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The Status and Distribution of the Freshwater Fishes of Southern California

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Abstract.—The fresh and low salinity waters of southern California include the Owens, Mohave, Colorado, and coastal drainages south of Monterey Bay to the Mexican border. The youthful topography presents a strong dichotomy between steep rocky streams abruptly meeting relatively flat deserts or coastal plains. Little or no intermediate, foothill habitat exists. Thirty-eight native freshwater and 23 estuarine fishes have been recorded from this area. In addition, at least 100 species have been introduced, with widely varying success. Since the late 1940s and 1950s the native fishes of the Owens, Colorado, and Mohave drainages have been in jeopardy or extirpated in California. At the same time, the lowland fishes in coastal drainages, particularly on the Los Angeles Basin, also disappeared. Upland species of the coastal drainages still remain in a few isolated areas but are so reduced that special protection is needed. Only one estuarine species, *Eucyclogobius newberryi,* is threatened. Some tropical estuarine species of extreme southern California were last collected 50 to 80 years ago, and are very rare or extirpated here. If the remaining elements of the fish fauna are to survive, immediate action is needed to preserve the remaining habitat and to restore areas within the native range.

Coastal and inland southern California has a distinctive, endemic native freshwater fish fauna. This fauna is also one of the smallest in the United States, apparently due to the high topographic relief, long geological isolation from other continental fish faunas, and the aridity of inland areas (Jordan 1895; Culver and Hubbs 1917; Miller 1958; Follett 1961; Soltz and Naiman 1978; Smith 1981; Miller and Smith 1986; Minckley et al. 1986; Swift 1989). Today all of the native freshwater and some of the euryhaline species are extirpated or severely reduced in numbers within their native range, and most have been recommended for special conservation status in California (Miller et al. 1989; Williams et al. 1989; Moyle and Williams 1990; Moyle et al. 1989; Lufkin 1991; Nehlsen et al. 1991; Minckley and Deacon 1991). Thirty-eight native freshwater taxa (species, subspecies, and geographic groups recognized for taxonomic and/or conservation purposes) are known from this area (Moyle and Williams 1990; this paper). Twenty-three more brackish or estuarine species depend on lower salinity water for at least part of their life cycle. Some of these are also extinct or much reduced in range. One brackish species, the tidewater goby, *Eucyclogobius newbenyi* (included as a freshwater species by Moyle and Williams 1990), is a "species of special concern" in California, and has been petitioned for Federal Threatened status (U.S. Fish and Wildlife Service 1991). Most of the native species in the Colorado River drainages (of California) declined severely or were extirpated many years ago. Since the last survey of the coastal fauna (Wells et al. 1975), it became apparent that the species of the coastal drainages were also in jeopardy. Here we document the status of this fauna and recommend measures to preserve them for the future. The status and distribution of all the native and introduced fishes known to us through August 1992 is reviewed.

With at least 100 non-native species now recorded from southern California, the area has the dubious honor of exceeding all other areas of the state in numbers of aliens established. California has been a leading recipient of non-native fishes in the nation (Moyle 1976b; Shapavalov et al. 1981; Courtenay et al. 1991; Baltz 1991; Williams and Jennings 1991). Many of these introductions first arrived in southern California; others came secondarily after being introduced farther north (Smith 1896; Shebley 1917a; Evermann and Clark 1931; Curtis 1949; Moyle 1976b; Courtenay et al. 1991; this paper). The success and effects of some of these introductions is largely due to the highly modified nature of local aquatic habitats. Moyle (1976b), Baltz (1991), and Minckley and Deacon (1991) reviewed the many reasons for the arrival of these fishes, including accidental ones.

The natural environment for freshwater fishes in southern California can be defined in a series of strong contrasts. The relatively well-watered coastal drainages have a mild, Mediterranean climate that has fluctuated little for the last few million years due to the ameliorating effect of the ocean (Johnson 1977). In the same time, the inland deserts have ranged from well-watered lake country with glaciers in the mountains to the extremely arid climate of today with only a few permanent streams and springs flowing into saline lakes, many lacking fish (Smith 1981; Miller 1981; Minckley et al. 1986; Norris and Webb 1990; Jannik et al. 1991; Enzel et al. 1992). The highest (Mount Whitney, 4430 m) and lowest (Death Valley, 86 m below sea level) points in the co-terminus United States fall within this area.

A few million years ago (late Miocene—early Pliocene) the area had a much flatter, rolling topography, one or more large rivers drained westward or south-westward to the Pacific, and large lakes and brackish coastal embayments existed both on the Pacific coast and lower Colorado River (Norris and Webb 1990; Woodburne et al. 1991). The compression of the local terrain by the Pacific plate subducting under the North American plate created the high, youthful mountains separating the coastal areas from the Colorado drainage. Many coastal streams that formerly flowed to the south or southwest turned west or northwest. Today most major streams in both coastal and inland areas lie in or are closely aligned with major faults (Norris and Webb 1990). Faults, often the interface between different rock types, force groundwater to the surface in the springs that comprise the habitat of many desert fishes (Soltz and Naiman 1978). They function this way in wetter areas also, and provide areas of permanent surface water even during dry periods (Miller 1961). The strongly elevated, still rising, youthful terrain also erodes rapidly. In most of the area, steep mountains are flanked by relatively flat coastal plains or desert alluvial fans. Foothills or intermediate areas are rare and mostly restricted to narrow bands at the interface of the mountains and plains.

Although commonly included with the inland deserts, the coastal areas were originally well-watered and the last few hundred years have seen this environment greatly altered Millet 1941; Miller 1961; Gordon 1985; Queenan 1986). Increased human population has led to drastic modification of water courses, and a dramatic lowering of the water table, to well below the ground surface in the lowlands. Even in the mountains where permanent water remains, logging, mining, flood control, and water storage projects have changed the character of the streams. The recent drought (1986—present) further reduced the available habitat. Thus, the coastal habitat is converging artificially toward the natural hydrological conditions of the inland deserts. The increasing threat to the remaining coastal freshwater fishes and the increasing appearance of introduced species has prompted this reassessment of the local fauna.

Methods

For this paper southern California drainages include Pacific coastal streams south of the Carmel River to the Mexican border, and Colorado River drainage of California which includes the Owens, Death Valley, Mohave, and Salton Sea systems (Figs. 1-5). Records are from museum collections, files of the California Department of Fish and Game and U.S. Forest Service, and a few from a variety of other sources. Museum collections examined include: Natural History Museum of Los Angeles County (including material formerly at California State University, Fullerton; Fullerton College; and California State University, Long Beach), California Academy of Sciences, Museum of Zoology of the University of Michigan, National Museum of Natural History, Field Museum in Chicago, University of California, Los Angeles, and Scripps Institution of Oceanography. Institutional abbreviations follow Leviton et al. (1985). Records without voucher specimens are accepted when by known authorities and/or with adequate descriptions. Records from the California Department of Fish and Game, Region 5, Long Beach are identified with initials (CFG LB), Willis A. Evans (WAE), Phillip A. Douglas (PAD), Robert R. Bell (RB), James A. St. Amant (JAS), Franklin G. Hoover (FGH), David Drake (DD), Linda Pardy (LP), and Unarmored Threespine Stickleback Recovery Team (UTSRT). Notes made by Ralph G. Miller are noted as RGM. Copies of all non-LACM sources for data are filed in the Section of Fishes (LACM). Collections from 1965 onward were entered into the California Fish Data Base and Preserve Design Project established by Peter Moyle, Jack Williams, and Roland White, Department of Fisheries and Wildlife, U.C. Davis, and into the California Department of Fish and Game's Natural Diversity Data Base (Betsy Bolster, pers. comm.).

The 38 native freshwater taxa listed are based on Moyle and Williams (1990) except that the San Antonio Creek stickleback (Vandenberg Air Force Base, Santa Barbara County) is considered a distinct taxon also. Subspecific names are used only if more than one subspecies occur in southern California. The conservation status of each taxon is based on Williams et al. (1989), Miller et al. (1989), Moyle et al. (1989), Moyle and Williams (1990), and Nehlsen et al. (1991). Moyle and Williams (1990) relied on preliminary data from this study for their determination of status of coastal southern California taxa.

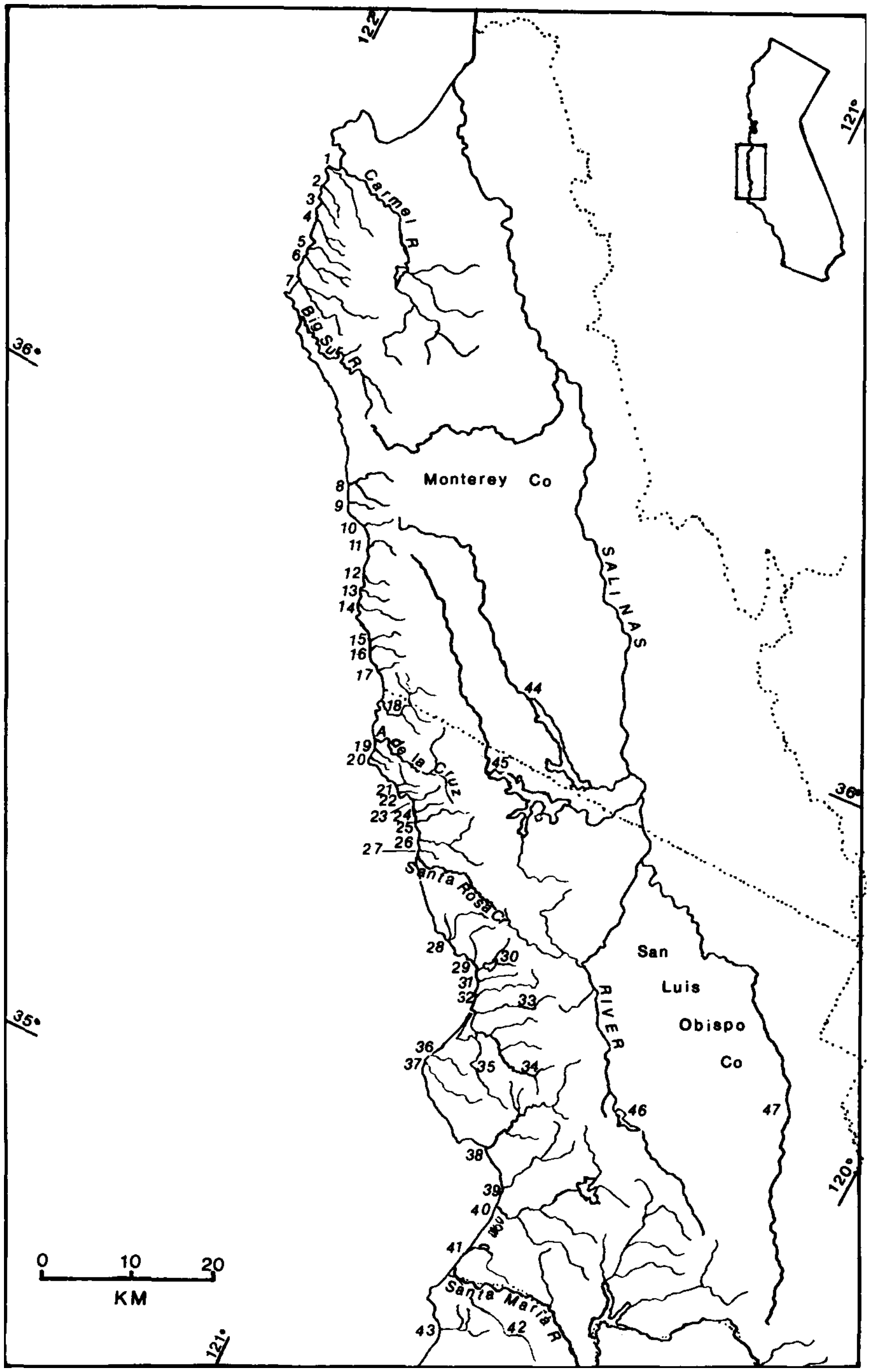


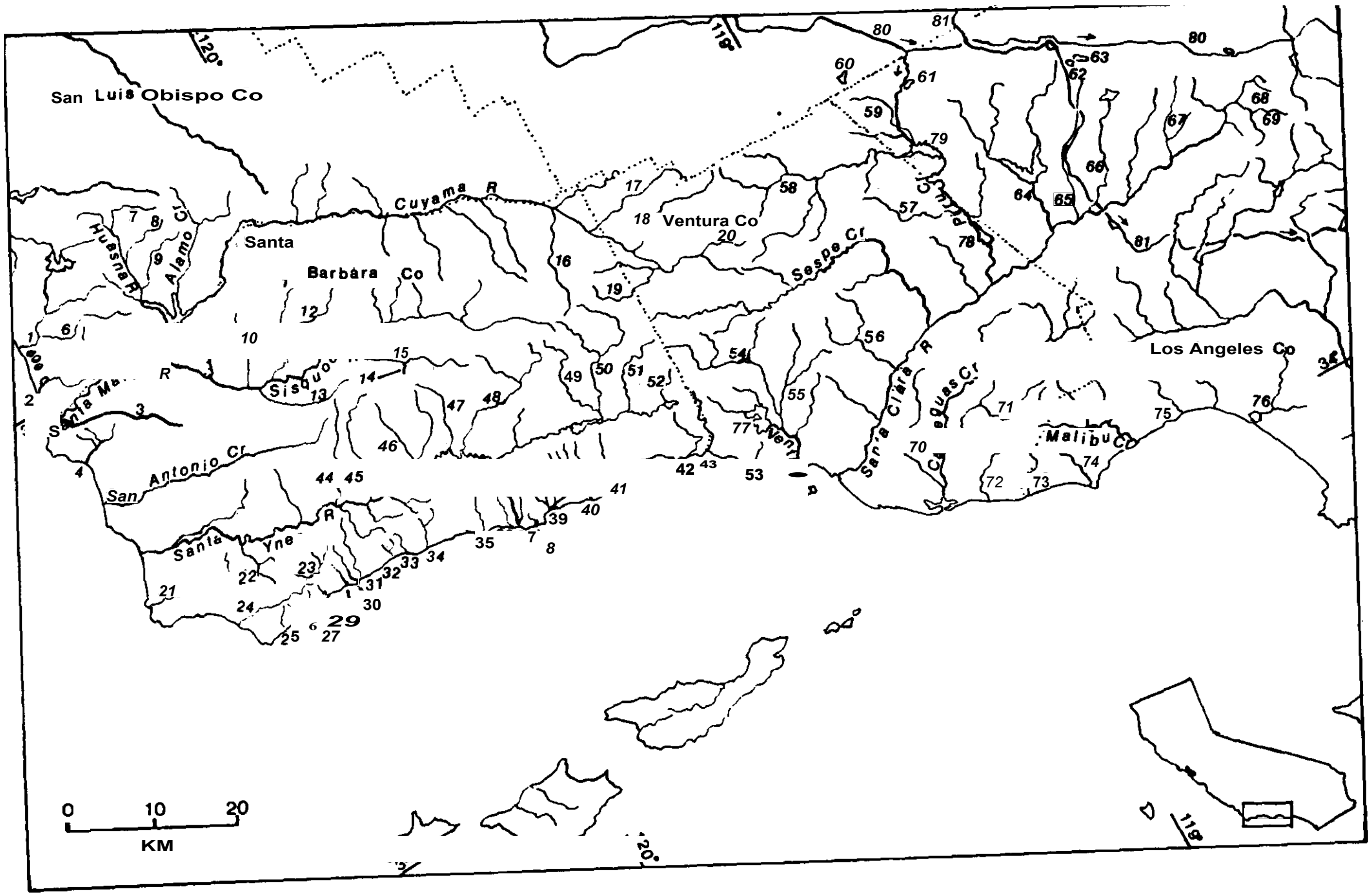
Fig. 1. Drainage map of coastal California from Carmel River to Santa Maria River (abbreviations in Methods; see Fig. 2 for stream names along southeastern edge). 1. San Jose Cr, 2. Malpaso Cr, 3. Soberanes Cr, 4. Garrapata Cr, 5. Palo Colorado Cr, 6. Bixby Cr, 7. Little Sur R, 8. Big Cr, 9. Vincente Cr, 10. Limekiln Cr, 11. Mill Cr, 12. Prewitt Cr, 13. Plaskett Cr, 14. Willow Cr, 15. Alder Cr, 16. Villa Cr, 17. Salmon Cr, 18. San Carpoforo Cr, 19. Ar del Oso, 20. Ar de Corral, 21. Oak Knoll Cr

We include as freshwater species those that spend all or a distinct portion of their life cycle in freshwater, thus including the primary and secondary freshwater and diadromous categories of previous authors (McDowall 1989). These are usually called inland fishes in the western United States (Moyle 1976a; Wydowski and Whitney 1979). Estuarine taxa are based on Moyle (1976a), Miller and Lea (1976), Shapavalov et al. (1981), and our interpretation of the degree of dependence on lowered salinity. Many other species known from bays and estuaries in California (Horn and Allen 1976), but not as limited to low salinity, are omitted. Also excluded (as native) are anadromous and euryhaline species recorded from marine waters in southern California but not native in freshwater in this area such as *Acipenser transmontanus* and *A. medirostris,* species of Pacific salmons *(Oncorhynchus* spp., in part), and *Thaleichthys pacificus* (Miller and Lea 1976; Eschmeyer et al. 1983). Some of these have been introduced into fresh waters in southern California. Most marine species introduced into the Salton Sea are not native there; some are native in marine coastal waters of southern California. Only freshwater records are listed. Following Shafland and Lewis (1984) and Allendorf (1991), introductions refer to any movement of fish from one place to another by humans whether the ultimate origin is local, regional, national, or international; examples of all these exist in southern California.

Native fishes were greatly reduced in the Colorado River in California/Arizona by the time Minckley (1973) published his maps, and these are not repeated here. Also not mapped are the endemics of the Mohave and Owens drainages that have had historically very limited distribution (except *Catostomus fumeiventris),* and are mapped in Lee et al. (1980) and Moyle et al. (1989). The distribution of *Eucyclogobius* was mapped by Swift et al. (1989). Maps are redrawn with some modifications from the U.S. Geological Survey map, State of California, 1:1,000,000, Lambert conformal conic projection, 1970 edition. Abbreviations on maps and in captions are: Ar, Arroyo (de); Ca, Canada (de); Cn, Canyon; Co, County; Cr, Creek; L, Lake; R, River; Re, Reservoir; Sl, slough; Spr, spring (s); trib, tributary(s) (of); W, Wash.

The term Los Angeles Basin is used here to include the drainage areas of the Los Angeles, San Gabriel, and Santa Ana rivers (the Santa Ana system of Culver and Hubbs 1917). The spelling of Mohave follows Miller et al. (1991, p. 32) as originally coined from the native American name rather than as subsequently changed to a Spanish word (Mojave). Common and scientific names of genera and species, including those required by the U.S. Food and Drug Administration for a few commercially important hybrids, usually follow Robins et al. (1991); some generic and family group names follow Page and Burr (1991; see Mayden 1992). Names for some subspecific groups based on taxonomic, biological, and conservation criteria follow Moyle and Williams (1990).

(Ar Laguna), 22. Ar Tortuga, 23. Ar del Puerto 24. Little Pico Cr, 25. Pico Cr, 26. San Simeon Cr, 27. Leffingwell Cr, 28. Villa Cr, 29. Cayucos Cr, 30. Old Cr and Whale Rock Re, 31. Willow Cr, 32. Toro Cr, 33. Morro Cr, 34. Chorro Cr, 35. Los Osos Cr, 36. Islay Cr, 37. Coon Cr, 38. San Luis Obispo Cr, 39. Pismo (Price) Cr, 40. Arroyo Grande Cr, 41. Oso Flaco Cr, 42. Orcutt Cr, 43. Shuman Cn, 44. San Antonio R and Re, 45. Nacimiento R and Re, 46. Santa Margarita L, 47. San Juan Cr.


San Luis Obispo Co
Santa Barbara Co
Ventura Co
Los Angeles Co
Cuyama R
Huasna R
Alamo Cr
Sisquoc
Santa Maria R
San Antonio Cr
Santa Ynez R
Sespe Cr
Santa Clara R
Piru Cr
Las Virgenes Cr
Malibu Cr
120°
119°
118°
0 10 20
KM

Freshwater Taxa

Petromyzontidae

1. *Lampetra* cf. *pacifica* Vladykov. Pacific brook lamprey. Extirpated in southern California. Hubbs (1967) documented the records of this small, non-parasitic species in the San Gabriel and Santa Ana drainages. Subsequent examination of the material of Ewy (1945) at Whittier College (now LACM 32593-1) verified that she had both this species and the much larger migratory one which follows. One lot (LACM 31615-1) taken from the Los Angeles River verifies its existence in that drainage. Very little preserved material of the fish survives, and it will be difficult to decide if it was a taxon distinct from the Pacific brook lamprey farther north. Robins et al. (1991), following Bond and Kan (1985), placed *L. pacifica* in the synonymy of *L. richardsoni*, the former including southern California populations. Carl L. Hubbs (in litt.) related that it was common in low gradient portions of Los Angeles Basin streams but disappeared before its distinction from the anadromous Pacific lamprey was appreciated. The last Pacific brook lampreys were taken in 1930 from the Los Angeles River near Griffith Park, in 1943 or 1944 from the San Gabriel River near the mouth of San Jose Creek, and in 1955 from the Santa Ana River just above the Prado Flood Control Basin (SIO 61-478).

2. *Lampetra tridentata* (Gairdner). Pacific lamprey. This anadromous lamprey still maintains runs in several creeks in Monterey and San Luis Obispo County, parts of the Santa Maria and Santa Ynez rivers, parts of the Ventura River, the Sespe Creek portion of the Santa Clara River drainage, and the lower, unimpounded reach of Malibu Creek (Fig. 6). Its habitat requirements are similar to those of steelhead, *Oncorhynchus mykiss*, and it reaches an elevation of about 900 m in Sespe Creek (Sam Sweet, pers. comm., LACM 45700-1). Shapavalov and Taft (1954) reported Pacific lamprey absent from all but the largest rivers on the central California coast; runs in small streams probably were not detected by

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Fig. 2. Drainage map of coastal California from Santa Maria River to Malibu Creek (abbreviations in Methods; arrows indicate direction of flow in aqueducts). 1. Arroyo Grande Cr, 2. Oso Flaco Cr, 3. Orcutt Cr, 4. Shuman Cn, 5. Nipomo Cr, 6. Los Berros Cn, 7. Stony Cr, 8. Arroyo Seco, 9. Carrie Cr, 10. Tepusquet Cr, 11. La Brea Cr, N Fk, 12. La Brea Cr, S Fk, 13. Foxen Cn, 14. Davy Brown Cr, 15. Manazana Cr, 16. Santa Barbara Cn, 17. Quatal Cn, 18. Apache Cn, 19. Rancho Nuevo Cr, 20. Alder Cr, 21. Honda Cr, 22. Salsipuedes Cr, 23. El Jaro Cr, 24. Jalama Cr, 25. Ca Cojo, 26. Ca St. Augustine, 27. Ca Bulito, 28. Ca Santa Anita, 29. Ca Alegria, 30. Ca Agua Caliente, 31. Gaviota Cr, 32. Ca Hondo, 33. Ar Quemado, 34. Refugio Cn, 35. Dos Pueblos Cn, 36. Tecolote Cn, 37. Winchester (Bell) Cn, 38. Devereaux Sl, 39. Goleta Sl and tribs. west to east, Tecolito, Cameros, San Pedro, San Jose, Maria Ignacio, and San Antonio cr, 40. Ar Burro, 41. Mission Cr, 42. Carpinteria Cr, 43. Rincon Cr, 44. Zaca Cr, 45. Alamo Pintado Cr, 46. Santa Agueda Cr, 47. Cachuma Cr and L, 48. Santa Cruz Cr, 49. Indian Cr, 50. Mono Cr (trib to Gibraltar Re), 51. Agua Caliente Cn, 52. Juncal Cr (trib to Jameson L), 53. Padre Juan Cn, 54. Matilija Cr and L, 55. San Antonio Cr, 56. Santa Paula Cr, 57. Agua Blanca Cr, 58. Lockwood Cr, 59. Gorman Cr, 60. Castac L, 61. Quail L, 62. Munz L, 63. Elizabeth L, 64. Castaic Cr and Re, 65. San Francisquito Cn, 66. Bouquet Cn and Re, 67. Agua Dulce Cn and trib Escondido Cn, 68. Kentucky Spr Cn, 69. Aliso Cn, 70. Revlon Sl trib Mugu Lagoon, 71. Ar Conejo, 72. Big Sycamore Cn, 73. Ar Sequit, 74. Zuma Cn, 75. Topanga Cn, 76. Ballona Marsh and Cr, 77. L Casitas, 78. L Piru, 79. Pyramid Re, 80. California Aq, 81. Los Angeles Aq.

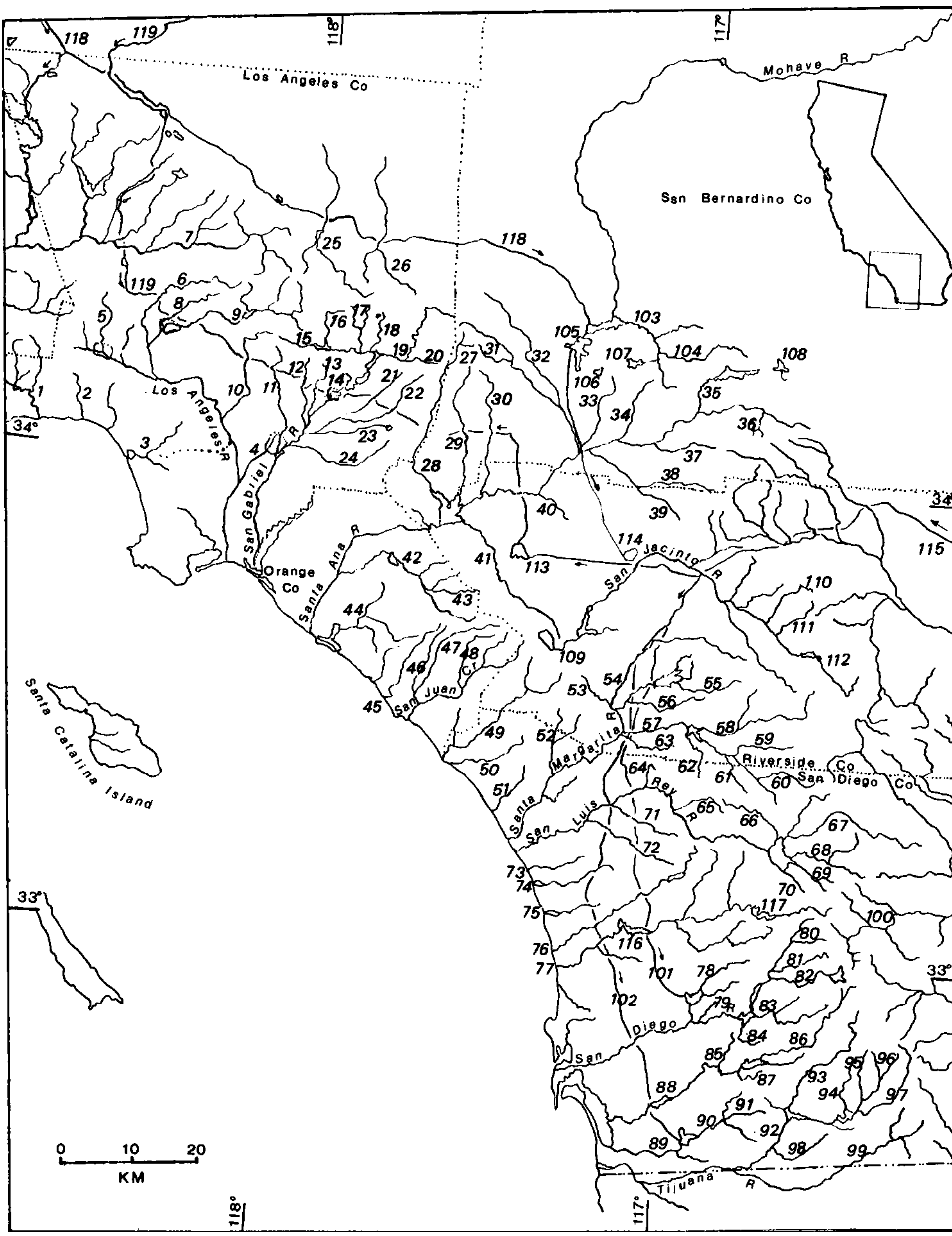

Fig. 3. Drainage map of coastal California from Malibu Creek (Los Angeles County) to the Tijuana River (Mexican border). (Abbreviations in Methods; arrows indicate direction of flow in aqueducts.) Malibu Cr, 2. Topanga Cr, 3. Ballona Marsh and Cr, formerly receiving the Los Angeles River (dotted line), 4. Rio Hondo and Whittier Flood Control Basin, 5. Bull Cn, trib Sepulveda Flood Control Basin, 6. Pacoima Cr, 7. Soledad Cn (upper Santa Clara R), 8. Little Tujunga Cn, 9. Big Tujunga Cr and Re, trib Hansen Dam Flood Control basin; 10. Arroyo Seco and upper trib Bear Cr, 11. Eaton Cn, 12. Santa Anita Cn, 13. Monrovia Cn, 14. Fish Cn, 15. W Fk San Gabriel R, trib Cogswell Re, 16. Devils Cn, 17. Bear Cr, 18. N Fk San Gabriel R and Crystal L, 19. E Fk San Gabriel R trib to San Gabriel and Morris re, 20. Cattle Cn, 21. Big Dalton Cn, 22. San Dimas Cn, 23. Walnut Cr draining Puddingstone Re, 24. San Jose Cr, 25. Little Rock Cr and Re, 26. Big Rock Cr, 27. San Antonio Cr, and

Shapavalov and Taft (1954), or some factor other than stream size accounted for their absence.

It spawned in Los Angeles Basin streams until about 1955 (Hubbs 1967), and was not recorded again until March 1991 when an adult was observed about one kilometer above the mouth of the Santa Ana River after heavy rains (Dave Raetz, pers. comm.). No freshwater records exist for the species south of the Santa Ana River. The recognition of a southern subspecies was based on the low myomere counts of the then-unrecognized freshwater non-parasitic form, and subspecies were not recognized later (Hubbs 1967; Hubbs et al. 1979).

Salmonidae

3. Oncorhynchus mykiss (Walbaum). Rainbow trout. Hubbs (1946) reported on possible native coarse-scaled trout from the headwaters of the San Luis Rey drainage, San Diego County. Otherwise southern California native populations of resident, non-migratory, rainbow trout are only known from coastal drainages and have not been recognized as taxonomically distinctive (Miller 1950; Hubbs 1946; Needham and Gard 1963; Berg and Gall 1988; Gall et al. 1991; Behnke 1992). Because all other freshwater fishes from this area are endemic or otherwise diagnostic, a distinctive native trout also would be expected in Los Angeles Basin streams. Careful examination of some isolated headwater populations may disclose such a form, namely upper tributaries of the San Luis Rey and Santa Margarita rivers; San Jacinto River, Santiago, Lytle, and Cajon creeks, all tributaries of the Santa Ana River; tributaries of San Juan Creek in the Santa Ana Mountains; upper tributaries of the San Gabriel River; Arroyo Seco (above Pasadena) and upper Big Tujunga Creek, both tributary to the Los Angeles River; upper tributaries of Piru and Sespe creeks, Santa Clara drainage; and possibly upper tributaries

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upper trib Icehouse Cn; 28. Chino Cr trib Prado Flood Control Area; 29. Cucamonga Cr, 30. Day Cr, 31. Lytle Cr, 32. Cajon Cr, 33. Strawberry Cr, 34. City Cr, 35. Bear Cr outlet of Bear L, 36. S. Fk Santa Ana R and Dollar L, 37. Mill Cr, 38. Yucaipa Cr, 39. San Timoteo Cn, 40. Ar Tepsequet, 41. Temescal W, 42. Santiago Cr and Re (Irvine L), 43. Silverado Cr, 44. San Diego Cr trib Newport Bay, 45. Aliso Cr, 46. Oso Creek, 47. Trabuco Cr, 48. Bell Cn, 49. San Mateo Cr, 50. San Onofre Cn, 51. Las Pulgas (Las Flores) Cn, 52. De Luz Cr, 53. Murietta Cr, 54. Warm Springs Cr, 55. Tucalota Cr, L Skinner inlet and outlet, 56. Santa Gertrudis Cr, 57. Temucula Cr outlet of Vail L, 58. Wilson Cr, 59. Tule Cr, 60. Chihuahua Cr, 61. Long Cn, 62. Arroyo Seco, 63. Pechanga Cr, 64. Pala Cr, 65. Pauma Cr, 66. W Fk San Luis Rey R, trib L Henshaw, 67. Agua Caliente Cr, 68. Buena Vista Cr, 69. Matagual Cr, 70. Carrizo Cr, 71. Keys Cr, 72. Moosa Cn, 73. Buena Vista Cr, 74. Agua Hedionda Lagoon and Cr, 75. Batiquitos Lagoon, 76. Escondido Cr, outlet L Wohlford, 77. San Dieguito R, 78. San Vincente Cr, 79. Wildcat Cr, 80. Temescal Cr, 81. Cedar Cr, 82. Boulder Cr, outlet of Cuyamaca L, trib El Capitan Re, 83. Conejos Cr, 84. Chocolate Cn, 85. Harbison Cr, 86. Sweetwater R trib Loveland Re, 87. Lawson Cr, 88. Sweetwater R and Re, 89. Otay R outlet of upper and lower Otay Re, 90. Deluzra Cr, 91. Hollenbeck Cn, 92. Cottonwood Cr outlet Barrett L, 93. Pine Valley Cr, 94. Morena Cr trib Morena Re, 95. Cottonwood Cr, 96. Long Cn, 97. La Posta Cr, 98. Potero Cr, 99. Campo Cr, 100. San Felipe Cr, 101. First San Diego Aq, 102. Second San Diego Aq, 103. Deep Cr, 104. Holcomb Cr, 105. Silverwood L, 106. Lake Gregory, 107. Lake Arrowhead, 108. Baldwin L and trib Shay Cr, 109. L Elsinore, downstream of Railroad Cn Re, 110. N Fk San Jacinto R, 111. Strawberry Cr, 112. S Fk San Jacinto R outlet L Hemet, 113. L Matthews and Colorado R Aq, 114. L Perris and California Aq, 115. Colorado R Aq, 116. L Hodges, 117. L Sutherland, 118. California Aq, 119. Los Angeles Aq.

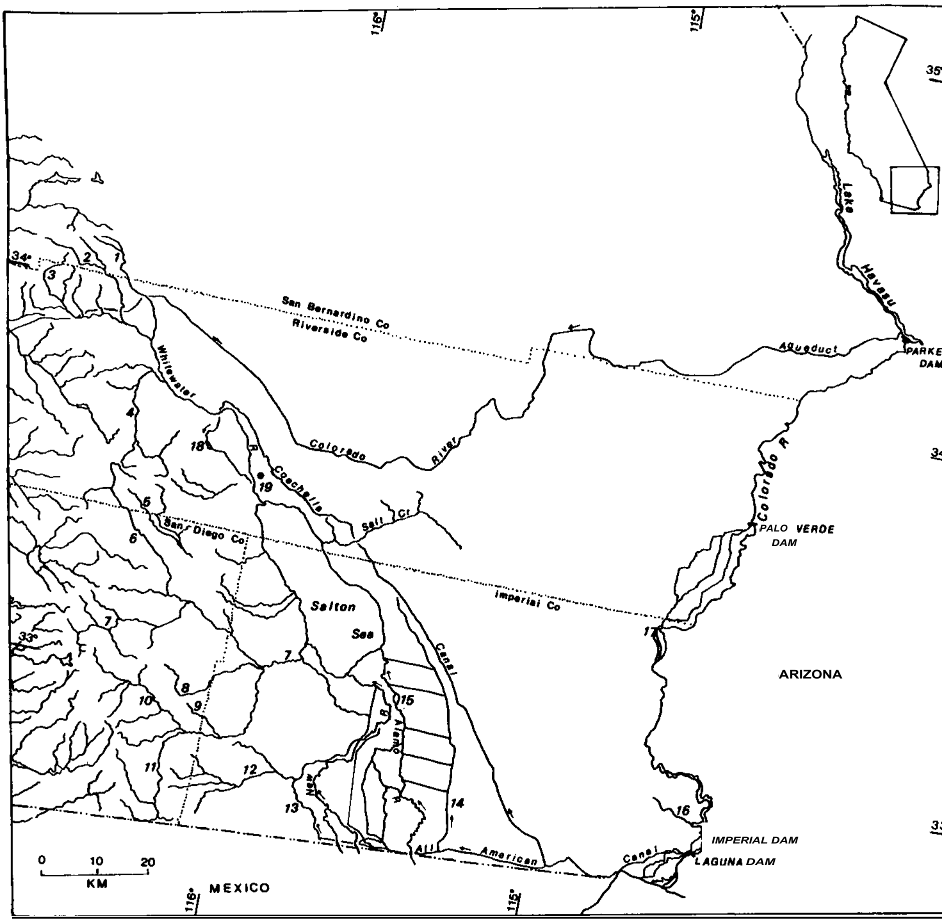
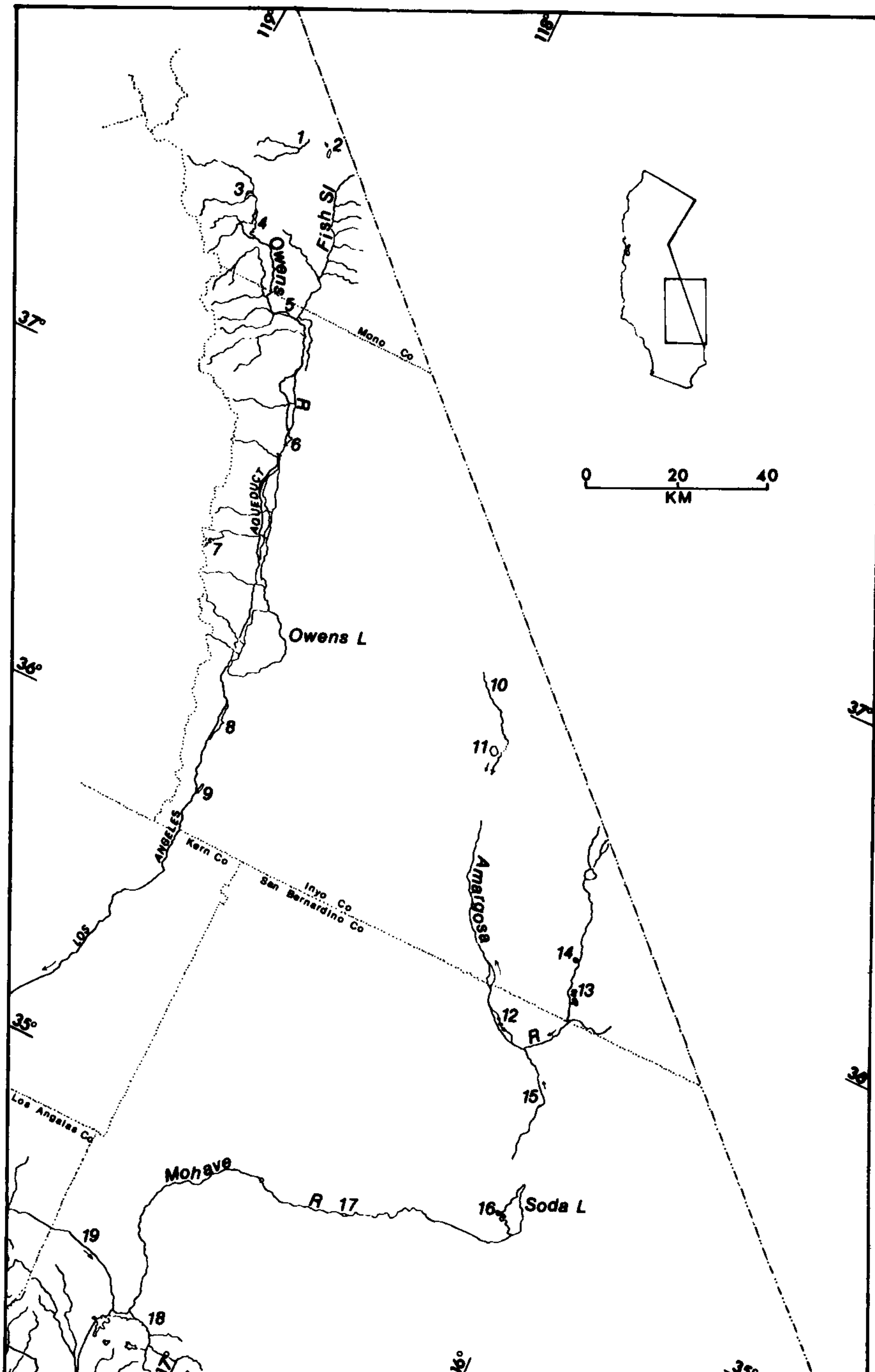


Fig. 4. Drainage map of the Colorado River and Salton Sea areas of California (abbreviations in Methods; arrows indicate direction of flow in aqueducts). 1. Mission Cr, 2. N and S **Fk** Whitewater R, 3. San Gorgonio R, 4. Palm Cn, 5. Dry W, 6. Coyote Cr, 7. San Felipe Cr, 8. Fish Cr W, 9. Deguynas Cn, 10. Vallecitos Cr, 11. Carizo Cn, 12. Coyote W, 13. Westside Main Canal, 14. East Highline Canal, 15. Ramer L, 16. Senator W, 17. Palo Verde Lagoon, 18. L Cahuilla, 19. Town of Mecca.

of the Ventura, Santa Inez, or Santa Maria drainages. Recent collections or reports of self-sustaining populations are known from these areas (Fig. 1-3).

Cooper (1874) reported native trout in San Diego County only in Warner's Pass at the head of the San Luis Rey River. Eigenmann and Eigenmann (1890) reported them in Pala Creek, tributary to the San Luis Rey farther downstream. Hubbs (1946), referring to Smith (1880, unpublished), reported them abundant in fresh-water streams near Smiths Mountain and Pala in the headwaters of the San Luis Rey system. Much of the Warner Ranch area was flooded by Lake Henshaw.

Fig. 5. Drainage map of the Owens and Mohave drainages in California; Mono to San Bernardino counties (abbreviations in Methods; arrows indicate direction of flow in aqueducts). 1. Adobe Cr, 2.



River Spr, 3. Hot Cr, 4. Crowley L, 5. Pleasant Valley Re, 6. Tinemaha Re, 7. Williamson L, 8. Haiwee Re, 9. Little L, 10. Salt Cr, 11. Cottonball Marsh, 12. Saratoga Spr, 13. Tecopa Hot Spr, 14. Shoshone Spr, 15. Salt Cr (fishless), 16. Zyzyx or Soda Spr, 17. Camp Cady L, 18. Deep Cr, trib Mohave Flood Control Basin; 19. California Aq.

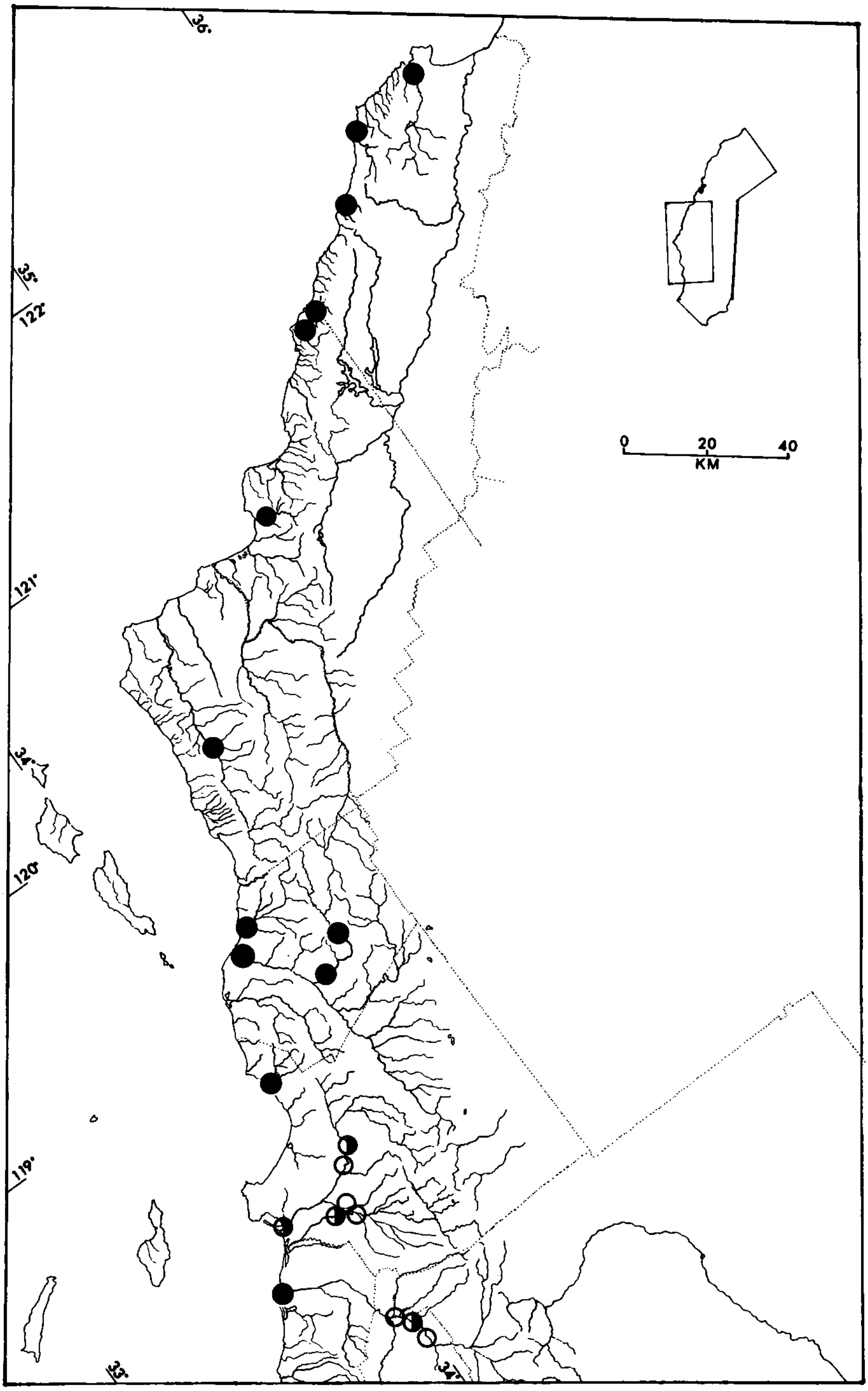


Fig. 6. Distribution of migratory (parasitic), *Lampetra trident ata,* and freshwater (non-parasitic), *L.* cf. *pacifica,* lampreys in coastal southern California. Black circles: *Lampetra tridentata* from 1970 onward; half circles: before 1970. Open circles: *Lampetra* cf. *pacifica,* all 1955 or before. See Figs. 1-3 for stream names.

Hubbs (1946) reported his examination of specimens of these fish in the San Diego Society of Natural History, but thought it unlikely that any stocks uncontaminated by introductions remained. Beginning in the 1890s and extending through the late 1930s fingerling rainbow trout were planted into almost all possible waters in southern California (CFG LB). Included were stocks identified at the time as both rainbow trout and steelhead (Busack and Gall 1980). Field notes made by State Fish and Game biologists, 1915 to 1945, document three other streams perennial enough to be strong candidates for permanent trout waters in San Diego County, south of the San Luis Rey drainage: Boulder Creek, tributary to San Diego River; Cold Creek, tributary to Green Valley Creek, Sweetwater River drainage; and Pine Valley Creek, tributary to the Otay River. Many southern California streams have one or more barrier falls and the extent to which, if any, native trout occurred above many of these is not known. Today such records can only be found by searching historical documents or prehistorical river deposits for remains of these fish.

Rainbow trout were first planted in the lower Colorado River of California in 1935 after the construction of Boulder Dam (Moffett 1942), and much earlier farther upstream in Arizona and Nevada (Miller and Alcorn 1946; Minckley 1973).

4. *Oncorhynchus mykiss* (Walbaum). Southern steelhead. Today steelhead have nearly the same distribution as the Pacific lamprey (Fig. 7) in southern California. Virtually every coastal stream in Monterey, San Luis Obispo, and Santa Barbara counties north of Point Conception has had at least a few fish entering it within the last ten years. South of Point Conception the following streams have recent records: Gaviota, Mission, and Atascadero creeks, Santa Barbara County; Ventura and Santa Clara rivers, Ventura County; and Mullholland, Big Sycamore, Malibu, and Topanga canyons, Los Angeles County. Historically, fish also entered streams farther south, including Los Angeles and San Gabriel rivers, Los Angeles County; and San Onofre and San Mateo creeks, Santa Margarita, San Luis Rey, San Diego and Tijuana rivers, San Diego County (Hubbs 1946). Spawning success south of the Los Angeles basin may have been sporadic. Large series of juvenile fish were taken in lower San Juan Creek (Miller 1939), lower San Mateo Creek near San Clemente (UMMZ 132964), and the lower Santa Margarita River (UMMZ 132968) in the summer of 1939, indicating successful reproduction at that time. Anglers referred to juvenile fish in coastal lagoons as sundowners, and often large numbers could be caught in coastal lagoons in the 1930s and earlier (R. Croker, pers. comm.).

Cyprinidae

5. *Gila bicolor snyderi* Miller. Owens tui chub. State and federally endangered. Once widespread in the Owens drainage, including Owens Lake (Gilbert 1893; Miller 1973), it is known only from Fish Slough, Owens Valley Native Fishes Sanctuary, Inyo County; a small spring and stream, Cabin Bar Ranch, west side of Owens Lake; about 13 km of the Owens River below Crowley Lake; two springs at the Hot Creek Fish Hatchery; Little Hot Creek Pond; and an artificial habitat on Los Angeles Department of Water and Power Land (Bolster 1990b). Many populations are introgressed with Lahontan tui chubs, *Gila bicolor obesa;* others were eliminated by introduced trout (three species) and largemouth bass.

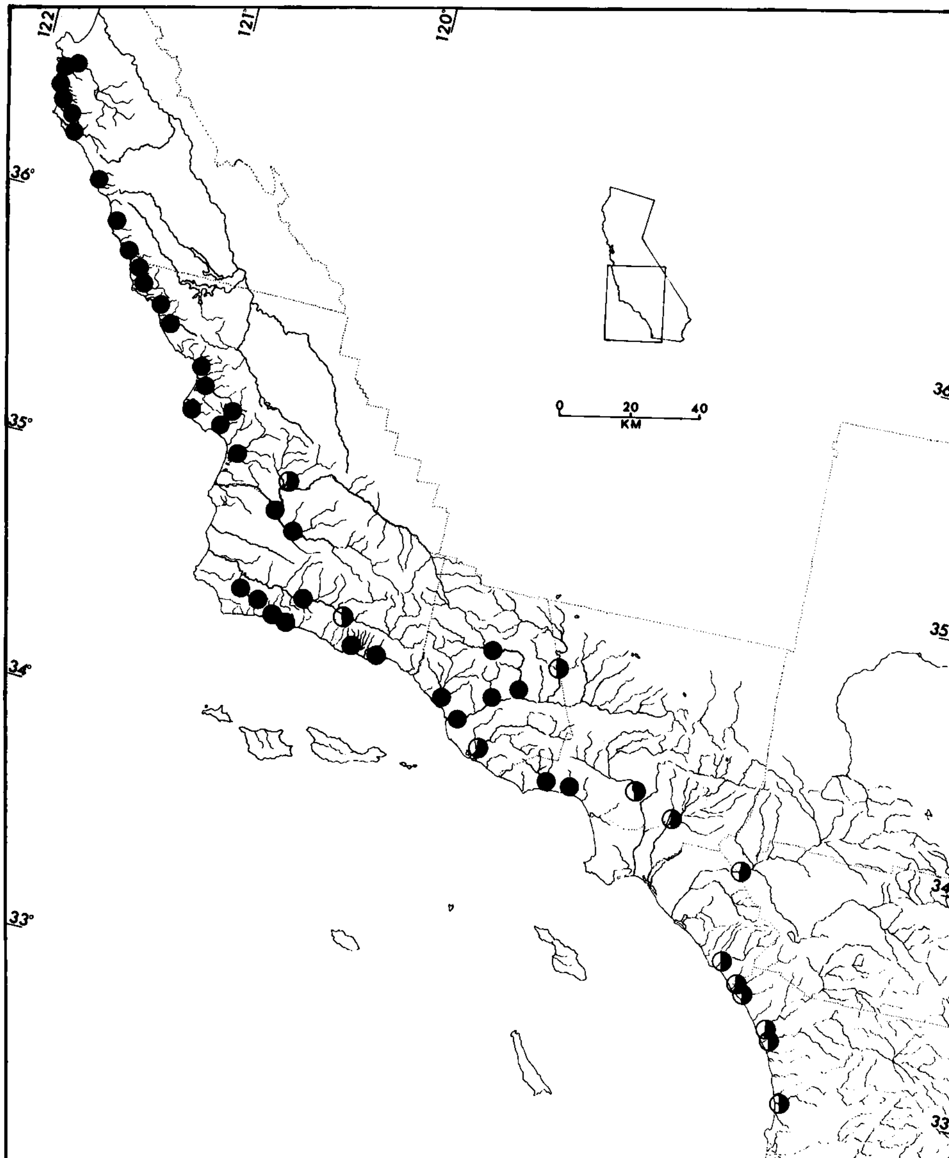


Fig. 7. Distribution of steelhead, *Oncorhynchus mykiss*, in coastal southern California. Black circles from 1970 onward; half circles before 1970. See Figs. 1-3 for stream names.

6. *Gila bicolor mohavensis* Snyder. Mohave tui chub, State and federally endangered. Once widespread in the Mohave drainage, it remains only in artificial habitats at Soda Springs near Baker; Desert Studies Center Pond at Hinkley; California Desert Information Center in Barstow; Camp Cady Wildlife Area near Newberry Springs, San Bernardino County; and China Lake Naval Weapons

Center, San Bernardino and Kern counties (Hoover and St. Amant 1983; Bolster 1990a). It hybridizes with the introduced *G. orcutti* (Hubbs and Miller 1943) in headwater portions of the Mohave drainage, particularly lower Deep Creek and Moyle (1976a) and Castleberry and Cech (1986) believed arroyo chubs eliminated the Mohave chub. However, a hybrid taken in the summer of 1991 (LACM 45542-1) indicates parental influence of both species still exists in the area. Miller (1968) and Hoover and St. Amant (1983) noted several unsuccessful introductions in southern California and northern Baja California.

7. Gila orcutti (Eigenmann and Eigenmann). Arroyo chub. State special concern. It is common at three localities within its native range, namely the upper Santa Margarita River and its tributary, De Luz Creek, Trabuco Creek below O'Neill Park and San Juan Creek (San Juan Creek drainage), and Malibu Creek. The Malibu Creek population may be introduced because elsewhere arroyo chubs always occur with *Gasterosteus aculeatus,* which is absent from this stream (Culver and Hubbs 1917). Miller (1968) considered it native in Malibu Creek, and this is confirmed by the finding of prehistoric remains of arroyo chub in middens along upper Malibu Creek (Gobalet 1990). It is present but scarce in Big Tujunga Canyon, Pacoima Creek above Pacoima Reservoir, and in the Sepulveda Flood Control Basin, Los Angeles River drainage; upper San Gabriel River drainage; and middle Santa Ana River tributaries between Riverside and the Orange County line. In the San Gabriel system it is most abundant in the west fork below Cogswell Reservoir where the gradient is low compared to the north and east forks (Richards and Soltz 1986). It is usually confined to backwater pools or pools created for recreational activities. It is scarce within its native range, because it does best in the lower gradient streams that have largely disappeared. Low water conditions (1986—present) made conditions more suitable to it in the West Fork of the San Gabriel River and Big Tujunga Creek where it became abundant. After the rains of 1991-1992 it again became scarce relative to *Catostomus santaanae* and *Rhinichthys osculus* in the San Gabriel. It remains common in Big Tujunga where *Catostomus* and *Rhinichthys* have become scarce and perhaps extirpated. Native populations of *Gila orcutti* have been reduced enough to deserve close monitoring to maintain or improve their status (Moyle and Williams 1990; Tres 1992).

Its rapid artificial range expansion in the 1930s and 1940s, as bait (Vestal 1942), with trout plants (Miller and Hubbs 1969; CFG WAE), or with mosquitofish (Miller 1945a), established it in many extralimital areas (Fig. 8). Shebley's (1922) reference to abundant minnows in Big Bear Lake probably refers to introduced arroyo chubs; they often became numerous and were eradicated as pests in southern California reservoirs (Vestal 1942; CFG LB). It was introduced into tributaries of the Mohave River, particularly Deep Creek, in the 1930s and has hybridized there with *Gila bicolor mohavensis* (Hubbs and Miller 1943; Miller 1946a, 1968). Fish introduced into the Cuyama drainage hybridize with *Hesperoleucas symmetricus* (Greenfield and Greenfield 1972; Greenfield and Deckert 1973). Miller (1968) documented unsuccessful introductions of arroyo chubs into the San Felipe Creek drainage (San Diego County) and the Rio San Tomas (northern Baja California) in the 1950s.

8. Gila elegans Baird and Girard. Bonytail chub. Extirpated in California, state and federally endangered. Originally known only from the lower mainstream Colorado River (and probably the Salton Sea) in California (Dill 1944; Minckley 1973). Occasional individuals possibly still occur in Lake Havasu (Tyus 1991a).

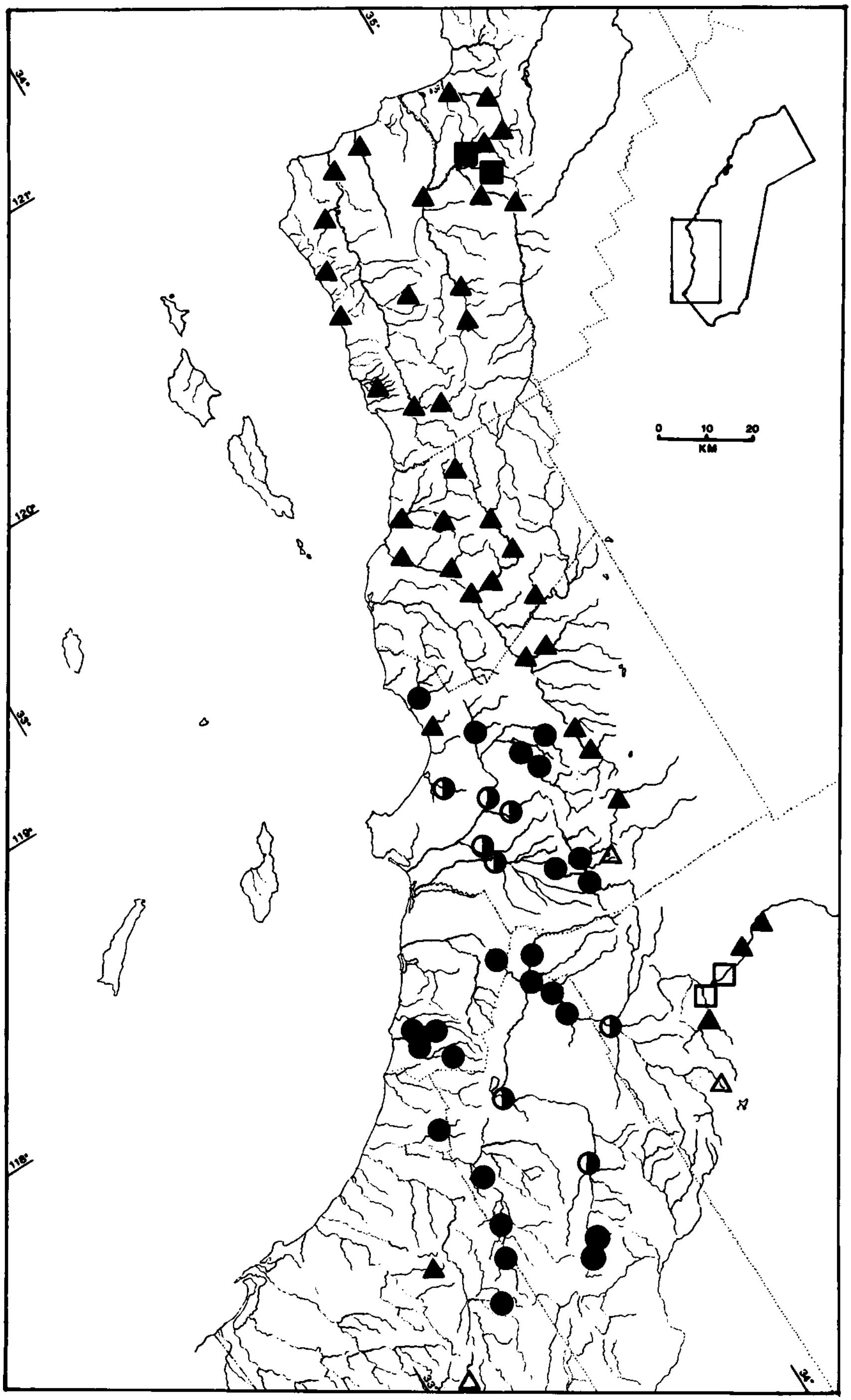


Fig. 8. Distribution of arroyo chub, *Gila orcutti,* in southern California. Black circles from 1975 onward; half circles before 1975; black triangles viable introduced populations; open triangles extirpated introductions; black square hybrids with roach, *Hesperoleucas symmetricus;* open squares hybrids with Mohave chub, *Gila bicolor mohavensis.* Recent reports of this species from Pine Valley Creek (Tijuana River drainage) occur off the map to the south. See Figs. 1-3 for stream names.

Early observers did not separate *G. cypha* Miller, not described until 1946, and it may have also occurred in the lower Colorado River in California (Gobalet 1992).

9. Gila robusta Baird and Girard. Roundtail chub. Extirpated in California. A few early records of this species from the lower Colorado River date from the early 1900s, and the species still occurs farther upstream (Minckley 1973; Tyus 1991a).

10. Plagopterus argentissimus Cope. Woundfin. Extirpated in California and federally endangered. The woundfin also was collected in the lower Colorado River in Arizona before 1900, and undoubtedly occurred in the main river in California, although extant specimens do not exist (Minckley 1973; Hubbs et al. 1979; Gobalet 1992).

11. Ptychocheilus lucius Girard. Colorado squawfish. Extirpated in California, state and federally endangered. Originally known only from the mainstream Colorado River in California (Minckley 1973), and abundant in irrigation canals near the river and the Salton Sea from 1904-1905 until about 1930 (Dill 1944). Fish have been introduced into the lower river by the Arizona Department of Fish and Game since 1985 with uncertain results (Tyus 1991b).

12. Rhinichthys osculus (Girard). Colorado speckled dace. One larval speckled dace was taken in the lower Colorado River (Minckley 1973); otherwise this species has not been taken in the lower river.

13. Rhinichthys osculus (Girard). Amargosa Canyon speckled dace. State taxon of special concern. This fish occurs only in the Armagosa River near Tecopa. Other populations are found in Nevada (Moyle et al. 1989). Fish were unsuccessfully introduced into the Borax Works on the west side of Death Valley in 1940 (Miller 1968).

14. Rhinichthys osculus (Girard). Owens speckled dace. State taxon of special concern. This taxon occurs only in Fish Slough east of Bishop and in a few other localities in the Owens drainage (Moyle et al. 1989). It was unsuccessfully introduced into Saline Valley in 1939 (Miller 1968).

15. Rhinichthys osculus (Giarard). Santa Ana speckled dace. State taxon of special concern. This is one of the rarest native freshwater fish in coastal southern California (Fig. 9). It is abundant only in the lower parts of the East, North, and West forks of the San Gabriel River. Small populations existed (sightings of one or a few individuals in the last five years or so) in Fish Canyon (a small tributary of the San Gabriel River); and Lytle, Cajon, City, Strawberry, Mill, and Silverado creeks, tributaries of the Santa Ana River system. Fish could not be found in 1990-1992 in Big Tujunga and Santiago creeks despite thorough search and may be extirpated in them. The fish in Big Tujunga are the last known in the Los Angeles River drainage (Moyle and Williams 1990).

Miller (1968) noted records of Santa Ana speckled dace in the foothills of the Montebello Oil fields just northwest of Whittier in 1940. Unpublished records from the lowlands, Chino Creek and the nearby Santa Ana River (RGM) in 1939, Santa Ana River, Riverside (LACM 9436) in 1951, and Los Angeles River in North Hollywood (RGM) in 1939 indicate that relict populations existed across the lowlands of the Los Angeles basin. Miller (1968) noted the successful establishment of the Montebello population in River Springs on the east side of Adobe Valley, Mono County, in 1940.

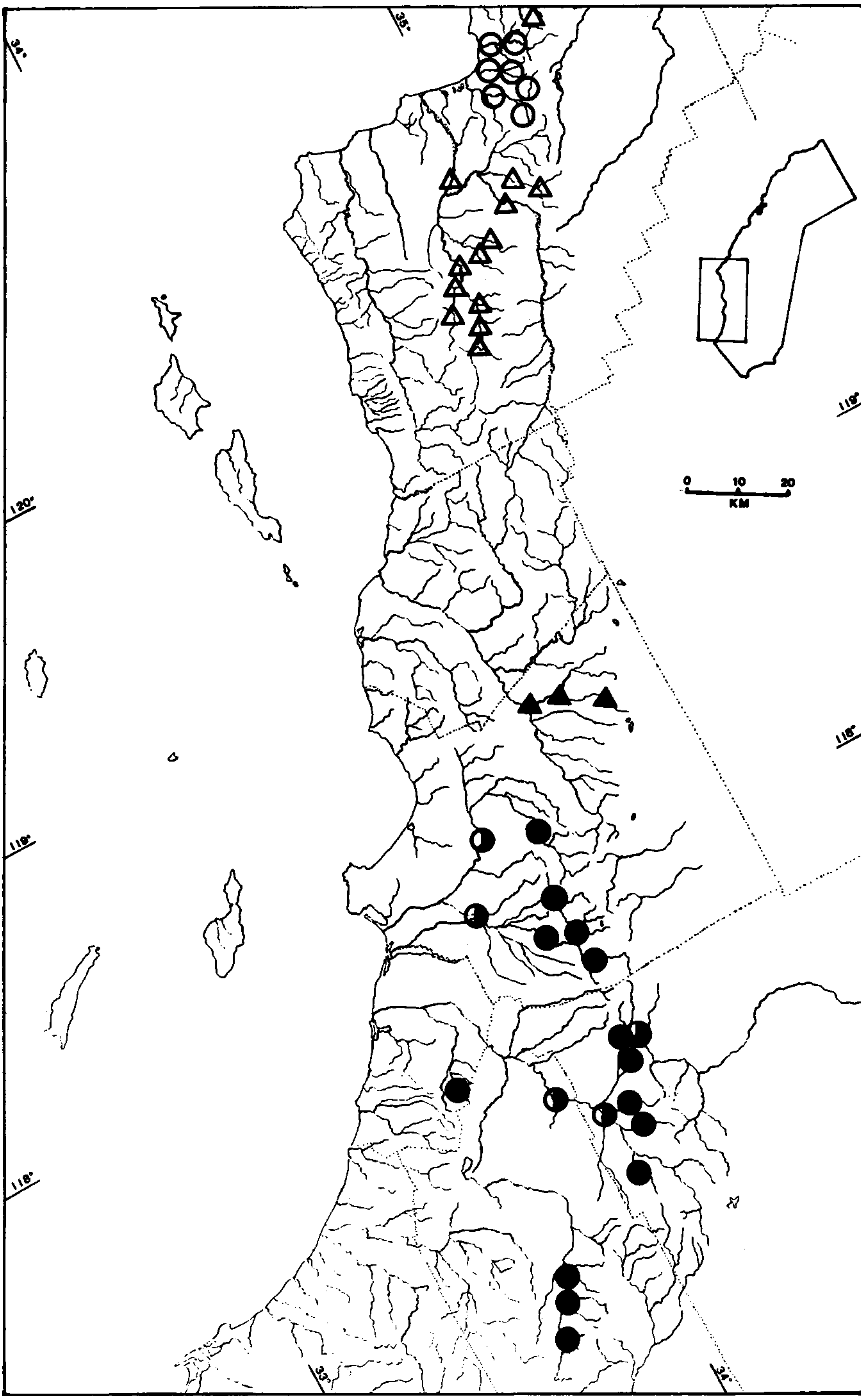


Fig. 9. Distribution of the two forms of speckled dace, *Rhinichthys osculus,* in coastal southern California. Black circles, Santa Ana speckled dace from 1970 onward; half circles before 1970; black triangles introduced. Open circles San Luis Obispo speckled dace; open triangles possibly introduced. See Figs. 1-3 for stream names.

Miller (1946b) reported speckled dace thought to be this taxon in Castaic Creek and Elizabeth Lake Canyon, both tributaries of the Santa Clara River. These have never been collected again and this supports Miller's suspicion that these may have been introduced.

16. Rhinichthys osculus (Girard). San Luis Obispo Speckled dace. The San Luis Obispo Creek population, first noted by Jordan (1895), is probably related (or identical) to those in the Salinas River, rather than to southern California fish (Cornelius 1969). Salinas River fish were combined with Sacramento Valley fish by Moyle and Williams (1990) and Hubbs et al. (1979). We have not found this taxon in streams north of San Luis Obispo Creek as intimated by Miller (1968), but rather in two streams to the south, Pismo and Arroyo Grande creeks. Miller (1968) considered this fish introduced into the next stream to the south, the Cuyama River of the Santa Maria drainage. Records from this drainage also include Davy Brown and Tepusquet creeks and the Sisquoc River.

Catostomidae

17. Catostomus latipinnis Baird and Girard. Flannelmouth sucker. Extirpated in California. Originally only in the lower Colorado River in California (Minckley 1973), the note of it by Dawson (1923) in the Salton Sea in 1913 is the basis for its inclusion in the California fauna (Dill 1944; Hubbs et al. 1979). Fish were introduced below Davis Dam, and specimens were taken in Imperial Reservoir as late as the 1970s (W. L. Minckley, pers. comm.).

18. Catostomus fumeiventris Miller. Owens sucker. The Owens sucker is common to abundant in much of the main Owens River including Crowley Lake (Buth and Murphy 1980). This species apparently entered the Santa Clara system with Owens River water in the 1930s (Hubbs et al. 1943; Miller 1973; Bell 1978). Records are from lower Sespe Creek, the outlet of Fillmore Hatchery into and including the nearby Santa Clara River, and Piru Creek above Piru Lake. It hybridizes with *Catostomus santaanae* (also introduced) in the Santa Clara River (Hubbs et al. 1943; Buth and Crabtree 1982). During winter and early spring high flows Owens suckers and hybrids with Santa Ana suckers are common in the Fillmore hatchery area, but are difficult to find at other times of the year when water flow is much reduced or absent. Formerly large numbers of spawning adults (100-150) gathered below the outlet of Fillmore hatchery for a few weeks in March, but only about half this number or less have been observed in the last three or four years. The artificial permanence of this flow may sustain the population during the rest of the year. Large suckers observed in the spring of 1990 and 1991 in Piru Creek above Piru Lake are probably this species and possibly hybrids as well. This species may have been part of the commercial catch in southern California reservoirs in the 1950s and 1960s (see *C. occidentalis* below).

19. Catostomus santaanae (Snyder). Santa Ana sucker. State species of special concern, Federal candidate 2 species. Native populations still exist in the East, North, and West forks of the San Gabriel River and in the lower Santa Ana River from about Mt. Roubidoux downstream to a few miles below Imperial Highway. In southern California, the Santa Ana sucker is distributed very much like *Rhinichthys osculus,* but in larger streams (Fig. 10). Thus it is absent from Fish and Santiago canyons and Cajon and City creeks of the Santa Ana drainage. It is common in the San Gabriel River system. Large numbers have been taken recently

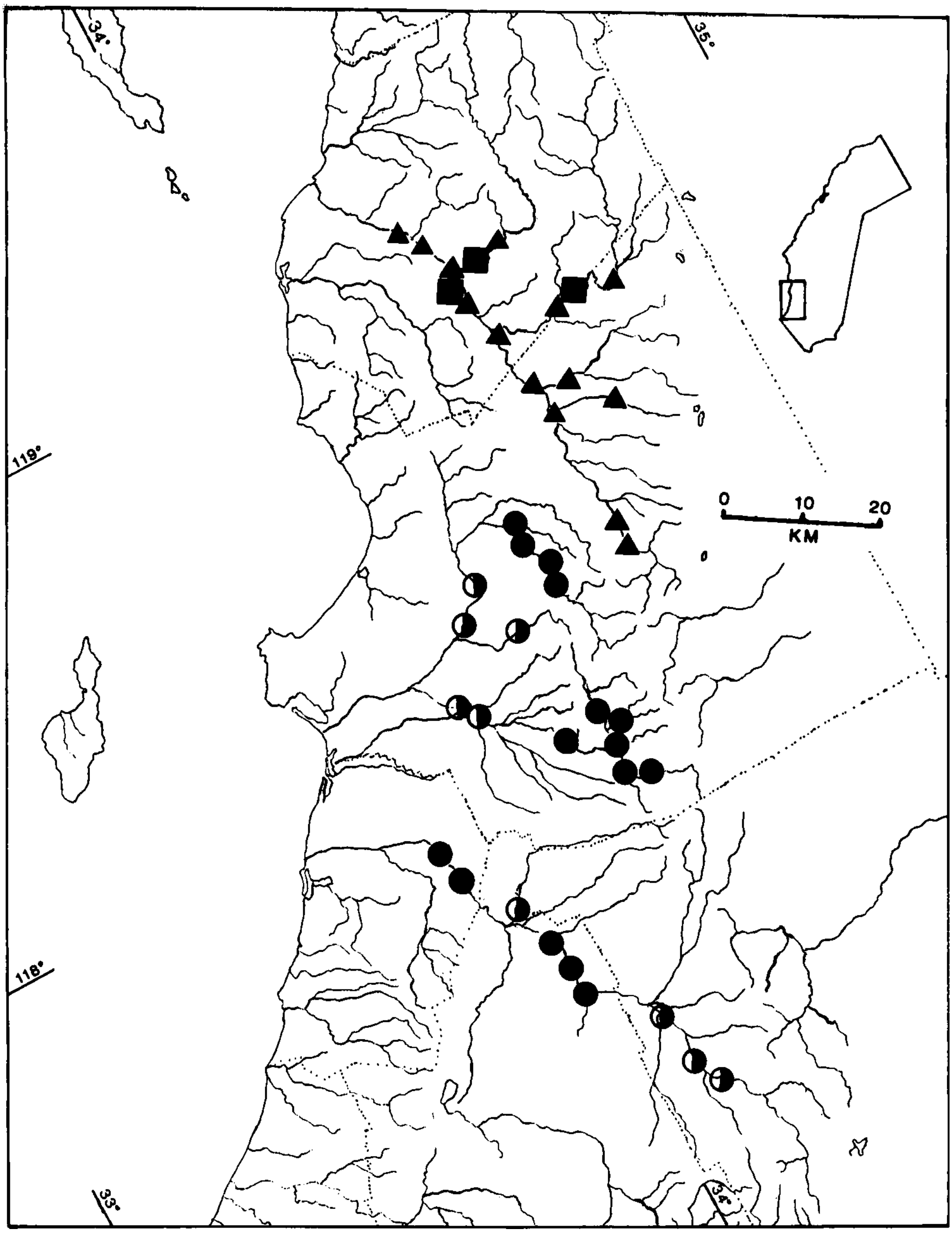


Fig. 10. Distribution of the Santa Ana sucker, *Catostomus santaanae,* in coastal southern Cali fomia. Black circles native records from 1970 onward; half circles native records before 1970; black triangles introduced; black squares hybrids with dusky suckers, *Catostomus fumeiventris.* See Figs. 2-3 for stream names.

in the lower Santa Ana River from Riverside to a few miles below Imperial Highway, but at other times few or none can be collected. It formerly was native in the uplands and lowlands of the Los Angeles Basin streams (Smith 1966; Swift 1980c); now it is restricted to the uplands of the Los Angeles and San Gabriel systems, and conversely, to the lowlands of the Santa Ana system. Fish became very rare in the Big Tujunga drainage in 1990-1992 and the species may soon be extirpated from the Los Angeles River drainage.

Large introduced populations occur in the Santa Clara River (Hubbs et al. 1943; Bell 1978). In the Sespe Creek area, some hybridization with dusky suckers, *C. fumeiventris,* occurs; a few downstream Santa Ana suckers have allozymes of dusky suckers (Don Buth, pers. comm.). Genetic contamination does not extend to the isolated Soledad Canyon area upstream (Buth and Crabtree 1982), where Greenfield et al. (1970) studied the biology of this species. This area is a possible refuge for *C. santaanae* since it is becoming rare in its native range. This population also became much reduced with the drought. A few Santa Ana suckers were introduced accidentally into River Springs, Mono County in 1940, but did not become established (Miller 1968).

20. Xyrauchen texanus (Abbott). Razorback sucker. State and federally endangered. The remaining, rare large individuals are believed to be old members of a dwindling, non-reproductive, remnant stock (Tyus 1991a; Minckley, Marsh et al. 1991). Buth et al. (1987) reported fertilized eggs collected from Senator Wash Reservoir, Imperial County in March, 1983 and raised in aquaria. No recruitment of wild-spawned fish occurs, probably because of predation by introduced fishes (Tyus 1991a). Razorback suckers (then called humpback sucker) occurred in commercial quantities in the Salton Sea until about 1930 (Croker 1934).

Cyprinodontidae

21. Cyprinodon macularius Baird and Girard. Desert pupfish. State and federally endangered. This species has declined precipitously in the last 10-15 years apparently due to the introduction of tilapias into the lower Colorado River including the Salton Sea (Bolster 1990c). Schoenherr (1988) believed only two native populations remained in California, in lower San Felipe and Salt creeks, Imperial County. Subsequent surveys (Lau and Boehm 1991) disclosed populations at more than 50 localities in canals on the southern and eastern margins of the Salton Sea, probably maintained by the habitat heterogeneity described earlier by Schoenherr (1979). A few other populations exist in Arizona and Mexico (Minckley Meffe et al. 1991). Fish were unsuccessfully introduced to the Owens Valley in 1940 (Miller 1968).

22. Cyprinodon nevadensis nevadensis Eigenmann and Eigenmann. Saratoga Springs pupfish. State subspecies of special concern. Known only from Saratoga Springs, southeastern corner Death Valley National Monument, Inyo County, California (Soltz and Naiman 1978; Minckley, Meffe et al. 1991). Fish were unsuccessfully introduced into Lucerne Valley Reservoir, San Bernardino County in 1939 and 1940 (Miller 1968).

23. Cyprinodon nevadensis amargosae Miller. Amargosa pupfish. State special concern. Known only in the Amargosa River from Tecopa down through Amargosa Canyon and for about 1.5 km northwest of Saratoga Springs (Soltz and Naiman 1978; Minckley et al. 1991). Miller (1968) noted the successful introduction of this species into River Springs, Mono County from 1940 to 1965, as well as its unsuccessful introduction to six other sites.

24. *Cyprinodon nevadensis shoshone* Miller. Shoshone pupfish. State special concern. Known only from Shoshone Spring at Shoshone, Inyo County, California according to Castleberry et al. (1990) and Minckley, Meffe et al. (1991), who noted that mosquitofish, *Gambusia affinis,* far outnumbered pupfish at this locality. Since then a captive population has been reintroduced into a refugium pond constructed at the headspring of this locality (Susan Ellis, pers. comm.). An unsuccessful introduction was made into the Old Borax Works, Death Valley in 1939 (Miller 1968).

25. *Cyprinodon nevadensis calidae* Miller. Tecopa pupfish. Extinct. Formerly occupied the outlets of North and South Tecopa Hot Springs. Alteration of the spring for bathing and upstream invasion of Armagosa pupfish led to the extinction of this form (Soltz and Naiman 1978; Minckley, Meffe et al. 1991).

26. *Cyprinodon radiosus* Miller. Owens pupfish. State and federally endangered. Fish Slough and surrounding marsh, west of Bishop, Inyo County (Owens Valley Native Fish Sanctuary), Marvin's Marsh, and BLM Spring are three relatively natural marshes and springs still holding Owens pupfish. These are augmented by four artificial Owens Valley sites (Bolster 1990d). This fish was considered effective in controlling mosquitos (Kennedy 1916) until habitat modification and introduced fishes reduced its numbers. Believed to be extinct, it was rediscovered in the 1940s and with great effort is now maintained in the refuges noted above (Miller and Pister 1971; Minckley, Meffe et al. 1991).

27. *Cyprinodon salinus salinus* Miller. Salt Creek pupfish. State subspecies of special concern. Known only from Salt Creek and associated marshes for about 1.5 to 6 km below McLean Springs, Inyo County, depending on rainfall (Soltz and Naiman 1978; Minckley, Meffe et al. 1991). It was successfully introduced into River Spring in Adobe Valley, Inyo County from 1945 to at least 1965 (Miller 1968).

28. *Cyprinodon salinus milleri* La Bounty and Deacon. Cottonball Marsh pupfish. State threatened. Known only from Cottonball Marsh, Inyo County, California (Soltz and Naiman 1978; Minckley, Meffe et al. 1991).

Fundulidae

29. *Fundulus parvipinnis* Girard. California killifish. Fish are common in most larger bays and marshes north to Goleta Slough, and occur disjunctly in Morro Bay where they are also common. None are known from Gaviota, Jalama, San Antonio or San Luis Obispo creeks, or the Santa Maria and Santa Ynez rivers, the most likely places for them to occur between Morro Bay and Goleta Slough. The record from Monterey Bay (Moyle 1976a) is considered an introduction that did not survive or a misidentification (Swift 1980d). Subsequent surveys did not find them in the Elkhorn Slough area (Yoklavich et al. 1991). Eigenmann's (1892) assertion that this species was abundant in Lake Elsinore is otherwise unsubstantiated. Freshwater records are numerous (Hubbs 1916; Miller 1939, 1943; Moyle 1976a); new freshwater records (LACM) are from Ventura River, Malibu Creek, Santa Clara River, and Ballona Marsh.

California killifish were sold for bait on the lower Colorado River in 1951 (Miller 1952). About 150 California killifish were placed in Lake Elsinore in April 1954 (CFG PAD) and did not survive. One or possibly two specimens were collected from the Salton Sea in March and April 1968, reportedly a release of fish being sold for bait four years previously (CFG JAS).

Poecilidae

30. *Poeciliopsis occidentalis* (Baird and Girard). Gila topminnow. Extinct in California, federally endangered. Hubbs et al. (1979) record this species from California, presumably along the Colorado River, but it has not been collected in California since before 1900. Moyle (1976a) and Shapavalov et al. (1981) did not include it as part of the California fauna.

Gasterosteidae

31. *Gasterosteus aculeatus aculeatus* Linnaeus. Fully armored threespine stickleback. Fully armored, non-anadromous threespine stickleback have been recorded south to San Luis Obispo Creek, San Luis Obispo County by Baumgartner and Bell (1984). They found the frequency of fully armored fish to increase northward, associated with decreasing mean January temperatures and increasing precipitation. Baumgartner and Bell (1984) and Miller and Hubbs (1969) thought anadromous sticklebacks did not occur in our area. Miller and Hubbs (1969) reported a collection from the Big Sur River that might represent the marine "trachurus" form.

32. *Gasterosteus aculeatus microcephalus* Girard. Partially armored threespine stickleback. This subspecies appears to be widespread north of Point Conception, but to the south has been declining rapidly during the last five years. Many local populations no longer exist, and it is possible many of these are gone permanently. South of the Los Angeles Basin, the only recent records (1991 onward) are from Trabuco Creek, in and below O'Neill Park; upper San Juan Creek near the mouths of Hot Spring and Cold Spring canyons; upper reaches of Bell Canyon on Starr Ranch (all in the San Juan Creek drainage); South Fork of the San Jacinto River below Lake Hemet, San Diego County, and a one kilometer reach of the Rio San Domingo in Baja California. Miller and Hubbs (1969) and Ross (1973) found slight morphological distinctions for San Juan Creek fish when compared to others south of the Los Angeles Basin.

Gasterosteus a. *microcephalus* apparently was absent from the Los Angeles Basin where G. a. *williamsoni* was present, but the lack of early coastal collections make any conclusion equivocal (Ross 1973; Miller and Hubbs 1969; Bell 1978; Swift 1989; Swift et al. 1989). Except for the steep Big Sur area, sticklebacks are continuously distributed in lowland areas north of Point Conception. South of the Santa Ynez drainage (which lies just north of Pt. Conception), localities are discontinuous (north to south); Gaviota Creek, lagoon in Carpenteria, Ventura River, Santa Clara River, Calleguas Creek, San Juan Creek, San Mateo Creek, Santa Margarita River, San Luis Rey River, and four localities in northern Baja California (Miller and Hubbs 1969). In addition fish occurred in Wildcat Canyon a few miles south of a locality at Tijuana Hot Springs (Smith 1883). These two records may be the same as those noted from San Diego by Eigenmann (1887); no other authors have reported them there. Thus several distributional gaps have always existed south of Point Conception (Fig. 11), in steep small streams lacking low gradient habitat, and in all but extreme northern and southern San Diego County.

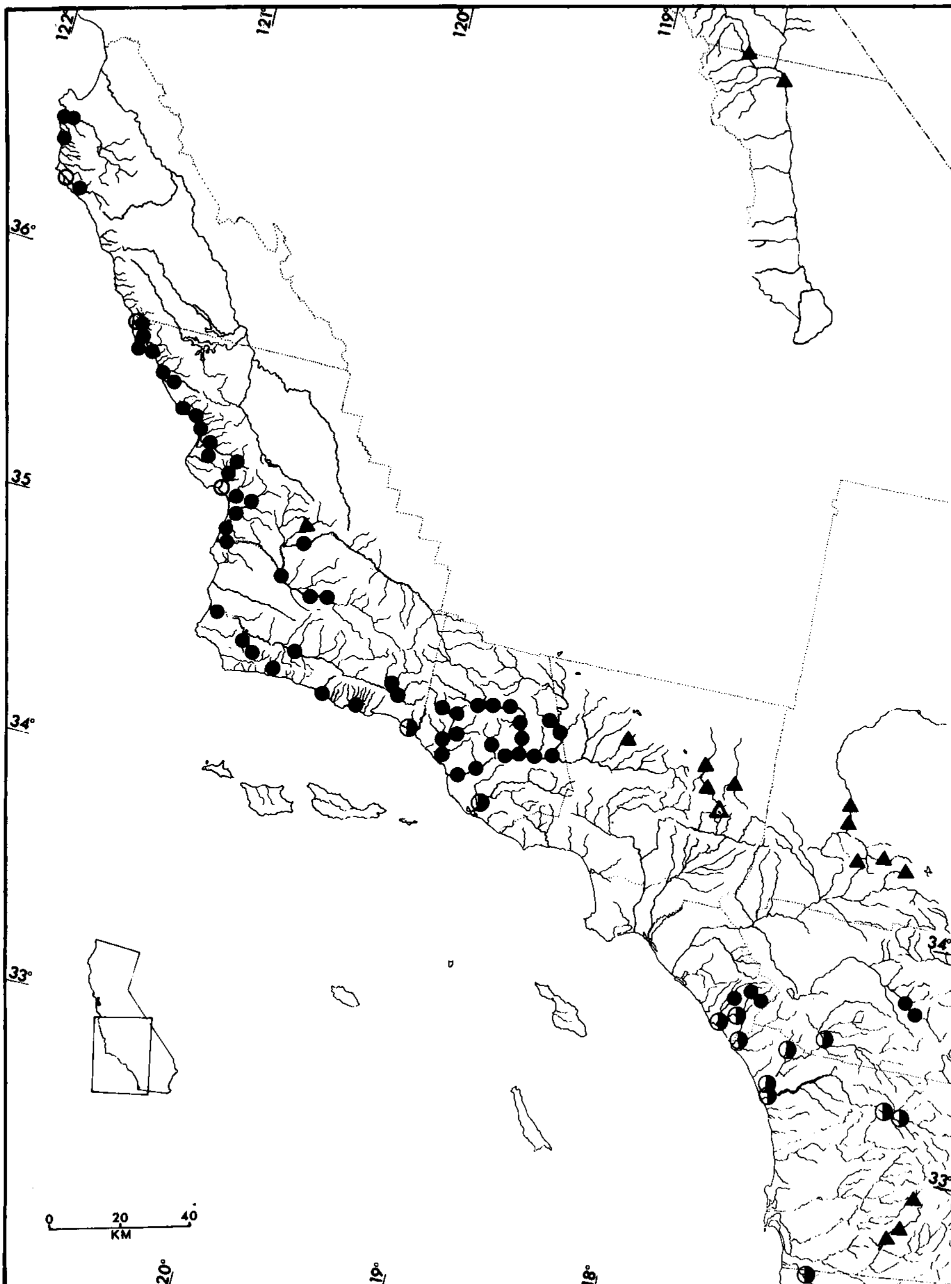


Fig. 11. Distribution of fully and partially armored stickleback, *Gasterosteus aculeatus,* in southern California. Open circles native fully armored fish; black circles native partially armored fish from 1970 onward; half circles native records of partially armored fish before 1970; black triangles viable introduced populations of partially armored fish; open triangles extirpated introduced populations of partially armored fish. See figures 1-3, 5 for stream names.

This taxon has been introduced widely, and native sticklebacks were promoted for mosquito control in the early 1900s (Scofield 1915; Hubbs 1919). In the late 1930s and 1940s sticklebacks from the Fillmore area became established in Fillmore and Mohave River hatchery ponds, and were introduced inadvertently with trout plants. Established populations have been recorded in Dos Pueblos Canyon, Santa Barbara County; Big and Little Rock creeks, Holcomb Creek, and Lake Arrowhead, Mohave River drainage; Big Bear Lake, San Bernardino County; Sweetwater River, and Pine Creek (tributary to Otay River), San Diego County (Fig. 11); June Lake, Mono County; and upper and lower Owens River downstream to Bishop, Mono and Inyo counties. A few were found among fishes eradicated from Crystal Lake, San Gabriel River drainage in the 1940s and 1950s (CFG LB). These sites had no previous records of sticklebacks. Bell (1982) believed the Holcomb Creek fish were native, but Buth (1984) and Haglund and Buth (1988) showed they were electrophoretically similar to fish from the lower Sespe Creek (near Fillmore Hatchery). Fish undoubtedly were placed in other localities already containing native stickleback populations. The extralimital distribution of arroyo chubs (Fig. 8), distributed by trout fishermen, may serve as a rough guide to the introductions of sticklebacks. Some introductions were documented previously by Ross (1973), Miller and Hubbs (1969), Bell (1982), Haglund and Buth (1988), and Hendrickson and Brooks (1991).

33. *Gasterosteus aculeatus williamsoni* Girard. Unarmored threespine stickleback. State and federally endangered. This subspecies, originally widespread and abundant in the Los Angeles Basin (Culver and Hubbs 1917; George 1927), is restricted to a 14 km stretch of the Soledad Canyon portion of the upper Santa Clara River and upper San Francisquito Canyon (U.S. Fish and Wildlife Service 1985; Buth 1984; Haglund and Buth 1988; Fig. 12). It is distinctive morphologically and electrophoretically (Miller and Hubbs 1969; Bell and Richkind 1981; Buth 1984; Buth et al. 1984). Unplated sticklebacks apparently native in the upper Huasna River and its tributary Alamo Creek (Santa Maria River drainage) and introduced into the Mohave River drainage (both based on pre-1940 collections) were eliminated by subsequent introductions of partially armored fish (Miller and Hubbs 1969; Buth 1984). Those from upper Piru Creek, Elizabeth Lake Canyon, and Castaic Creek (Miller and Hubbs 1969) have disappeared (U.S. Fish and Wildlife Service 1985), and a population was recently discovered in Escondido Canyon tributary to Agua Dulce Canyon in September 1992 (Linda Pardy, Jonathan Baskin, pers. comm.). This population is only one to two kilometers upstream of the main extant population in Soledad Canyon.

Gasterosteus a. williamsoni has been absent from the Los Angeles Basin since the early 1950s. The last records were in 1925 (Los Angeles River, LACM 982, 987), 1951 (San Gabriel River, Mission Creek, Whittier Narrows, CFG RB, PAD), and 1947 (Santa Ana River, Lake Norco, DFG WAE). In 1972 and 1973, 458 fish from upper Soledad Canyon were placed in upper San Felipe Creek and Sentenac Canyon, Salton Sea drainage, San Diego County. These did well until the winter of 1979-1980, after which they disappeared. In 1981, 180 more fish were placed in the stream, and these have survived through September of 1990. Unsuccessful transplants have been made of fish from upper Soledad Canyon: in July 1975 to Malibu Creek in the vicinity of Tapia Park, in September 1973 to the West Fork of the San Gabriel River just below Cogswell Reservoir, in 1982

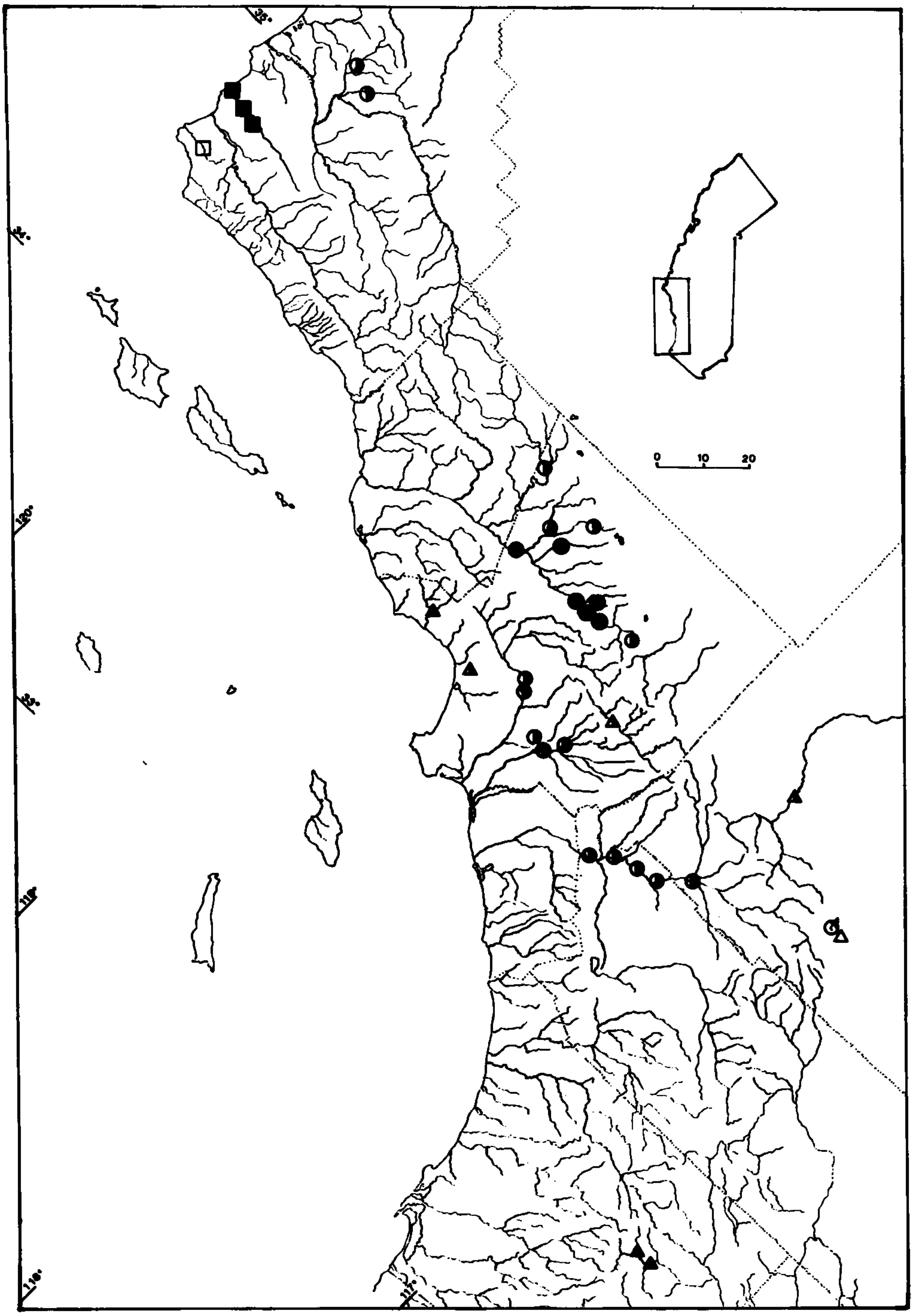


Fig. 12. Distribution of the forms of **unplated stickleback**, *Gasterosteus aculeatus,* in southern California. Black circles native records of *Gasterosteus aculeatus williamsoni* from 1960 onward; half circles before 1960; black triangles viable introduced populations; half blackened triangles extirpated introductions. Black squares San Antonio Creek stickleback; open squares introduced viable popu-

about 300 fish to a small artificial stream in the Botanical Garden on the campus of the University of California, Los Angeles (LACM W82-13), and in 1972 into Piru Pond, Ventura County (CFG LB UTSRT; Wells et al. 1975).

34. *Gasterosteus aculeatus.* San Antonio Creek stickleback. Status undetermined. This taxon is known only from the lower 6 to 8 km of San Antonio Creek, Vandenberg Air Force Base, Santa Barbara County (Fig. 12). It is also low-plated and originally was considered *G. a. wilhamsoni* (Irwin and Soltz 1982; U.S. Fish and Wildlife Service 1985), based on morphology. Electrophoretically it does not differ significantly from local populations of the subspecies *G. a. microcephalus* (Buth 1984; Haglund and Buth 1988). It is distinct morphologically, and such evolutionary novelties are the reason the population is important to preserve. Fish from San Antonio Creek (about 850) were planted into Honda Canyon on Vandenberg Air Force Base in 1984 and survive today (CFG UTSRT).

35. *Gasterosteus aculeatus.* Shay Creek stickleback. This population is low-plated and distinctive electrophoretically (Haglund and Buth 1988). It was recently discovered (1984) in the Baldwin Lake drainage just east of Big Bear Lake (Fig. 12) and is restricted to two or three large pools and interconnecting meadow (CFG UTSRT). It has been transplanted to one other site, Sugarloaf Meadows, 7 miles airline southeast of Baldwin Lake in the San Bernardino Mountains. This form is certainly one of the strongest candidates for immediate protection among the taxa covered here.

Because all native southern California sticklebacks known are from lower elevations, this may be an introduced population. Shebley (1927) participated in the first introductions of fish into the Big Bear area in 1891-1892, transporting rainbow trout by muleback on the old trail up the Santa Ana River. Although most southern California mountains are highly eroded, Norris and Webb (1990) note that the San Bernardino Mountains uncharacteristically retain a significant rolling upland plateau. Pre-historical continuity of this feature possibly provided habitat for the survival of native sticklebacks as the mountains were uplifted.

Moyle et al. (1989) and Moyle and Williams (1990) use the subspecific combination *G. a. santaanae* Regan (1909) for this fish Regan described from fish taken from the Santa Ana River, Riverside. Shay Creek is not in the Santa Ana River drainage today, and it is premature to assign this name until adequate comparisons are made. Thus we only use the vernacular, Shay Creek stickleback.

Cottidae

36. *Cottus asper* Richardson. Coastal prickly sculpin. This sculpin is widespread in coastal streams north of Point Conception where juveniles are common in coastal lagoons (Fig. 13). Farther southward only four localities are known: Santa Anita Canyon (LACM 36657-2), Gaviota Creek (LACM 35423-1), Arroyo Quemado (SBMNH), and lower Ventura River (UMMZ 132891). The first three date from 1975, and the last from 1938. The few, rarely collected, large individuals indicate that larvae stray southward and colonize, but do not reproduce. Larval *Cottus asper* occur in near-shore plankton farther north (Matarese et al. 1989).

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lations. Open circle Shay Creek stickleback; open triangle viable introduced population. See Figs. 1-3 for stream names.

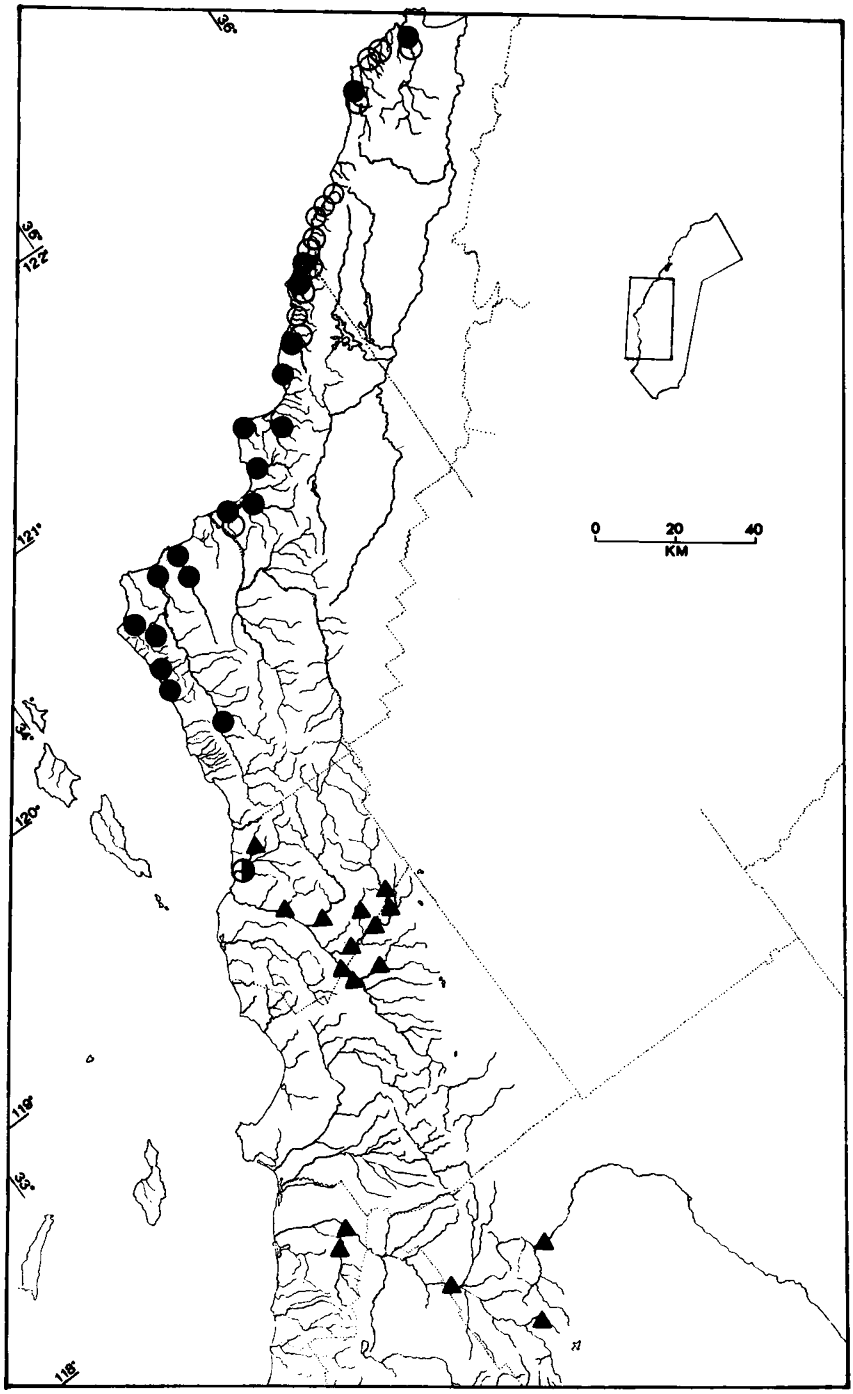

Fig. 13. Distribution of the species of *Cottus* in coastal southern California. Black circles native records of coastal prickly sculpin, *C. asper* from 1970 onward; half circle records before 1970; black triangles introduced inland prickly sculpin, *Cottus asper;* circles coastrange sculpin, *C. aleuticus.* See Figs. 1-3 for stream names.

Recent single collections from reservoirs, Lake Cachuma in 1975 and Lake Casitas in 1989, probably are introduced, but could possibly be native coastal forms trapped on the upstream side of dams.

Hubbs (1921) and Kresja (1967a) note variation in the degree of prickling in the vicinity of San Luis Obispo. Juveniles of the coastal form can have half or more of the lateral sides of the body with prickles. These are lost with growth in coastal prickly sculpin. Adults of the inland form (discussed below) retain prickling on the body. This is the only catadromous taxon in California, namely that descends from streams into tidal or lagoonal waters to spawn (Kresja 1967b). Prickly sculpin (and threespine stickleback) have been recorded from only a few localities between the Carmel River and Arroyo de la Cruz (Fig. 13); these larger streams have lagoon development, apparently a requirement for *C. asper*. Hubbs (1921) noted that Jordan's (1895) record of *C. gulosus* from San Luis Obispo Creek was based on C. *asper* (see account of *C. aleuticus* below).

37. Cottus aleuticus Gilbert. Coastrange sculpin. This sculpin has been recorded south to Oso Flaco Creek, Santa Barbara County (LACM 35163-1), extending the range southward from "a stream between San Simeon and Piedras Blancas" (Hubbs 1921) (Fig. 13). Despite the fact Matarese et al. (1989) thought the larvae may not occur in marine plankton, it occurs in many coastal streams, even several steep ones that lack *C. asper*. No specimens have been found to verify various records of riffle sculpin, *Cottus gulosus*, from coastal streams of San Luis Obispo County (Barclay 1975; CFG records); we believe all such records were based on misidentifications of coastrange sculpins. The latter keys out with *C. gulosus* in Robins and Miller (1957).

Gobiidae

38. Eucyclogobius newberryi (Girard). Tidewater goby. Petitioned for federal threatened status. In our area 28 localities remain and more of these may disappear with the continuing drought. Extant localities are (north to south): Arroyo Laguna (Oak Knoll Creek), Tortuga Canyon, Arroyo del Puerto, Little Pico, Pico, San Simeon, Santa Rosa, Villa, San Geronimo, Cayucos, Pismo creeks, and Santa Maria River (San Luis Obispo County), Shuman Canyon, San Antonio Creek, Santa Ynez River, Jalama Creek, Canadas de Cojo, Las Agujas, Santa Anita, and Alegria, Gaviota Creek, and Refugio and Bell canyons (Santa Barbara County), Ventura and Santa Clara rivers (Ventura County), Malibu Creek, re-established 1991 (Los Angeles County), San Onofre Creek, Las Pulgas Canyon, and Santa Margarita River (San Diego County). In September 1992 a few were seen in Cockleburr Canyon (between Santa Margarita and Las Pulgas), a site that lacked them or was dry on many previous visits since 1980. Only fourteen localities exist south of Point Conception.

Tidewater gobies have disappeared from many localities, and rarely recolonize (Swift et al. 1989). Small lagoons often have only a few adult fish, thus lacking continuously established populations, such as Arroyo de Corral and Leffingwell and Willow creeks in San Luis Obispo County. In 1989 fish were newly collected from Refugio Creek (Tom Taylor, in litt.) and lower San Luis Obispo Creek (Tim Pafford, pers. comm., LACM 44824-1). None had been previously taken at these localities since 1916 despite collecting by many individuals in the intervening years.

Swift et al. (1989) suggested re-introducing fish to localities where they formerly occurred, and in June 1991, 52 adults from the mouth of the Ventura River were placed in Malibu Lagoon by the Topanga—Las Virgines Resources Conservation District and California Department of Parks and Recreation. In August about 75 mostly smaller fish were collected. In April 1992 and April 1993, several adults that had overwintered were collected and in August 1992 many fish were seen in the lagoon, indicating successful establishment.

Estuarine Fishes

Carcharhinidae

1. *Carcharhinus leucas* (Valenciennes). Bull shark. Miller and Lea (1976) report this species from southern Caifornia, based on Fry and Roedel (1945) and Rosenblatt and Baldwin (1958). Compagno (1984) did not record it north of southern Baja California, but Eschmeyer et al. (1983) state that it possibly reached southern California. Robins et al. (1991) accept it as recorded from the Pacific coast of the United States. Elsewhere in the world this species is closely tied to fresh and low salinity water, and the early demise of this habitat in southern California may have led to its disappearance here.

Elopidae

2. *Elops affinis* Regan. Machete. Minckley (1973) and Swift (1980a) summarized the marine and freshwater records from southern California. A fish (43 gm) taken in October 1980 (Colorado River below the confluence of the Gila River) was listed as an angling size record for the state of Arizona (Sport Fishing Institute Bulletin, Oct.—Nov., 1980, p. 8). Thus this species is a regular, if rare (or at least rarely collected), member of the fauna of the lower Colorado River in California. Fish have not been recorded upstream of Laguna Dam since the 1940s. All freshwater records are from the Colorado River and the Salton Sea, although marine records exist for coastal Ventura (Swift 1980a; Fitch and Schultz 1978) and San Diego (R. N. Lea, pers. comm.) counties.

Clupeidae

3. *Clupea pallasi* Valenciennes. Pacific herring. Pacific herring spawn in low salinity water in mid-winter in southern California; populations have been recorded from Morro Bay, San Luis Obispo Creek, Santa Ynez River lagoon, Goleta Slough, San Diego Bay, and are suspected in Los Angeles Harbor (Miller and Schmidtke 1956; Spratt 1981; Milton Love, pers. comm.). Miller and Schmidtke (1956) note that Morro Bay and San Luis Obispo Creek fish are larger than others in California.

Engraulidae

4. *Engraulis mordax* Girard. Northern anchovy. Common in bays and estuaries, the northern anchovy only rarely enters fresh water. Two records known to us are those of Hubbs (in Lane 1977a) and one juvenile taken in upper Santa Margarita lagoon on 23 December 1983 (UT 30.8).

5. *Anchoa delicatissima* (Girard). Slough anchovy. This species has often been reported from low salinity and fresh water in southern California (Allen 1982), and occurs northward to Los Angeles Harbor.

6. *Anchoa compressa* (Girard). Deepbody anchovy. This species is also abundant in bays and harbors north to Morro Bay and also from fresh water (Horn 1981; Allen 1982). A hiatus in distribution occurs between Mugu Lagoon and Morro Bay.

Syngnathidae

7. *Syngnathus auliscus* (Swain). Barred pipefish. This tropical species occurs north to the Santa Barbara channel but is frequent only in southern San Diego Bay (Fritzsche 1980) and Newport Bay (LACM, 7 collections). Starks and Morris (1906) note that it favors more upstream, lower salinity locations than *S. leptorhynchus.*

8. *Syngnathus leptorhynchus* Girard. Bay pipefish. This is the only other species of pipefish that can be taken in brackish or fresh water in our area. Freshwater records include Morro Bay and Malibu lagoon. This species was once common in many bays but is much more scarce in Anaheim Bay than formerly (Lane 1977a) and possibly is declining.

Atherinidae

9. *Atherinops affinis* (Ayres). Topsmelt. Topsmelt enter fresh water in the upper portions of coastal lagoons and estuaries, particularly in spring when spawning in waters of lowered salinity. They dominate southern California estuaries numerically and in biomass (Horn 1981, 1988; Allen 1982; Horn and Allen 1985), but possibly were much less common originally (Lane 1977a). At many localities north of Point Conception topsmelt are found primarily near the mouths of estuaries and lagoons except in spring when they move inland to spawn in lower salinity waters (Schultz 1934).

10. *Leuresthes tenuis* (Ayres). Grunion. Occasional fish are washed over the barrier sand bars into coastal lagoons where they can be collected in brackish and fresh water. Some early observers felt they tended to spawn near stream mouths, but this was discounted by Hubbs (1916), Thompson (1919) and Walker (1952). Most beaches occur, however, where stream and river mouths deposit sand and where originally much more freshwater influence existed.

Hemirhamphidae

11. *Hyporhamphus rosae* (Jordan and Gilbert). California halfbeak. This species also was recorded as common in San Diego and Mission bays near the turn of the century (Eigenmann 1892), and has been rarely collected since (Miller and Lea 1976). It is known from low salinity and fresh water farther south (Miller 1945b; Castro-Aguirre 1978) as *H. patris,* now a synonym of *H. rosae* (Collette et al. 1992).

Embiotocidae

12. *Cymatogaster aggregata* Gibbons. Shiner surfperch. This species is common in bays and estuaries in southern California. During the breeding season in spring, it enters the warmer estuaries and lagoons, often of lowered salinities (Odenweller 1977; Moyle 1976a).

Cottidae

13. *Leptocottus armatus* Girard. Staghorn sculpin. This species is ubiquitous in the mouths of streams throughout our area, particularly in mid-winter when the young-of-the-year invade and coastal lagoons are mostly or completely dominated by freshwater (Tasto 1977; Moyle 1976a; Horn 1981; LACM records).

Mugulidae

14. *Mugil cephalus* Linnaeus. Striped mullet. Silvery young-of-the-year individuals are often taken from December to March in coastal streams tributary to lagoons and bays (Eigenmann 1892; Horn and Allen 1985). We know of such fish taken as far north as the Santa Clara River (LACM 45110-1), and adults have been taken in marine waters north to San Francisco Bay (Eschmeyer et al. 1983). In December 1972 twelve juveniles were taken in the Santa Ana River at Featherly Park about 35 km upstream from the mouth in the ocean (LACM 35223-2; 22-26 mm SL). Individuals of all sizes occur today in the lower Colorado River (Minckley 1973); commercial quantities occurred in the Salton Sea until about 1930 (Croker 1934), and adults were taken through the 1970s (CFG JAS). In March 1966 about 50 "half-pound" striped mullet were placed in Puddingstone Reservoir, Los Angeles County, and a few were caught up to two years later (CFG LB).

Paralichthyidae

15. *Paralichthys californicus* (Ayres). California halibut. This species depends on estuarine conditions for the first few years of life (Haaker 1977; Allen 1988; Kramer 1991a, b, 1992). It occurs primarily in larger estuaries with tidal openings, but we have records of individual juveniles from Ballona Marsh and Malibu Lagoon (LACM).

Pleuronectidae

16. *Hypsopsetta guttulata* (Girard). Diamond turbot. Young and juveniles of this species are mostly taken in estuaries which it uses as nursery areas (Lane 1977b; Kramer 1991b). It is more numerous than starry flounder in southern California estuaries; all of our records of young-of-the-year and juveniles in low salinity water are south of Point Conception.

17. *Platichthys stellatus* (Pallas). Starry flounder. Juveniles of this species invade fresh or low salinity water in winter and early spring. Most such records are north of Point Conception, but the southernmost is from Goleta Slough, Santa Barbara County in the late 1960s (Milton Love, pers. comm.).

Sciaenidae

18. *Cynoscion parvipinnis* Ayres. Shortfin corvina. This species was collected in San Diego and Mission bays until about 1925 (Follett 1976), and again in 1991 (R. N. Lea, pers. comm., SIO material). Eigenmann (1892) noted its probable occurrence in the lower Sweetwater River in San Diego County. It is known from low salinity and fresh water farther south in Mexico (Castro-Aguirre 1978). *Cynoscion parvipinnis* was introduced into the Salton Sea from the Gulf of California from 1953 to 1955 (Walker et al. 1961), where it established a breeding population for a number of years (Shapavalov et al. 1981).

Eleotridae

19. Eleotris picta Kner and Steindachner. Spotted sleeper. Recorded once in 1953 in the lower Colorado River and not taken since (Hubbs 1953; Minckley 1973).

Gobiidae

20. Gillichthys mirabilis Cooper. Mudsucker. This goby is often taken in fresh water in the upper parts of bays and sloughs and can tolerate a wide range of salinity. One juvenile (LACM 38569-1) was taken from the stomach of a garter snake, *Thamnophis c. atratus,* from Arroyo de Corral in northern San Luis Obispo County (Marc Hayes, pers. comm.).

Mudsuckers have long been used as live bait both in fresh and salt water. Dealers obtain fish from coastal southern California and the outer coast of Baja California near San Quintin (Miller 1952; Walker et al. 1961; Turner and Sexsmith 1967). Fish from San Diego Bay were introduced to the Salton Sea by 1931 (California Department of Fish and Game 1931). Miller (1952) recognized two subspecies of *G. mirabilis.* He noted the only California record of the Gulf of California form, *G. m. detrusus* Gilbert and Scofield, was based on dead specimens from a pelican rookery near the Salton Sea. Later Barlow (1963) did not recognize subspecies because of wide variation in many characters. Probably both Gulf of California fish imported to California and southern California fish have been released in the lower Colorado River, and into some southern California bays and estuaries. Fish in lower Salt Creek near the Salton Sea successfully reproduce (CFG JAS). *Gillichthys seta* Ginsburg, endemic to the upper Gulf of California, was also introduced once into the Salton Sea (Walker et al. 1961).

21. Clevelandia ios (Jordan and Gilbert). Arrow goby. Lane (1977a) recorded the early collections of Carl Hubbs (1916) from fresh or low salinity water in upper Anaheim Bay, and other southern California freshwater records are from the mouths of the Santa Clara (LACM 45110-1) and Santa Margarita (UT 122.36) rivers and Malibu Creek.

22. Gobionellus sagittula (Gunther). Longtail goby. Only a few early records exist for this species in San Diego Bay, as *G. longicauda* (Starks and Morris 1906), and it apparently is extirpated in California.

Scombridae

23. Scomberomorus concolor (Lockington). Gulf sierra. Extirpated in California. This species was last recorded in the early 1950s and disappeared soon thereafter (Fitch and Flechsig 1949; Fitch 1952). Now only known from the upper Gulf of California (Collette and Nauen 1983). Other species in the genus are estuarine and its disappearance may be due to alteration of local estuaries.

Introduced Species

Acipenseridae

1. *Acipenser transmontanus* Richardson. White sturgeon. In March 1967, 39 white sturgeon were planted in Lake Havasu, Colorado River from San Pablo Bay, California (CFG LB). Several more were released in 1968 (Minckley 1973). In June 1967 and March 1969 single fish were taken downstream at Imperial

Dam. Another was caught at the mouth of the Bill Williams River, Arizona in 1976 (Los Angeles Times, 27 March 1981, Pt. III, p. 16). No evidence of reproduction has been found. Over 200 white sturgeon (from the Arrowhead Fishery in Red Bluff) were planted in Irvine Lake and the Santa Ana River lakes in September 1987 (Los Angeles Times, 18 September 1987, Pt. III, p. 12) and several have been captured since.

Osmeridae

2. *Hypomesus nipponensis* McAllister. Wakasagi. This species was introduced into Big Bear Lake in 1959, and several hundred were recorded during chemical treatment of the lake in the fall of 1960 (Wales 1962). None have been recorded since.

Esocidae

3. *Esox lucius* Linnaeus. Northern pike. Shebley (1917a) and Smith (1896) note that in 1891, 400 yearling northern pike were placed in Lake Cuyamaca, San Diego County, and were still common in January 1896. Smith (1896) and Shapavalov et al. (1959) provide evidence that some (or possibly all) of these fish were *E. americanus americanus* Gmelin, redfin pickerel.

Salmonidae

4. *Oncorhynchus clarki* (Richardson). Cutthroat trout. *Salmo evermanni* Jordan and Grinnell from the San Gorgonio Mountains was based on introduced Lahontan cutthroat trout, *O. c. henshawi* (Gill and Jordan), that were placed in several tributaries of the Santa Ana River before 1900 (Benson and Behnke 1961). This population survived into the 1930s in the upper south fork of the Santa Ana River below Dollar Lake (R. Croker, in litt.; Miller 1950; Needham and Gard 1963). Gold et al. (1978) noted the survival of pure Colorado cutthroat trout, *O. c. pleuriticus* (Cope), in the Williamson Lakes, Owens River drainage after their introduction in 1931. Most likely, several early literature records of this subspecies from the lower Colorado River and the Salton Sea were misidentified rainbow trout introduced earlier; straying downstream of cutthroat trout was considered almost impossible (Dill 1944; Miller 1950; Minckley 1973).

5. *Oncorhynchus aguabonita* (Jordan). Golden trout. Widely introduced into high lakes in the eastern Sierra Nevada Mountains (Moyle 1976a), golden trout were also placed into the upper Santa Ana River in 1918 (Shebley 1919), but were not recorded subsequently.

6. *Oncorhynchus kisutch* (Walbaum). Silver or coho salmon. Hatchery raised young and juvenile coho salmon have been introduced into southern California reservoirs, estuaries, and the Salton Sea from as early as 1935 (Walker et al. 1961; CFG LB). Some have been caught in coastal waters, but no returns to freshwater streams are known.

We have several verbal reports of a "salmon," in addition to steelhead trout, that entered southern California coastal streams prior to the 1950s. However, no well-authenticated records of wild fish entering fresh water south of Monterey Bay are known to us. Only this salmon species commonly enters spawning streams south of San Francisco Bay. All five species of Pacific salmon have been recorded southward at sea to between Los Angeles and northern Baja California (Hubbs

1946; Miller and Lea 1976; Eschmeyer et al. 1983). Given the large numbers at sea locally and the hatchery fish introduced into local estuaries it is surprising some have not been taken in local streams.

7. *Oncorhynchus tshawytscha* (Walbaum). Chinook salmon. Since 1984 young chinook salmon from outside California have been raised and released in lower San Luis Obispo Creek. This effort has created some returns of adult fish from the sea, but to date depends on artificial propagation (CFG; San Luis Obispo County Telegram Tribune, 12 February 1991, p. A-3).

Jordan's (1895) record for king (now called chinook) salmon in San Luis Obispo Creek was probably based on steelhead (Hubbs 1946). Jordan and Gilbert's (1883) early contention that the southern limit of king salmon was the Ventura River was probably based on Jordan and Henshaw (1878) (quoted by Stone 1884) who visited fish markets, talked to local fishermen, and did not actually secure specimens from fresh water.

8. *Oncorhynchus nerka* (Walbaum). Kokanee salmon. This species was introduced into Lake Arrowhead in the late 1950s and supported a fishery through the 1960s (CFG LB; R. Croker, pers. comm)

9. *Salmo trutta* Linnaeus. Brown trout. Although as widely introduced as the other trout, and well established and famous in the Owens River since before 1900, brown trout have not fared as well in desert streams and coastal drainages farther south. Fish were even placed in reservoirs on Catalina Island (Shebley 1925). Since 1970, authentic verbal and/or specimen records of this introduced fish exist for Piru Creek, the Arroyo Seco-Bear Creek drainage, Deep Creek-Mohave drainage, Ice House Canyon (San Antonio Creek drainage, Los Angeles-San Bernardino county line), and the upper Santa Ana River including Bear Creek. Reproduction by brown trout has been documented for Deep Creek and the Santa Ana River and tributaries, where rainbow trout are very rare or non-existent (Deinstadt et al. 1988). These authors demonstrate the virtual absence of brown trout where rainbows are abundant in Piru Creek and the West Fork of the San Gabriel River. Before 1938 more streams supported reproducing populations of brown trout, such as the upper San Gabriel River, Santa Anita Canyon, Fish Canyon, and Holy Jim Canyon (Trabuco Creek drainage). After the severe floods of 1938-1939 many of these populations diminished or disappeared.

10. *Salvelinus fontinalis* (Walbaum). Brook trout. Thousands of fingerling brook trout were introduced in many mountainous streams in the 1877-1940 period (Smith 1896; CFG LB). These only became established in high lakes and creeks of the eastern Sierra Nevada mountains tributary to the Owens River.

Clupeidae

11. *Alosa sapidissima* (Wilson). American shad. This species was introduced into the lower Colorado River from 1884-1886 (Smith 1896) but did not survive (Minckley 1973). Marine records from coastal southern California date from 1880 (Los Angeles County, Smith 1896), and are known south to northern Baja California (Eschmeyer et al. 1983). American shad also should be expected with aqueduct water from central California.

12. *Dorosoma petenense* (Gunther). Threadfin shad. The original introduction of this species from the Tennessee River into southern California was recorded by Kimsey (1954) and Shapavalov et al. (1959) (SIO H53-180 and 183). It also

is imported with Central Valley and Colorado River water. It occurs in freshwater lakes, reservoirs, larger rivers, and coastal bays and estuaries (Moyle 1976a), the lower Colorado River and, formerly, the Salton Sea (Walker et al. 1961; Minckley 1973).

Anguillidae

13. Anguilla australis Richardson. Shortfinned eel. Three specimens (LACM) of about three dozen noted by biologists between 1978 and 1986 came from Puddingstone Reservoir, Legg Lake, and lower Los Angeles River, Los Angeles County. The origin of these is not known, but many live eels were imported during this period (McCosker 1989; Williamson and Tabeta 1991). Williamson and Tabeta found no evidence for natural straying by *A. japonica* into the northeastern Pacific Ocean. McCosker reviewed California anguillid records, provided a key to the species most likely to be imported, and pointed out that freshwater eels probably would not successfully reproduce here. They may significantly prey on native fishes; *A. australis* greater than 50 cm are largely piscivorous in New Zealand (Ryan 1986).

Characidae

14. Astyanax mexicanus (Fillippi). Mexican tetra. This species was collected a few times in the lower Colorado River in 1950 (Minckley 1973) as releases of fishes sold for bait (Miller 1952).

Cyprinidae

15. Carassius auratus (Linnaeus). Goldfish. Goldfish have been known from California fresh waters since before 1900 (Moyle 1976a, b), and were widely used for bait (Dill 1944). They occur in reservoirs, ponds and lowland streams. The sources and times of arrival are not well documented, but Gill (1862) reported a collection from California taken a year or two earlier. They appeared in San Diego County reservoirs with the importation of Colorado River water (CFG LB).

16. Cyprinus carpio Linnaeus. Common carp. This species was imported from Germany in 1872 and Japan in 1877 (Shebley 1917a). It was abundant in the Owens River by 1891 (Gilbert 1893), and occurs in most major reservoirs and lowland portions of the larger rivers. It was commercially fished in many of the larger lakes and reservoirs until the 1960s (Davis 1963).

17. Ctenopharyngodon idella (Valenciennes). Grass carp. This species, well established in the central United States (Courtenay et al. 1984, 1986), was imported, discovered, and eradicated at one coastal southern California locality, Padre Juan Canyon, Ventura County in November 1975 (LACM 35498-1, 2). Since the late 1970s they have been widely introduced in the Imperial Valley (CFG LB, JAS; Thiery 1991). In April 1980 hybrids between this species and *Hypophthalmichthys nobilis,* bighead carp, were planted in several waterways in the Cochella Valley, and two were taken from Lake Cahuilla, Riverside County in April 1981 (CFG LB). In 1985 18,000 triploid grass carp were introduced in the Coachella Canal (Thiery 1991).

18. Gila bicolor obesa (Cope). Lahontan tui chub. Native to the Lahontan Basin, this chub has been widely introduced into the Owens drainage, where it has introgressed with the Owens chub (Miller 1973).

19. *Hesperoleucas symmetricus* (Baird and Girard). California roach. This species, possibly introduced into the Cuyama River (Miller 1945c), hybridizes with *Gila orcutti,* definitely introduced there (Miller 1945a; Greenfield and Greenfield 1972; Greenfield and Deckert 1973). The occurrence of *Rhinichthys* in this drainage lends support to Greenfield and Greenfield's (1972) contention that the dace and roach are native.

20. *Ptychocheilus grandis* (Ayres). Sacramento squawfish. This species, established before 1975 in Chorro and Los Osos creeks, tributaries to Morro Bay (Barclay 1975; Moyle 1980), occurs down to upper tidal areas of the bay. One specimen was taken in Lake Arrowhead in June 1966 (SIO66-75), and in 1988 from Pyramid Lake (CFB LB). The latter probably arrived with central California water. In the Eel River, introduced squawfish restrict habitat use by other native fishes (Brown and Moyle 1991).

21. *Lavinia exilicauda* Baird and Girard. Hitch. This species was reported from Pyramid Lake in 1984 (CFG DD), Lake Silverwood in 1988 (CFG FGH, LP), and one was taken in June 1992 at Pyramid Lake (LACM 45701-1). It is possibly established or at least a regular immigrant from central California. Miller (1952) reported hitch sold as bait in the lower Colorado River, and Kimsey and Fisk (1960) reported one collected in Ramer Lake, Imperial County. Hitch were collected in the spring of 1992 from isolated pools of Aliso Canyon, tributary to Santa Clara River in Soledad Canyon (LACM 45699-1), and thought to have been there for about 40 years (Tom Hale, pers. comm.).

22. *Orthodon microlepidotus* (Ayres). Blackfish. Blackfish were in Tweedy Lake in 1918 and by 1938 had spread into Munz and Elizabeth lakes and into Lake Hughes in northern Los Angeles County (CFG LB). These were eradicated in the early 1940s. One was taken in Echo Park Lake, Los Angeles in February 1984. The species has been established in the lower Santa Ana River below Prado Reservoir since about 1986. It is one of the few native Central Valley species to thrive in highly modified aquatic habitats (Jennings and Saiki 1990).

A specimen from Pyramid Lake taken in June 1992 has intermediate features and apparently is a hybrid with *Lavinia exilicauda* (LACM 45701-2), a combination first reported by Hopkirk (1974), and found to be common in San Luis Reservoir in central California by Moyle and Massingill (1981).

23. *Pogonichthys microlepidotus* Ayres. Splittail. One fish was reported taken in Lake Silverwood in February 1977 (CFG LB). The specimen was not kept, but the species would be expected to come in with aqueduct water.

24. *Notemigonus crysoleucas* (Mitchill). Golden shiner. This well known bait fish can be taken almost anywhere that permanent fresh water exists that is also utilized by fishermen. It arrived in 1891 in San Diego County and quickly became widespread (Hubbs 1919; Kimsey and Fisk 1964; Miller 1952). Since about 1980, bait farms outside California have raised rudd, *Scardinus erythrophthalmus* (Linnaeus), a minnow that closely resembles golden shiner. It has been distributed to 14 states, and wild captures have occurred in eight states (Burkhead and Williams 1991). Burkhead and Williams (1991) document hybridization between golden shiners and rudd. Since rudd are popular bait for striped bass, they will probably turn up in California.

25. *Cyprinella lutrensis* (Baird and Girard). Red shiner. Between 1948 and 1951 red shiners cultured near Blythe became established in the lower Colorado

River and Salton Sea areas (Hubbs 1954). About 100 were unsuccessfully introduced to Puddingstone Reservoir in 1955. Red shiners appeared in Big Tujunga Creek in 1983 and were established by August 1985 (DFG DD; Jennings and Saiki 1990). They were still present in the lower creek below Tujunga Reservoir in June 1992. Red shiners occurred in uppermost Newport Bay in September 1986 at the mouth of San Diego Creek (LACM 44508-1, 44509-1), and further upstream at Peters Canyon Wash in 1983. Fish were abundant in the lagoon at the mouth of San Juan Creek in this same period, could not be found there in August 1992, but were recorded farther upstream at the crossing of Ortega Hwy in July 1992. They occur with arroyo chubs in Big Tujunga Canyon, but so far occur downstream of arroyo chub populations in San Juan Creek.

26. *Pimephales promelas* Rafinesque. Fathead minnow. This bait fish is common and established in most if not all the larger low gradient streams in the area, as well as in some lakes and reservoirs. It first appeared along the lower Colorado River with red shiners near Blythe in 1950 and quickly became widespread in southern California (Miller 1952; Shapavalov et al. 1959; Kimsey and Fisk 1964).

Catostomidae

27. *Catostomus occidentalis* Ayres. California sucker. This species, established in Cayucos Creek and Whale Rock Reservoir, San Luis Obispo County from 1986 to 1989, was absent after low water conditions in 1990 (Dan Holland, pers. comm.). Fish were present in Chorro and Morro creeks (Barclay 1975) until 1978 (CFG SLO); all of these probably were introduced from the Salinas drainage. Although Davis (1963) noted "western suckers" (often used in reference to *C. occidentalis)* in the commercial catch from southern California reservoirs, these most likely were Owens suckers (see above). Since 1972 California suckers are potential immigrants with central Valley water.

28. *Ictiobus cyprinellus* (Valenciennes). Bigmouth buffalo. The bigmouth buffalo was introduced (probably from Arizona) into the Los Angeles Aqueduct system in Inyo and Los Angeles counties, and supported a commercial fishery through the 1960s in southern California reservoirs (Evans 1950; Davis 1963). Minckley (1973) noted that Arizona fish rarely occurred in the lower Colorado River, and that two other species existed in Arizona reservoirs, *I. niger* (Rafinesque) and *I. bubalus* (Rafinesque). Shapavalov et al. (1981) reported a fish from a southern California waterway (1969) identified as *I. bubalus* by C. Hubbs and J. St. Amant. None have been collected since and they probably no longer occur outside the Colorado River (Shapavalov et al. 1981).

Ictaluridae

29. *Ictalurus punctatus* Rafinesque. Channel catfish. This species is widespread in rivers and reservoirs in this area as well as the Colorado River (Minckley 1973; Moyle 1976a). It was first introduced into Lake Cuyamaca, San Diego County in 1891 (Smith 1896) with fish originating from the northeastern United States. Later introductions have come from Texas (CFG LB).

30. *ktalurus furcatus* (Lesueur). Blue catfish. Richardson et al. (1970) document the introduction of this species into Lake Jennings, San Diego River drainage, San Diego County, in October 1969 (the 1966 date of Shapavalov et al. [1981]

undoubtedly a misprint). It has since been placed in many southern California reservoirs, the lower Colorado River, and has appeared in the Sacramento-San Joaquin Delta (Taylor 1980; Young and Marsh 1991).

31. Ameiurus natalis (Lesueur). Yellow bullhead. This species is rare in southern California, being first introduced in California in 1874, along with the black and brown bullheads and white catfish (Smith 1896; Curtis 1949). We have records from Evans Lake, Riverside County; and Santa Ana River, Orange County; and another (UCLA) from Cochella Valley irrigation canals. Minckley (1973) noted that they were widespread but rare in collections from Arizona, including the Colorado River. The original plants of yellow and brown bullheads came from the Schuylkill River, Pennsylvania (Neale 1915), as did channel and white catfish. One or more species of bullheads also came from Lake Champlain, Vermont and the Mississippi Valley (Shebley 1917a).

32. Ameiurus nebulosus (Lesueur). Brown bullhead. Definite records of brown bullhead are from Zaca Lake in the Santa Ynez drainage near Buellton; lower Owens River, Inyo County; Irvine Lake and the Santa Ana River in Orange County; Evans Lake and Lake Hemet, Riverside County; and San Luis Rey River just below Lake Henshaw, San Diego County. Brown bullheads were abundant in the Owens River near Lone Pine by 1891 (Gilbert 1893). In August 1963 in Lake Hemet, Riverside County numerous (but not counted) bullheads thought to be brown turned out to be four black to one brown (L. K. Puckett, CFG LB). These two species are often confused. Minckley (1973) expected them to occur in the lower Colorado River but they had not actually been collected.

33. Ameiurus melas (Rafinesque). Black bullhead. Black bullheads are the most common bullhead in the streams and rocky areas of reservoirs, and are the basis for many unpublished reports of brown bullheads (see above). Minckley (1973) reported black bullheads numerous but stunted in the lower Colorado River.

34. Ameiurus catus (Linnaeus). White catfish. In 1933 white catfish were noted from upper Otay Lake, Tia Juana (sic) River drainage, San Diego county (CFG LB); these may have been channel catfishes, but *A. catus* was reported (as Schuylkill catfish) introduced to Los Angeles and San Diego counties in 1874 (Smith, 1896). Specimens were "verified from San Diego County" by Curtis (1949) and taken from the Los Angeles Aqueduct system in 1951 (SIO H51-337). In 1988 they were recorded in Pyramid and Castaic lakes, probably recent arrivals with central California water (CFG LB).

35. Pylodictis olivaris (Rafinesque). Flathead catfish. Bottroff et al. (1969) and Minckley (1973) reported the introduction of this species into the lower Colorado River in Arizona in March 1962. It was first taken in California in the Highline Canal, Imperial County, in 1968 and subsequently spread west into canals of the Salton Sea area (Shapavalov et al. 1981).

Cobitidae

36. Misgurnus anguillicaudatus (Cantor). Oriental weatherfish. First discovered in 1968 in Westminster flood control channel, Orange County (St. Amant and Hoover 1969), oriental weatherfish survived at least through June 1979 (LACM collections; Shapavalov et al. 1981). Courtenay (in litt., January 1990 to P. Moyle) believed it remained in flood drains in Westminster.

Atherinidae

37. *Menidia beryllina* (Cope). Inland silverside. This species was reported in Lake Silverwood, Pyramid and Castaic lakes, and Skinner Reservoir in 1988 (CFG LP, FGH), and young-of-the-year and adults were taken in June 1992 in Pyramid Lake (LACM 45698-1), indicating an established population. Inland silversides have been in the Central Valley since 1967 (Moyle 1976a) and spread rapidly (Shapavalov et al. 1981).

Fundulidae

38. *Lucania parva* (Baird and Girard). Rainwater killifish. McCoid and St. Amant (1980) reported fish collected in Irvine Lake (1963 and 1964) and Arroyo Seco Creek, tributary to Vail Lake (1976). *Cyprinodon* sp. was on a list of fishes introduced to Vail Lake from Dexter, New Mexico in November 1948 (CFG RRB); undoubtedly these were rainwater killifish as suspected by McCoid and St. Amant (1980). In the early 1980s a population was established in the campus lagoon near Goleta Point, University of California, Santa Barbara (Sam Sweet, pers. comm.).

Rivulidae

39. *Rivulus harti* (Boulenger). Trinidad rivulus. St. Amant (1970) and Moyle (1976b) report the existence of this fish in drains near the Salton Sea in the late 1960s. Thought to have disappeared after 1969 (Shapavalov et al. 1981), fish were collected again in mid-1990 (CFG JAS).

Poeciliidae

40. *Gambusia affinis* (Baird and Girard). Western mosquitofish. Mosquitofish are found in almost all fresh and low salinity waters, and are continually being reintroduced by county mosquito abatement districts. It was introduced to southern California in December 1922 (John D. Lynch, in litt.) and was noted frequently by field biologists by the late 1930s (CFG LB). Shapavalov et al. (1981) report frequent California introductions of eastern mosquitofish, *Gambusia holbrooki* Girard. John D. Lynch (pers. comm.) believes only western mosquitofish have been placed in California waters, and all fish we have identified have been western mosquitofish. Although implicated in the demise of native southwestern fishes (Minckley 1973; Meffe 1985), including sticklebacks in the Los Angeles Basin (Miller 1946b), Bell (1978) questioned this latter conclusion because both species coexist in many other areas of southern California today. In captivity mosquitofish feed much less on larval fishes than formerly believed (Hubbs 1991). The species is less prevalent at cooler coastal localities north of Point Conception (Swift et al. 1989) because it has slow growth and a low reproductive rate at 20°C or lower (Vondracek et al. 1988).

41. *Poecilia latipinna* (Lesueur). Sailfin molly. This species has been established in the Salton Sea, lower Colorado River, and environs since the 1950s (Minckley 1981; Schoenherr 1979). A population existed in a coastal, tidal slough in Oxnard from April 1977 (LACM 36402-3) to April 1983 and probably still lives there. Fish were found in Ballona Marsh in July 1990 (David Soltz, pers. comm.), and in the Santa Ana River near Prado reservoir in 1991 (Paul Winkel,

pers. comm.). This herbivorous, euryhaline species survives well in degraded environments (Felley and Daniels 1992), and may disperse (or be transported by man) to other coastal and inland localities.

42. *Poecilia mexicana* (Steindachner). Shortfin molly. This species is restricted to a small area south of Mecca near the Salton Sea, and to a few areas of the lower Colorado River (Schoenherr 1979; Lau and Boehm 1991).

43. *Poeciliopsis gracilis* Heckel. Porthole livebearer. First collected in 1965 from a drain south of Mecca near the Salton Sea (Mearns 1975), this species remains locally established (Schoenherr 1979; Courtenay et al. 1986).

44. *Xiphophorus helleri* Heckel. Green swordtail. This species was collected from a drain in Westminster and near Mecca (St. Amant and Hoover 1969; Mearns 1975) in the late 1960s and early 1970s but disappeared soon thereafter (Courtenay et al. 1986).

45. *Xiphophorus maculatus* (Gunther). Southern platyfish. This species was present for a year or so in Westminster flood control drain in the late 1960s (St. Amant and Hoover 1969) but has since disappeared (Courtenay et al. 1986).

46. *Xiphophorus variatus* (Meek). Variable platyfish. This fish was collected at a few localities in Orange and Riverside counties in the late 1960s (St. Amant and Hoover 1969; St. Amant and Sharp 1971). Courtenay et al. (1986) thought they had disappeared, but a few were caught in the spring of 1991 in the vicinity of the Salton Sea (Lau and Boehm 1991).

Moronidae

47. *Morone saxatilis* (Walbaum). Striped bass. The introduction of this well known sport fish into northern California and the lower Colorado River is well documented (Minckley 1973; Moyle 1976a; Baltz 1991). Introductions into the Salton Sea in 1929 and 1930 were unsuccessful (Walker et al. 1961). Colorado River fish, introduced in 1959, migrate from Lake Havasu down into the Imperial Valley and the river delta in Mexico and back up through the New and Alamo rivers (Minckley 1973, pers. comm.). Although natural reproduction occurred, repeated plantings once were necessary (Minckley 1973), but the species is self-sustaining today. From at least 1972 to 1982 small numbers of striped bass strayed into Lake Cahuilla near Indio at the end of the Coachella Canal that originates in the Colorado River (CFG LB).

Fish may stray southward in marine waters from central California. This has not been definitely documented, and is confused by the unsuccessful introduction of fish from Cambria to San Diego since 1903 (Shebley 1917b; Scofield and Bryant 1926; Horn et al. 1984). Since the early 1970s fish entered Pyramid and Silverwood lakes via the California Aqueduct, and large individuals caught when dewatering the aqueduct were put in Pyramid Lake also (CFG LB).

Hybrids between striped and white basses have been raised by fish farms in Riverside and San Diego counties for several years to supply marketable food fish. In August 1992, some of these hybrids were introduced into Irvine and Anaheim lakes, Orange County, as sport fish and probably will be placed in other waters as well. Both possible hybrids have separate common names; those reared from striped bass eggs are palmetto bass and those from white bass eggs are sunshine bass (Robins et al. 1991).

48. *Morone chrysops* (Rafinesque). White bass. This species was introduced

unsuccessfully into the lower Colorado River near Yuma in the late 1960s (Minckley 1973; Shapavalov et al. 1981). White bass were introduced into Nacimiento Reservoir, Salinas drainage (von Geldern 1966) rather than into south-central coastal drainages as Moyle (1976b) indicated.

Percidae

49. *Percina macrolepida* Stevenson. Bigscale logperch. This logperch has been established in the Central Valley of California since 1953 (Moyle 1976a). Its pelagic larvae and adaptation to large turbid rivers (Simon and Kaskey 1992) facilitated its transport southward to Silverwood, Pyramid, and Castaic lakes in 1988 (CFG LP), and to Irvine Lake in July 1990 (LACM 45147-1,45701-3). It is apparently established in these lakes.

50. *Perca flavescens* (Mitchill). Yellow perch. This species was introduced into Lake Cuyamaca in 1891 (Smith 1896; Curtis 1949) and into the lower Colorado River (Dill 1944; Minckley 1973) at an unknown date, both unsuccessfully.

51. *Stizostedion vitreum* (Mitchill). Walleye. Walleye were unsuccessfully introduced into Puddingstone Reservoir, Los Angeles County (1959-1962), and San Vicente (1959-1960), and El Capitan (1962-1963) reservoirs, San Diego County (CFG LB); these fish grew and entered the sport catch, but did not reproduce (Shapavalov et al. 1981).

Centrarchidae

52. *Archoplites interruptus* (Girard). Sacramento perch. One specimen was collected in Ramer Lake, near the Alamo River, Imperial County in May 1956 (SIO 56-53). Introduced into Crowley Lake, Owens drainage in the late 1960s, it now occurs downstream in Pleasant Valley and Hiawee reservoirs and in Little Lake in the Owens Valley (Aceituno and Nicola 1976), and may be further distributed in southern California.

53. *Micropterus salmoides* (Lacepede). Largemouth bass. This species is widespread in southern California, first arriving between 1888 and 1891 (Smith 1896; Shebley 1917a; Glidden 1931). It was later introduced to the Colorado River (Minckley 1973). These fish all came from the north central United States. In 1959 and 1960, fish came from Texas, and the southern subspecies, *M. s. floridanus* (Lesueur), was brought in to many southern California waters (Shapavalov et al. 1981). Largemouth bass are established also in reservoirs on Santa Catalina Island, Los Angeles County (LACM 42309-1).

54. *Micropterus dolomieui* Lacepede. Smallmouth bass. This species is much less common than the largemouth in southern California. It is known from the Santa Ynez River (Moyle 1976a) and a few other southern California reservoirs; Morris Dam, San Gabriel River and Pyramid Lake, Los Angeles County; Lake Hemet, San Diego County; and Lake Arrowhead and Big Bear Lake, San Bernardino County (CFG LB). Smith (1896) reported smallmouth bass planted in San Diego and Los Angeles counties in 1889 and 1894, respectively. They were brought to lower Otay and Chimney lakes, San Diego County from Friant in central California in 1933 (CFG LB). They can be locally abundant in the lower Colorado River (Minckley 1981) where they were introduced in 1950 (Beland 1953).

55. *Micropterus coosae* Hubbs and Bailey. Redeye bass. Redeye bass were

introduced into the Santa Ana River, Riverside County, Santa Margarita River, San Diego County and the Sisquoc River, Santa Barbara County in 1962 and 1963 and again in 1968 and 1969 (Moyle 1976a; Shapavalov et al. 1981). The Santa Margarita fish survived at least into 1987, the Santa Ana fish have not been recollected, and the status of the Sisquoc fish is not known.

56. *Micropterus punctulatus* (Rafinesque). Spotted bass. Several San Diego County reservoirs and Lake Perris, Riverside County have established populations of spotted bass dating from 1974 (Moyle 1976a). The stocks originated in Alabama (CFG LB).

57. *Lepomis cyanellus* Rafinesque. Green sunfish. This sunfish is found in many freshwater streams, ponds, and reservoirs in coastal southern California. They are usually common and self-sustaining. It is also found throughout the lower Colorado River (Minckley 1973). The first arrived in southern California from Illinois in 1891 for placement in Lake Cuyamaca, San Diego County (Shebley 1917a).

58. *Lepomis macrochirus* Rafinesque. Bluegill. Bluegill are common to abundant in many ponds and reservoirs in the area, including the lower Colorado River. They may have arrived in 1891 with the green sunfish, but were not definitely recorded until 1908 (Smith 1896; Curtis 1949). The original stocks were from the northeastern United States, but from the late 1940s onward stocks from Texas and Florida were planted as well (Miller 1952; Shapavalov et al. 1981; CFG LB). Fish have been taken from reservoirs on Santa Catalina Island, Los Angeles County also.

59. *Lepomis gibbosus* (Linnaeus). Pumpkinseed. This species is occasionally found in lakes and ponds. It was first collected in southern California near Mecca, Riverside County in 1939 after arriving about 25 years earlier (Dill et al. 1955). Miller (1968) reported them in Lucerne Valley, San Bernardino County in 1940. Minckley (1973) found most, if not all, records of pumpkinseed from the Colorado River were based on redear. Pumpkinseed often hybridize with bluegills adding to the confusion in identification.

60. *Lepomis microlophus* (Gunther). Redear. This species was first introduced into the Headgate Rock Dam area of the lower Colorado River in 1948 (Beland 1953; California Department of Fish and Game 1973), and Minckley (1973) reported them common there though not often collected. Redear were brought into coastal southern California in 1954 (Shapavalov et al. 1959), and were introduced into San Diego County reservoirs beginning in 1962 to prey on snails known to be vectors of bass and sunfish parasites (CFG LB).

61. *Lepomis gulosus* (Cuvier). Warmouth. Fish placed in Lake Cuyamaca in 1891 did not survive (Smith 1896). This species has been abundant in the lower Colorado River since being introduced in 1961 (Lanse 1965; Minckley 1973; Moyle 1976b). It should be expected in reservoirs receiving water from both the Colorado River and the Central Valley.

62. *Pomoxis annularis* Rafinesque. White crappie. In both the lower Colorado River (Minckley 1973) and coastal southern California, this species is less common than the black crappie, *Pomoxis nigromaculatus*. Both crappies arrived in California in 1891 from Illinois and were placed in Lake Cuyamaca, San Diego County (Smith 1896; Curtis 1949). These died out and other transplants in 1908 to Ventura, Los Angeles, Riverside, and Orange counties (Vogelsang 1931) and in

1917 to San Diego County (Glidden 1931) survived and became widespread (California Department of Fish and Game 1973). Some fish probably also represent immigrants from both central California and the Colorado River.

63. *Pomoxis nigromaculatus* (Lesueur). Black crappie. Most, if not all, of the larger reservoirs hold this species, which, as noted above, arrived in southern California in 1891 and later. In 1981 fish from the St. John's River, Florida were brought to Buena Vida Farms, Lakeview, Riverside County and the Chino Fish and Wildlife Base in December 1981 (CFG LB) for distribution in southern California.

Sciaenidae

64. *Cynoscion xanthulus* Jordan and Gilbert. Orangemouth corvina. This species has been established in the Salton Sea since the 1950s (Walker et al. 1961). In September 1966 fish were taken about three-fourths of a kilometer up the Whitewater River from the Salton Sea (CFG LB). They also invade freshwater in Mexico (Castro-Aguirre 1978); in March 1961, 37 fingerlings were introduced to Puddingstone Reservoir and not recorded subsequently. Horn and Allen (1978) erroneously list them from coastal southern California.

65. *Bairdiella icistia* Jordan and Gilbert. Bairdiella. One specimen of this species was taken in the fresh water of the lower Whitewater River, with the orangemouth corvina noted above. Otherwise biardiellas are restricted to the saline waters of the Salton Sea (Walker et al. 1961), but invade fresh water in Mexico (Castro-Aguirre 1978).

Gobiidae

66. *Acanthogobius flavimanus* (Temminck and Schlegel). Yellowfin goby. Haaker (1979) noted the first records of this species in southern California (Los Angeles Harbor) and it has been subsequently taken in Newport Bay (Allen 1982) and upstream in lower San Diego Creek, Ballona Marsh (LACM 39764-6), and Mugu Lagoon (44205-1). It is rare or absent in smaller coastal estuaries: Malibu Lagoon (Manion and Dillingham 1989), San Onofre, San Mateo, Las Pulgas, and Santa Margarita lagoons, and Morro Bay.

67. *Tridentiger trigonocephalus* (Gill). Chameleon goby. Established in the 1960s in San Francisco Bay and Los Angeles Harbor (Haaker 1979), it was collected in Pyramid Lake, Los Angeles County (LACM 45016-1) in October 1990. Locally abundant in some rocky areas of the lake, it was also taken downstream in Piru Creek on 25 June 1992 (LACM 45688-1). It presumably will move downstream throughout the Santa Clara River drainage. A record upstream invasion of salt water into the Sacramento-San Joaquin delta enabled chameleon gobies to be entrained with water diverted south (Kathy Heib, pers. comm.). Establishment of the species in fresh water was predicted by Moyle (1976a).

Cichlidae

68. *Oreochromis aurea* (Steindachner). Blue tilapia. The blue tilapia has become established in several areas of the lower Colorado River (Courtenay et al. 1986, 1991), and some have turned up in the Salton Sea area as well (Courtenay, in litt.). In 1992 *0. aurea* have been collected from the Salton Sea, as well as fish

that appear to be hybrids between *O. aurea* and *O. mossambica* (W. L. Minckley, W. Courtenay, in litt.).

69. *Oreochromis mossambica* (Peters). Mozambique tilapia. This species became established in drains of the lower Colorado River near Yuma in 1963, the Salton Sea area in January 1964, and tidal channels of the Santa Ana, San Gabriel, and Los Angeles rivers by 1974 (St. Amant 1966; Shapavalov et al. 1981). A few unidentified tilapias taken from the Sepulveda Flood Control Basin on the Los Angeles River and the Prado Flood Control Basin on the Santa Ana River are believed to be this species. Courtenay et al. (1984, 1986, 1991) note that some of these introductions may be of *O. honorum* Trewavas or of hybrids between *O. mossambica* and *O. honorum,* the last sometimes treated as a subspecies of *O. urolepis* Norman. The hybrid combination is called the red tilapia (Robins et al. 1991). *Oreochromis mossambica* largely has replaced *T. zilli* in the Salton Sea and possibly in coastal southern California as well, having been taken in upper Newport Bay (LACM 44375-2). Tilapias obviously have been a major factor in a decline of the desert pupfish in the Salton Sea area, but their impact on native coastal estuarine species is not known (Horn 1988). By 1983 five pure species, *O. mossambica, O. honorum, O. aurea, T. zilli,* and *T. nilotica,* and ten possible hybrid combinations of these were tentatively identified in the lower Colorado River area of California and Arizona (Barrett 1983; Lopez and Ulmer 1983).

70. *Tilapia zilli* (Gervais). Redbelly tilapia. Introductions of this species for weed control (Salton Sea area) and mosquito abatement (Orange County drains) led to established populations (Knaggs 1977; Moyle 1976a, b; Courtenay et al. 1984, 1986), and even to records from the open coast off Huntington Beach after heavy winter rains in December 1974 (LACM 36203-1). The only other estuarine collections are those of *O. mossambica* from Newport Bay noted above. Despite their salinity tolerance, tilapias have invaded local estuaries only in highly modified channels where power plant effluent keeps the water warm. *Tilapia zilli* has been partially and possibly completely replaced by other tilapias locally (Courtenay et al. 1984, 1986, 1991).

Embiotocidae

71. *Hysterocarpus traski* Gibbons. Tule perch. This species was collected in Lake Silverwood in 1988 or 1989 (CFG FGH, LP), and about twenty adults were taken from widely scattered localities in Pyramid Lake in June 1992 (LACM 45701-7), indicating establishment there or continued immigration with imported water.

Cottidae

72. *Cottus asper* Richardson. Interior prickly sculpin. Bell (1978) recorded presence of this species in the Santa Clara River. They have remained common in most of the drainage, but have never been taken in the Soledad Canyon section upstream. A specimen of *Cottus* sp. was noted in June 1972 in the Gorman Canal, tributary to Pyramid Lake (CFG LB), the first year this water began to flow into the Santa Clara Basin. In 1987 they were taken in the lower Santa Ana River (LACM 44384-1, 44385-1) and Irvine Lake (LACM 45146-1), Orange County, and upstream in Big Bear Lake and its outlet Bear Creek, San Bernardino County

(Deinstadt et al. 1988). Prickly sculpin are known from Skinner, Castaic, Silverwood (including the west fork of the Mohave River downstream), Cachuma, and Casitas reservoirs also (CFG LB). Casitas and Cachuma do not receive imported water, and are in drainages originally inhabited by the native coastal form noted above. The recency of these two collections in otherwise previously well collected drainages indicates they are introduced. Mixing of coastal and interior forms in southern California seems inevitable (Fig. 13).

Other Introductions

About twenty-five additional freshwater fishes have been placed in southern California waters, caught once and never seen again. A specimen of *Pimep hales notatus,* bluntnose minnow, was taken in Victorville in a shipment of channel catfish from Arkansas in 1968 (SIO-164). A specimen of *Notropis atherinoides,* emerald shiner, was collected from a fish pond in Oak Glen in the summer of 1975 (LACM 35569-1). Several urban aquatic sites in Los Angeles received Asian milfoil from Florida in late 1980; viable eggs on these plants hatched into bluefin killifish, *Lucania goodei,* that survived several months in an outdoor pond (LACM 39884-1). Marine, estuarine, and anadromous species, both northern and southern, were released into southern California waters with live bait discarded by returning tuna boats in the 1930s and 1940s (Clark 1932, 1940). Additional species documented include twenty-eight marine and estuarine fishes introduced into the Salton Sea (Walker et al. 1961), 16 freshwater fishes taken from bait dealers along the lower Colorado River (Miller 1952), and aquarium species captured once near fish farms or in warm springs (St. Amant 1966; St. Amant and Hoover 1969; Naiman and Pister 1974; Shapavalov et al. 1981). These bring the total number of introductions to at least 100 and probably more for southern California, not including local transfers of native species and the recent plantings of hybrids.

Discussion

The native freshwater fish fauna of coastal drainages of southern California comprises a meagre southwestern extreme of an already depauperate temperate freshwater fish fauna in western North America. South of the Carmel River to Point Conception, two species almost continuously inhabit freshwater streams, namely *Oncorhynchus mykiss* and *Cottus aleuticus. Cottus aleuticus* does not quite range southward to Point Conception. A third, *Lampetra tridentata,* may be continuous also, but is rarely collected and data are not complete enough to establish a pattern. *Lampetra tridentata* extends southward to the Los Angeles Basin, and *Oncorhynchus mykiss* ranges to northern Baja California in drainages of the outer Pacific Coast. *Cottus asper* and *Gasterosteus aculeatus* are continuously distributed in lower gradient areas, but are absent from most of the steeper streams. *Cottus asper* ranges southward to the mouth of the Ventura River, and *Gasterosteus aculeatus* occurs south to northern Baja California. All of these species, except *C. aleuticus,* are polytypic in California and all but *C. aleuticus* and C. *asper* have one or more California populations that have special conservation status. None is continuously distributed south of Point Conception, and C. *asper* may only accidentally stray south of this point. Fish collections before 1950 were not numerous and it is difficult to separate the effects of natural causes from those due to human alteration of the environment since the mid-1700s. Holocene sediments hold remains of some of this fauna and may help document the historical distribution of these taxa (Swift 1989).

Only one area of coastal southern California, the Los Angeles Basin, contains endemic freshwater fishes, namely *Rhinichthys osculus, Gila orcutti, Catostomus santaanae, Lampetra* cf. *pacifica,* and one or two taxa of threespine stickleback. These taxa are distributed in one or more of the four physiographically defined freshwater fish communities that can be defined from the region, namely 1) lowland (and low gradient), 2) upland (and high gradient), 3) anadromous, and 4) coastal lagoon. These correspond somewhat to those formulated by Hopkirk (1974) and Moyle and Nichols (1974) in the Clear Lake region and the southern Central Valley, respectively, of California. These latter two classifications also include a foothill fish community defined as an intermediate one between the upland and lowland communities. This foothill component is not well developed in southern California; steep mountains rather abruptly meet the relatively flat alluvial coastal plains leaving little or no foothill habitat to intervene between the upland trout-dace habitat and the lowland stickleback-chub habitat. In steep, coastal streams, upland (high gradient) habitat extends directly to the sea without either lowland or foothill habitat intervening.

Upland habitat is dominated by rainbow trout (and/or steelhead) and speckled dace, with trout extending farther upstream than the dace. In some larger rivers (Los Angeles, San Gabriel, Santa Ana), Santa Ana suckers also inhabit the upland zone. Arroyo chubs are infrequent in this zone and may be mostly introduced, maintaining themselves only in the scarce low gradient areas or in artificial impoundments. Today, steelhead and Pacific lamprey use this zone for spawning in mid-winter, and probably also utilized the lowlands formerly. Farther north *Cottus aleuticus* inhabits high gradient streams of upland character where they flow directly into the ocean without intervening foothills or lowlands.

The lowland habitat was occupied primarily by Pacific brook lamprey, arroyo chub, and unarmored threespine stickleback. Arroyo chubs and sticklebacks were particularly widespread (Culver and Hubbs 1917; George 1927). Santa Ana suckers inhabited large streams in the lowlands, and speckled dace occurred in a few, isolated, often spring-fed, foothill localities. Steelhead and Pacific lamprey traversed this area to spawn. Lowland and upland streams and coastal lagoons served as nursery areas for juveniles of these migratory fishes before they returned to the sea. Moore (1980) observed steelhead spawning in the lowlands of the Ventura River. Lowland spawning was probably more prevalent before dams flooded the major rivers where they meet the lowlands. These areas of alluvial gravels and strong spring flow undoubtedly were significant for the spawning of both anadromous species. In lowland streams north and south of the Los Angeles Basin, partially armored sticklebacks replaced the unarmored forms, and Pacific brook lampreys were absent. North of Point Conception, prickly sculpins occupy lowland areas as well.

The foothill zone in southern California consists of large alluvial fans at the base of steep mountains. True foothills are small isolated hills between the mountains and the coast. During the dry season, streams might dry up in the alluvial fan areas, and return to the surface farther downstream (Miller 1961; Pourade 1968). Originally, during hot weather, evapotranspiration by the extensive riparian gallery forests caused streams to dry up during the day and begin flowing again in the evening, a phenomenon often noted by early explorers (Pourade 1968). It seldom occurs today in the lowlands since artificial lowering of the water table led to the loss of much of the gallery forests. The few, widely scattered, apparently relict, populations of Rhinichthys osculus on the Los Angeles Basin indicate that the foothill habitat was attenuated and almost non-existent.

Coastal streams often were perennial in the mountains, but disappeared underground in the large alluvial fans at the bases of the mountains, and reemerged at places like Whittier Narrows (San Gabriel River), the Riverside-Mt. Roubidoux area (Santa Ana River), and along the north side of the present day Hollywood Hills (Los Angeles River) (Miller 1961). Thus, coastal and inland populations of freshwater species were probably often isolated from each other seasonally. South of the San Luis Rey drainage, the mountains are farther from the coast, rainfall is less, and native freshwater fishes consisted of a few widely scattered populations of threespine sticklebacks, rainbow trout, and steelhead (Cooper 1874; Eigenmann and Eigenmann 1890; Hubbs 1946; Miller and Hubbs 1969).

Farther north in Cuyama River tributaries, Huasna River and Alamo Creek, Rhinichthys osculus, Hesperoleucas symmetricus, Gila orcutti, and unplated Gasterosteus aculeatus are considered introduced (Miller 1945a, c, 1968; Miller and Hubbs 1969; Greenfield and Greenfield 1972). Gila orcutti is an obvious introduction, but the other three are not as certain. These fish were restricted to upland areas of the Cuyama River and could have been missed by early collectors. Low divides separate the upper Huasna drainage from the Salinas system where these species occur. Rhinichthys particularly can fluctuate widely in numbers from year to year, and is restricted to spring-fed rocky and riffle areas that may not be in good supply in the Cuyama River. The unplated stickleback were lost with the introduction of partially plated fish (Miller and Hubbs 1969), and Hesperoleucas and Rhinichthys still occur in the drainage. These two species should be studied further to clarify their relationships.

The coastal lagoon habitat, largely absent in southern California today, contains a mixture of lowland freshwater, estuarine, and a few marine species dependent on low salinity during part of their life cycle. Five estuarine species, California killifish, tidewater goby, longjaw mudsucker, cheekspot goby, arrow goby (Swift et al. 1989; Allen 1991) would live almost exclusively in such habitats, although the larvae of the latter three occur along the open coast. The lagoons provided nursery areas for juvenile steelhead and, farther north, coastrange and prickly sculpins. There are three groups of estuarine fishes: 1) widespread tropical species reaching their extreme northern extent, 2) northern temperate species reaching their southern limit, and 3) a group endemic to this area, often called the Californian province of authors (Ricketts et al. 1985; Horn and Allen 1978). Californian species are typically distributed between Point Conception on the north and Magdalena Bay, outer Baja California on the south, often with an isolated disjunct population in the northern Gulf of California. Two tropical species occur inland only in the Colorado River, Elops affinis and Eleotris picta. Five of the tropical coastal species are rare or extirpated in California, namely Carcharhinus leucas, Hyporhamphus rosae, Cynoscion parvipinnis, Scomberomorus concolor, and Gobionellus sagittula. Some of these are listed as coastal but non-bay inhabiting by Horn and Allen (1978), but are so scarce now as to be undeterminable.

Definite bay records are known for *Gobionellus sagittula (as G. longicauda)* and *Cynoscion parvipinnis,* and strongly suspected for *Carcharhinus leucas, Eucinostomus argenteus, Oligoplites saurus, Chaetodipterus zonatus, Myrophis vafer, Trichiurus nitens, Mugil curema,* and *Bagre panamensis.* Other tropical species, rare in coastal southern California, fall in this same category, but are not as exclusively associated with low salinity water, such as *Galeocerdo cuveri, Polydactylus opercularis,* and *P. approximans.* Some of these species were caught for live bait by tuna boats from the 1930s to the 1950s (Alverson and Shimada 1957). Clarke (1932, 1940) noted that both northern and southern estuarine species were inadvertently introduced into southern California coastal waters by these vessels. Four tropical species still occur in southern California, *Anchoa delicatissima, A. compressa, Syngnathus auliscus,* and *Paralichthys californicus.* Although from tropical genera, three of these (excluding *S. auliscus)* are Californian in distribution. The tropical species represent a combination of: extirpation of taxa restricted to brackish waters; occasional colonization by taxa with more marine life stages but dependent on warmer waters that infrequently invade southern California; introductions of bait species by tuna vessels; and taxa that have continuously inhabited the coastal estuaries of southern California.

Eight temperate estuarine species are all common, except *Eucyclogobius newberryi,* which has been rapidly disappearing. Some of the temperate species, like *Atherinops affinis* and *Fundulus parvipinnis,* are probably much more common than in the past because of the changed character of California estuaries (Lane 1977a; Swift et al. 1989) particularly in southern California. The California endemic, *Eucyclogobius newberryi,* only survives in a few coastal lagoons and river mouths in southern California that are at least partially in a natural state. Some of these localities went from virtual disappearance in February 1991 to a tentative reprieve for another year due to heavy rains in March 1991.

The history of droughts and the aridity of the spectacular deserts of southeastern California have masked awareness of the relatively wet conditions that existed in much of coastal southern California until the arrival of Europeans. The high mountain ranges stopped considerable moisture that accumulated in deep sedimentary basins fronting the coast. Early observers and paleontological records document extensive surface water, springs, fresh and brackish water marshes, and artesian springs in the lowlands and near the coast in many areas (Willett 1941; Emery et al. 1957; Gorsline 1967; Miller 1961; Warme 1971; Gordon 1985; Swift et al. 1989). Gorsline (1967) noted:

> "The southern California rivers are seasonal streams and in their natural state are sealed off at their mouths by beach deposits during the dry season. A few southern California estuaries (Mugu Lagoon, Newport Bay) are abandoned mouths of the major streams which have been closed off by longshore drift and then opened to the sea by artificial channels."

The original coastal lagoons were largely brackish or fresh and were cooler in summer and warmer in winter than the nearby ocean. The need for harbors during the last 150 years led to these habitats being replaced by much smaller estuaries with regular tidal action artificially maintained. Temperature and salinity now closely parallel that of the ocean. These systems harbor a much larger and more marine fauna (Lane 1977b; Horn and Allen 1976; Zedler 1984). The original coastal lagoon habitat is important to preserve as a unique physiographic feature indispensable for certain life stages of many aquatic and terrestrial organisms (Barnes 1991), but only rarely are aquatic taxa exclusively restricted to them (i.e., tidewater goby, Swift et al. 1989).

The native freshwater fishes of the lower Colorado River drainage in California have been extirpated or very rare since the 1950s. Most are riverine forms with at least small populations farther upstream in tributaries outside California. Two of these, *Oncorhynchus clarki* and *Rhinichthys osculus,* are at best strays in the lower river. *Poeciliopsis occidentalis* exists only by virtue of great effort to manage the few remaining populations in Arizona and Mexico, and may not have lived along the main river in California. *Cyprinodon macularius* still exists in many small populations around the Salton Sea; with increasing salinity it may be the only fish to survive (Lau and Boehm 1991), a situation that probably has repeated itself many times in the Salton Sea area for thousands of years (Miller 1946a; Norris and Webb 1990). Lower Colorado River freshwater fishes invaded the Salton Sea with river floodwaters in 1904-1907 (Gobalet 1992), a phenomenon that occurred six times (on a smaller scale) from 1840 to 1891 (Carpelan 1961). Since 1907 only the controlled release of irrigation water comes into the Salton Sea area. Farther north in the Mohave, Armagosa, and Owens drainages, native fishes only occurred in the lowland areas originally flooded by Pleistocene lakes; many tributaries at higher elevations with perennial water originally lacked native fish as far as is known (Miller 1948). The efforts to protect the native fishes of these areas are discussed by Minckley and Rinne (1991) and in Minckley and Deacon (1991).

The accelerating rate of habitat reduction, partially drought related, means all the native coastal freshwater fishes require protection to prevent their disappearance. The reductions in habitat make it less likely that native fishes will be able to expand their ranges with the return of wetter conditions. Low water concentrates native fishes in the larger pools favored by introduced centrarchids, particularly green sunfish. Local residents build small dams to store this water for supression of potential fires, and stock these ponds with predatory warm water fishes. Farther north low water levels in streams made stickleback vulnerable to predation by introduced bullfrogs (Dan Holland, pers. comm.). Introduced clawed frogs prey on stickleback in southern California (CFG UTSRT). Brown trout predation may explain the scarcity of native fishes today (including trout?) in the mountainous portions of the Santa Ana River and tributaries. They have been implicated in the reduction of native fishes in northern California (Moyle 1976a) and elsewhere (Taylor et al. 1984).

In some areas, secondary water sources, usually sewer treatment plant effluent, provide more surface water than was available historically. Although potentially useful to preserve riparian habitats, this water is often detrimental. It is much warmer than natural waters emerging from underground sources. Its high nutrient load encourages a different suite of species and can put the native fauna (and flora) at a competitive disadvantage (Morris 1991). These conditions favor introduced aquatic vertebrates like red shiners, grass carp, goldfish, common carp, sailfin mollies, tilapia, and clawed frogs. These are all known to impact native species, and the severity of impact seems related to degree of habitat alteration (Ross 1991). Several other introduced species known to have been established in the late 1970s and early 1980s for a few years or more may still exist, but have not been reassessed recently (Courtenay et al. 1984, 1986, 1991).

The established, successful introduced stream fishes in coastal southern California comprise an assemblage of five species from the central United States already known for survival in small plains streams, often turbid and fluctuating widely in flow. They are both pioneer and colonizing species elsewhere (Capone and Kushlan 1991; Fausch and Bramblett 1991; Meador and Matthews 1991). These species thrive in similar conditions in southern California, and include fathead minnows, black bullheads, mosquitofish, green sunfish (Moyle 1976a, b) and, recently, the red shiner. All typically become self-sustaining. Mosquitofish are actively distributed by local mosquito abatement districts, despite early evidence that native sticklebacks and pupfishes effectively controlled mosquitos (Scofield 1915; Kennedy 1916; Hubbs 1919). In addition, sailfin mollies and tilapias, long established in the lower Colorado River and Salton Sea, turn up in a few more coastal drainage localities each year.

The community of reservoir fishes is much more dependent on continual introductions and highly modified (impounded) habitat for survival (Minckley 1973; Moyle 1976a, b). This assemblage of introduced species characterizes ponds, lakes, and reservoirs, namely threadfin shad, golden shiner, goldfish, carp, channel catfish, mosquitofish, bluegill, redear, pumpkinseed, black crappie, and largemouth bass. Most of these species would not be self-sustaining in the natural streams of southern California. Since the early 1970s, additional native and introduced fishes of the Central Valley have been carried into southern California reservoirs with imported water. The following are known or suspected to be established in one or more of these reservoirs: inland silverside, white catfish, inland prickly sculpin, tule perch, striped bass, bigscale logperch, and chameleon goby. Most are restricted to lake and reservoir environments. Some, like the inland prickly sculpin and chameleon goby (Santa Clara River and some tributaries) and blackfish (lowland Santa Ana River), are established in outlet streams. Earlier efforts to prevent a similar invasion of carp and goldfish from the Colorado River into the San Diego reservoir system in the early 1900s were unsuccessful (CFG LB), and the prognosis is no better now. For sculpins, sticklebacks, minnows, and suckers, the possibility exists of introducing closely related taxa and mixing natural gene pools. This is in addition to the usual problems of competition and predation. Non-native genetic additions are almost always detrimental to the integrity of the native stock (Hindar et al. 1991), as well as being undesirable for a variety of other ecological and economic reasons (Allendorf 1991). Such genetic additions are justifiable only when no alternative exists to maintain genetic diversity (Echelle 1991). A recent trend, introducing sterile hybrids among the grass carps, tilapias, and temperate basses, is still being evaluated. Such fish theoretically will not become self-sustaining or reproductive, but have many of the same effects attributed to the parental species while living.

As expected from the mixture of flowing and impounded areas on the lower Colorado River bordering California, it and the larger water distribution canals have an introduced fish fauna that is a mixture of the stream and reservoir species, with a few taxa restricted to the Colorado River area (Schoenherr 1979; Minckley 1981; Lau and Boehm 1991). In addition the cool, hypolimnic water released from some of the dams creates thermal conditions that segregate the species. Cool sections are dominated by rainbow trout and striped bass. Farther downstream carp, red shiners, channel catfish, green sunfish, bluegill, green sunfish, and black bullhead predominate. Only in the warmest lower river are tilapias and sailfin mollies abundant. As pointed out by Minckley (1981), the instability of the river temperature and water levels means that the species live in transitory habitats where "populations explode, stunt, then stabilize and often disappear."

The irrigation canals in and around the Salton Sea are dominated by tilapias, mosquitofish, porthole livebearer, shortfin, and sailfin mollies, and red shiners (Schoenherr 1979, 1988; Lau and Boehm 1991). Several other species occur in small numbers, including the only native species in these habitats, the desert pupfish, *Cyprinodon macularius.* Usually most of these species will occur at any given locality, but in areas of natural or artificially induced thermal gradients, considerable species segregation can occur. Individual species often segregate from each other linearly along a canal (Schoenherr 1979). Such conditions allow the desert pupfish to survive by taking advantage of such scattered optimal micro-habitats. Only the tilapias and sailfin mollies occur extensively in the main Salton Sea, along with the few marine and estuarine species acclimated there (Walker et al. 1961; see above).

Introduced species from eastern North America are usually of mixed genetic stocks with more than one species or subspecies having been stocked in California (Miller and Alcorn 1946; Miller 1952; Shapavalov et al. 1959, 1981). Moyle (1976b) noted two eras of introductions into California, namely 1871-1890 and 1960-1976. Superimposed on these are three periods representing changing sources for stocks of the fishes involved. Early introductions came from the northeastern United States, including the Great Lakes and upper Mississippi Valley. In the 1940s and 1950s stocks of the same species originated in Texas and arrived via the Dexter National Fish Hatchery, New Mexico. In the late 1950s and 1960s stocks from Florida (or other southern localities) were brought in. The species known or suspected of being polytypic are *Notemigonus crysoleucas, Micropterus salmoides, M. punctulatus, Lepomis macrochirus, Ictalurus punctatus, Pomoxis nigromaculatus,* and *Morone saxatilis* (Hubbs and Lagler 1964; Miller 1952; Swift et al. 1986; Page and Burr 1991). The sources for several other species are less certain but may be equally diverse, particularly for *Ameiurus nebulosus, A. natalis, A. melas, Gambusia affinis, Micropterus dolomieui,* and *Pimephales promelas.* Cultured varieties also complicate the picture, and Minckley (1973) contended that distinctive forms will be swamped out by the established one. Pelzman (1980) documented the mixing of genes of northern and southern largemouth bass in California reservoirs.

Conservation Recommendations

As noted above, the native fish fauna of the greater Colorado River drainage covered in this paper has been threatened, endangered or extirpated for a long time. With a few exceptions the conservation of remaining populations primarily or exclusively involves stocks outside southern California (Minckley and Deacon 1991).

Today, natural habitats for the freshwater fishes of coastal southern California exist in hilly or mountainous headwater areas and in a few coastal localities that have remained protected. The broad lowland areas between are highly modified and largely uninhabitable for resident species and those that migrate between the headwaters and the coast. Thus the priorities for the preservation of the native fauna are, 1) protection of the remaining coastal and interior habitats still containing elements of the native fauna, and 2) restoration and/or rehabilitation of some portion of the now unsuitable intervening areas. These objectives are similar to those proposed for the recovery of the federally endangered unarmored three-spine stickleback (U.S. Fish and Wildlife Service 1985). To succeed the whole ecosystem must be considered and a variety of natural stocks must be preserved to re-establish populations (Nehlsen et al. 1991).

The areas between the mountains and the coast suffer primarily from extreme channel modification and degraded water quality. Many are completely concrete lined. In addition, introduced species dominate these sites. Man-made structures encroach so closely on the water courses that they represent a major obstacle to returning the areas to more natural conditions. In other areas, particularly flood control basins, semi-natural habitat exists. Often the stream bottom could not be covered over with concrete since groundwater upwelling had to be accommodated. Maintenance of stable surface flow and improvement of water quality would return the habitat to conditions that could support native fishes. However, non-native fishes also have to be controlled or removed for the native fishes to maintain themselves.

The habitats critical for preserving the native freshwater fish fauna of coastal southern California fall into the same four categories noted above as habitat types. One or a few localities are critical in the Los Angeles Basin for the three endemic cypriniform fishes. A mutually exclusive five to eight streams south of Morro Bay to Malibu Creek still hold anadromous steelhead and lamprey. About twenty coastal lagoons and marshes contain populations of *Eucyclogobius newberryi.* Several additional freshwater and estuarine localities formerly held native fishes and must be improved to restore populations of the native fish involved.

Recently, the remaining native species endemic to the Los Angeles Basin existed only in the Big Tujunga Creek drainage (Los Angeles River drainage), the combined east, west and north forks of the San Gabriel River above San Gabriel Reservoir, and widely scattered and isolated portions of the Santa Ana River drainage. The Los Angeles and Santa Ana river populations of these species are restricted in distribution and rare where they occur. Only the San Gabriel system appears large, stable, and unimpacted enough to maintain the three native species, *Gila orcutti, Rhinichthys osculus,* and *Cat ostomus santaanae* (and possibly native *Oncorhynchus mykiss).* Conditions in the other two systems have to be improved so the native stocks can increase in numbers, and in the Santa Ana drainage this may require the removal of brown trout. *Gila orcutti* also naturally still occurs in parts of the San Juan Creek and Santa Margarita River drainages farther south. However, these populations are also restricted in distribution and need formal protection (Moyle et al. 1989). Particularly San Juan Creek and its tributary Trabuco Creek also hold one of two extant native populations of partially armored sticklebacks south of the Los Angeles Basin in the United States, the other in the South Fork of the San Jacinto River below Lake Hemet. Only one other population is known today from northern Baja California.

The two anadromous species, *Lampetra tridentata* and *Oncorhynchus mykiss,* occur in several drainages where relatively natural habitat exists continuously from ocean to headwaters, noted above. Their maintenance and increase will depend on restoration of lowland areas, both as migratory routes to spawning areas and as coastal lagoons for nursery grounds, the latter probably important for steelhead only. Dams and debris basins block migration and obliterate large areas that were undoubtedly used for spawning in the past. Even if access is provided to headwaters above such impoundments, they may not provide as much habitat as expected unless adequate beds of spawning gravel are available. Intermittent streams can be important for spawning habitat in spring, and lower reaches, including coastal lagoons, equally so for summer and fall habitation after the smaller headwater areas lose adequate flow (Erman and Leidy 1975). Such transitory habitat should be relatively more important in southern California and is often not included in fish habitat listings that concentrate on permanent watercourses. Southern California populations may be particularly important as genetic stocks that are better adapted to warmer water conditions than more northerly populations. The occurrence of adult Pacific lamprey at the mouth of the Santa Ana River in March 1991 is an encouraging sign that stocks are present to colonize Los Angeles Basin streams that recover enough for these fish to complete their life cycle.

The heavily impacted lowland areas where streams are cement-lined channels must be improved to assure continued survival of native fishes. Two taxa have been extirpated from Los Angeles Basin streams, namely *Lampetra* cf. *pacifica* and *Gasterosteus aculeatus williamsoni.* Both taxa exist elsewhere and reintroduction is possible. A high conservation priority must be the existing habitat of the three taxa of unplated threespine sticklebacks, the federally endangered form in the upper Santa Clara River, the Shay Creek stickleback in the Baldwin Lake area, and the San Antonio Creek stickleback. Both the maintenance of the existing populations and designation of areas suitable for their expansion are of highest priority. Unplated stickleback and Pacific brook lamprey formerly occurred in lowlands of the Sepulveda Basin (Los Angeles River) system, of the Whittier Narrows area (San Gabriel River), and the middle Santa Ana River from Mt. Rubidoux (City of Riverside) downstream to a few kilometers below Prado Flood Control Basin. *Gila orcutti* and *Catostomus santaanae* still occur in a few areas on the Santa Ana and Los Angeles rivers. These areas have artificially permanent water flow, albeit of low quality water, and are the best candidates for restoration for management of native fishes. They are also the intermediate areas needed for anadromous fishes and could be managed as spawning areas as well.

No brackish marshes or coastal lagoons exist in the conditions that were present at first European contact. A few small systems have remained relatively unchanged by human activity, namely several small lagoons in San Luis Obispo and western Santa Barbara counties, Morro Bay, the mouths of the Ventura and Santa Clara rivers, Mugu Lagoon, and four lagoons on Camp Pendleton. The two largest of these, Santa Margarita Lagoon (on Camp Pendleton) and Morro Bay, are particularly important as the only two remaining with a full complement of bay gobies (Swift et al. 1989). Most of these have artificially maintained entrances that make them more like bays and estuaries than the coastal lagoons they once were. Having irreparably lost most of the larger systems, it is important to maintain all that remain, only two of which are large. The tidewater goby is the only coastal fish in jeopardy, but a whole suite of other threatened organisms requires this habitat for survival (Smith et al. 1989, Barnes 1991).

The current drought accelerated the reduction of natural habitat for native fishes previously due to increases in human population, demand for water, and a general lack of appreciation for scarce aquatic habitats in the southwestern United States (Moyle and Williams 1990; Moyle and Ellison 1991). During the last surge in human population after World War II, all the species of the lower Colorado River drainage in California became threatened, endangered or extirpated (Minckley 1973). At this same time the large flood control projects on the Los Angeles basin were completed (Van Wormer 1991), and about 40% of the freshwater fishes of the Los Angeles Basin were extirpated. As the originally well-watered habitat of coastal southern California has become artificially desertified, the fishes became subjected to many of the same impacts affecting the desert regions (Minckley and Deacon 1991). Today all of the remaining coastal species are, to some degree, in jeopardy for long term survival as wild populations. As noted above, a variety of threats impinge on the habitat, and a unified effort is needed to maintain the integrity of the native aquatic systems and the riparian habitat associated with them to allow these fishes, and a host of other riparian dependent species, to survive (Nehlsen et al. 1991; Gregory et al. 1991; Johnson 1991; Moyle and Leidy 1992).

To organize the effort to save the freshwater fishes of California, Moyle and Ellison (1991) classified the aquatic habitats of California, and defined criteria important for the survival of native fish populations, namely Aquatic Diversity Management Areas (ADMA). One hundred ADMAs are proposed for the southern California area covered here. They are heavily biased towards sites where native fishes still occur, or sites perceived to be recoverable for native fishes. The protection of these habitats must be incorporated into long term management plans for the land areas involved. If the distinctive freshwater fish fauna of southern California is to survive, protection must be implemented immediately.

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Symposium

NATURAL RESOURCES IN THE PUENTE HILLS—CHINO HILLS CORRIDOR

IMPLICATIONS FOR LAND USE AND PLANNING

WHITTIER
MARCH 18-19, 1994
WHITTIER COLLEGE

CALL FOR PAPERS: Professional and student papers on topics pertaining to existing natural resources, conservation, and land use policy in this geographic region are solicited. The purpose of the symposium is to provide a forum for discussion of completed or continuing research on these issues within this geographic location. The Puente Hills—Chino Hills Corridor encompasses a large amount of both private and public open space under the jurisdiction of three counties and numerous municipalities. Professionals and students engaged in research on land use policy in this region are encouraged to attend.

Direct abstracts and correspondence to: Dr. Cheryl Swift
Department of Biology
Whittier College
Whittier, CA 90602

Please see other side for instructions regarding abstract preparation and submission. **ABSTRACTS DUE FEBRUARY 1, 1994.**

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Sample Abstract

AGE STRUCTURE OF SYCAMORES, *Platanus Racemosa,* IN THE WHITTIER HILLS. C. Quirarte, C. Allen, and C. Swift, Department of Biology, Whittier College, Whittier, CA 90608.

The age structure of a population of sycamores, *Platanus racemosa,* in Sycamore Canyon in the Whittier Hills was determined, *etc.* . . .

MAIL ABSTRACT AND CARD TO: Dr. Cheryl Swift
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