francisco Bay and at the mouth of Coyote Creek in Santa Clara County, but recent surveys indicate that splittail are no longer present in these locations (Leidy 1984).

Splittail are now largely confined to the Delta, Suisun Bay, Suisun Marsh, Napa Marsh, other parts of the Sacramento-San Joaquin estuary (Caywood 1974, Moyle 1976). In the Delta, they are most abundant in the north and west portions, although other areas may be used for spawning (CDFG 1987). This may reflect a shrinking of their Delta habitat because Turner (1966) found a more even distribution throughout the Delta. Recent surveys of the San Joaquin Valley streams found only a few individuals at one locality in the San Joaquin River below its confluence with the Merced River (Saiki 1984; Brown and Moyle, In Press). Occasionally, splittail are caught in San Luis Reservoir (Caywood 1974) which stores water pumped from the Delta. Splittail are largely absent from the Sacramento River as well, although large individuals are caught during spring in the lower river in large fyke traps set to catch striped bass migrating upstream to spawn. Presumably the splittail are also on a spawning migration.

Habitat Requirements: Splittail are primarily freshwater fish, but are tolerant of moderate salinities and can live in water with salinities of 10-12 ppt (Moyle 1976). In the 1950's, they were commonly caught by striped bass anglers in Suisun Bay during periods of fast tides (D. E. Stevens, pers. comm.). During the past 20 years, however, they were mostly found in slow-moving sections of rivers and sloughs, and in the Delta they seemed to congregate in dead-end sloughs (Moyle 1976, Moyle et al. 1982, Daniels and Moyle 1983). They require flooded vegetation for spawning and as foraging areas for young, thus are found in habitat subject to periodic flooding (Caywood 1974). Daniels and Moyle (1983) found that spawning success in splittail was positively correlated with river outflows, and Caywood (1974) found that a successful year class was associated with winter runoff sufficiently high to flood the peripheral areas of the Delta.

Life History: Splittail are relatively long-lived (about 5 yrs) and are highly fecund (over 100,000 eggs per female). Their populations may fluctuate on an annual basis depending on spawning success and strength of the year class (Daniels and Moyle 1983). Both male and female splittail mature by the end of their second year (Daniels and Moyle 1983), although occasionally males may mature by the end of their first year and females by the end of their third year (Caywood 1974). Fish are about 180-200 mm SL when they attain sexual maturity (Daniels and Moyle 1983), and the sex ratio among mature animals is 1:1 (Caywood 1974).

There is some variability in the reproductive period, with older fish reproducing first, followed by younger fish which tend to reproduce later in the season (Caywood 1974). Generally, gonadal development is initiated by fall, with a concomitant decrease in somatic growth (Daniels and Moyle 1983). By April, ovaries reach peak maturity and account for approximately 18% of the body weight. The onset of spawning seems to be associated with increasing water temperature and day length and occurs in late April and May in the marsh (Daniels and Moyle 1983) and between early March and May in the upper Delta (Caywood 1974). However, Wang (1986) found that in the tidal freshwater and oligohaline habitats of the Sacramento-San Joaquin estuary, spawning occurs by late January/early February and continues through July. Fish probably spawn on submerged vegetation in flooded areas, and spawning occurs in dead-end sloughs (Moyle 1976) as well as in the larger sloughs such as Montezuma Slough (Wang 1986). Larvae remain in the shallow, weedy areas inshore in close proximity to the spawning sites and move into the deeper offshore habitat later in the summer (Wang 1986).

Status: Class 2.

Splittail have disappeared from much of their native range because dams, diversions, and agricultural development have eliminated or drastically altered much of the lowland habitat these fish once occupied. Access to spawning areas or upstream habitats is now blocked by dams on the large rivers because splittail seem incapable of negotiating existing fishways. As a result they are restricted to water below Red Bluff Diversion Dam on the Sacramento River, below Nimbus Dam on the American River, and below Oroville Dam on the Feather River. Caywood (1974) found a consensus among splittail anglers that the fishery has declined since the completion of Folsom and Oroville Dams.

Today the principal habitat of splittail is the Sacramento-San Joaquin estuary, especially the Delta (Fig. 25). Their abundance in this system is strongly tied to outflows, presumably because spawning occurs over flooded vegetation. Thus, when outflows are high, reproductive success is high, but when outflows are low, reproduction may fail (Daniels and Moyle 1983). Proposed diversion of even more water from the Delta and estuary could cause a rapid decline of splittail populations by eliminating the frequency of successful spawning as well as suitable freshwater habitats. Channelization or riprapping projects that eliminate potential spawning areas in the upper Delta may also contribute to population declines.

Management: Principal spawning areas of splittail need to be identified so they can be protected. Habitat requirements of young-of-year splittail, especially for the first month of life, need to be identified to determine special protective measures. Any plans to divert more water from the Delta or to reduce spring flooding in the lower reaches of inflowing rivers should include measures to protect splittail. Furthermore, the splittail populations should be monitored on an annual basis.

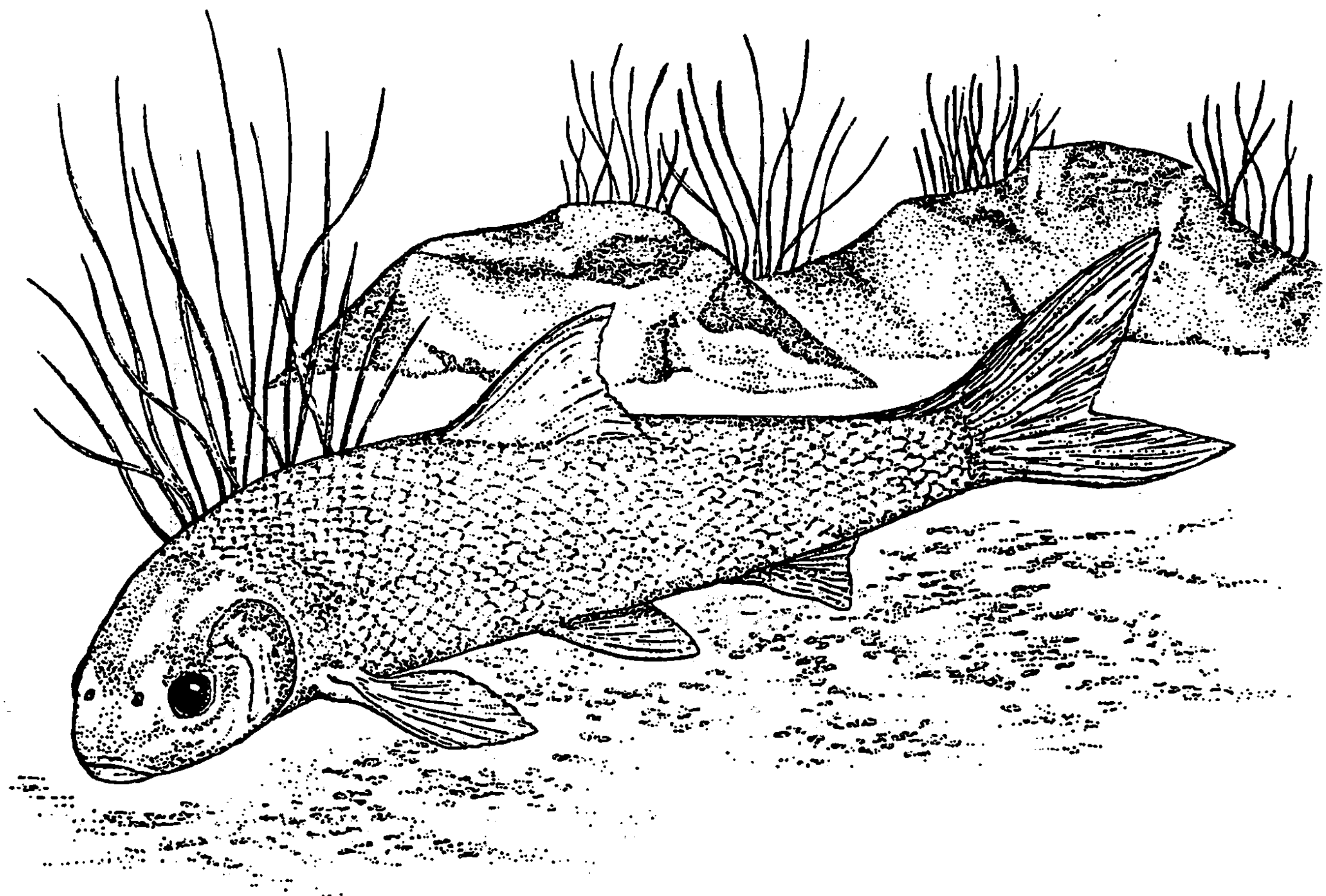


FIGURE 25. Distribution of Sacramento splittail, *Pogonichthys macrolepidotus*, in California.

SACRAMENTO RIVER WINTER CHINOOK SALMON
Oncorhynchus tshawytscha (Walbaum)

Description: Winter chinook are similar in morphology to spring chinook but are generally smaller because they migrate at a younger age.

Taxonomic Relationships: Four runs of chinook salmon are recognized from the Sacramento River: winter, fall, late-fall, and spring. The runs are distinguished by timing of adult upstream migration, spawning, egg incubation, and juvenile downstream migration. Winter chinook are further distinguished by their younger age at time of upstream migration, relatively low fecundity, rapid upstream movement of adults during spawning runs, and extended holding staging period of adults in headwaters prior to spawning (Hallock and Fisher 1985). For these reasons, the winter chinook are considered to be racially distinct from all other runs of chinook salmon (National Marine Fisheries Service 1987, Williams and Williams In Press).

Distribution: Prior to construction of Shasta and Keswick dams in 1943 and 1955, respectively, winter chinook spawned in the upper reaches of the Sacramento River, the McCloud River, and the lower Pit River. Presently, spawning is limited to habitat in the Sacramento River, immediately downstream of Keswick Dam. Since the late-1940's, release of cold hypolimnetic water from Shasta Reservoir has allowed for successful spawning below the historic spawning grounds (Williams and Deacon In Prep., Slater 1963) (Fig. 6). Nevertheless, less suitable spawning habitat is now available for this race, and records indicate a severe decline in the number of winter chinook (Table 6).

Life History: Adult winter chinook migrate up the Sacramento River to spawn during December to May (Hallock and Fisher 1985). Adults move upstream much more quickly than the spring run race and stage in the headwaters for some time before spawning. Peak spawning occurs from May to June in the Sacramento River. No spawning occurs in tributary streams. Fry are known to pass by the Red Bluff Diversion Dam from mid-September to mid-October.

Approximately 67% of the migrating winter chinook adults are 3 years old, 25% are 2 years old, and only 8% are 4 years of age (Hanson et al. 1940). This contrasts with the other runs, where most of the migrating/spawning fishes were historically between 4 and 5 years old (Hanson et al. 1940). Even in these runs, however, fishing pressure has tended to reduce the average age of returning fish. Females of winter chinook are also generally less fecund (Hallock and Fisher 1985), presumably due to their smaller size and younger age.

Habitat Requirements: Winter chinook require clean, cold water over gravel beds for successful spawning and egg incubation. Eggs incubate during summer months when water temperature in the Sacramento River is often critically high. Water temperatures of 6-14°C are necessary for successful hatching (Slater 1963). Water cold enough for successful spawning of winter chinook seldom occurs downstream of Red Bluff Diversion Dam (Hallock and Fisher 1985). Most suitable spawning areas are located between the Red Bluff Diversion Dam and Keswick Dam. Therefore, passage through Red Bluff Diversion Dam must be provided for winter chinook adults during spawning runs.

Status: Class 1.

Sacramento River winter chinook has consistently declined since construction of Red Bluff Diversion Dam in 1966. The first year classes of mostly 3-year-old winter chinook to reach Red Bluff Diversion Dam from 1967-1969 averaged 86,509 (Williams and Williams In Press). Subsequent year classes of 1970-72 and 1973-75 declined to averages of 43,544 and 23,135 adults, respectively. Since 1982, annual spawning runs have averaged 2,376 (Hallock and Fisher 1985, Williams and Williams In Press). In 1989, only about 500 adults returned to spawn and the Fish & Game Commission agreed to list it as an endangered species.

Because winter chinook require cooler water during summer for egg incubation, they are particularly susceptible to losses by drought. Poor recruitment during the 1976-77 drought returned only 0.07 fish per spawning adult 3 years later (National Marine Fisheries Service 1987). For example, because of this drought the 1976 run of 35,096 winter chinook was reduced to only 2,364 adults in 1979 (Williams and Williams In Press). At the presently low population sizes, another drought could eliminate population viability.

In addition to problems of dams and drought, numerous other factors have contributed to the decline of the winter chinook. Pollution from agricultural and industrial sources, toxic wastes from Iron Mountain Mine, gravel mining in tributary streams, channelization and bank stabilization of the Sacramento River, and operation of the Anderson-Cottonwood and Glen-Colusa irrigation district's diversion dams have hastened the decline of the winter chinook in the Sacramento River.

Management: Operation of Red Bluff Diversion Dam and Shasta Dam are key factors in providing suitable water conditions for spawning (Williams and Williams In Press). Sufficient cold water releases from Shasta Reservoir are required to provide water temperatures between 6-14°C downstream of Keswick Dam during critical egg incubation periods. The gates at Red Bluff Diversion Dam should be raised when adult winter chinook are moving upstream to allow them access to spawning areas. Modifications at the Anderson-Cottonwood and Glen-Colusa irrigation facilities are needed to conserve the winter chinook. Toxic flows from Iron Mountain Mine must be cleaned up. Presently, a small reservoir holds toxic water from Iron Mountain Mine. The reservoir discharges contaminated water into Spring Creek, which flows into Keswick Reservoir. Operation error at the containment reservoir or Keswick Dam could flush lethal water into winter chinook spawning areas. A flash flood at Iron Mountain would result in a similar problem.

In addition to reducing present threats and operating dams to provide for winter chinook conservation, new projects that reduce recruitment of this run should not be authorized. The proposed Lake Redding Hydroelectric Project would eliminate much of the remaining spawning areas of the winter chinook.

TABLE 6. Estimates of spawning winter chinook populations at the Red Bluff Diversion Dam from 1967-1987. Numbers represent at least 95% of the fish that moved past the dam. The table is modified from Williams and Deacon (In Press).

Year	Estimated numbers
1967	57,306
1968	84,414
1969	117,808
1970	40,409
1971	53,089
1972	37,133
1973	24,079
1974	21,897
1975	23,430
1976	35,096
1977	17,214
1978	24,862
1979	2,364
1980	1,156
1981	20,041
1982	1,242
1983	1,831
1984	2,663
1985	3,962
1986	2,326
1987	2,236
1988	2,085
1989	<500

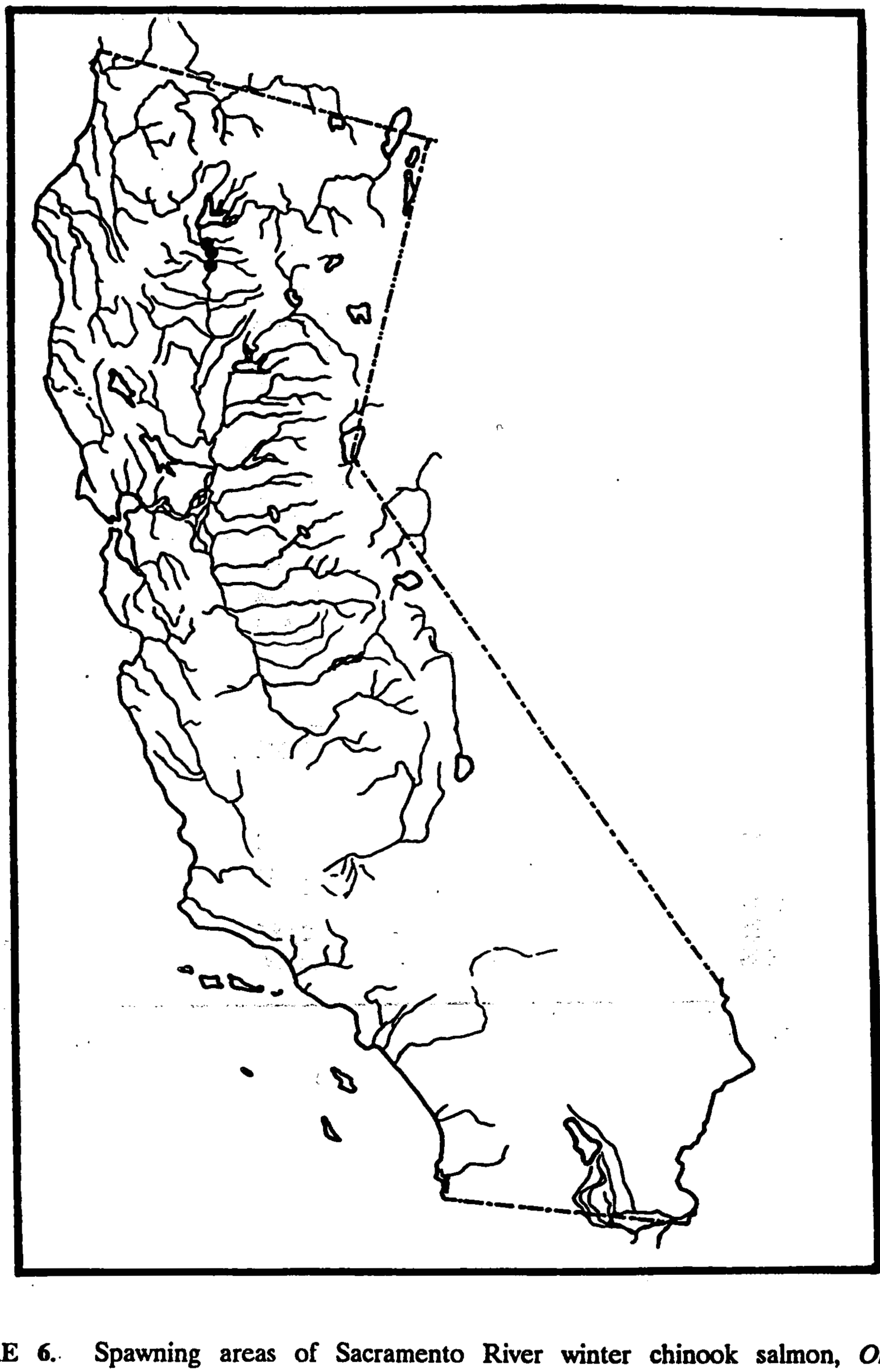


FIGURE 6. Spawning areas of Sacramento River winter chinook salmon, *Oncorhynchus tshawytscha*.

TIDEWATER GOBY
Eucyclogobius newberryi (Girard)

Description: This is a relatively small goby that rarely exceeds 50 mm SL. Its body shape is typical of species in the family Gobiidae, being elongate and somewhat dorso-ventrally flattened, especially anteriorly. The head is blunt and the mouth terminal, oblique, and large, with the maxillary extending to the posterior margin of the eye. Eyes are near-dorsal in location. Pelvic fins are fused to form a ventral sucker, another characteristic of gobiid species. Pectoral fins are large and the caudal fin elongate and rounded. There are 6-7 spines in the anterior dorsal fin and 9-13 elements in the posterior dorsal fin. The anal fin has 9-12 elements. Gill rakers number from 8-10. Scales are small and cycloid and are absent on the head. There are 66-70 lateral line scales. Body coloration is a dark olive, with darker mottling along the sides, back, and dorsal fin. The pelvic fins are yellow or dusky and the anal fin is dusky.

Taxonomic Relationships: This is the only species in the genus *Eucyclogobius*. Its closest relatives are marine species.

Distribution: The tidewater goby is endemic to California and is distributed in brackish water habitats along the California coast (Fig. 39) from the Agua Hedionda Lagoon, San Diego County, in the south to the mouth of the Smith River, Del Norte County, in the north (Swift 1980, Swift et al. 1988). Swift et al. recorded its presence at 63 localities in 1984, only 11 of them north of San Francisco Bay. However, populations now seem to be declining, especially since 1950, and according to Swift (pers. comm. in Moyle 1976) since 1900 they have disappeared from 74% of the coastal lagoons south of Morro Bay. In the San Francisco Bay and associated streams, nine of ten previously identified populations have disappeared (Wang 1982), and a survey of streams of the bay drainage by Leidy (1984) failed to record any populations.

Habitat Requirements: The tidewater goby is found in shallow lagoons and lower stream reaches where the water is brackish (salinites usually less than 10 ppt) to fresh (Miller and Lea 1972, Moyle 1976, Swift 1980, Wang 1982, Irwin and Soltz 1984) and slow moving or fairly still but not stagnant (Irwin and Soltz 1984). Gobies are capable of living in saline water ranging from 0 to over 40 ppt salinity and at temperatures of 8-23°C (Swift et al. 1989). Water depth in tidewater goby habitat ranges from 25-100 cm and dissolved oxygen is fairly high (Irwin and Soltz 1984). The substrate usually consists of sand and mud, with abundant emergent and submerged vegetation (Moyle 1976). Severe salinity changes and tidal and flow fluctuations have a detrimental effect on the survival of tidewater gobies, resulting in population declines (Irwin and Soltz 1984).

Life History: This is a benthic species that inhabits shallow lagoons and the lower reaches of coastal streams. It differs from other species of gobies in California in that it is able to complete its entire life cycle in fresh or brackish water (Wang 1982, Irwin and Soltz 1984, Swift et al. 1989).

The diet consists mostly of small crustaceans (i.e., mysid shrimp, ostracods, amphipods), aquatic insects (i.e., chironomid larvae, diptera larvae , and molluscs (Swift 1980; Wang 1982, 1986; Irwin and Soltz 1984). Inorganic material consistently found in the guts indicates a benthic foraging mode, complementing its benthic life-style.

It appears to be an annual species (Swift 1980; Wang 1982, 1986; Irwin and Soltz 1984) although according to Swift (1980) individuals in the northern part of the range may live up to 3 years. Irwin and Soltz (1984) found that there is a marked decrease in the number of adults in the population during winter.

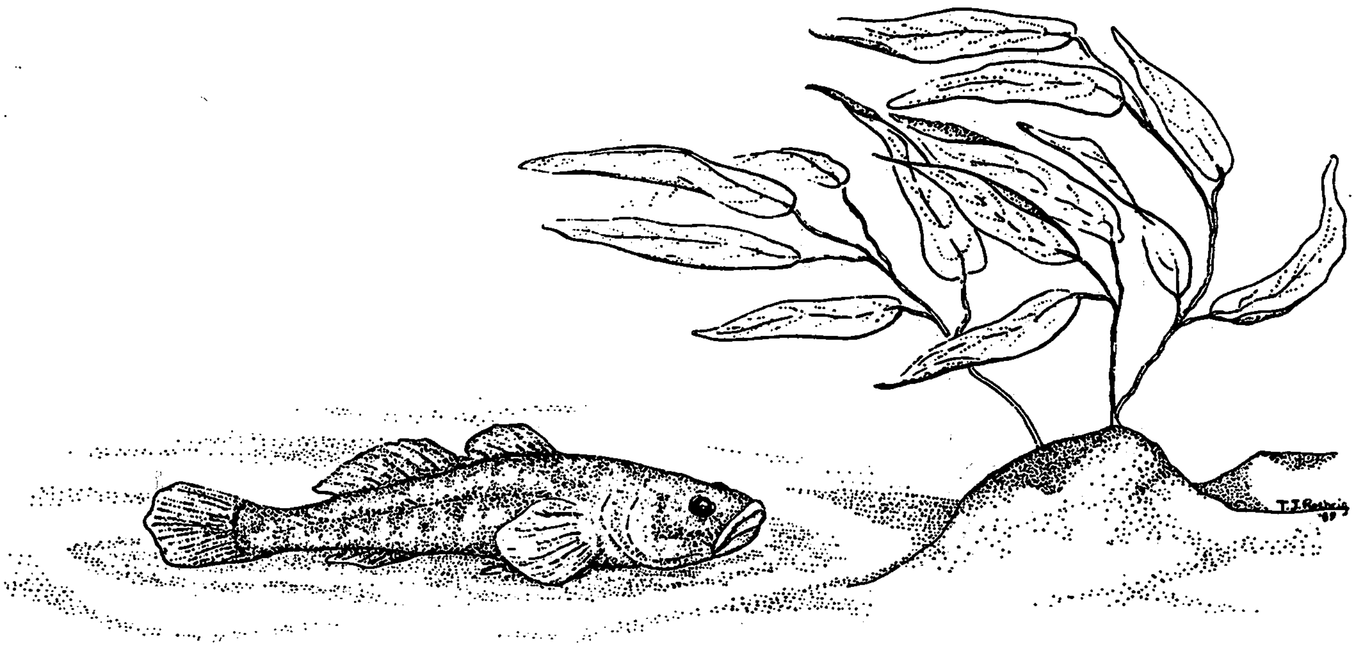
Goldberg (1977) found that in tidewater gobies of southern California, ovarian maturation is asynchronous, i.e. females with various stages of ovarian development are found throughout the year. The occurrence of larvae throughout the year, albeit in small numbers, supports the theory for year-round reproduction. However, there are definitive peak spawning periods when most recruitment takes place. In southern California, peak spawning occurs during April-June when water temperature is 18-22°C (Swift 1980, Swift et al. 1989). In the San Francisco Bay area streams, peak spawning occurs from late August to November when water temperature ranges from 13.5-21°C (Wang 1982). In Santa Barbara County, gravid females were collected from February to October, but there was a distinct peak in spawning concentrated in the fall and most recruitment took place during winter (Irwin and Soltz 1984). Fecundity is fairly low in this species: females between 43-47 mm TL produce 640-800 eggs (Wang 1982).

Wang (1982) observed adults in spawning condition (identified by darker color) in shallow ditches and along the inshore areas of lagoons. According to Swift et al. (1989), during spawning the male digs a vertical burrow approximately 10-20 cm into the sandy substrate, usually in water 25-50 cm deep, in which the female deposits her eggs. The male then guards the nest. The proximal ends of the eggs bear adhesive filaments with which they are attached to the burrow walls (Wang 1982). Larvae emerge in 9-10 days when they are 5-7 mm SL and live in the water among vegetation until they are 15-18 SL.

Status: Class 2.

Despite the fact that tidewater gobies are found in lagoons along much of the California coast, their potential for becoming endangered is considerable. Each of the populations is relatively small and is isolated. Crabtree (1970) noted that populations had differentiated genetically, indicating long isolation. Because they are a small, nondescript species, local extinctions are likely to go unnoticed. A number of populations have already disappeared during the past 20 years, especially in southern California and the San Francisco Bay area. Only 15 populations remain south of Point Conception (Swift et al. 1989). Such extinctions can occur rapidly, given the goby's short life cycle and specialized habitat requirements. Coastal lagoons are highly susceptible to degradation through diversion of their freshwater supplies, pollution, siltation, and urban development of surrounding lands. When degradation is severe, tidewater gobies disappear. Thus, of 20 populations of gobies in San Luis Obispo county, six were extirpated between 1984 and 1989 due to drought coupled with water diversions and pollution (K. Worcester, CDFG, pers. comm.). Other populations show signs of decline in this area. Because the tidewater goby is sensitive to such changes, they are a good indicator species of the health of small coastal lagoon ecosystems that are important to many other species as well.

Management: Coastal lagoons should be surveyed at least once every five years to determine the status of each population, and steps should be taken to protect declining populations. Because coastal lagoons are considered to be threatened habitats in general, especially in southern California, a major effort needs to be made to protect the integrity of the remaining lagoons and to restore those that have been severely degraded. Once restored, lagoons from which tidewater gobies have been eliminated should have gobies reintroduced. Other suggestions for management are provided by Swift et al. (1989).



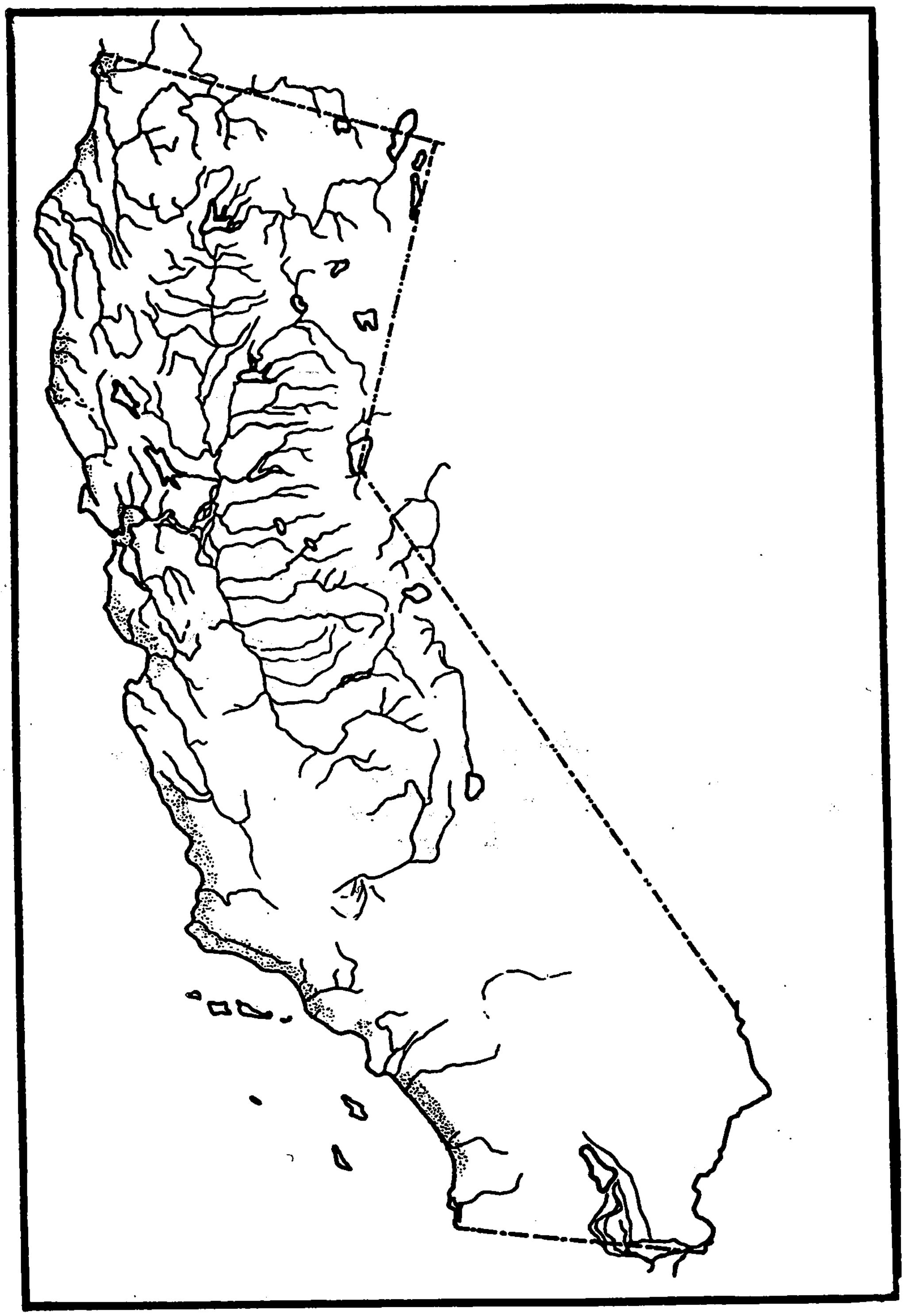


FIGURE 39. Distribution of the tidewater goby, *Eucyclogobius newberryi*, in California.