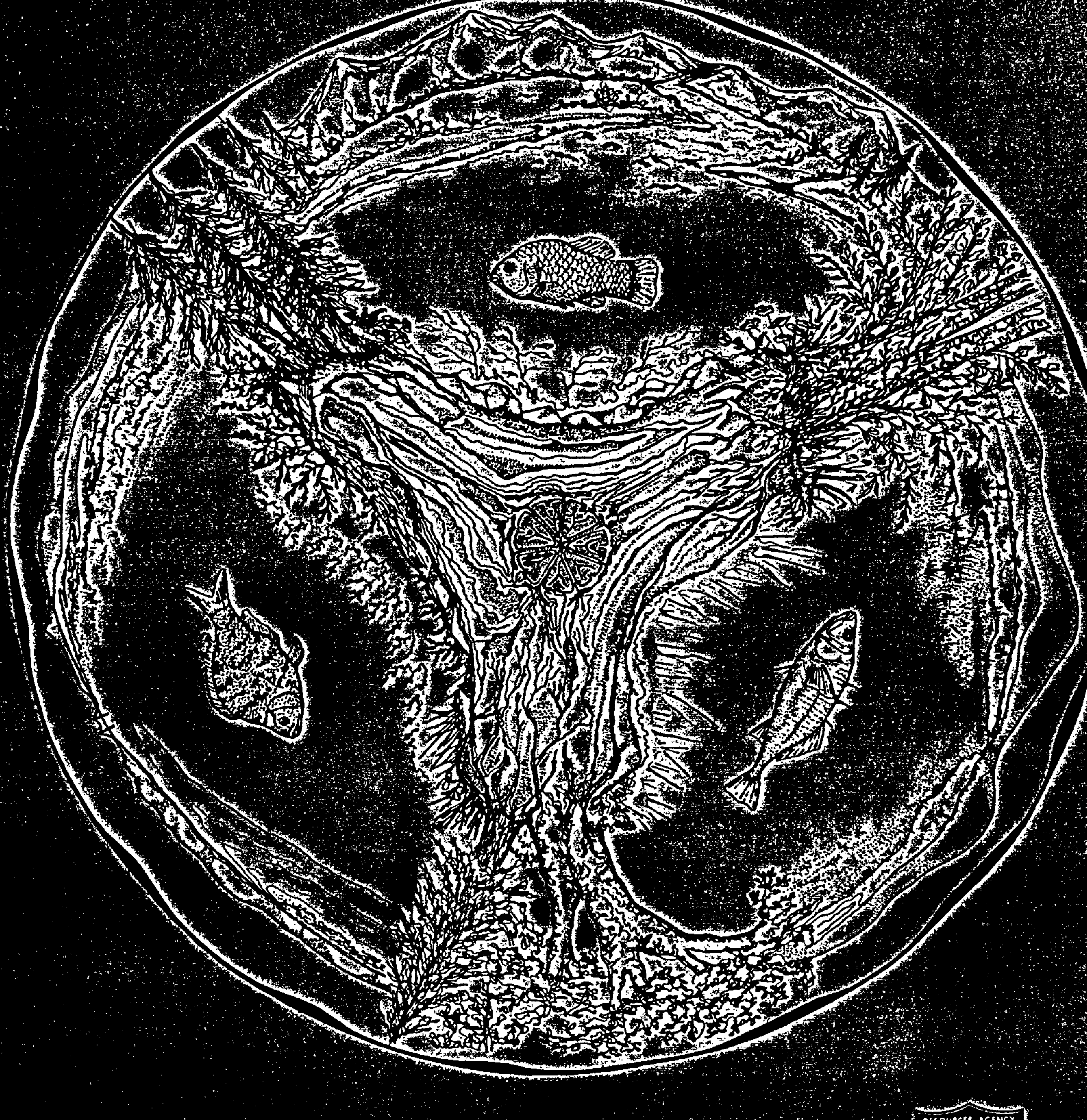
FISH SPECIES OF SPECIAL CONCERN OF CALIFORNIA



CALIFORNIA DEPARTMENT OF FISH AND GAME

FISH SPECIES OF SPECIAL CONCERN OF CALIFORNIA

by

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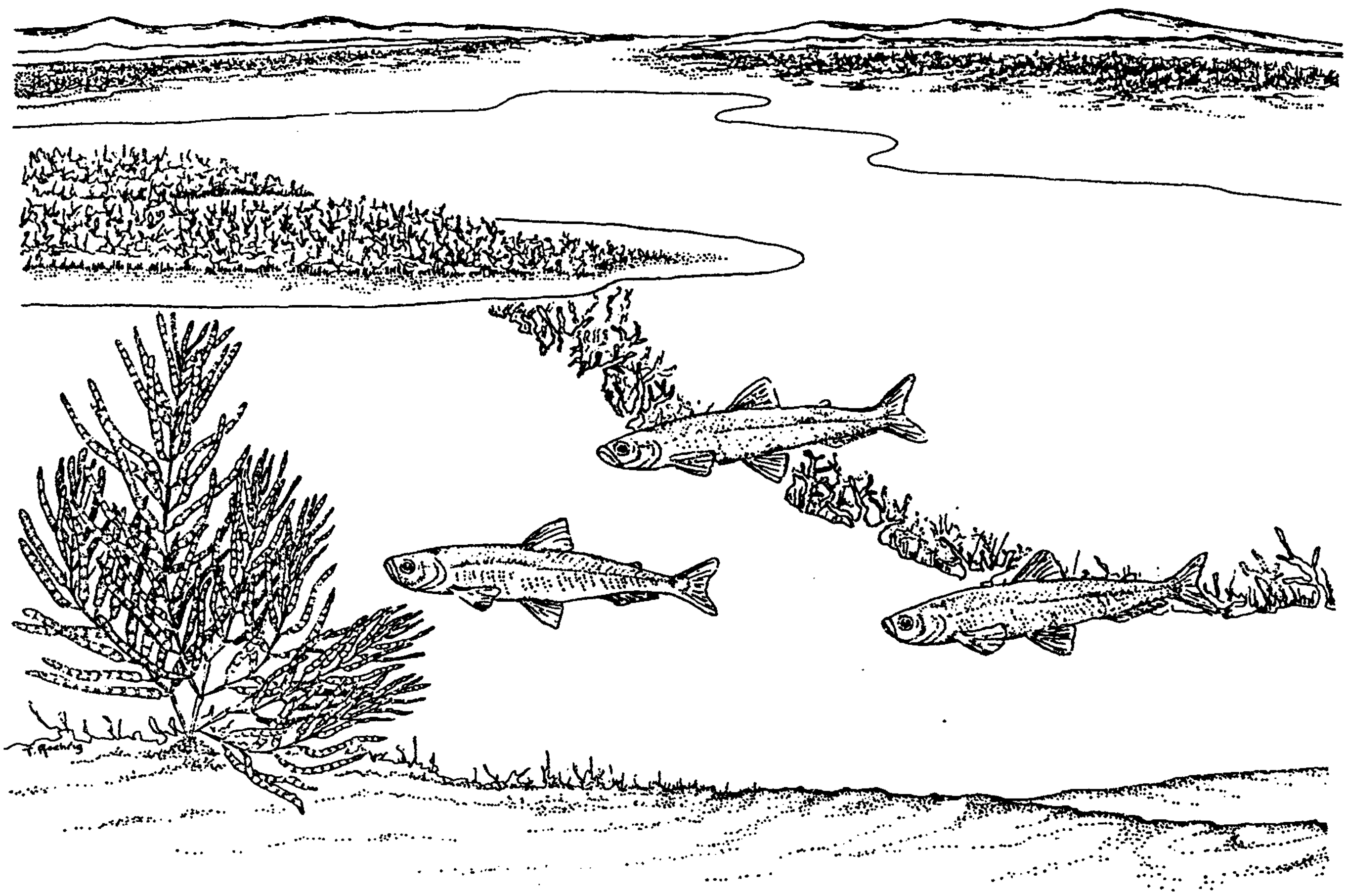

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INTRODUCTION

The fish fauna of California is characterized by a high degree of endemism. Sixty-five of the 113 species and subspecies are found only in the state, and many of the remainder are shared only with a few other western states (Moyle et al. 1989). This endemism is the result of long isolation of California's drainage basins, coupled with aquatic environments requiring special adaptations for long-term persistence of fish populations (Moyle 1976). Fish are found in habitats ranging from tiny desert springs, to rivers that have huge fluctuations in flow, to shallow alkaline lakes and sloughs. Although the native fishes are admirably suited for surviving the vagaries of nature, they have done poorly when forced to compete with humans for the water in which they live. In California, most streams have been dammed, diverted, or otherwise altered; many lakes and marshes have been drained; much of the water has been polluted; and numerous fish species have been introduced into both altered and unaltered waters. As a result, five species or subspecies have become extinct in recent years and 16 others have been recognized as threatened or endangered by state or federal governments (Table 1).

Unfortunately, the forms that are formally recognized as extinct, endangered, or threatened are only the most obvious part of the picture. In this report, we describe four species or subspecies and two major runs of salmonids that deserve immediate recognition as threatened or endangered. Forty-four other taxa are described that need special protection because they appear to have seriously declining populations, because they have very limited ranges, or because we know so little about their status. In the latter case, we listed them on the assumption that the lack of information is at least partially a reflection of rarity. Three other taxa described in this report, Sacramento perch, arroyo chub, and Volcano Creek golden trout, would probably deserve listing as threatened or endangered if they had not been widely planted outside their native ranges; we list them because their native populations are still in trouble. Altogether, counting taxa that are extinct, taxa that are already listed as threatened or endangered, and taxa covered in this report, there are 72 species, subspecies, or salmon runs that need special protection or management, 64% of the native freshwater fish taxa! The decline of the native fishes should also be regarded as indicative of the decline of native aquatic habitats and ecosystems, which no doubt contain many poorly known endemic invertebrates and plants as well.

The decline of California's native aquatic organisms will continue and many extinctions will occur unless the widespread nature of the problem is recognized and a systematic effort is made to protect aquatic habitats in all drainages. The task of protecting the native fauna is going to be extraordinarily difficult because California's human population is growing rapidly and the demand for the state's limited water is growing with it. It is nonetheless a task well worth undertaking.

METHODS

The first step in creating this report was compiling the list of California fishes based on Moyle (1976) and more recent literature and knowledge of the authors. For the freshwater fishes the biggest problem faced was the inclusion of forms of uncertain taxonomic status; there are many isolated populations of undescribed fishes around the state whose relationship to described forms is poorly known yet seem to have distinctive morphological or ecological characteristics. Usually,

TABLE 1. Status of native freshwater fishes within the state of California. Fish classified as C1-C4 are species of special concern treated in this report. FE and FT are federally listed endangered and threatened species, respectively. SE and ST are state listed endangered and threatened species, respectively. Extinct species may be either globally extinct or extinct in California.

Petromyzontidae
Kern brook lamprey, *Lampetra hubbsi* (C2)
Pacific lamprey, *Lampetra tridentata*
  Sea-run Pacific lamprey, *L. t. tridentata* (C5)
  Goose Lake lamprey, *L. t.* subsp. (C2)
Pit-Klamath brook lamprey, *Lampetra lethophaga* (C5)
Klamath river lamprey, *Lampetra similis* (C3)
Modoc brook lamprey, *Lampetra folletti* (C3)
River lamprey, *Lampetra ayresi* (C3)
Pacific brook lamprey, *Lampetra pacifica* (C5)

Acipenseridae
White sturgeon, *Acipenser transmontanus* (C5)
Green sturgeon, *Acipenser medirostris* (C5)

Salmonidae
Mountain whitefish, *Prosopium williamsoni* (C5)
Chinook salmon, *Oncorhynchus tshawytscha*[2]
  Spring chinook salmon (C2)
  Winter chinook salmon (C1)
  Fall chinook salmon (C5)
  Late-fall chinook salmon (C5)
Coho salmon, *Oncorhynchus kisutch* (C3)
Pink salmon, *Oncorhynchus gorbuscha* (C2)
Chum salmon, *Oncorhynchus keta* (C5)[3]
Sockeye salmon, *Oncorhynchus nerkes* (C5)[3]
Rainbow trout, *Oncorhynchus mykiss*
  Coastal rainbow trout
    Resident rainbow trout *O. m. gairdneri*[4] (C5)
    Summer steelhead (C1)
    Winter steelhead (C5)
  Eagle Lake rainbow trout, *O. m. aquilarum* (C3)
  Kern River rainbow trout, *O. m. gilberti* (C2)
  Little Kern golden trout, *O. m. whitei* (FT)
  Volcano Creek golden trout, *O. m. aguabonita* (C4)
  Goose Lake redband trout, *O. m.* subsp. (C2)
  McCloud River redband trout, *O. m.* subsp. (C3)
Cutthroat trout, *Oncorhynchus clarki*
  Coastal cutthroat, *O. c. clarki* (C3)
  Lahontan cutthroat, *O. c. henshawi* (FT)
  Paiute cutthroat, *O. c. seleniris* (FT)

Bull trout, *Salvelinus confluentus* (EXTINCT)[4]

Osmeridae
Delta smelt, *Hypomesus transpacificus* (C1)
Longfin smelt, *Spirinchus thaleichthys* (C5)
Eulachon, *Thaleichthys pacificus* (C5)

Cyprinidae
Tui chub, *Gila bicolor*
  Lahontan creek tui chub, *G. b. obesa* (C5)
  Lahontan lake tui chub, *G. b. pectinifer* (C2)
  Mohave tui chub, *G. b. mohavensis* (SE, FE)
  Owens tui chub, *G. b. snyderi* (SE, FE)
  Cowhead Lake tui chub, *G. b. vaccaceps* (C2)
  Goose Lake tui chub, *G. b. thalassina* (C3)
  Eagle Lake tui chub, *G. b.* subsp. (C3)
  High Rock Springs tui chub, *G. b.* subsp. (C2)
  Klamath River tui chub, *G. b. bicolor* (C5)
  Pit River tui chub, *G. b.* subsp. (C5)
Blue chub, *Gila coerulea* (C5)
Arroyo chub, *Gila orcutti* (C4)
Thicktail chub, *Gila crassicauda* (EXTINCT)
Bonytail chub, *Gila elegans* (SE, FE)
Lahontan redside, *Richardsonius egregius* (C5)
Hitch, *Lavinia exilicauda*
  Sacramento hitch, *L. e. exilicauda* (C5)
  Clear Lake hitch, *L. e. chi* (C3)
  Monterey hitch, *L. e. harengus* (C5?)
California roach, *Lavinia symmetricus*
  Sacramento roach, *L. s. symmetricus* (C5)
  San Joaquin roach, *L. s.* subsp. (C3)
  Monterey roach, *L. s. subditus* (C3)
  Navarro roach, *L. s. navarroensis* (C3)
  Tomales roach, *L. s.* subsp. (C3)
  Gualala roach, *L. s. parvipinnis* (C2?)
  Pit roach, *L. s. mitrulus* (C2)
Sacramento blackfish, *Orthodon microlepidotus* (C5)
Sacramento splittail, *Pogonichthys macrolepidotus* (C2)
Clear Lake splittail, *Pogonichthys ciscoides* (EXTINCT)
Hardhead, *Mylopharodon conocephalus* (C3)
Sacramento squawfish, *Ptychocheilus grandis* (C5)
Colorado squawfish, *Ptychocheilus lucius* (SE, FE, EXTINCT)
Speckled dace, *Rhinichthys osculus*
  Amargosa Canyon speckled dace, *R. o.* subsp. (C2)
  Klamath speckled dace, *R. o. klamathensis* (C5)
  Lahontan speckled dace, *R. o. robustus* (C5)

Owens speckled dace, *R. o.* subsp. (C2)
Sacramento speckled dace, *R. o.* subsp. (C5)
Santa Ana speckled dace, *R. o.* subsp. (C1)

Catostomidae
Flannelmouth sucker, *Catostomus latipinnis* (EXTINCT)
Sacramento sucker, *Catostomus occidentalis*
Sacramento sucker, *C. o. occidentalis* (C5)
Goose Lake sucker, *C. o. lacusanserinus* (C3)
Tahoe sucker, *Catostomus tahoensis* (C5)
Owens sucker, *Catostomus fumeiventris* (C3)
Modoc sucker, *Catostomus microps* (SE, FE)
Klamath smallscale sucker, *Catostomus rimiculus* (C5)
Klamath largescale sucker, *Catostomus snyderi* (C2)
Lost River sucker, *Deltistes luxatus* (SE, FE)
Mountain sucker, *Catostomus platyrhynchus* (C3)
Santa Ana sucker, *Catostomus santaanae* (C2)
Razorback sucker, *Xyrauchen texanus* (SE)
Shortnose sucker, *Chasmistes brevirostris* (SE,FE)

Cyprinodontidae
Desert pupfish, *Cyprinodon macularius* (SE,FE)
Amargosa pupfish, *Cyprinodon nevadensis*
Saratoga Springs pupfish, *C. n. nevadensis* (C3)
Amargosa pupfish, *C. n. amargosae* (C3)
Shoshone pupfish, *C. n. shoshone* (C1)
Tecopa pupfish, *C. n. calidae* (EXTINCT)
Owens pupfish, *Cyprinodon radiosus* (SE,FE)
Salt Creek pupfish, *Cyprinodon salinus*
Salt Creek pupfish, *C. s. salinus* (C3)
Cottonball Marsh pupfish, *C. s. milleri* (ST)
California killifish, *Fundulus parvipinnis* (C5)

Atherinidae
Topsmelt, *Atherinops affinis* (C5)[6]

Gasterosteidae
Threespine stickleback, *Gasterosteus aculeatus*
Unarmored threespine stickleback, *G. a. williamsoni* (SE,FE)
Santa Ana threespine stickleback, *G. a. santannae* (C1)
Partially plated threespine stickleback, *G. a. microcephalus* (C5)[7]
Fully plated threespine stickleback, *G. a. aculeatus* (C5)[7]

Centrarchidae
Sacramento perch, *Archoplites interruptus* (C4)

Embiotocidae
Tule perch, *Hysterocarpus traski*
Sacramento tule perch, *H. t. traski* (C5)
Russian River tule perch, *H. t. pomo* (C2)
Clear Lake tule perch, *H. t. lagunae* (C5)
Shiner perch, *Cymatogaster aggregata* (C5)[6]

Mugilidae
Striped mullet, *Mugil cephalus* (C5)[6]

Gobiidae
Tidewater goby, *Eucyclogobius newberryi* (C2)
Longjaw mudsucker, *Gillichthys mirabilis* (C5)[6]

Cottidae
Prickly sculpin, *Cottus asper*[8]
Coastal prickly sculpin, *C. a.* subsp. (C5)
Sacramento prickly sculpin, *C. a.* subsp. (C5)
Clear Lake prickly sculpin, *C. a.* subsp. (C5)
Riffle sculpin, *Cottus gulosus* (C5)
Pit sculpin, *Cottus pitensis* (C5)
Reticulate sculpin, *Cottus perplexus* (C3)
Marbled sculpin, *Cottus klamathensis*
Upper Klamath marbled sculpin, *C. k. klamathensis* (C5)
Bigeye marbled sculpin, *C. k. macrops* (C3)
Lower Klamath marbled sculpin, *C. k. polyporus* (C5)
Paiute sculpin, *Cottus beldingi* (C5)
Coastrange sculpin, *Cottus aleuticus* (C5)
Rough sculpin, *Cottus asperrimus* (ST)
Pacific staghorn sculpin, *Leptocottus armatus* (C5)[6]
Pleuronectidae
Starry flounder, *Platichthys stellatus* (C5)[6]

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[1]*The population of "L. pacifica" from Los Angeles Basin probably represent a distinct species, now extinct (C. Swift, pers. comm.).*

[2]*Chinook salmon have genetically distinct populations (runs) in each major drainage. Probably all wild populations have declined in recent years, but we only list spring run and winter run chinook salmon as Class 1 species.*

[3]*Only strays into California freshwater; probably have never had established populations in California.*

[4]*Like chinook salmon, steelhead have a number of genetically distinct runs in each drainage.*

[5]*Listed as "state endangered," but recent surveys indicate that the bull trout is extinct in California.*

[6]*Marine species common in lower reaches of coastal streams.*

[7]*See Bakker and Svenster (1988) for alternate "subspecies" terminology for sticklebacks. Copeia 1988(2):569-571.*

[8]*Hopkirk (1973) suggested at least three subspecies of prickly sculpin exist in California. The Clear Lake population especially may deserve recognition as it is distinctive ecologically.*

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we included undescribed or poorly described forms if they were listed in Hubbs et al. (1979) and one or more other sources, or we had some personal experience in working with them that indicated their distinctness. The poor descriptions and lack of life history information for many subspecies indicate the need for more work on the systematics and biology of widely distributed species with many isolated populations such as tui chub (*Gila bicolor*) and California roach (*Lavinia symmetricus*). The extensive work done on one such species, rainbow trout (*Oncorhynchus mykiss*), demonstrates that many of these populations probably do deserve recognition as distinct taxa (e.g., Berg 1987). The ones listed as undescribed subspecies in this report are only the most obvious of these populations. All taxa described in this report, however, fit the definition of species in the Federal Endangered Species Act of 1973 as "any species, subspecies, or distinct population that interbreeds when mature."

Unless otherwise indicated, descriptions of species are based on Moyle (1976). Fish lengths are reported as total length (TL), fork length (FL), or standard length (SL), although the latter is used wherever possible.

The status of each species described in this report is based solely on the condition of the species within California. Taxa were excluded that were already extinct or listed as endangered or threatened by state or federal agencies. After evaluating the evidence available, the remaining species were placed in five classes according to the likelihood of their becoming extinct in the near future. Class 5 species were considered secure and not included in this report. The classes are as follows:

Class 1 Species (C1).

These are taxa that seem to conform to the state definitions of the threatened or endangered species and should be added to the official list.

Class 2 Species (C2).

These taxa have populations that are low, scattered, or highly localized. Their populations have declined in abundance in recent years and so require management to prevent them from becoming threatened species.

Class 3 Species (C3).

These are uncommon taxa occupying much of their natural range, formerly more abundant, but still with pockets of abundance within their range. These species should be periodically monitored to see if their decline is accelerating. Taxa with very restricted distributions but stable populations are also included here.

Class 4 Species (C4).

These fishes have declined in abundance within their native range but have been introduced and established in greater numbers outside their native range. Special management is required to prevent loss of native populations.

Class 5 Species (C5).

These are common or widespread taxa whose populations appear stable or increasing in the face of habitat alterations. However, at least four species in this category need investigation to

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see if our designation is accurate: green sturgeon, blue chub, Lahontan speckled dace, and mountain whitefish.

The following agency and institution abbreviations are used in this report: AFS (American Fisheries Society), BLM (Bureau of Land Management), CDFG (California Department of Fish and Game), PG&E (Pacific Gas and Electric Company), UCD (University of California, Davis), USFS (United States Forest Service), and USFWS (United States Fish and Wildlife Service).

Species accounts in this report were initially assembled from the literature and files of Moyle and Williams by Wikramanayake. Moyle and Williams determined the status of each taxon, wrote the status and management sections, and revised the species accounts.

ACKNOWLEDGMENTS

Preparation of this report was aided greatly by the use of unpublished data from various scientists throughout California. In particular we would like to think Donald G. Buth, Tom R. Haglund, and Camm C. Swift for information on southern California fishes; Donald W. Sada for data on speckled dace in the Owens Valley; Don C. Erman on Lahontan fishes; and Eric R. Gerstung for material on numerous salmonids. The following employees of CDFG improved quality of this document through their careful reviews: Betsy C. Bolster, Almo Cordone, Paul P. Chappell, Susan Ellis, Eric R. Gerstung, John M. Hayes, Terry Healey, Frederick Meyer, Edwin P. Pister, Forrest Reynolds, Mike Rode, Donald E. Stevens, and Don W. Weidlein. Financial support was provided by the CDFG through the Endangered and Rare Fish, Wildlife, and plant Species Conservation and Enhancement Account (Income Tax Check-Off). We especially appreciate the assistance of our contracting officer, Betsy C. Bolster. This report was prepared while Jack E. Williams was participating in an Intergovernmental Personnel Act appointment from the U.S. Fish and Wildlife Service. Final editing and manuscript preparation was completed by Shirley H. Cable; illustrations are by T. J. Roehrig.

KERN BROOK LAMPREY
Lampetra hubbsi (Vladykov and Kott)

Description: The Kern brook lamprey is a non-parasitic lamprey endemic to the San Joaquin drainage (Brown and Moyle 1988). Its morphology is like that of other lampreys: eel-like body, no paired fins, and a sucking disc instead of jaws. Larvae, known as ammocoetes, are similar to adults in shape but lack eyes and a well-developed oral disc. The Kern brook lamprey is much smaller than the parasitic anadromous lampreys; adults range from 81 to 139 mm TL and ammocoetes from 117 to 142 mm TL. Ammocoetes are typically larger than adults because non-parasitic lampreys shrink following metamorphosis (Vladykov and Kott 1976). The number of trunk myomeres (i.e. the "blocks" of muscle mass along the body), ranges from 51 to 57 in ammocoetes and provides some separation from the partially sympatric *L. pacifica* (Tables 2, 3). Dentition also is distinctive. The supraoral lamina typically has 2 cusps, with 4 inner lateral teeth on each side of the disc. The typical cusp formula is 1-1-1-1 (Vladykov and Kott 1976). The sides and dorsum are a grey-brown and the ventral area is white. Dorsal fins are unpigmented, but there is some black pigmentation restricted to the area around the notochord in the caudal fin (Vladykov and Kott 1976).

Taxonomic Relationships: *Lampetra hubbsi* was first described by Vladykov and Kott (1976) as a dwarf, non-parasitic species in the genus *Entosphenus*. The status of this genus is under debate (see Vladykov and Kott 1976); meanwhile, we conform to the nomenclature of Robins et al. (1980).

The non-parasitic species of lampreys along the Pacific States are considered to be derived from parasitic anadromous species (Bond and Kan 1973). Thus *L. hubbsi* is thought to be derived from the parasitic *Lampetra tridentata*. The only other parasitic species of lamprey in this genus is *L. minima* (now extinct), which is a dwarf form described by Bond and Kan (1973) from Miller Lake, Oregon. Another small non-parasitic species, *L. pacifica*, is also found in south-central California and is differentiated from *L. hubbsi* on the basis of certain anatomical features (Tables 2,3). A complex of non-parasitic lamprey species is also found in the Pit and Klamath river drainages.

Distribution: *L. hubbsi* was first discovered in the Friant-Kern Canal, but it has since been found in the lower reaches of the Merced River, Kaweah River, Kings River, and San Joaquin River (Brown and Moyle 1987, 1989; Fig. 1). In 1988, ammocoetes and adult lampreys were found in several siphons of the Friant-Kern canal, but they were poisoned during an effort to rid the canals of white bass (*Morone chrysops*). The "low count" lampreys (i.e., low numbers of trunk myomeres) reported from the upper San Joaquin River between Millerton Reservoir and Kerckhoff Dam by Wang (1986) may also be *L. hubbsi*.

Habitat Requirements: Principle habitats of Kern brook lamprey are silty backwaters of large rivers in the foothill regions (mean elevation = 135 m; range = 30-327 m). Ammocoetes are usually found in shallow pools and along edges of run areas where flow is slight (L. Brown, pers. comm.) at depths of 30 to 110 cm in summer water temperatures that rarely exceed 25°C. Common substrates associated with these lampreys are sand, gravel, and rubble (average compositions being 40%, 22%, 23%, respectively). Ammocoetes seem to favor sand/mud substrate where they usually remain buried with the head protruding above the substrate and feed by filtering diatoms and other micro-organisms from the water. This type of habitat is apparently present in the siphons of the Friant-Kern canal. Adults likely require the coarser gravel-rubble substrate for spawning.

Life History: No documentation of the life history of Kern brook lamprey exists. However, if its life history is comparable to other non-parasitic brook lampreys, they should live for approximately 4-5 years as ammocoetes before metamorphosing into adults. Metamorphosis occurs during fall. The adults overwinter and spawn the following spring after undergoing nuptial metamorphosis. Individuals of some species, however, are known to mature neotenically, retaining prenuptial pigmentation and body morphology; such lampreys spawn during the summer or the following year after overwintering.

Status: Class 2.

Since this species was first discovered in 1976, attempts to fully document its range have been largely unsuccessful. This lack of success is primarily because most collections have been of ammocoetes and transformers that cannot be readily distinguished from other species. However, data collected to date suggest that this species is a San Joaquin endemic (Brown and Moyle 1988). Isolated populations of Kern brook lamprey seem thinly distributed throughout the San Joaquin drainage, and their abundances are probably much reduced. Such a fragmented distribution makes them susceptible to local extirpations. Ammocoetes apparently thrive in the dark siphons of the Friant-Kern canal, but it is unlikely that there is suitable spawning habitat in the canal.

Immediate threats are damming and other alterations of rivers in the foothill areas that reduce the amount of silt-laden backwaters required by the ammocoetes. Because Kern brook lamprey require water with a slight flow, reservoirs are most likely poor habitats for them. Most known populations presently are located below dams where stream flows are regulated without considerations for lamprey populations. Thus, habitat loss may be the major threat to the species' existence.

Management: We recommend more extensive surveys to determine the present range and distribution of *L. hubbsi*, including determination if ammocoetes use the silty bottoms of siphons in the Friant-Kern canal. The surveys should focus on adults. Several known areas of suitable habitat should be selected for special management or protection from incompatible uses. Known or probable populations should be monitored by sampling every two to five years.

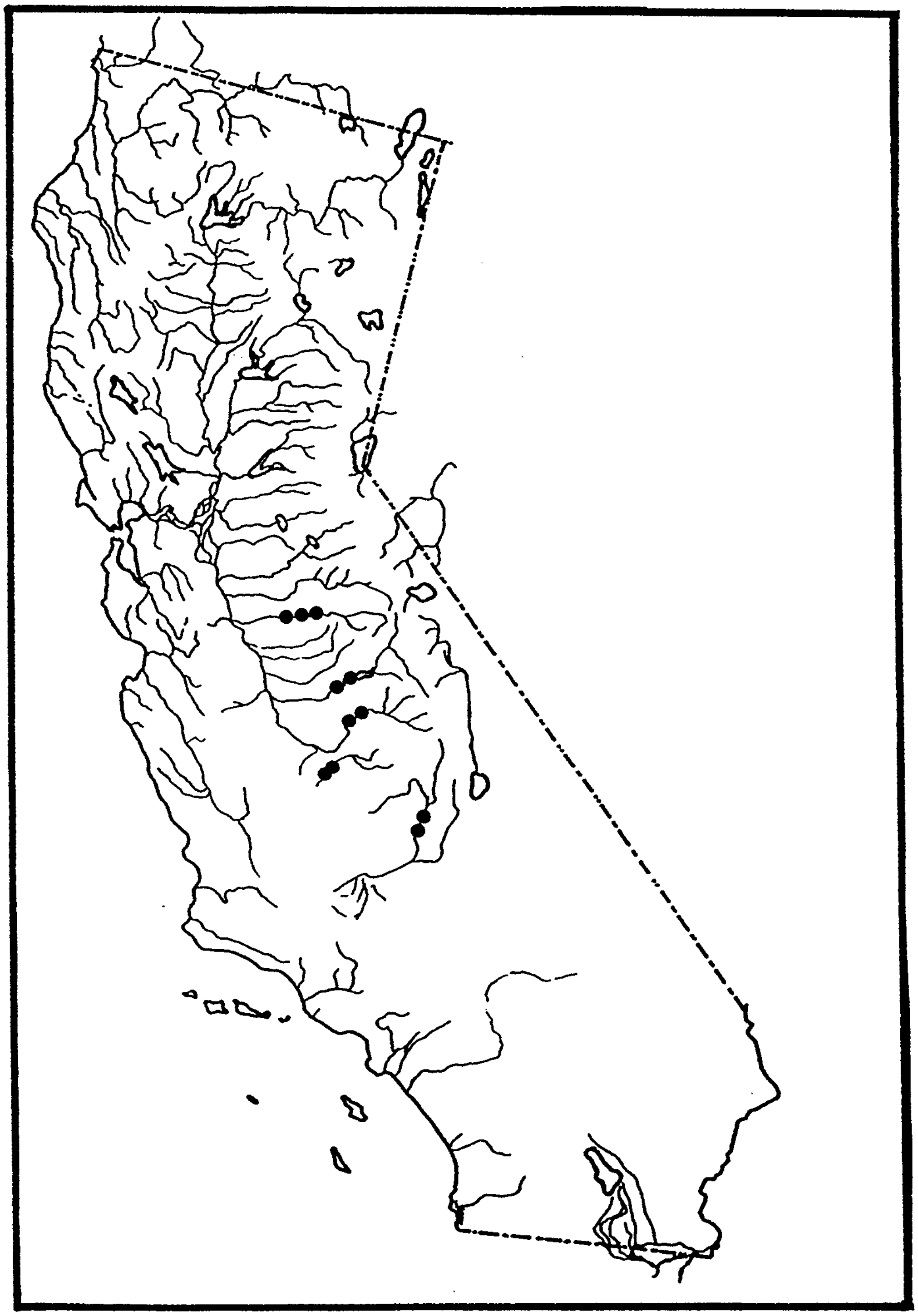


FIGURE 1. Distribution of the Kern Brook lamprey, *Lampetra hubbsi*, in California.

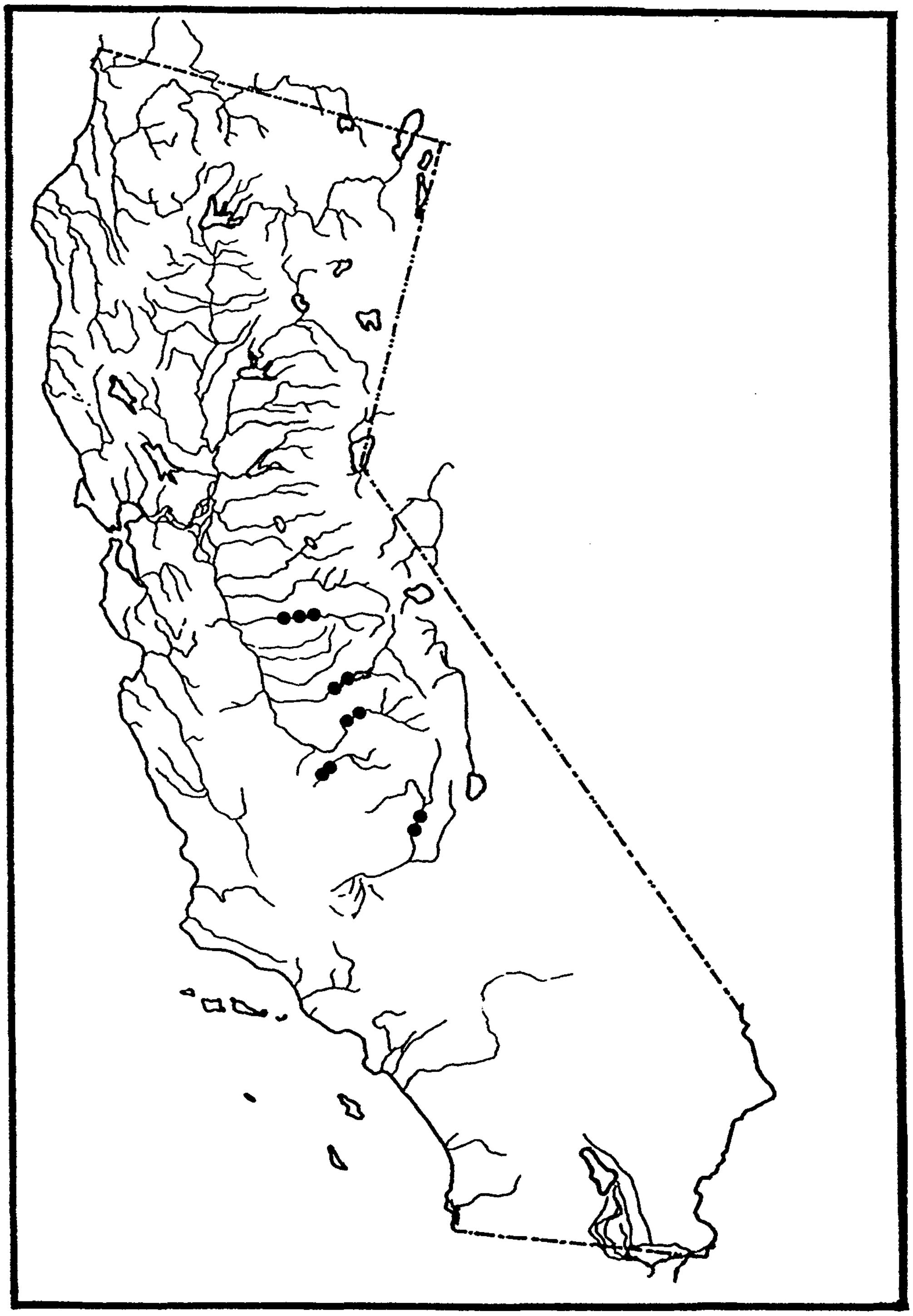


FIGURE 1. Distribution of the Kern Brook lamprey, *Lampetra hubbsi*, in California.

GOOSE LAKE LAMPREY
***Lampetra tridentata* subsp.**

Description: This parasitic lamprey is similar to the widespread Pacific lamprey, *L. tridentata tridentata*, except it is much smaller (adult TL 190-250 mm vs. 300-400 mm for Pacific lamprey). Both forms can be recognized by the sharp horny plates in the sucking disc, the most distinctive being the crescent-shaped supraoral plate, which has three distinct cusps. The middle cusp is smaller than the two lateral cusps. Adult Goose Lake lamprey are shiny bronze. Ammocoetes can be distinguished from those of the sympatric *L. lethophaga* by the larger number of myomere segments (64-70 between the last gill opening and anus).

Taxonomic Relationships: The Goose Lake lamprey is presumably derived from sea-run Pacific lamprey from the Klamath drainage. Its closest relatives are found in the confusing complex of lamprey taxa found in the upper Klamath River; it is most similar to *L. similis*. It probably also has affinities with the Pit-Klamath brook lamprey, *L. lethophaga*, a non-parasitic species with which it is sympatric (Hubbs 1971). However, Goose Lake and the Pit River drainage to which it connects have been separated from the Klamath drainage since the early Pleistocene (1-3 million years), so it is almost certain that the Goose Lake lamprey deserves recognition as a distinct taxon.

Distribution: The Goose Lake lamprey is confined to Goose Lake and its tributaries in Oregon and California (Fig. 2). However, the streams most important for spawning and as habitat for the ammocoetes have not been identified with certainty. Most ammocoetes collected in tributaries to Goose Lake have been identified as *L. lethophaga*.

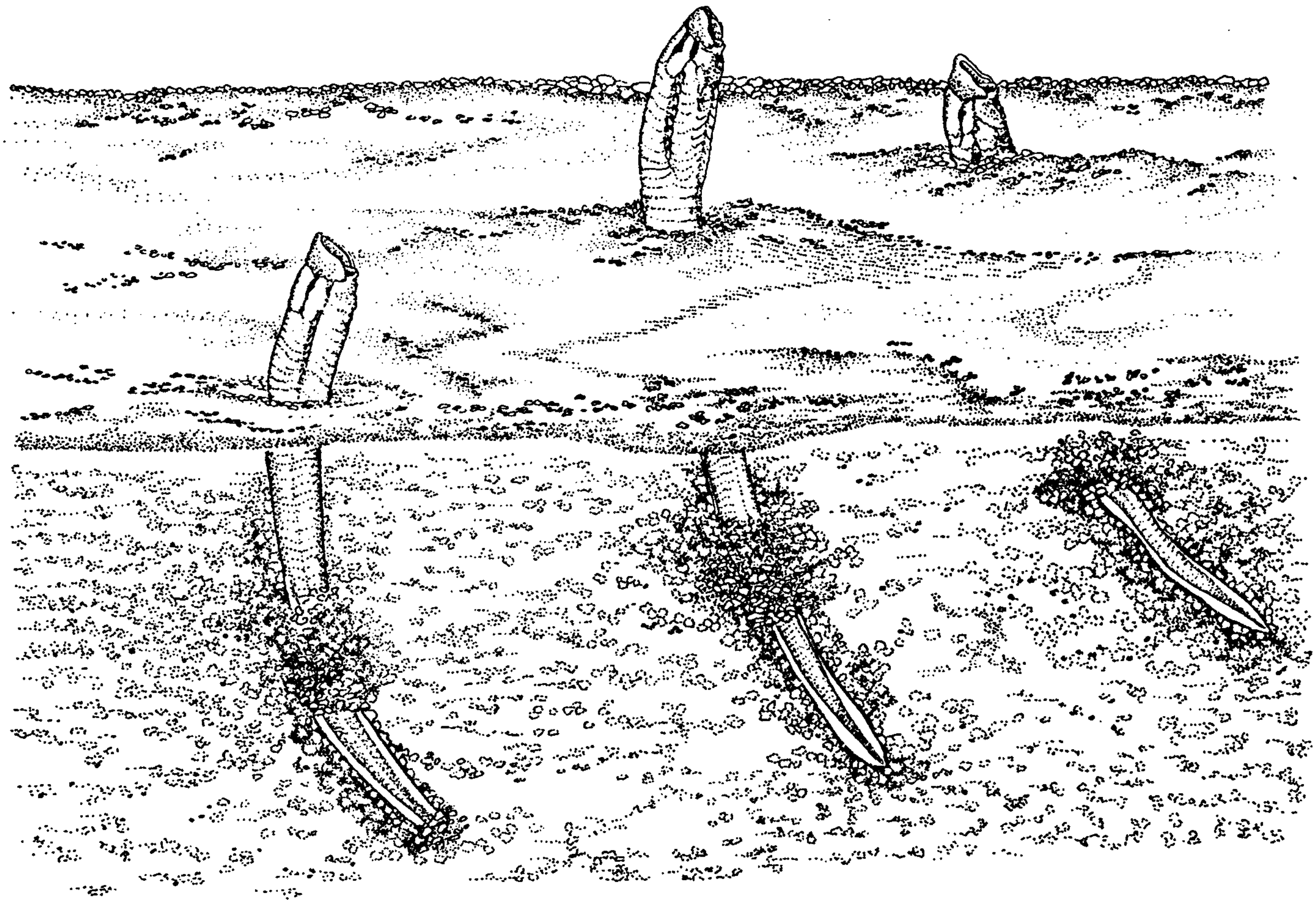
Habitat Requirements: Adults live in shallow, alkaline Goose Lake, where they prey on larger fishes. Like other lampreys, they require gravel riffles in streams for spawning, and the ammocoetes require muddy backwater habitats downstream of the spawning areas. However, the requirements of this lamprey have never been studied.

Life History: The life history of this taxon is largely unknown, but presumably the adults live for a year or two in Goose Lake, preying on Goose Lake suckers, tui chubs, and redband trout. It is likely that they migrate up suitable tributary streams in the spring for spawning. They have to move up far enough to find gravel for spawning and to have enough suitable habitat downstream of the spawning area for survival of the ammocoetes. Thus, spawning areas may be as much as 20-30 km upstream from the lake. Ammocoetes probably spend 4-6 years in the stream before metamorphosing into adults and moving out into the lake.

Status: Class 2.

The Goose Lake lamprey appears to be relatively uncommon although no population surveys have been completed. It is probably affected by the same factors that have caused the decline of Goose Lake redband trout. Diversions, dams, culverts, and other obstructions may prevent migrating adults from reaching spawning areas in tributary streams. The diversion of water from streams for irrigation also may have caused many habitats required by ammocoetes to dry up or to be made unsuitable.

Management: An investigation of this unusual lamprey's life history and habitat requirements should be done as soon as possible to determine what management measures need to be taken. Improving access and flows in streams in California, especially Lassen and Willow Creeks, would benefit not only this lamprey, but also lake-dwelling populations of Goose Lake redband trout.



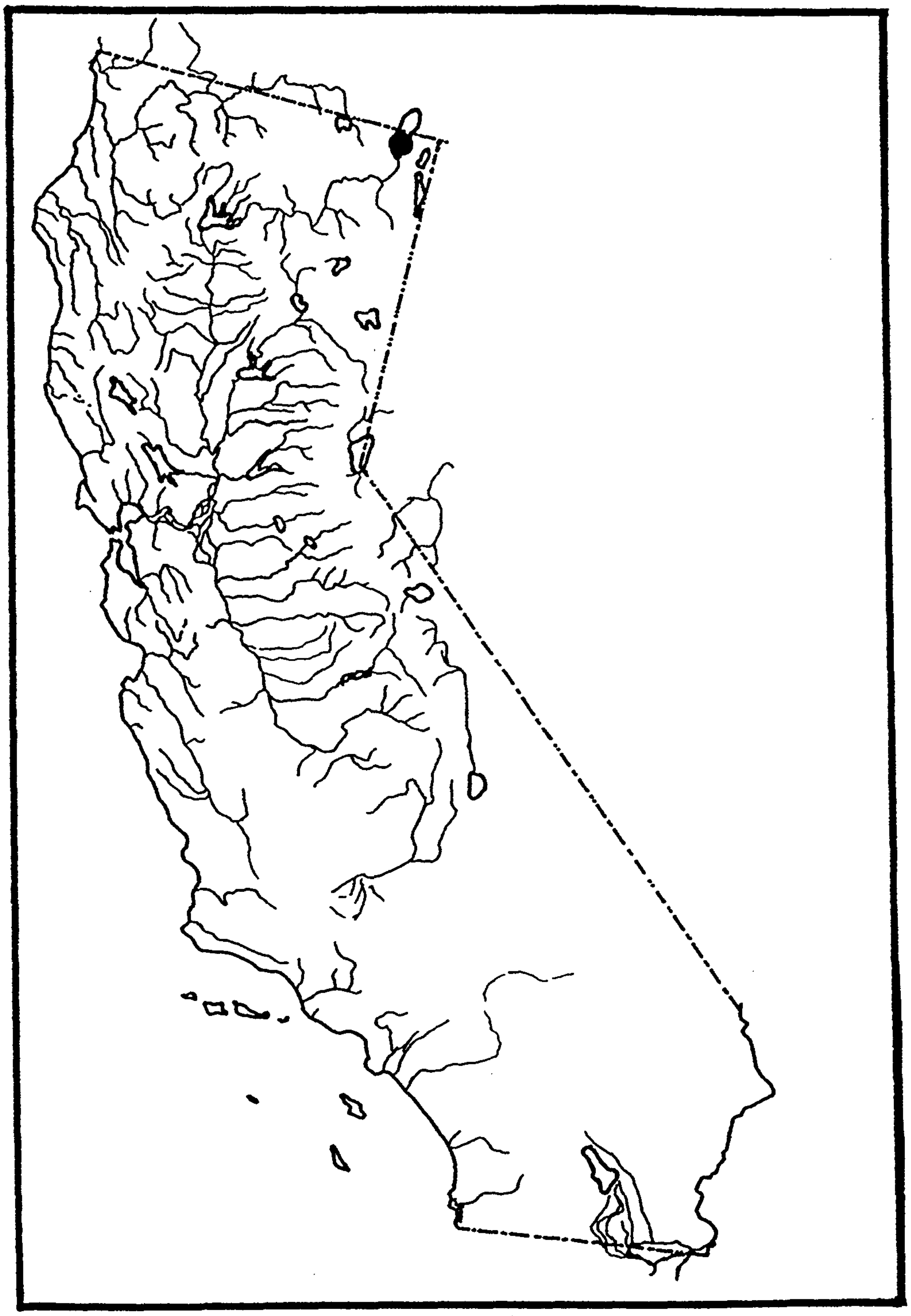


FIGURE 2. Distribution of the Goose Lake lamprey, *Lampetra tridentata* subsp., in California.

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KLAMATH RIVER LAMPREY
Lampetra similis (Vladykov and Kott)

MODOC BROOK LAMPREY
Lampetra folletti (Vladykov and Kott)

Explanatory Note: Five species of lampreys have been described from the upper Klamath River basin: *Lampetra tridentata* (landlocked Pacific lamprey), *L. lethophaga* (Pit-Klamath brook lamprey), *L. minima* (Miller Lake lamprey), *L. similis*, and *L. folletti.*

Lampetra tridentata is a parasitic form and is presumably ancestral to the other lampreys; it is, in turn, descended from sea-run lampreys of the same species. *Lampetra lethophaga* is a widely distributed non-parasitic species, i.e. it spends most of its life as a filter-feeding larvae and transforms to the adult form only to spawn and die without feeding (Hubbs 1971). *Lampetra minima* from Miller Lake, Oregon, is the smallest parasitic lamprey known. It became extinct when the suckers it fed upon were eliminated by a poisoning operation to improve the fishery for trout. *Lampetra similis* and *L. folletti* were described by Vladykov and Kott (1976, 1979). Both species are parasitic, although *L. folletti* was described as a non-parasitic species (C. Bond, pers. comm.). These lampreys are all closely related taxonomically and their validity as distinct species has been questioned (Robins et al. 1980). C. Bond (pers. comm.) has examined both forms closely and regards *L. similis* as a distinct species but *L. folletti* as closely tied to *L. tridentata*. *Lampetra similis* and *L. folletti* are, however, listed here because both their taxonomy and their abundances are poorly known.

Description: The most important characteristics of *L. similis* and *L. folletti* are given in Table 4. Overall body form of *L. similis* is similar to the Pacific lamprey. Adult *L. similis* differ from Pacific lamprey by their smaller size, fewer myomeres, smaller eye, and greater oral disc diameter (Vladykov and Kott 1979). The Modoc brook lamprey is most similar in body form to the Kern brook lamprey.

Taxonomic Relationships: *Lampetra similis* was described by Vladykov and Kott (1979) from specimens collected from the Klamath River, California. *Lampetra folletti* was also described by Vladykov and Kott (1976) from specimens caught in Willow Creek, a tributary to the Lost River, Modoc County, California, and described previously as an intermediate form of *L. lethophagus* and *L. tridentata* (Hubbs 1971). The relationships of these species with the other Klamath River lampreys are described above.

Distribution: *Lampetra similis* is known only from the Klamath River and Upper Klamath Lake of the Klamath River drainage of northern California and southern Oregon (Vladykov and Kott 1979) (Fig. 3). According to these authors, the *L. tridentata* reported from Copco Reservoir by Coots (1955) is very likely *L. similis*. *Lampetra folletti* is known from Willow Creek and the Lost River of the Klamath River drainage (Vladykov and Kott 1976).

Habitat Requirements: Nothing is known specifically about the habitat requirements of *L. similis* and *L. folletti*, but presumably they are similar to the Kern brook lamprey.

Life History: No information is available on the life histories of these species, but they are probably similar to other species of *Lampetra* (see account for the Kern brook lamprey).

Status: Class 3.

This designation is based on their restricted range, which is an area that has been severely modified by dams, diversions, and pollution. Its status should be regarded as provisional until more is known about the systematics of these forms.

Management: Genetic and morphometric studies should be conducted to unravel the complex taxonomy of these fishes. Additional management recommendations will await completion of taxonomic studies.

TABLE 4. Distinguishing characteristics of adults of four species of lamprey (Lampetra) from the upper Klamath River drainage, based on Vladykov and Kott (1976, 1979).

Character	similis	tridentatus	foletti	lethophaga
Parasitic	yes	yes	no	no
Teeth	sharp, strongly hooked	sharp, weakly hooked	dull, unhooked	weak, unhooked
Total length				
Mean (mm)	207	259	206	142
Range (mm)	136-269	190-270	186-228	126-184
Number of myomeres				
Mean	62	65	63	62
Range	58-65	63-66	61-65	59-65
Number of velar tentacles	8 (7-9)	9 (7-11)	9 (8-9)	8 (7-11)

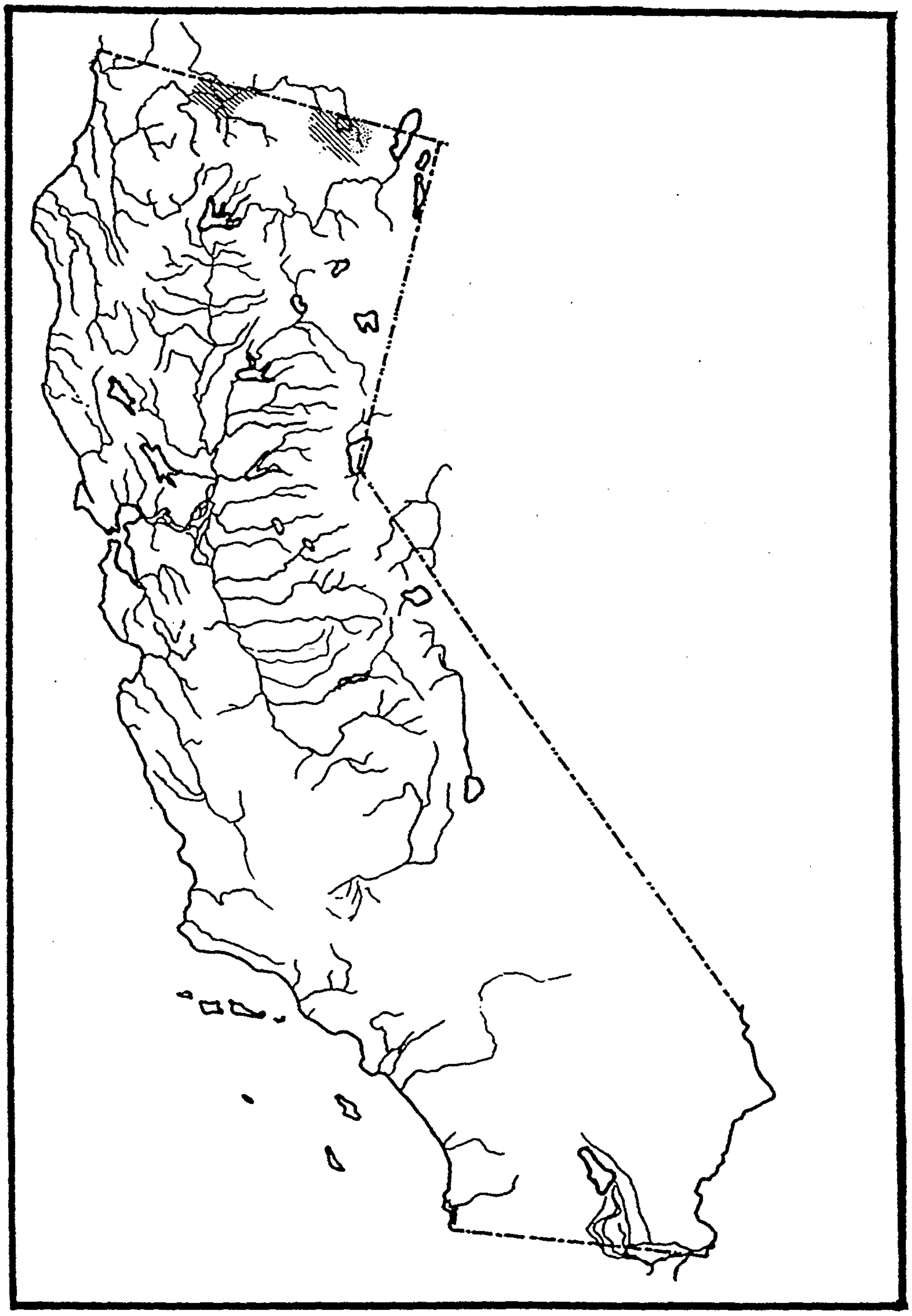

FIGURE 3. Distribution of *Lampetra folletti* and *Lampetra similis* in California.

C-045955

RIVER LAMPREY
Lampetra ayresi (Gunther)

Description: This is a small lamprey that averages about 170 mm total length. Its general body morphology is typical of other lampreys (see Kern brook lamprey). The following description is based on Vladykov and Follett (1958), Moyle (1976), and Wydoski and Whitney (1979). It is a parasitic species with well developed horny plates incorporated in its oral disc, but the plates become progressively blunter in reproductive adults. The middle cusp of the transverse lingual lamina is well developed, and there are three inner lateral plates on each side, the outer plates being bicuspid. There are two cusps in the supra-oral plate, but no posterior teeth. Compared to other lampreys, the eyes of the river lamprey are relatively large, the diameter being 1-1.5 times the distance from the posterior edge of the eye to the anterior margin of the first branchial slit. The number of trunk myomeres is high, with a mean myomere count of 68 in adults and 67 in ammocoetes.

Adults are dark dorsally and laterally, but the ventral surface is silver to yellow. With sexual maturity, the dorsal fins grow closer together and eventually fuse. In adults, the gut also degenerates. Larvae have a black blotch at the tip of the caudal fin.

Taxonomic Relationships: This species was first described as *Petromyzon plumbeus* by Ayres in 1855 from a single specimen collected from San Francisco Bay (Vladykov and Follett 1958, Moyle 1976). Because this name had already been assigned to a species of lamprey in Europe, the river lamprey was reclassified as *Petromyzon ayresi* by A. Gunther in 1870. However, C. T. Regan, in 1911, considered *P. ayresi* to be the same species as the European river lamprey, *Lampetra fluviatilis*. Finally, Vladykov and Follett (1958) reclassified it as a separate species, *Lamptera ayresi*.

Distribution: This lamprey is widely distributed along the western Pacific coast from coastal streams of Juneau, Alaska, to San Francisco Bay (Moyle 1976) (Fig. 4). In California, it is probably most abundant in the Sacramento-San Joaquin River system but has not been observed or collected in large numbers (Moyle 1976).

Habitat Requirements: River lampreys are anadromous and probably spend much of their adult life in estuaries. They require small, clean tributary streams for spawning. The ammocoetes live in silty backwaters of such streams.

Life History: Little is known of the life history of populations of river lamprey in California, but it is presumably similar to that of British Columbia populations. The ammocoetes transform when about 12 cm TL (Beamish 1980). Metamorphosis begins in July and the process is completed during April of the following year when the esophagus opens (Beamish and Youson 1987). This extended metamorphosis differs from other lamprey species. Just prior to the completion of metamorphosis they congregate immediately upriver of salt water and enter the ocean from May to July; they are able to osmoregulate in salt water only after complete opening of the esophagus (Beamish and Youson 1987). Length-frequency analysis suggested that the adults in the Strait of Georgia were of a single age class (Beamish and Williams 1976). During the approximately 10 week period that they are in salt water they are parasitic and grow rapidly, reaching about 250 mm TL (Beamish and Youson 1987).

In British Columbia, the adults migrate back into freshwater by September and spawn during the winter months in small tributary streams (Beamish and Youson 1987). They dig saucer-shaped depressions in sand-gravel riffles for spawning (Wydoski and Whitney 1979). Fecundity has been estimated as up to 37,000 eggs. In males, the gonads are long, with extensive folding, and extend almost the full length of the body cavity (Beamish and Williams 1976). Adults die soon after spawning. The ammocoetes remain in silt-sand substrate backwaters and eddies for several years and feed on algae and micro-organisms (Wydoski and Whitney 1979).

Unlike other species of lamprey, this species usually attaches onto the dorsal and dorsolateral surface of the body of the host fish (Roos et al. 1973, Cochran 1986), although ventral attachments do occur (Beamish 1980). They feed mainly on muscle tissue and typically kill their "host" in the process of feeding. Beamish and Williams (1976) found that they were a major predator on young herring and salmon in the Strait of Georgia. They are known to attack mainly mid-sized salmonids, and estimates reveal that up to 2% of the salmonids in some areas may be attacked by this species (Roos et al. 1973).

Status: Class 3.

This species probably does not need any special protection as it is presumably widely distributed in northern California coastal areas and is abundant in British Columbia, the center of its range. However, there are relatively few records from California and the state does constitute the southernmost portion of its range. Its distribution and abundance in California needs to be investigated, as well as the distinctiveness of the California populations.

Management: Studies on the ecology and systematics of this species are needed before habitat management can be recommended.

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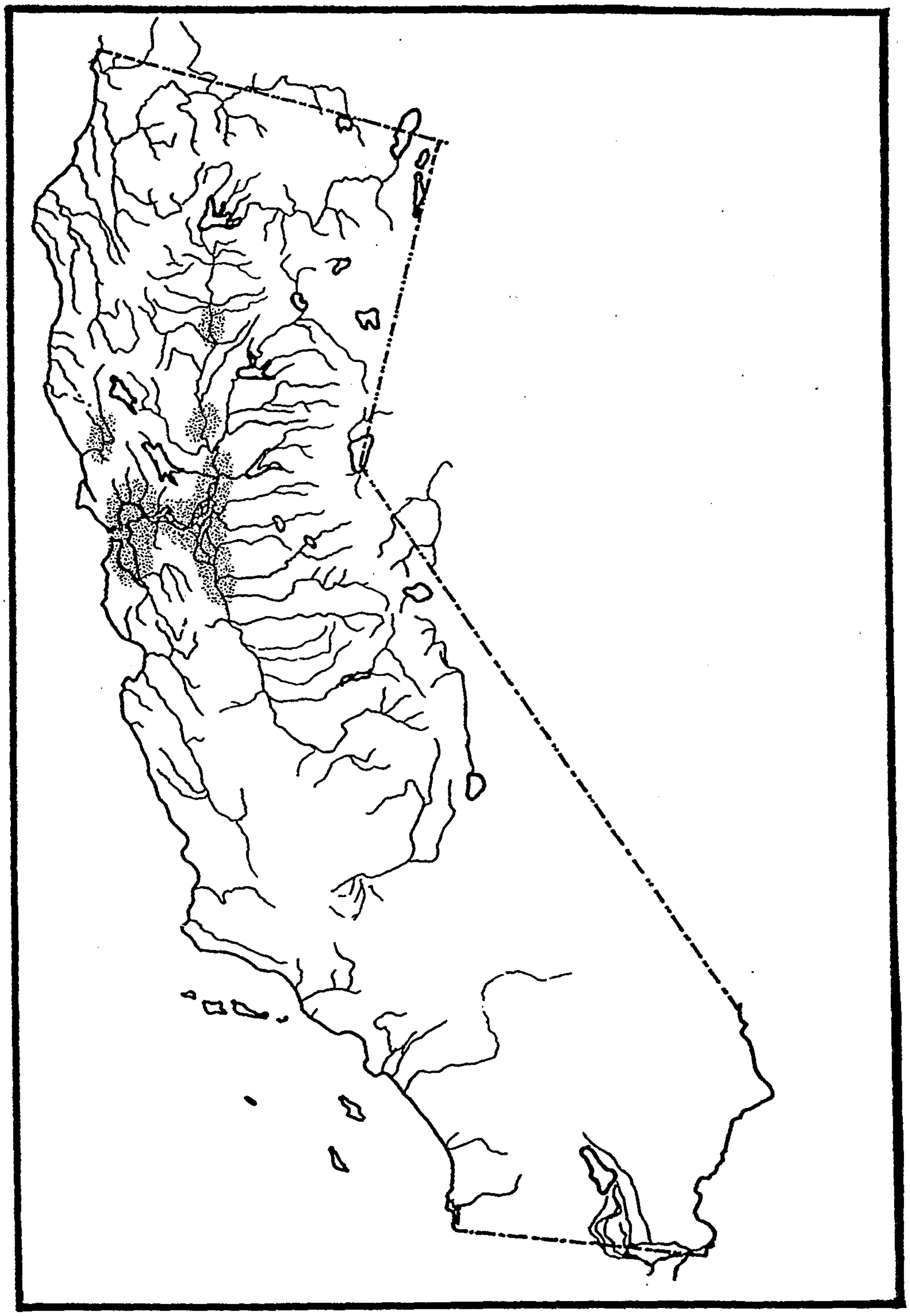

FIGURE 4. Distribution of river lamprey, *Lampetra ayersi*, in California.

SPRING CHINOOK SALMON
***Oncorhychus tshawytscha* (Walbaum)**

Explanatory Note: Presently there are at least eight runs of wild, spring-run chinook salmon in California, all of which are badly depleted. Other runs have become extinct in the past 50 years. Spring chinook salmon are genetically distinct from chinook of other runs and consequently deserve special protective management (see discussion under "Taxonomic Relationships" in the section on winter chinook salmon). Because of their habit of spending the summer months before spawning in deep riverine pools, spring run chinook are highly visible and thus are the most vulnerable of California's salmon runs to poaching.

Description: These are large salmonids, reaching 75 to 100 cm SL, and weighing up to 9-10 kg or more. They have 10-14 major dorsal fin rays, 14-19 anal fin rays, 14-19 pectoral fin rays, and 10-11 pelvic fin rays. There are 130-165 lateral line scales, and 13-19 branchiostegal rays on either side of the jaw. The gill rakers are rough and widely spaced, with 6-10 rakers on the lower half of the first gill arch.

Reproductive adults are uniformly olive brown to dark maroon, but males are darker than females and have a hooked jaw and an arched back. Chinook salmon are distinguished from other species of salmonids by the body coloration, specifically the spots on the back and tail and by the solid black color of the lower jaw.

Parr generally have 6-12 parr marks, evenly spaced and centered along the lateral line. The adipose fin of the parr is pigmented along the upper edge but clear at the base. The other fins are clear, except for the dorsal, which may be spotted.

Taxonomic Relationships: The runs of chinook salmon are differentiated by the maturity of fish entering fresh water, time of spawning migrations, spawning areas, incubation times, incubation temperature requirements, and migration of juveniles. Differences in life histories effectively isolate spring chinook salmon from other runs; thus, the traits are undoubtedly inherited. Therefore, each run of salmon must be considered to be genetically distinct, even from other runs in the same stream.

Distribution: Spring chinook salmon are found in rivers in British Columbia, Washington, Oregon, and California, but their populations are depleted throughout their range or maintained by hatchery production (Shepherd 1989). In California, spring chinooks were once abundant in all major river systems but are now reduced to scattered populations in the Klamath, Trinity, and Sacramento drainages, with small numbers found on occasion in the Smith River, Redwood Creek, Mad River, Mattole River, and Eel River (Fig. 5). In the Sacramento-San Joaquin drainage, the principal holding and spawning areas were in the middle reaches of the San Joaquin, Feather, upper Sacramento, McCloud, and Pit Rivers, presumably with smaller populations in most of the other tributaries large and cold enough to support the salmon through the summer. The main populations were all extirpated when dams were constructed that blocked access to the holding areas, primarily in the 1940's and 1950's. Today, the most consistent self-sustaining wild populations in the drainage are in Deer and Mill Creeks, Tehama County, with fish present in Antelope, Battle, and Big Chico creeks in some years (Vogel 1987a,b; Sato and Moyle 1987). Substantial numbers of spring chinook can also be present in Butte Creek, but numbers have been highly variable and it is not certain if this is a self-maintaining population. Juveniles from the CDFG Feather River Hatchery have been planted there in the past (including 1984 and 1985). Spawning habitat is largely lacking in the reaches above Centerville, but there are adequate spawning gravels and holding pools in the lower reaches. Natural reproduction may nevertheless be disrupted by regulated flow regimes (the stream is regulated for hydroelectricity), high temperatures, poaching, and human disturbance. Historically, Butte Creek apparently had very small runs of spring chinook (Clark 1929). However, in 1989 large numbers of spring chinook occupied Butte Creek and these fish were apparently derived from natural spawning in the creek (F. Myer, pers. comm.). In the Feather River, a run of fish is maintained by hatchery production. In 1986, for example, 1,433 adults were captured and over 1.6 million fingerlings were planted (Schlicting 1988). These fish may also stray into the Yuba River where apparently spring chinook have been observed in the cold water below Engelbright Reservoir.

In the Klamath drainage, the principal remaining run is in the Salmon River and its tributaries. The south fork of the Trinity River also supports a few fish. However, a large run of spring chinook in the main stem Trinity River is maintained by hatchery production.

Life History: In general, chinook migrate considerable distances up streams to spawn. They enter the rivers from March through May, the period of snow-melt flows (Marcotte 1984). These migrating fish are between 2-5 years old at this time. While migrating and holding in the rivers, chinook do not feed, relying instead on stored body fat reserves for maintenance and for gonadal maturation. The runs may also be bi-modal, with some fish holding downstream to migrate later in the summer, possibly because of increasing water temperatures later in the spring (Marcotte 1984). They are fairly faithful to the home streams in which they are spawned, using visual and chemical cues to locate these streams. However, quite a few become disoriented, especially during high water years, and ascend other streams.

When they enter freshwater, spring chinooks are immature; their gonads mature during the summer holding period (Marcotte 1984). Spawning occurs from mid-September through October. Eggs are laid in large depressions (redds) hollowed out in gravel beds. The embryos hatch following a five to six month incubation period and the alevins (sac-fry) remain in the gravel for another 2-3 weeks. Once their yolk sac is absorbed, the juveniles emerge and begin feeding. In some populations, they may begin moving downstream almost immediately, spending only 3-4 weeks in the natal stream. Most downstream movement takes place in March, April, and May (Cramer and Hammock 1952, F. Meyer, pers. comm.). In Deer and Mill creeks, Tehama County, the juvenile salmon spend 9-10 months in the streams where they feed on drift insects. By the end of the summer, they are 8-9 cm SL (Moyle, unpubl. observ.). Presumably, these latter fish move downstream in the first high flows of winter and spend some time in the food-rich estuary to gain additional size before going out to sea. Once in the ocean, salmon are largely piscivorous and grow rapidly.

Adult spring chinooks migrate up Deer and Mill Creeks to spawn during April through June (Vogel 1987a,b) and aggregate in the upper reaches (Airola and Marcotte 1985). In Deer Creek, most hold and spawn between the Ponderosa Way bridge and upper Deer Creek falls, which apparently is a barrier to migrating fish (Marcotte 1984). In Mill Creek they hold and spawn between the Little Mill Creek confluence and approximately 1.6 km above the Highway 36

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bridge, with about 80% of this spawning habitat being within the Lassen National Forest boundary (Marcotte 1984).

There does not appear to be a diurnal pattern to migration, but surges in movements seem to occur following rain sufficient to cause a slight discoloration in water after a period of clear weather, and surges also occur when there is a sudden increase in water temperature to about 24°C (Cramer and Hammack 1952). When water temperatures stabilize at about 27°C, fish usually hold in cooler water in deep pools and migrate upstream in the night. The fish hold in deep pools in the upstream reaches during the summer and spawn in early fall. Prespawning activity has been observed by the last week in August, and intensive nest building activity and spawning occurs from the first week of September through the end of October (Parker and Hanson 1944). Usually, spawning first occurs in the upper reaches of the streams and subsequently in the lower reaches, when water temperatures decrease (Parker and Hanson 1944). Spawning salmon are usually well distributed in the stream section, thus competition for gravel nest sites is reduced (Cramer and Hammack 1952). Nests average 4 m^2 (42 ft^2) (n=87) in area.

Historically, spawning adults were mostly between 4 or 5 years old, although with more intense ocean fishing, 5 year old fish are less abundant. Presently, 3 and even 2 year old fish are more common.

Habitat Requirements: The quality of the physical habitat is important in determining salmonid densities (Platts et al. 1983). For chinook salmon adults, numbers holding in an area seem to depend on the size (volume) and depth of pools, amount of cover (especially "bubble curtains" created by inflowing water), and proximity to patches of gravel suitable for spawning (G. Sato, unpubl. data). Mean water temperatures in pools where adult chinook held during the summer (of 1986) in Deer and Mill creeks were 16°C (range 11.7-18°C) and 20°C (range 18.3-21.1°C), respectively, and for juveniles in Mill Creek the temperature ranged from 13.3-22.2°C (Sato and Moyle 1987). Records indicate that spring chinook in the Sacramento-San Joaquin River system spend the summer holding in large pools where summer temperatures were usually below 21-25°C (Moyle 1976). Sustained water temperatures above 27°C are lethal to adults (Cramer and Hammack 1952). The pools in which the adults hold are at least 1-3 m deep, with bedrock bottoms and moderate velocities (G. Sato, unpubl. data; Marcotte 1984). The pools usually have a large bubble curtain at the head, underwater rocky ledges, and shade cover throughout the day (Ekman 1987). The salmon will also seek cover in smaller "pocket" water behind large rocks in fast water.

Habitat preference curves determined by the USFWS for adult chinook in the Trinity River indicate that pool use declines when depths become less than 2.4 m and optimal water velocity range is 15-37 cm/sec^{-1} (Marcotte 1984).

Spawning occurs in gravel beds and the gravel should be of a size that the fish can excavate. Optimum substrate for embryos has been reported as a mixture of gravel, rubble (mean diameter 1-4 cm) with less than 25% fines (less than 6.4 mm diameter) (Platts et al. 1979, Reiser and Bjornn 1979).

Status: Class 2.

Sacramento River spring chinook salmon were perhaps once the most abundant run of salmon in the Sacramento-San Joaquin drainage. Their decline probably began when streams were disrupted by gold mining and irrigation diversions, but the decline accelerated following the closure of Shasta Dam in the 1940's and access to major spawning grounds in the McCloud and upper Sacramento Rivers was cut off. In recent years the decline has continued. CDFG estimates of spawning escapement in the mainstem Sacramento River range from 3600-25000 fish between 1969 and 1980, with an average population of 17000 fish per year (Marcotte 1984). However, most of these fish probably originated in the Feather River hatchery. In Deer and Mill Creeks the estimates of spawning fish average 2300 and 1200 fish, respectively (Marcotte 1984), although in 1988 less than 400 and 150 fish were present in Deer and Mill creeks, respectively (Table 5). Spawning populations in other tributary streams are considerably less, with an estimated 40-100 fish (incomplete survey in 1983) in Antelope Creek (Airola 1983). Up to 100 fish have held in Big Chico Creek (Marcotte 1984), but the most recent CDFG survey was 1979. In Butte Creek, numbers have fluctuated considerably from year to year and have been augmented by planting smolts there from the Feather River Hatchery in the past. However, well over 1000 adults held in the creek in 1989 and these presumably resulted from natural reproduction.

Other populations have interbred with the fall-run race after dams in the Sacramento River removed the natural spatial segregation of spawning sites during breeding (Vogel 1987a,b). During the pre-dam period, spatial segregation of the races by downstream and upstream spawning sites maintained their genetic integrity.

In the Salmon River drainage, an estimated 1000 to 1500 adults use the North and South Forks and Wooley Creek each year. This run appears to be fairly stable. An additional 100-300 fish hold in the South Fork of the Trinity River (E. Gerstung, unpubl. data). The low numbers now using the South Fork are largely the result of the 1964 flood, which triggered landslides that filled in holding pools and covered spawning beds. Prior to the flood, as many as 11000 spring chinooks held in the stream (E. Gerstung, pers. comm.).

In both the Sacramento and Klamath-Trinity drainages, the majority of spring run chinooks are the result of hatchery spawning. In the Feather River hatchery, spring-run fish are kept separate from other runs by assuming that all salmon taken there before October 1 are spring-run chinook, fish taken after this date are fall-run fish. Despite the large numbers of fish produced by the hatcheries, the hatchery fish should not be regarded as substitutes for wild fish, as hatcheries ultimately select for different traits than the natural environment. Also hatcheries are subject to whims of funding and to decimation of fish by disease, contaminated water supplies, and other problems.

Management: Spring chinook need protection at all stages of their life cycle, but the most important is their fresh water stage. It is important to (1) provide adults access to holding and spawning areas, (2) protect adults holding in pools, (3) provide passage flows for outmigrating juveniles, and (4) in Deer and Mill creeks, protect over-summering juvenile fish. All populations should be monitored annually to determine the effectiveness of the management measures.

The most important remaining natural populations in the Sacramento drainage are in Deer and Mill creeks. During wet or normal years, natural flows are sufficient to enable salmon to surmount the diversion dams in the lower reaches of these streams and reach the holding pools. In dry years, however, diversions of water for irrigation may decrease flows in the lower reaches to such an extent that adults are unable to negotiate dams. Because the diversions are on private land and represent long-held water rights, this problem can only be solved with the cooperation of local landowners or land acquisition. In 1989, California Department of Water Resources was planning to drill wells to provide an alternate source of water for Tehama County farmers, so less water would be diverted from Mill Creek during the spring months.

Many large adult salmon holding in pools during the summer are caught by fishermen, some by poachers and others by anglers who snag them accidentally with spinning lures. The importance of this source of mortality is indicated by the distribution of the fish; they are most abundant in the more remote canyon areas, but scarce in pools close to roads. This source of mortality can be reduced by a combination of more frequent patrolling by wardens and changing angling regulations to prohibit fishing in principal holding pool areas.

Protection of out-migrating juveniles requires a combination of adequate flows in the lower reaches of the streams in March and April and adequate flows in the Sacramento River to move them rapidly downriver and through the Sacramento-San Joaquin estuary.

Similar measures will have to be taken to protect spring chinook populations in other streams. However, each stream will have its unique set of problems that can best be addressed by conducting annual surveys of the respective streams to determine the most important holding and spawning areas, as well as the present size of the salmon runs.

TABLE 5. Population counts and estimates of spring run chinook salmon from Deer and Mill Creeks. Data based on counts at diversion dam ladders and spawning surveys conducted by CDFG.

Year	Deer Creek	Mill Creek
1954	NE	1789
1955	NE	2967
1956	NE	2233
1957	NE	1203
1958	NE	2212
1959	NE	1580
1960	NE	2368
1961	NE	1245
1962	NE	1692
1963	1702	1315
1964	2874	1539
1965	NE	NE
1966	NE	NE
1967	NE	NE
1968	NE	NE
1969	NE	NE
1970	2000	1500
1971	1500	1000
1972	400	500
1973	2000	1700
1974	3500	1500
1975	8500	3500
1976	NE	NE
1977	467	563
1978	1200	925
1979	NE	NE
1980	1500	500
1981	NE	NE
1982	1500	700
1983	400	200
1984	NE	NE
1985	300	121
1986	543	62
1987	291	90
1988	371	126

NE = no estimate

FIGURE 5. Major holding and spawning areas of the Sacramento River spring chinook salmon, *Oncorhynchus tshawytscha*.

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SACRAMENTO RIVER WINTER CHINOOK SALMON
Oncorhynchus tshawytscha (Walbaum)

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

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

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

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

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

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

Status: Class 1.

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

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

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

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

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

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

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

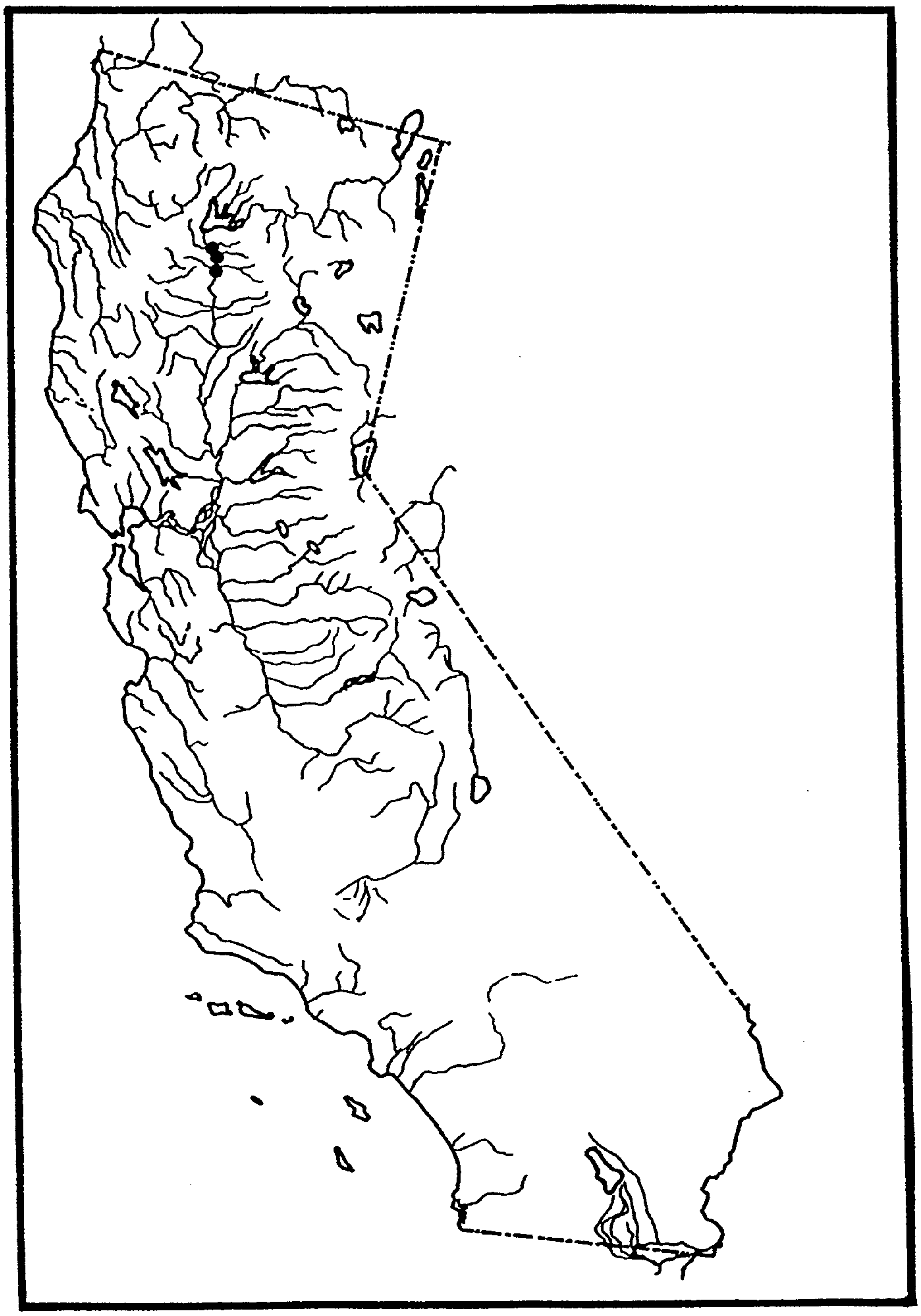

FIGURE 6. Spawning areas of Sacramento River winter chinook salmon, *Oncorhynchus tshawytscha*.

COHO SALMON
Oncorhynchus kisutch (Walbaum)

Description: These are fairly large salmon, with spawning adults typically attaining 45 to 60 cm SL and weighing up to 4-6 kg. They have 9-12 dorsal fin rays, 12-17 anal fin rays, 13-16 pectoral fin rays, and 9-11 pelvic fin rays. Lateral line scales number from 121-148 and the scales are pored. There are 11-15 branchiostegal rays on either side of the jaw. Gill rakers are rough and widely spaced, with 12-16 on the lower half of the first arch.

Spawning adults are dark and drab. The head and back are dark green, the sides are a dull maroon to brown but with a bright red lateral stripe. The belly is grey to black. Females are paler than males and lack the lateral red stripe. Spawning males are also characterized by a hooked jaw and a slightly humped back. Both sexes have small black spots on the back, dorsal fin, and upper lobe of the caudal fin. The gums of the lower jaw are grey, except the upper area at the base of the teeth which is generally whitish (Fry 1973).

Parr have 8-12 narrow parr marks centered along the lateral line. The marks are narrow and widely spaced. The adipose fin is finely speckled, imparting on it a grey color, but the other fins lack spots and are tinted orange.

Taxonomic Relationships: Coho salmon are one of five species of Pacific salmon (*Oncorhynchus*) found in California. They do not appear to have the genetically distinct, temporally segregated runs that characterize the more abundant chinook salmon and steelhead trout. However, the strong homing abilities of coho salmon make it likely that each coastal stream has a distinctive strain of coho adapted for local environmental conditions. For the purposes of this section, we divide the coho populations into big river coho salmon and short-run coho salmon. Big river cohos are those that migrate up into the main river systems 100-200 km or more to spawn in the river or tributaries. They typically start entering the streams in September or October somewhat earlier than short-run coho. In the Klamath River and some other systems, much of the production of the big river fish takes place in hatcheries. Short-run coho salmon occupy the smaller coastal streams and the tributaries of the lower reaches of the big rivers and rarely migrate more than 100 km upstream. These populations in any one stream system are typically small and highly dependent on natural reproduction.

Distribution: Coho salmon are widely distributed in the northern temperate latitudes. In North America, they spawn in coastal streams from California to Alaska. In Asia, they range from northern Japan to the Anadyr River in the Soviet Union.

In California, principal populations are located in the Klamath, Trinity, Mad, Noyo, and Eel rivers, with other populations in smaller coastal streams south to the San Lorenzo River, Santa Cruz County (Fig. 9). In the Eel River system, they ascend 390 km (246 miles) of stream in 69 tributaries (Mills 1983) of the South Fork Eel, the lower mainstem Eel River, and the Van Duzen River (Brown 1987). Annual runs in the Eel River system have been estimated at over 40,000 fish (U.S. Heritage Conservation and Recreation Service 1980). Coho salmon are rare in the Sacramento River even though several attempts have been made to establish runs (Hallock and Fry 1967). Coho salmon of hatchery origin have also been stocked in reservoirs such as Lake

Berryessa with considerable success. The coho do not reproduce in reservoir tributaries, however, and thus have to be restocked annually.

Habitat Requirements: Coho salmon move upstream in response to an increase in stream flows caused by fall storms, especially in small streams when water temperatures are 4-14°C. Spawning sites are typically at the heads of riffles or tails of pools where there are beds of loose, silt-free, coarse gravel and cover nearby for the adults. Spawning depths are 10-54 cm, with water velocities of 0.2-0.8 m/sec (Hassler 1987). Optimal temperatures for development of the embryos in the gravel is 6-10°C.

Juveniles prefer deep (1+ m), well shaded pools with plenty of overhead cover; highest densities are typically associated with logs and other woody debris in the pools or runs. Juveniles require that water temperatures not exceed 22-25°C for extended periods of time and that oxygen and food (invertebrates) levels remain high. Preferred temperatures are 10-15°C (Hassler 1987).

Life History: The life history of the coho salmon in California has been well documented by Shapavalov and Taft (1954) and Hassler (1987). Coho salmon return to their parent streams to spawn after spending one to three years in the ocean. Males may, however, return after one growing season in the ocean (at age 2 yrs), but most females return after 2 growing seasons in the ocean (age 3 yrs). The spawning migrations begin when heavy fall rains breach the sand bars at the mouths of the coastal streams, allowing the fish to move into the streams. The early part of the run is dominated by males, with females returning in greater numbers during the latter part of the run. Coho salmon will migrate up and spawn in any coastal stream accessible to them regardless of stream size.

Females choose the spawning sites (redds) usually near the head of a riffle (just below a pool) where the water changes from a smooth to a turbulent flow and there is medium to small gravel substrate. The flow characteristics of the location of the redd usually ensure good aeration, and the circulation facilitates fry emergence from the gravel. Each female builds a series of redds, moving upstream as she does so, and deposits a few hundred eggs in each. Thus spawning may take about a week to complete and a female can lay between 1400 to 5700 eggs. There is a positive correlation between fecundity and size of females. Both males and females die soon after spawning.

Eggs hatch following 8 to 12 weeks of incubation, the time being inversely related to water temperature. Hatchlings remain in the gravel until the yolk sacs have been absorbed 4-10 weeks after hatching. Upon emerging, they seek out shallow water, usually along the stream margins. Initially they form schools, but as they grow bigger the schools break up and the juveniles (parr) set up individual territories. The larger parr tend to occupy the heads of pools; the smaller parr are found further down the pools (Chapman and Bjornn 1969). As the fish continue to grow, they move into deeper water and expand their territories until, by July and August, they are in deep pools. Growth rates slow down at this stage, possibly due to lack of food or because the fish stop or reduce feeding as a result of the colder temperatures.

Between December and February, winter rains result in increased stream flows and by March, following peak flows, fish again begin to feed heavily on insects and crustaceans and grow rapidly. Towards the end of March and the beginning of April they begin to migrate downstream

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and into the ocean. At this point, they are about one-year-old and 10-13 cm in length. The fish migrate in small schools of about 10-50 individuals. Parr marks are still prominent in the early migrants, but the later migrants are silvery, having transformed into smolts.

When in the ocean, coho salmon usually stay within 30 km of their natal stream and remain over the continental shelf. Thus, most cohos caught off California in ocean fisheries were reared in California streams. Oceanic cohos tend to school together. Although it is not known if the schools are mixed, consisting of fish from a number of different streams, fish from different regions are found in the same general areas. Adult coho salmon are primarily piscivores.

Status: Class 3.

Coho salmon are widely distributed in coastal streams of California. Their populations show large fluctuations but the general trend seems to be downward in the wild, short-run populations of small coastal streams. The big river populations are largely maintained by hatchery production. The decline of short-run coho salmon is linked to poor stream and watershed management, especially logging practices that cause stream temperatures to increase, fill in pools with silt, and otherwise alter habitats.

Management: The key to stopping the decline of short-run coho salmon is to protect their spawning and rearing streams and to restore damaged habitat (Emig et al. 1988). This is a difficult task because it means modifying logging and road construction plans in dozens of coastal drainages and implementing habitat restoration plans in many small streams. Monitoring the populations is also a necessity: spawning streams should be identified and populations should be sampled annually. This would allow population trends to be followed and provide focus for restoration efforts.

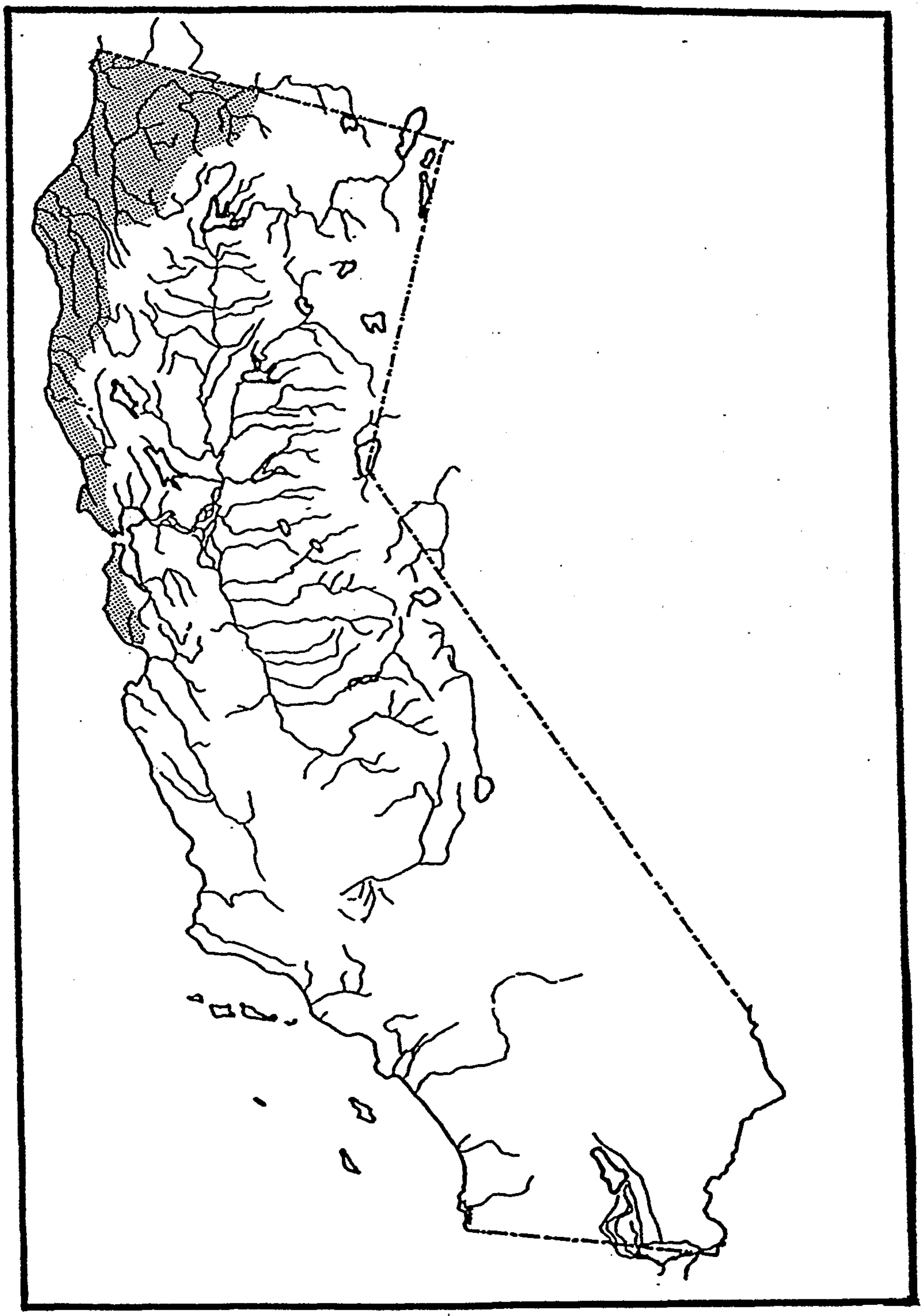

FIGURE 7. Distribution of coho salmon, *Oncorhynchus kisutch*, in California.

PINK SALMON
Oncorhynchus gorbuscha (Walbaum)

Description: Pink salmon are the smallest of the Pacific salmon, usually reaching 50-60 cm FL (2-2.5 kg). Maximum recorded length is 76 cm (6.3 kg). They are distinguished from other salmon species by the black oval markings on both caudal lobes and back. The number of gill rakers, which range from 16-21 on the lower, first gill arch, is also distinctive (McPhail and Lindsey 1970).

The mouth is terminal and there are sharp teeth on both jaws, the vomer, palatines, and on the tongue. The dorsal fin has 10-16 complete rays, the anal fin 13-19, the pectoral fins 14-18, and the pelvic fins 9-11 rays. There are 147-198 scales along the lateral line. Branchiostegal rays number from 10-15 on either side of the jaw.

Marine phase fish are steel-blue to blue-green dorsally, white ventrally, and have silver sides. The back and upper parts of the lateral surfaces have large black spots which are also present on the adipose and caudal fin lobes (Scott and Crossman 1973).

Spawning males have a pronounced hump immediately distal to the head and the snout is greatly enlarged and hooked. The body color becomes darker, especially on the head and back. The sides become pale red, with brown to olive-green markings. Reproductive females lack the conspicuous hump of the males and resemble trout in general body shape. Their sides are olive green, with long, dusky, vertical markings. Scales in reproductive pink salmon become deeply embedded.

Taxonomic Relationships: This species was first described in 1792 (see Scott and Crossman 1973 for complete synonymy). Nothing is known about the genetic identities of California fish or how they relate to more northern populations.

Distribution: Spawning pink salmon ascend coastal streams of northern Asia, from Korea through Japan to Siberia (Moyle 1976). Along the northwestern Pacific coast of North America they range from the MacKenzie River in the Yukon Territory of Canada south to coastal streams of California. Isolated oceanic records have been documented as far south as La Jolla (Hubbs 1946). However, the most significant runs on the southernmost end of their range are in streams tributary to Puget Sound (Hallock and Fry 1967).

In California, small numbers have been reported from the San Lorenzo River (Scofield 1916), the Sacramento River and tributaries (Hallock and Fry 1967), the Klamath River (Snyder 1931), the Russian, Garcia, Mad, and Ten Mile Rivers (Taft 1938) (Fig. 10). One specimen each has also been reported from Prairie Creek, Humboldt County (Smedley 1952), and from Mill Creek, Tehama County (Taft 1938). However, the only recorded spawning has been in the lower Russian River, where Fry (1967) observed at least six pink salmon redds.

Habitat Requirements: As most of their life is spent in the ocean, the only freshwater habitat requirements for this species consists of spawning streams (Scott and Crossman 1973). These streams should have shallow, riffle sections with small gravel substrates.

Life History: Pink salmon live for two years (Scott and Crossman 1973, Moyle 1976), although occasionally three-year-old fish are reported (Anas 1959, Turner and Bilton 1968). All individuals mature by the second year (Hallock and Fry 1967). The adults move into fresh water between June and September (Scott and Crossman 1973) and spawn from mid-July to late October, depending on the distribution within the range (Scott and Crossman 1973, Moyle 1976). Pink salmon do not migrate long distances up rivers to spawn as other salmonids do (Hallock and Fry 1967). Instead, they spawn in the intertidal or lower reaches of streams and rivers (Moyle 1976).

Spawning occurs in gravelly riffles with water depths between 20-60 cm. The six redds built by females in the lower Russian River were all situated along the stream edges where the substrate was finer (Fry 1976). No redds were found in the middle portion of the riffle where the substrate was composed of coarser gravel. During nest building, the female lays on her side and excavates a depression approximately 90 cm in length and 45 cm deep (Scott and Crossman 1973). The female indicates spawning readiness by sinking down into the redd until her anal fin touches the gravel. The male then swims up alongside and both fish settle down in the redd, quivering and gaping as they release gametes. Once egg deposition is completed, the female covers the redd with gravel by displacing substrate from the upstream margin of the redd. A single female will dig several redds and spawn with several males (Scott and Crossman 1973). Likewise, a single male will spawn with several females. During the spawning season males are aggressive and defend territories.

A female is capable of laying between 1000 to 2000 eggs during the spawning period which lasts for several days. Both males and females die a few days to a few weeks after spawning. Eggs, when deposited, sink to the bottom and lodge in the gravel interstices. They hatch in late December to late February after 4-6 months of incubation. The alevins remain in the gravel until April or May, at which time the yolk-sac has been absorbed. They emerge when about 35 mm TL and immediately begin to migrate downstream into the estuary. Juvenile migration takes place at night and fish move rapidly downstream, reaching the estuary in one night (Hunter 1959, Scott and Crossman 1973). Once in the estuary they form large schools and remain in the inshore areas for several months before moving out to sea. Pink salmon wander great distances while in the oceans, and tagged fish have been captured 2700 km (1700 mi) from where they were tagged (Scott and Crossman 1973). However, they are fairly faithful to their parent streams.

The two-year life span of pink salmon results in distinctive populations which form odd- and even-year spawning runs (Scott and Crossman 1973). Some streams may support major runs of both (odd and even) years whereas others may support major runs of one or the other year. Most juveniles do not remain in freshwater long enough to feed, although those that hatch from redds further upstream have been known to feed on aquatic insects (Scott and Crossman 1973). Adults do not feed during their spawning runs. At sea, juveniles feed on small crustaceans and other invertebrates. Adults feed mostly on fish, squid, euphausiids, amphipods, and copepods.

Status: Class 2.
In Alaska and Canada, pink salmon are extremely abundant and support major commercial fisheries. California is the southern edge of their range so they probably never have been common here. Today, however, they are extremely rare in California. Most fish recorded in the state are probably fish that strayed while at sea and followed other species of salmon upstream. However,

there is evidence that there was at least a small run that spawned in the Russian River (Fry 1967), the southernmost run for the species. This run has not been recorded since Fry's report, but it apparently has not been looked for either. Given the major changes that have taken place in the Russian River in the past 20 years, such as the construction of Dry Creek Dam and a number of major pollution events, it is likely that pink salmon no longer spawn in the river. However, an effort should be made to see if the run still exists so appropriate protective measures can be made.

Management: The first step is to determine if reproducing populations exist anywhere in California. The lower reaches of the Russian River should be surveyed carefully for them; recent records elsewhere in the state carefully investigated. If viable spawning populations exist, then habitat, flow, and water quality should be protected.

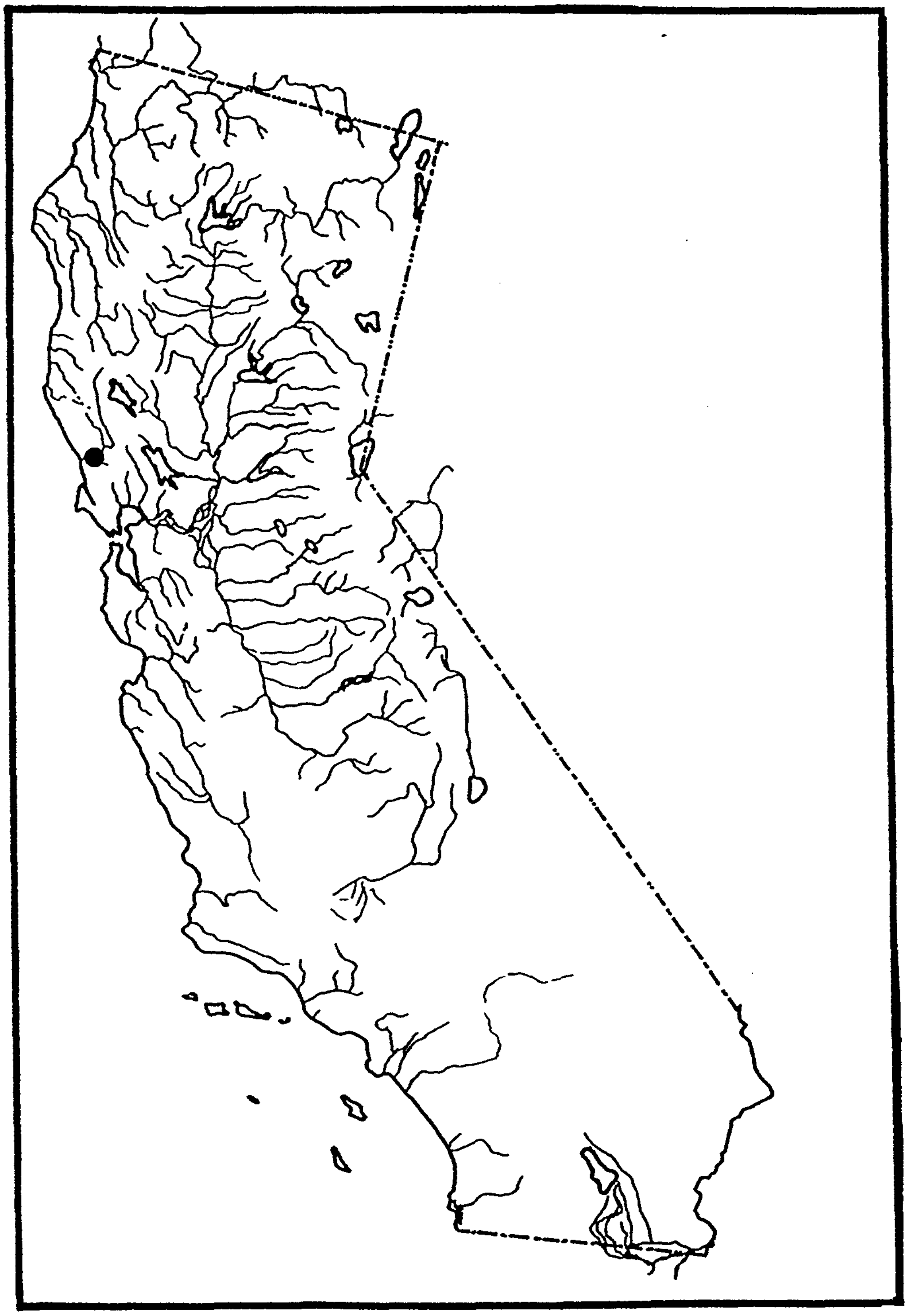

FIGURE 8. Spawning areas of pink salmon, *Oncorhynchus gorbuscha*, in the Russian River, California.

SUMMER STEELHEAD
Oncorhynchus mykiss gairdneri (Richardson)

Description: Summer steelhead are anadromous rainbow trout that returns to spawn in freshwater streams during the spring from April to June (Roelofs 1983). They are sometimes referred to as spring-run steehead in California. Adults are silver laterally, grading into a silver-white ventrally. Dorsal coloration is blue-green with dark spots (Jones 1980). Some adults may also have pale red lateral stripes during the summer.

Summer steelhead usually reach 60 to 80 cm FL (range 48-84 cm from Eel River system) and weigh 3-4 kg (Puckett 1975, Jones 1980). Males are slightly larger (about 6 cm) than females. They have large mouths with well developed teeth on both upper and lower jaws, the head and shaft of the vomer, the palatines, and on the tongue. Basibranchial teeth are absent. Gill rakers number from 16-22 and branchiostegal rays from 9-13. There are 10-12 dorsal fin rays; 8-12 anal fin rays; 9-10 pelvic fin rays; and 11-17 pectoral fin rays. The caudal fin is forked. Scales are small, with 18-35 rows above the lateral line and 14-29 below. The 100-160 lateral line scales are pored.

Smaller fishes (25-35 cm) returning later in the summer and early fall (usually from late August to early October) are called "half-pounders." These are usually immature fish that have spent only a few months in the ocean and, if they survive their first upstream migration, will return to the ocean in the spring to return as mature adults that summer or fall (Barnhart 1986).

Taxonomic Relationships: Summer steelhead get their name from their habit of ascending rivers in the spring, then holding in deep pools in canyons through the summer, and spawning in the fall. Thus they are distinguished from other steelhead by (1) time of migration (Roelofs 1983), (2) state of gonadal maturity at migration (Shapovalov and Taft 1954), and (3) time and location of spawning activity (Everest 1973, Roelofs 1983). Attempts to distinguish juvenile summer and winter steelhead and resident juvenile rainbow trout using otolith nuclei widths, scale circuli densities, and visceral fat content have only been partially successful (Rybock et al. 1975, Tippets 1978, Winter 1987) primarily because of difficulties in setting up rigidly controlled experiments (Winter 1987). The temporal and spatial isolation of spawning fish from other steelhead serves to maintain their genetic integrity (Barnhart 1986). Until recently steelhead was listed as *Salmo gairdneri gairdneri*. However, recent taxonomic work shows that steelhead are closely related to Pacific salmon (genus *Oncorhynchus*) and are conspecific with Asiatic steelhead, *Salmo mykiss*. As a result, rainbow trout, including steelhead, are officially recognized by the American Fisheries Society as *Oncorhynchus mykiss*. North American steelhead can be referred to as *O. m. gairdneri*.

Distribution: Along the eastern Pacific, steelhead trout are distributed from central California north to Alaska and range west to Siberia (Sheppard 1972). In California (Fig. 9), summer steelhead runs have been recorded from a number of north coast streams south to the Eel River. These streams include the Middle Fork Eel River, main stem Eel River, Van Duzen River, Mad River, North Fork Trinity River, New River (tributary to the Trinity), South Fork Trinity River, Canyon Creek (in the Trinity River system), the Klamath River drainage (Dillon, Elk, Indian, Redcap, Bluff, and Clear creeks), Salmon River, Wooley Creek (a tributary to Salmon River), and Redwood Creek (Puckett 1975, Roelofs 1983, Table 7). Up to 50% of California summer steelhead are concentrated in the Middle Fork Eel River (Puckett 1975). Records indicate that runs also occurred in the North Fork Eel River, Black Butte River and Woodum Creek (tributaries to the Eel), and the Mattole River (Puckett 1975).

In the Middle Fork Eel River, returning steelhead usually hold in deep pools between Bar and Uhl creeks during the summer and fall (Jones 1980). However, the locations of the holding areas vary, depending on accessibility, water temperatures, and water flows (Easthouse 1985).

During their ocean stage, fish from California streams are known to range all the way up to Alaska. Little is known about the habits and movements of summer steelhead while in the ocean.

Habitat Requirements: Steelhead habitat requirements are reviewed in Barnhart (1986). Water depth does not seem to be critical to migrating fish because they usually migrate when stream flows are high, but a minimum depth of 18 cm is required. Water velocities greater than 3-4 m/sec^{-1} may impede their upstream progress. They spawn in cool, clear, well-oxygenated streams. Water velocity and depth measured at redds range from 23 to 155 cm/sec^{-1} and 10 to 150 cm, respectively, and diameter of the gravel substrate ranges from 0.64 to 13 cm (Smith 1973, Bovee 1978, Barnhart 1986). They are known to spawn in intermittent streams, but the juveniles emigrate into perennial streams soon after hatching (Everest 1973, Carroll 1984, Barnhart 1986). Preferred summer water temperatures of adults seem to be from 10 to 15°C, although they can live in water up to 20°C for extended periods. Under conditions of fluctuating temperatures, summer steelhead may survive 27°C water for short periods of time (M. Moford, pers. comm.). Dissolved oxygen requirements for spawning fish should be at least 80% saturation, with temporary levels not less than 5.0 $mg.l^{-1}$ (Reiser and Bjornn 1979).

A survey of the Eel River drainage indicated that the best spawning gravels are located at Balm of Gilead Creek, North Fork of Middle Fork of Eel River, and in the Middle Fork from Hoxie Crossing to the North Fork of Middle Fork (Jones 1980). Redds have been observed in the Middle Fork approximately 0.5 km below the North Fork (Jones 1980). Migrating fish require deep (>3 m) holding pools (Puckett 1976, Roelofs 1983) with cover, such as underwater ledges, caverns, and bubble curtains, which they seek when disturbed (Puckett 1975, Roelofs 1983).

Life History: Summer steelhead migrate up coastal streams and rivers during and soon after the final spring high flows of April, and the migration continues through June (Puckett 1975, Jones 1980). The migration may extend into July but tapers then, presumably due to decreasing flows and increasing temperatures (Jones 1980). As the largest numbers of summer steelhead are in the Eel River system (Puckett 1975) and as this population is being managed as a sensitive species by the U.S. Forest Service (Jones and Ekman 1980), most available information is about this population.

In the Eel River system, summer steelhead migrate to the upper reaches of the Middle Fork Eel and the Van Duzen Rivers where they hold in deep pools during the summer months (Puckett 1975, Jones 1980). Easthouse (1985) reported a record number of 280 fish in a single pool in the Middle Fork Eel River, but most pools contain fewer fish. Usually, there is no period of peak migration, as indicated by the frequency of fish trapped in a wier on the Van Duzen River (Puckett 1975). In the Middle Fork Eel, males dominated the early part of the run, with females migrating in greater numbers towards the latter part (Smith and Elwell 1961). The gonads of the migrating fish were immature and did not begin to mature until they had spent 8-10 months in freshwater

(Roelofs 1983). Thus spawning occurs from late December through April (Jones 1980), but the exact information on the duration, location, and extent of spawning is unknown (Puckett 1975, Jones 1980, Roelofs 1983). Fecundity is normally 2000 to 3000 eggs per female.

In the Rogue River, Oregon, summer steelhead spawn in small headwater streams with relatively low (<50 CFS) winter flows (Roelofs 1983). Most of these streams are intermittent and dry up in the summer. If spawning behavior is similar in California, this indicates that (1) the adults move into smaller tributary/headwater streams for spawning and (2) the fry move out of the smaller natal streams into larger tributaries soon after emerging. In Rogue River tributaries, spawning begins in late December, peaks in late January, and tapers off by March. Roelofs (1983) suggested that use of small streams for spawning may reduce egg and juvenile mortality because (1) eggs are less susceptible to scouring by high flows and (2) decreased predation of juveniles by adults because spawning adult densities in smaller streams will be less.

Scale analyses indicate that summer steelhead migrate to sea when 1-3 years old (Puckett 1975). Of these, the majority smolt at 2 years (79%), some at 3 years (17%), and very few at 1 year (4%). Most return at age 3 (46%) to 4 (44%), and a smaller proportion returns when 2 (1%) and 5 (9%) years of age (Puckett 1975). About 9% of the returning fish are repeat spawners (Jones 1980).

Smaller fry usually migrate passively during the night and larger fry actively move out by day (Roelofs 1983). Migrating adults seldom feed, and stomachs examined are mostly empty or contain only a few aquatic insect larvae (Puckett 1975). However, migrating "half-pounders" do feed in fresh water (Barnhart 1986). Studies of adult summer steelhead in British Columbia also suggest that they feed little, if at all, during the summer (Smith 1960).

Status: Class 1.

In most river systems in which they occur, summer steelhead have declined considerably in the past 30-40 years. Most populations in California are represented by less than one hundred fish each, based on mid-summer surveys (Table 7). As the "effective" (breeding) population sizes are probably less than the actual counts, the populations are probably close to or below the minimum size needed for long-term survival (Meffe 1986). Because these estimates are of fish holding in pools in mid-summer, the number surviving to spawn in the fall is probably considerably less. Most of the populations were severely affected by the extraordinary floods of 1964 that caused extensive erosion and filled in many holding pools with gravel. The habitat is gradually recovering from the 1964 disaster, but summer steelhead populations have not increased dramatically in response to the increase in habitat. The status of each major population is a follows:

<u>Smith River</u>. Only 10-20 fish are estimated to occur in each of five tributaries in recent years, less than 100 fish total, but this stream may never have supported summer steelhead in numbers (Roelofs 1983).

<u>Eel River</u>. Summer steelhead remain in two tributaries, the Van Duzen River and the Middle Fork Eel River. The former run is down to less than 100 fish per year. The Middle Fork run is the largest in California and is estimated to be between 400 and 1700 fish per year between 1978 and 1988. However, poaching after annual surveys have been completed may mean these numbers do not represent the reproductive population.

Mad River. In the 1940's and early 1950's Shapovalov and Taft (1954) indicated that 600-700 summer steelhead used this river each year. Present counts are highly variable, but in most years the estimates are less than 100 fish. These fish may be derived from hatchery fish from Washington or from hybrids between native and introduced stocks. The native fish were severely depleted, and perhaps eliminated, in the 1960's by poaching, especially at the Sweasey Dam fish ladder.

North Fork Trinity River. There is little historical or recent information on summer steelhead in this stream, but the present population seems to fluctuate between 200 and 700 fish per year. Given that this stream has been heavily impacted by mining, it is likely that runs were much higher in the past (Roelofs 1983).

South Fork Trinity River. In 1964, the California Department of Fish and Game estimated that this stream contained 3,500 summer steelhead. Present estimates are now less than 50 fish per year.

New River. This tributary to the Trinity River was presumably a major summer steelhead stream in the past, but it is highly accessible and heavily dredged for gold. Last estimates (1988) indicated about 600 fish, although past estimates were around 350 fish.

Klamath River. Summer steelhead are known from six small tributaries, most with populations of less than 100 fish. Most of the 800-1200 fish usually found in these steams are found in the inaccessible portions of Clear and Dillon creeks (Roelofs 1983).

Salmon River. Despite the presence of many suitable holding areas, the two forks of the Salmon River combined now only support 100 to 300 fish per year.

Wooley Creek. Like the Salmon River, to which Wooley Creek is tributary, this rather inaccessible stream has maintained a run of steelhead that is usually 100-300 fish per year.

Redwood Creek. It has only recently been recognized that this small coastal drainage supports summer steelhead with runs of 4 to 44 fish per year. Given the degraded nature of much of the drainage, it probably supported larger runs in past.

In short, California now supports 1500 to 4000 summer steelhead each year. These fish are divided among at least 25 isolated populations, many on the verge of extinction.

Habitat degradation, poaching, and other factors have combined to reduce these natural populations to critical levels. The most immediate threat to summer steelhead is poaching during the summer in the canyon pools. They are unusually vulnerable at this time because they are conspicuous, aggregate in some pools, and are prevented from leaving pools by the low stream flow. They can thus be snagged from the bank or speared by divers. The fact that summer steelhead are now almost entirely confined to canyons where access is difficult indicates that poaching has probably eliminated them from more accessible areas. In virtually all the stream systems they presently inhabit, there are many kilometers of stream with suitable pools that are presently not used by summer steelhead. Roelofs (1983) indicated that the most stable populations of summer steelhead are in the most inaccessible streams, whereas those that are showing signs of severe decline are in areas that are accessible to people.

The most severe immediate threat by poaching is to the population existing in the Middle Fork of the Eel, which is about half the summer steelhead in California. In 1988, counts made in July indicated the population was 711 fish, one of the lowest counts in recent years. However, the area is currently without the protection of a game warden or other law enforcement officials, and there were reports of extensive removal of fish by poachers in late summer of 1988 (M. Morford, pers. obs.). An attempt to briefly resurvey part of the area in which fish had been counted earlier revealed no fish (W. Jones, pers. comm.). Poaching may also be occurring in other populations of summer steelhead, but they are monitored less closely than the Middle Fork Eel population. Roelofs (1983) indicated that poaching is a factor affecting populations of summer steelhead in at least the North Fork of the Trinity, New River, Wooley Creek, and some tributaries to the Klamath River. The South Fork of the Trinity is also heavily poached (P. Higgins, pers. comm.).

Although poaching appears to be the most immediate threat to the populations, other factors have also contributed to the decline of summer steelhead, but their contribution is poorly understood:

1. Adults may be harvested as they move upstream towards their holding pools during the spring.

2. During low-flow years, out-migrating juveniles may suffer heavy mortality when moving downstream, especially if trapped in pools that become too warm for them in summer.

3. Poor watershed management (heavy grazing, poor logging practices) has increased erosion, causing deep pools to fill with gravel, decreasing the amount of habitat and increasing the vulnerability of the fish to poachers and predators. Such practices may also decrease summer flows, raising water temperatures to levels that may stress the fish or even be lethal to them. Poor watershed management probably exacerbated the effects of the 1964 floods in all the drainages containing summer steelhead. These floods deposited enormous amounts of gravel in pools throughout major drainages like the Eel and Trinity, gravel that originated from landslides and mass wasting, especially from areas with steep slopes that had been logged. These floods not only filled in pools, but widened stream beds and eliminated riparian vegetation that served as cover and kept streams cooler. The gravel accumulated from the 1964 floods is gradually being scoured out of the pools, but much of it still remains. The potential for further mass wasting along the Eel and Trinity Rivers is high as logging still occurs on steep slopes and recent fires may be contributing to soil instability (increased by road building for salvage logging). In short, it is likely that accumulation of gravel in stream beds in recent years has reduced the amount of suitable habitat for summer steelhead, increased water temperatures, and made the fish more vulnerable to poaching by decreasing cover.

4. As populations are reduced and habitat more restricted, it becomes more difficult for them to withstand the effects of natural predation, particularly that of otters. Assuming otter populations are fairly constant, they are likely to capture the same number of steelhead each year, regardless of whether the populations of fish are large or small. Thus their effects may be proportionally greater on small populations. In the Eel River, squawfish predation on outmigrating juveniles may be a growing problem, as this predatory cyprinid was illegally introduced into the river around 1980 and is building up populations at the present time (L. Brown and P. Moyle, unpubl. data).

5. Heavy use of a stream by gold dredgers, swimmers, and rafters may stress the fish by continuous disturbance. This may make them less able to survive natural periods of stress (e.g., high temperatures) or may make them less able to spawn or to survive spawning in the fall. In some streams, such disturbances may be as big a factor contributing to summer steelhead declines as poaching.

6. There is concern that unrestricted high seas gillnet fishery for squid and other species may be killing steelhead from California streams. The impact of marine fisheries on steelhead in general is poorly known, but such fisheries may be a major source of ocean mortality.

7. Summer steelhead are raised in the Mad River Hatchery on the Mad River. These fish are derived from fish brought in from the Washougel River in Washington in 1971 (Roelofs 1982). The effects of these hatchery fish on native wild stocks is not known, but wild stocks may be decreased through (1) competition between hatchery and wild juveniles, (2) genetic swamping of small wild populations by large populations of strays from hatcheries, and (3) increased harvest of wild fish because wild and hatchery fish cannot be distinguished by anglers. Hatchery fish, especially of non-native origin, cannot be regarded as replacements for wild fish because they are less likely to persist in the face of natural environmental fluctuations to which native wild fish are well adapted.

8. The gillnet fishery of Native Americans in the Klamath River may be having an adverse impact on summer steelhead populations in that river, although large mesh sizes may allow most summer steelhead to escape (D. E. Naylor, pers. comm.).

Management: Comprehensive management recommendations have been made by Jones and Ekman (1980) and Roelofs (1983), but summer steelhead populations show no signs of increasing. In general, each population of summer steelhead should be managed to increase numbers to the point where some harvest is possible during their migratory period and to where some of the fish are visible to visitors to coastal streams. There are few sights more spectacular than a school of large shadowy steelhead cruising about the depths of a cool, clear pool in a hot canyon, but few people get to experience this sight.

Management plans for each population must be formalized. Management will have to consist of a mixture of (1) better protection of summering areas from poachers, (2) better watershed management to keep summer flows up and temperatures down, (3) better regulation of adult harvest during the migrations, (4) better management of downstream reaches to favor out-migrating smolts, (5) rebuilding present populations through natural and artificial means including habitat improvement, (6) restoration of populations that have become extinct, and (7) some protection of adult and juvenile fish in depleted populations from predation. The problem with poaching has been particularly severe in recent years in the Middle Fork of the Eel River because of the virtual absence of adequate law enforcement in the area.

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TABLE 7. Summer steelhead population estimates in northern California streams from 1977-1988 (CDFG data).

River/Stream	1988	1987	1986	1985	1984	1983	1982	1981	1980	1979	1978	1977
Middle Fork Eel	711	1550	1000	1463	1524	666	1051	1600	1052	1298	377	654
Van Duzen River	42[b]	51[a]	nd	nd	58[a]	13[b]	8[a]	nd	25[b]	31[b]	nd	nd
Mad River	60[b]	19[b]	nd	52[b]	147[b]	37[b]	172[b]	8[b]	42[b]	nd	nd	nd
N.F. Trinity River	624[a]	nd	nd	nd	179[a]	159+[a]	116[b]	225[a]	454[a]	320[a]	nd	nd
S.F. Trinity River	26[a]	nd	73[a]	8[c]	nd	nd	27[a]	nd	nd	91[a]	nd	nd
New River	600[d]	nd	nd	nd	355[a]	nd	350[d]	236[a]	320[a]	344[a]	nd	nd
Salmon River[e]	200[d]	100[d]	106[d]	97[d]	nd	nd	257[a]	108[d]	233[a]	nd	nd	nd
Wooley Creek	379	280	nd	290	92	78	353	245	165	160	105	510
Canyon Creek	32	nd	nd	10	9	3	20	4	6	nd	nd	nd
Redwood Creek	8[b]	17[a]	19[b]	44[b]	44[b]	5[b]	2[b]	16[b]	4[b]	nd	nd	nd
Elk Creek	63[a]	31[a]	nd	nd	18[a]	nd	249[a]	47[b]	90[a]	nd	408[a]	4[c]
Indian Creek	41[b]	nd	nd	nd	nd	nd	16[b]	nd	nd	nd	421[a]	nd
Clear Creek	678[a]	512[a]	428[b]	162[c]	156[b]	258[b]	618[a]	270[a]	241[a]	79[a]	1810[a]	nd
Dillon Creek	294[b]	77[a]	nd	nd	200[a]	300[a]	344[a]	187[a]	268[a]	nd	nd	nd
Red Cap Creek	25[b]	29[b]	nd	18[b]	11[b]	12[a]	45[b]	nd	10[b]	nd	nd	nd
Bluff Creek	91[a]	73[a]	73[b]	23[c]	48[a]	23[a]	87[a]	16[d]	37[d]	41[b]	nd	nd
S.F. Smith River	12[b]	nd	nd	nd	nd	nd	5[a]	nd	nd	nd	nd	nd

[a]Population estimated from surveys of 70-100% holding areas.
[b]Population estimated from surveys of 50-69% holding areas.
[c]Population estimated from surveys of <24% holding areas.
[d]Estimate based on expansion of a partial count.
[e]Data combined from the North Fork, South Fork, and East Fork Salmon River.
nd = no data.

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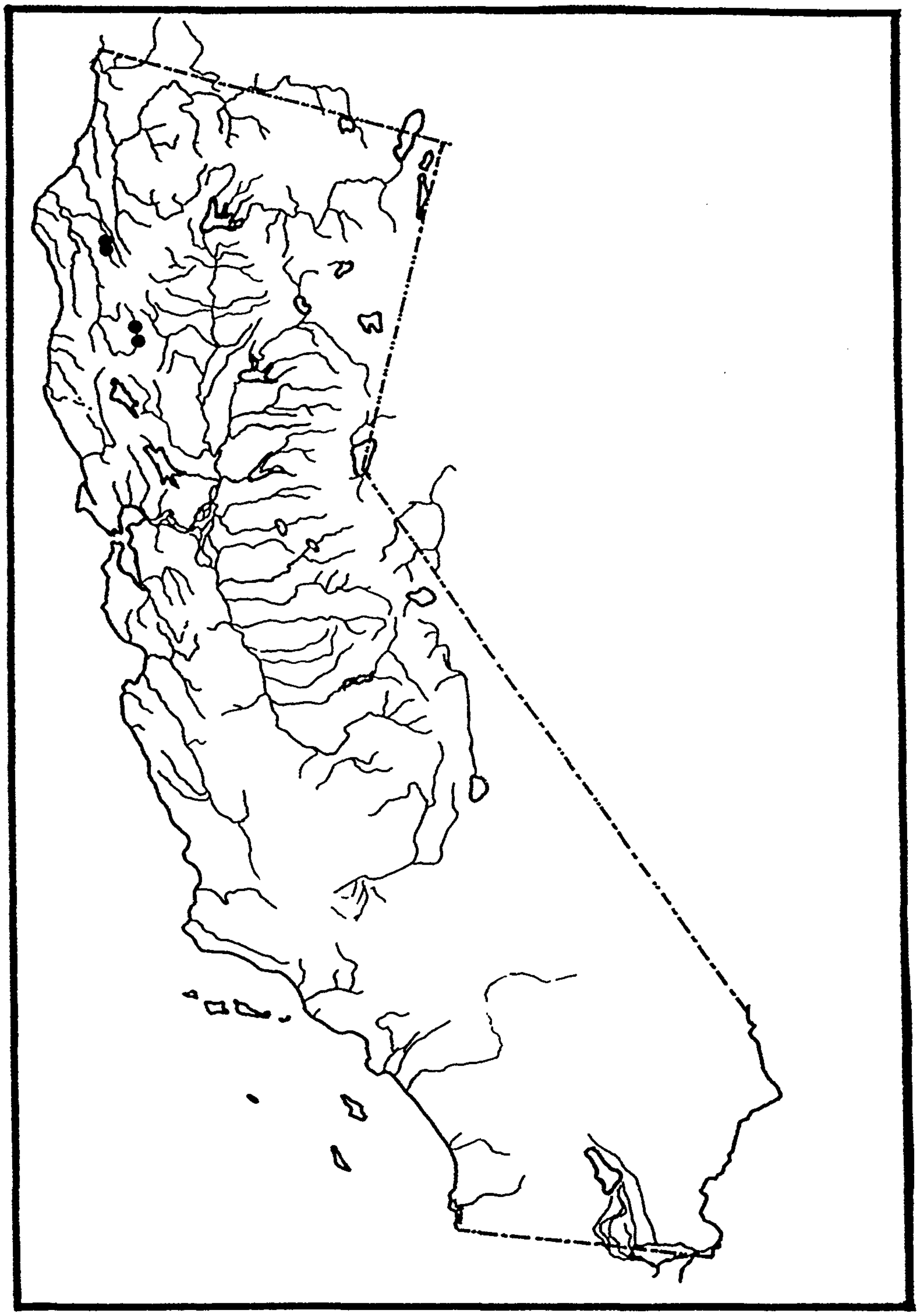

FIGURE 9. Spawning areas of summer steelhead trout, *Oncorhynchus mykiss gairdneri*, in the Eel and Van Duzen river drainages.

EAGLE LAKE RAINBOW TROUT
***Oncorhynchus mykiss aquilarum* (Snyder)**

Description: This subspecies is similar to other rainbow trout in gross morphology, but differs slightly in meristic counts (Table 8) and in the number of chromosomes (58 in Eagle Lake rainbow trout, 60 in most other rainbow trout according to Busack et al. 1980).

TABLE 8. Meristic characteristics (mean ± SD) of Eagle Lake and other western trout. Table modified from Busack et al. (1980).

Character	Eagle Lake trout	Rainbow trout	Cutthroat trout	Redband* trout
Lateral series	138.3 ± 1.47	135	166	162
Scale rows above lateral line	27.4 ± 0.28	25	37	33
Gill rakers	19.2 ± 0.25	19	24	16
Pyloric caeca	57.0 ± 2.5	55	48	36
Branchiostegal rays	10.9 ± 0.11	12	11	10
Pectoral rays	14.3 ± 0.14	15	14	13
Pelvic rays	10.0 ± 0.06	10	9	9
Vertebrae	62.0 ± 0.23	64	62	61

*McCloud River redband.

Taxonomic Relationships: Since Snyder (1917) described it as a subspecies of rainbow trout, *Salmo gairdneri aquilarum*, the taxonomic status of the Eagle Lake rainbow trout has been controversial. Hubbs and Miller (1948) examined Snyder's specimens and concluded that Eagle Lake rainbow trout were derived from hybridization between native Lahontan cutthroat trout and introduced rainbow trout, although Miller (1950) retracted the hybridization theory. Behnke (1965, 1972) proposed a redband X rainbow hybrid origin. Needham and Gard (1959) suggested that the Eagle Lake rainbow trout may be descended from introduced or immigrant rainbow trout from the Feather or Pit River drainages. More recently, Busack et al. (1980), in an extensive analysis of electrophoretic, karyotypic, and meristic analyses found that even though the Eagle Lake trout is electrophoretically and meristically close to rainbow trout, their karyotype (of 58 chromosomes) is distinctive and suggested that Eagle Lake rainbow trout is derived from immigration or the unrecorded introduction of rainbow trout with 58 chromosomes. Given the distinctive morphology, ecology, and physiology of this form, it is highly unlikely that the Eagle Lake trout is derived from an introduction.

Distribution: Eagle Lake rainbow trout are endemic to Eagle Lake, Lassen County, California (Fig. 10). They have been planted in numerous waters in northern and central California, but it is unlikely that naturally-reproducing populations of genetically pure Eagle Lake trout are present in any of these waters (such populations are maintained entirely from hatchery

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stocks originating annually from Eagle Lake stock captured at the Pine Creek Spawning Station).

Habitat Requirements: Eagle Lake trout spend most of their life in Eagle Lake, a large (24-km long by 3-4-km wide), highly alkaline (pH 8-9) lake. The lake consists of three basins, two of them averaging 5-6 m deep, the third averaging 10-20 m and reaching a depth of nearly 30 m. The shallow basins are uniform limnologically, and water temperatures may exceed 20°C in the summer. The deep basin stratifies, so in late summer most of the trout are in the deeper, cooler water of this basin. Otherwise, they are found throughout the lake.

Eagle Lake trout are stream spawners. They formerly migrated over 45 km upstream to spawn in the shaded, gravelly upper reaches of Pine Creek. Young then spent their first year or two in the stream before moving into the lake during high run-off periods. During the summer, upper Pine Creek is a "typical" spring-fed trout stream, flowing at 1-5 cfs through meadows and deep forest, with modest gradients. Today, the degraded nature of lower Pine Creek requires Eagle Lake trout to be propagated in a fish hatchery. Barriers have been constructed to exclude spawners from tributaries because flows are too short in duration to recruit enough juveniles to sustain a natural lake population.

Life History: Eagle Lake trout are late maturing (at 3 yrs) and long-lived (up to 11 yrs), although trout older than 5 years are rare (McAfee 1966). They apparently reached 15-20 cm FL in Pine Creek before entering the lake, and then grew to about 40 cm in their second year (first year in the lake), 45 cm in the third, 54-55 cm in the fourth, and 60 cm in the fifth year (McAfee 1966). The present population has a similar, if more variable, growth pattern as they are planted in the lake at ages ranging from 14 to 18 months at sizes of about 30 cm FL (CDFG, unpubl. data). Mature females produce 2500-3000 eggs.

The trout become reproductively mature between March and May when they move upstream to spawn in response to high flows in Pine Creek. Today they are trapped by CDFG at the mouth of Pine Creek. The eggs and sperm are stripped from the fish and then taken to Crystal Lake, Darrah Springs, and Mt. Shasta hatcheries where they are reared for restocking the lake. Some fish reared from the eggs are planted in the mouth of Pine Creek (generally in October or November) so that spawners will home to the trap. Most of the fish derived from hatchery broodstock are planted in the south portion of the lake (generally in April or May) where they survive better initially and contribute more to the lake-wide fishery.

The diet of the trout varies with age and season. Newly-planted trout in their first year in the lake feed mainly on zooplankton, including *Daphnia* spp. and *Leptodora kindti*, and benthic invertebrates, especially leeches and amphipods. By August, most of the trout switch to feeding on young-of-year tui chubs (King 1963, unpubl. data, UCD).

Status: Class 3.

If CDFG had not begun trapping the last of these trout in the 1950's, it is likely that this unusual subspecies would now be extinct. It is currently maintained entirely by hatchery production, although a few fish have managed to spawn successfully in Pine creek during wet years (Moyle, unpubl. data). Although the fish are raised in three hatcheries and their relatively long life provides a measure of safety, reliance on hatchery production puts an element of uncertainty into the long-term survival of this species, especially as hatchery conditions may alter the population genetically.

Management: The present hatchery and planting programs have been successful and need to be continued. However, it is important that Pine Creek and possibly Papoose Creek be restored so that the natural life cycle of Eagle Lake trout can be resumed and the quality and quantity of water flowing into the lake improved. This should be possible, as most of the drainage is on USFS lands. Although the decline of the stream, from being semi-permanent in its lower reaches to being highly seasonal in its flows as it is today, was caused by a multitude of factors, including logging and road and railroad construction, the major factor presently preventing recovery is poor management of livestock grazing. Reduction or elimination of grazing in some riparian areas, coupled with rotational grazing plans in other areas, could allow the stream to recover its natural hydrologic regime (W. Platts, unpubl. memo). The recovery, however, would take many years, so hatchery production would have to continue indefinitely. Once a recovery plan is underway, brook trout (*Salvelinus fontinalis*) should be eliminated from the upper reaches of Pine Creek and Eagle Lake rainbows planted in their stead. Fishing in the creek would have to be closely regulated until a large population of native trout is present.

For a discussion of the management of Eagle Lake itself, see Eagle Lake tui chub.

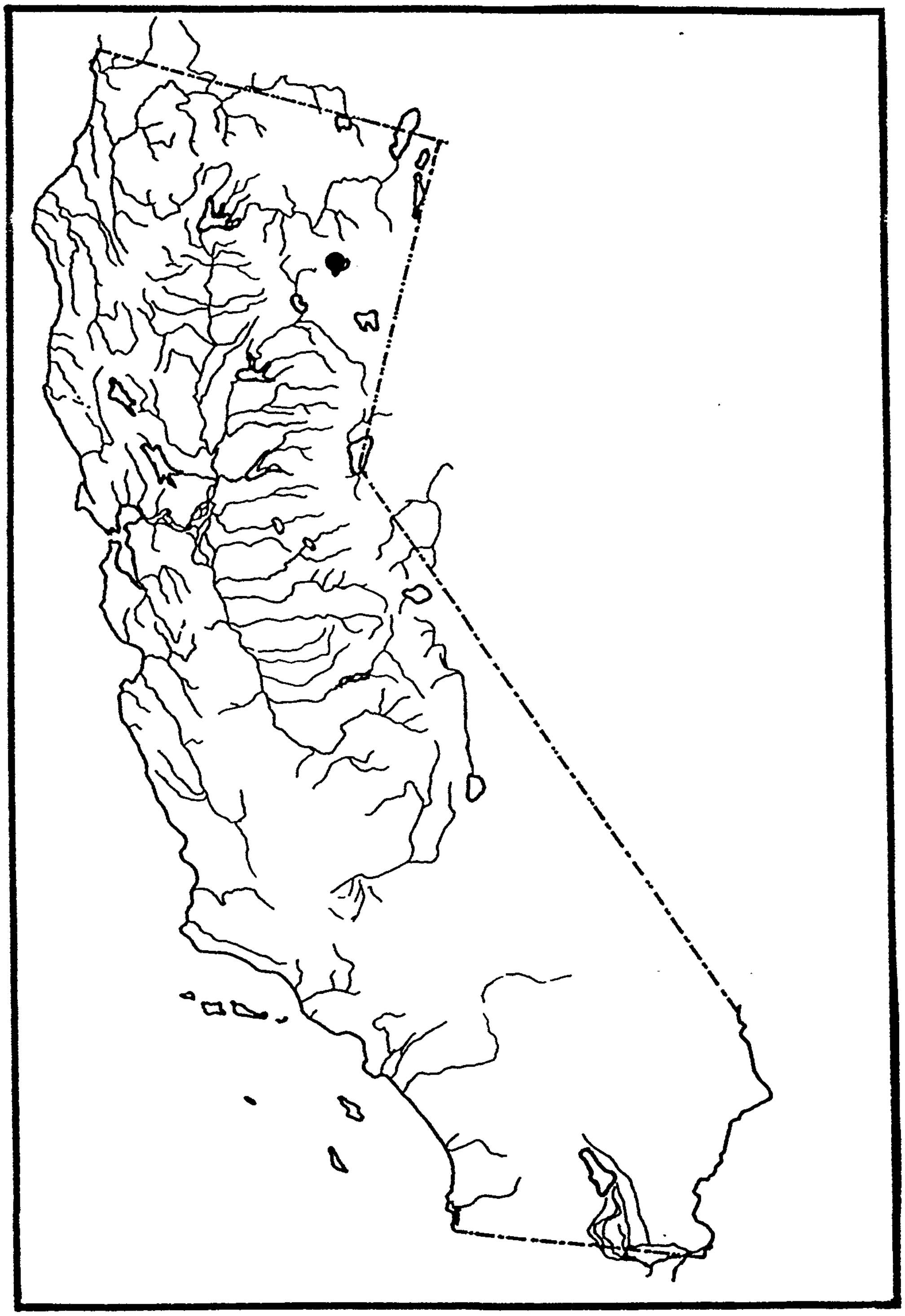

FIGURE 10. Distribution of Eagle Lake rainbow trout, *Oncorhynchus mykiss aquilarum*, in California.

KERN RIVER RAINBOW TROUT
Oncorhynchus mykiss gilberti (Jordan)

Description: This subspecies is similar to other rainbow trout (Table 8), but its coloration is brighter and it has heavy spotting over most of its body (see Moyle 1976).

Taxonomic Relationships: Like the other members of the rainbow trout complex in the Kern River system, the taxonomic status of this subspecies has been controversial. D. S. Jordan's designation of this fish as a distinctive subspecies of rainbow trout was accepted until Schreck and Behnke (1971) described it as a population of golden trout. Their decision was based mostly on limited comparisons of lateral scale counts and on aerial surveys that led them to believe that there were no effective barriers on the Kern River which might have served to isolate trout in the Kern River from the Little Kern River. However, in a subsequent analysis, Gold and Gall (1975) determined that the populations were effectively isolated genetically and physically. Meristic (Gold and Gall 1975) and genetic characteristics (Berg 1987) of *O. m. gilberti* are sufficiently distinctive to warrant its subspecific status (Berg 1987). Genetically, this subspecies is intermediate between the coastal rainbow trout (*O. m. gairdneri*) and the Little Kern River golden trout (*O. m. whitei*), but closer to the former (Berg 1987). Berg (1987) also speculated that its origin was due to hybridization and introgression of coastal rainbow trout and Little Kern River golden trout, followed by isolation.

Distribution: This subspecies is endemic to the upper Kern River and tributaries, Kern County (Fig. 11). It has been reported from the North Fork Kern River, from the forks of the Kern to Junction Meadow, and in Rattlesnake, Osa, Soda, and Hells Hole creeks. About 29 stream km are in Sequoia National Forest and an undetermined number in Sequoia National Park.

Habitat Requirements: Little information is available on Kern River rainbow trout, but in general the habitat requirements should be similar to other rainbow trout (see Moyle 1976 for details).

Life History: No life history studies have been done on this subspecies, but its life history is probably similar to rainbow trout (see Moyle 1976 for details).

Status: Class 2.

This native trout of the mainstem Kern River and tributaries has only recently been recognized as persisting in a genetically pure form (Berg 1987). Previously, it was feared to have introgressed with nonnative rainbow and with golden trout (Gerstung 1980). Much of its present habitat, however, suffered from the Flat Fire of 1976 and subsequent landslides that filled in pools and deposited silt in spawning areas. Primary threats to remaining populations are introgression with introduced trouts, habitat losses from poor management, and stochastic events such as floods, drought, and fire.

Management: All efforts should be made to identify and secure streams still retaining Kern River rainbow trout. Controls on trout introductions and establishment of instream barriers are needed to prevent the spread of hybrid trout. Annual population surveys should be conducted to monitor trout populations and identify habitats in need of improvement. Reestablishment of secure riparian plant communities along occupied habitat would increase trout populations.

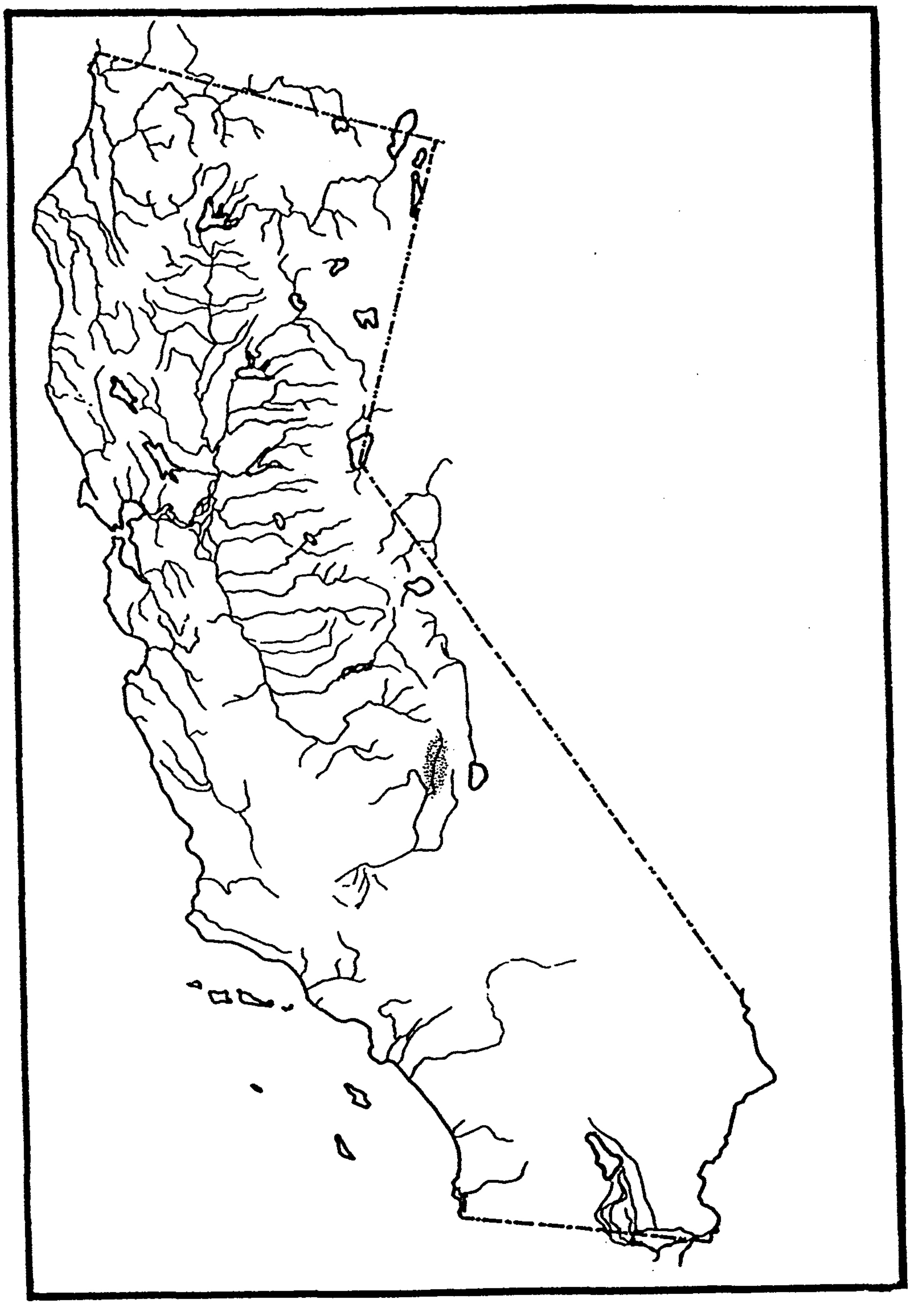

FIGURE 11. Distribution of Kern River rainbow trout, *Oncorhynchus mykiss gilberti*, in California.

VOLCANO CREEK GOLDEN TROUT
Oncorhynchus mykiss aguabonita (Jordan)

Description: The Volcano Creek golden trout, like other golden trout, is characterized by the bright red to red orange on the ventral surface and head. The lower lateral surfaces are a bright gold with a central red-orange lateral band. The dorsal surface is a deep olive green. Young and adults have about 10 parr marks centered along the lateral line. The parr marks on adults are considered to be a genetic characteristic (Needham and Gard 1959). Large spots are present, mostly on the dorsal and caudal fins, and smaller spots are scattered on the back and sides. The pectoral, pelvic, and anal fins are orange. The anal fins also have white to yellow tips, preceded by a black band. The dorsal fin has a white to orange tip.

Basibranchial teeth are absent and there are 17-21 gill rakers. There are 175-210 scales along the lateral line and 34-45 scales above the lateral line. There are 8-10 pelvic rays. Pyloric caeca number from 25-40 and vertebrae from 58-61.

Taxonomic Relationships: The systematics and taxonomic relationships of this taxon has been the subject of much confusion and controversy (see summary in Moyle 1976). Originally, three species of golden trout were described; *Salmo aguabonita* from the South Fork Kern River (Volcano Creek), *S. whitei* from the Little Kern River, and *S. roosevelti* from Golden Trout Creek. However, the first two forms were eventually recognized as subspecies of *S. aguabonita*, *S. a. aguabonita*, and *S. a. whitei*, whereas *S. roosevelti* was shown to be a color variant of *S. a. aguabonita*. Recently, Berg (1987), in a detailed study of the taxonomic relationships of rainbow trout in California, concluded that the two recognized subspecies of golden trout are more closely related to the Kern River rainbow trout (*O. m. gilberti*) than either are to each other. Therefore, the Volcano Creek golden trout is considered a subspecies of rainbow trout and classified as *O. m. aguabonita*.

Distribution: The Volcano Creek golden trout is native to the drainage of the South Fork of the Kern River and is found in Cottonwood Lake, Cottonwood Creek, Mulkey Creek, Golden Trout Creek, and Volcano Creek (Berg 1987, Fig. 13). However, this fish has been translocated into many other waters within and outside California. In California, they are now found in more than 300 high mountain lakes and streams outside their native range (Moyle 1976).

Habitat Requirements: Little information is available specifically on the Volcano Creek golden trout in its native habitat, but in general golden trout are adapted to cold, clear mountain streams, where water temperatures are usually below 22°C, above 2100 m in elevation. Although they coexist naturally with Sacramento suckers (*Catostomus occidentalis*) in their native range, they are generally unable to coexist with other salmonids.

Life History: Golden trout have slow growth rates, reflecting the low productivity and short growing season of the cold waters they inhabit (Moyle 1976). Little data are available on growth rates, but they are known to live for 6-7 years and they reach lengths of 40-50 mm FL during the first year, 100-150 mm by the second year, 130-230 mm during the third, and 210-280 mm by the fourth year (Curtis 1934). However, fish over 250 mm FL or over 5 yrs are rare (Moyle 1976). In lightly fished lakes, golden trout will reach 350-430 mm FL by the seventh year. The largest on record from California was 4.5 kg and was taken from Virginia Lake, Madera County.

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Golden trout become reproductive by their third or fourth year and spawn when water temperatures reach 7-10°C, usually in late June and July. They spawn in gravel riffles in streams; only rarely will they spawn in lakes. A female is capable of laying between 300-2300 eggs, depending on her size (Curtis 1934). The eggs hatch within 20 days at an incubation temperature of 14°C. The fry emerge from the gravel two to three weeks after hatching, at which time they are about 25 mm TL. In lake populations, fry move into the lakes from the spawning streams when they are about 45 mm TL.

Golden trout will feed on any autochthonous or allochthonous invertebrates, mostly adult and larval insects. Although the bright coloration makes them highly visible, there are very few natural predators in the range occupied by this subspecies. Thus, the bright coloration has been proposed as an adaptation for reproductive advantage. However, the bright coloration has also been implicated as providing camouflage against the bright colors of the volcanic substrates in the clear, shallow streams (Needham and Gard 1959). When these trout are removed from the mountainous streams and brought down to low elevational streams, they lose the brightness and take on dull gray and red colors (Needham and Gard 1959).

Status: Class 4.
This trout has a very restricted native range but has been widely introduced throughout the Sierras and the Rocky Mountains. It is therefore safe as a subspecies, but the original gene pool of golden trout in Volcano Creek should be protected as (1) a source for future fish transplants, (2) a stock that can be genetically compared with introduced populations, and (3) an aesthetic measure. Fortunately the drainage is in Inyo National Forest.

Management: The drainage should be managed by USFS in a manner beneficial to golden trout. Management measures must include restrictions on grazing.

FIGURE 12. Native range of the Volcano Creek golden trout, *Oncorhynchus mykiss aguabonita*, in California.

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GOOSE LAKE REDBAND TROUT

***Oncorhynchus mykiss* subsp.**

Description: The Goose Lake redband trout has two forms: a lake dwelling form that attains lengths of 450-500 mm TL and a stream dwelling form that rarely grows larger than 250 mm TL (J. Williams, unpubl. data). Behnke (1979) examined 6 specimens collected by J. O. Snyder in 1904 from Cottonwood Creek in the Oregon portion of the basin. These fish had 21-24 ($\bar{X}$ 22.8) gill rakers, 61-64 ($\bar{X}$ 62.8) vertebrae, and averaged 30 scales above the lateral line and 139 scales in the lateral series. More recent collections from Thomas Creek, Oregon, and Lassen and Davis Creeks, California, may have been influenced by hatchery rainbow trout introductions as they exhibited gill raker counts that averaged 20-21 (Behnke 1979). Otherwise the gross morphology is similar to other redband trout (see description of McCloud River redband trout).

Taxonomic Relationships: Redband trout are inland forms of rainbow trout. In an extensive electrophoretic analysis of the biochemical-genetic integrity of redband trout, Berg (1987) determined that all California redband trout were distinctive from cutthroat trout with no indication of past redband trout/cutthroat trout introgression (see McCloud River redband trout). Although redband trout populations examined (inland redband, stream-dwelling Goose Lake redband, and McCloud River redband) seemed closely related to coastal rainbow trout, each is distinctive enough to warrant subspecific status (Berg 1987). No genetic differences between the lake and stream forms in the Goose Lake drainage have been documented, although Berg (1987) only sampled the stream form. Behnke (1981) documented meristic differences between lacustrine and resident stream forms of redband trout in the Klamath Basin, and it is likely such differences exist in the Goose Lake Basin as well. Among the various redband trout subspecies, the Goose Lake form may be closely related to redband trout of nearby Warner Basin, Oregon. This conclusion was based on the lower vertebral counts and higher gill raker counts of redband trout in both basins (Behnke 1979). Behnke (1981) reported that the redband trouts of Goose Lake and Warner Basin were probably established prior to the invasion from the Columbia River of rainbow trout into other nearby basins. Goose Lake redband has not yet been assigned a subspecific name; the generic and specific names are discussed in the summer steelhead section.

Distribution: The Goose Lake redband is endemic to Goose Lake and its major tributaries (Lassen and Willow creeks in California and the extensive Thomas Creek system and Crane Creek in Oregon) as well as to smaller streams such as Cottonwood Creek in California and Augur, Bauer, Camp, Cox, Drews, Snyder Meadow, Shingle Mill, and Warner Creeks in Oregon. Berg (1987) reported that Joseph, Parker, and East creeks, tributaries of the upper Pit River in California, contained trout genetically similar to Goose Lake redband.

Habitat Requirements: The lake-dwelling form can survive the high temperatures, alkalinities, and turbidity that exist in the lake in summer that would be lethal to other trouts. It is possible that springs in the lake may provide refuges to the trout when the lake becomes too warm. Spawning areas are located in high-elevation sections of tributary streams and are up to 40-50 km from the lake. Prior to spawning, adults must have access from the lake to spawning areas. In every stream this means negotiating extensive agricultural areas characterized by water diversions, erosion, and channelization. Log jams and beaver dams also may prohibit or restrict upstream movement of spawners during low flow conditions. After spawning, adults and eventually the young must have passage back to Goose Lake. The spawning sites themselves must be non-degraded reaches of streams with clean gravels and suitable riparian cover for maintenance of cool water temperatures. Goose Lake redband have been observed to spawn in lower reaches of Willow and Lassen Creeks when access to upstream areas is blocked (P. Chappell, pers. comm.), but siltation and high temperatures probably preclude successful recruitment in lower reaches of these streams. The stream-dwelling form has not been studied, but its requirements are presumably similar to other stream populations of redband trout.

Life History: In California, the lake-dwelling form spawns in the headwater drainages of Lassen and Willow creeks on private and Modoc National Forest lands. If sufficient flows are available, they spawn primarily in Cold Creek, a small tributary of Lassen Creek, and in Buck Creek, a small tributary of Willow Creek. Upstream of its confluence with Cold Creek, a steep, rocky gorge appears to prevent spawners from ascending further up Lassen Creek. In Oregon they formerly spawned in Thomas Creek and its tributaries and possibly in Cottonwood and Drews creeks. In recent years, the largest spawning run has occurred in Lassen Creek (J. Williams, unpubl. data). Although large spawners have been observed in lower Willow Creek, diversion structures have prevented most or all the fish from reaching suitable spawning and rearing habitat in Buck Creek. Buck Creek has been severely degraded by irrigation diversion structures, but it has considerable potential for improvement as a spawning stream.

Spawning migrations occurred in Willow and Lassen creeks during late March 1988. Adults returned to the lake in April. Young trout may spend one or more years in the stream before moving down into Goose Lake. In the lake, the trout presumably feed on the abundant Goose Lake tui chub.

Status: Class 2, lake-dwelling form.
Class 3, stream-dwelling form.

The lacustrine form of Goose Lake redband has become quite rare in recent decades. Interviews with local residents indicate that both sport and commercial fisheries for the lake-dwelling form have existed in the past and that large runs had existed in local creeks, especially Thomas Creek in Oregon. The last spawners in Thomas Creek were observed in the early 1970's. The only large documented run during the 1988 spawning season occurred in Lassen Creek when several hundred spawners were present (J. Williams, unpubl. data) and suggests that there are fewer than 1000 adults in Goose Lake. In 1989, however, only a small number of fish appeared in the creek and there was no evidence of successful spawning (G. Sato, USFS, pers. comm.).

The status of lake-dwelling Goose Lake redband trout should be reclassified to Class 1 if populations continue to decline in Lassen Creek or if introgressive hybridization or other contamination of the native stock by hatchery rainbow trout is documented. Desiccation of Goose Lake during extended drought, however, would appear to lessen the chances for maintaining genetic differences between stream and lake forms, although local residents indicated that even during the drought of the 1930's there were pools on the lake bottom from which trout could be obtained. The possibility of genetic contamination of Goose Lake redband by hatchery trout has also been indicated by Behnke (1979). The status of the resident stream form would appear to be more secure as populations are supported in Willow, Lassen, Davis, and other creeks in the upper Pit River drainage, as well as in numerous streams in the Oregon side of the basin.

Management: The biology of the Goose Lake trout, especially the lake-dwelling form, is poorly known so there is urgent need for studies on the genetic identities of the lake and stream populations and on the life history and habitat requirement of the lake-dwelling form. More importantly, there is an immediate need for habitat management of (1) lake habitat, (2) valley floor stream habitat, and (3) spawning and rearing habitat. The goal of management should be to restore Goose Lake redband trout populations to the point where they can sustain substantial sport fishery.

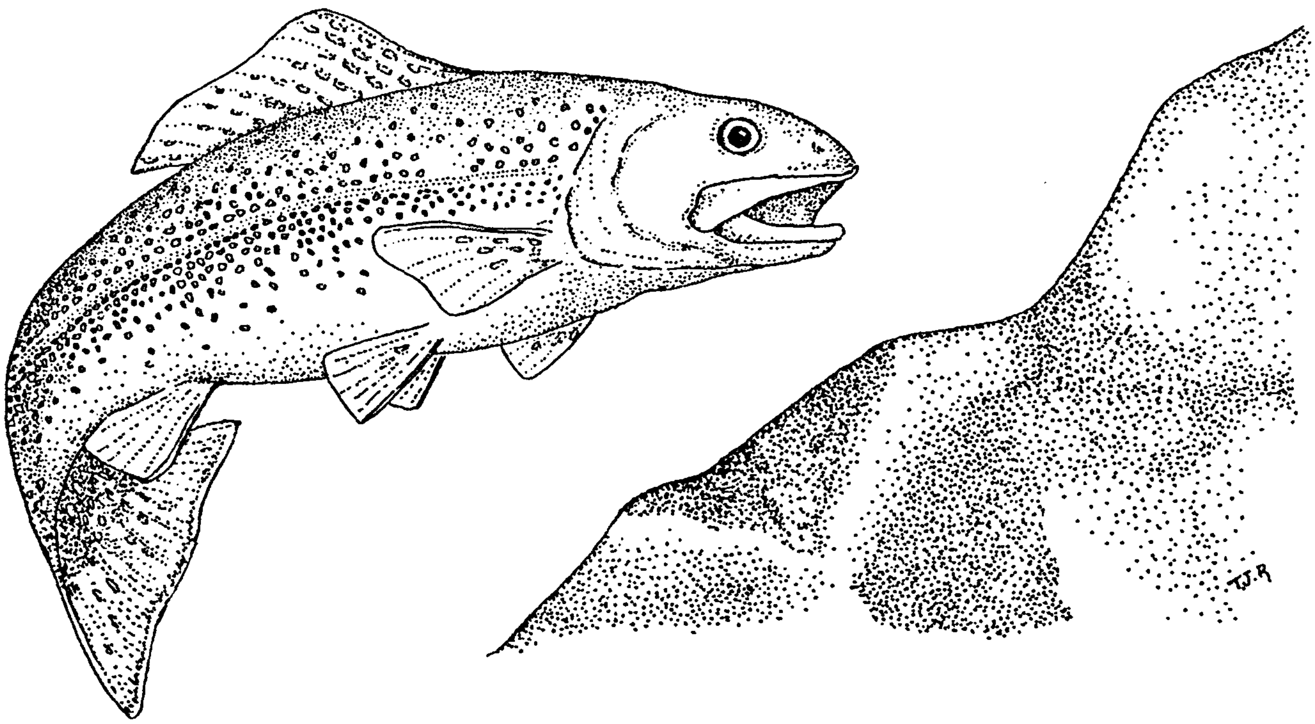
For lake habitat, it is important to maintain the native fish assemblage and to maintain adequate lake levels. Goose Lake is dominated by native fishes. The abundant and varied tui chub population provides an excellent food resource for the larger redband trout, which is the dominant predator in the system. Introductions of exotic fishes that could alter the forage base or add another predator should be avoided. Numerous fishes have been stocked into Goose Lake, but none survive outside of the tributary streams because water conditions in the lake are too harsh for most game fishes. Therefore, management to provide a sport fishery should focus on improving spawning conditions for redband trout rather than stocking exotic predatory fishes. The effects of water diversions on lake levels needs to be investigated.

The valley floor habitat surrounding Goose Lake is largely devoted to agriculture. Streams in the valley do not provide year-round trout habitat but are critical for passage of Goose Lake redband trout to and from spawning areas. To the best of our knowledge, adults migrate to spawning areas during late March or early April and return to the lake between mid- to late April. Early placement of boards in diversion dams, therefore, can prevent either the upstream movement of adults or the return of adults and young back to Goose Lake. In California, Willow and Lassen creeks are critical spawning streams. The valley floor section of Willow Creek is typically impassable to adult redband moving upstream. A diversion structure downstream of US-395 has been particularly harmful and prevented most adult spawners from moving upstream in 1988 despite recent attempts to install a fish ladder. Major modification of this structure is needed to allow upstream movement of spawners. On both Lassen and Willow creeks, agreements with landowners are needed to coordinate timing of board placements in diversion structures. Screens are also needed on irrigation structures to prevent diversion of young and adults into fields.

Headwaters of Willow and Lassen creeks are the only remaining spawning habitats for Goose Lake redband in California. Depending on water flows and access past barriers, Buck Creek (a tributary of Willow Creek) and Cold Creek (a tributary of Lassen Creek) may be major spawning areas. Access to Cold Creek is generally good, but access to Buck Creek is impeded downstream of US-395 (noted above) and at its confluence with Willow Creek. At present, a diversion structure often diverts the flows of lower Buck Creek from Willow Creek. This problem should be corrected through agreement with the landowner or acquisition of the property. The upper Willow Creek watershed has been severely degraded by overgrazing and timber harvest practices. Erosion control should be implemented on upper Willow Creek and tributaries. Changes in management should include reductions in cattle grazing, juniper revetment, and willow planting along streams, and/or other appropriate measures.

Because of the small size of spawning streams and large size of adults, spawning redband trout are susceptible to poaching. Therefore, patrols are necessary to prevent poaching as adults mass below diversion structures and in shallow spawning areas.

Close coordination with Oregon resource agencies is also necessary for proper management of the redband trout. It is particularly important that runs of lake-dwelling trout be reestablished in Thomas Creek, as this is the largest tributary drainage and presumably once supported the largest runs of trout. Agreements should be made with the Oregon Department of Fish and Wildlife to prevent introductions of exotic fishes into Goose Lake. No non-native fish should be introduced into Goose Lake or tributary streams so that the genetic integrity of native redband trout and the integrity of the fish communities can be preserved.



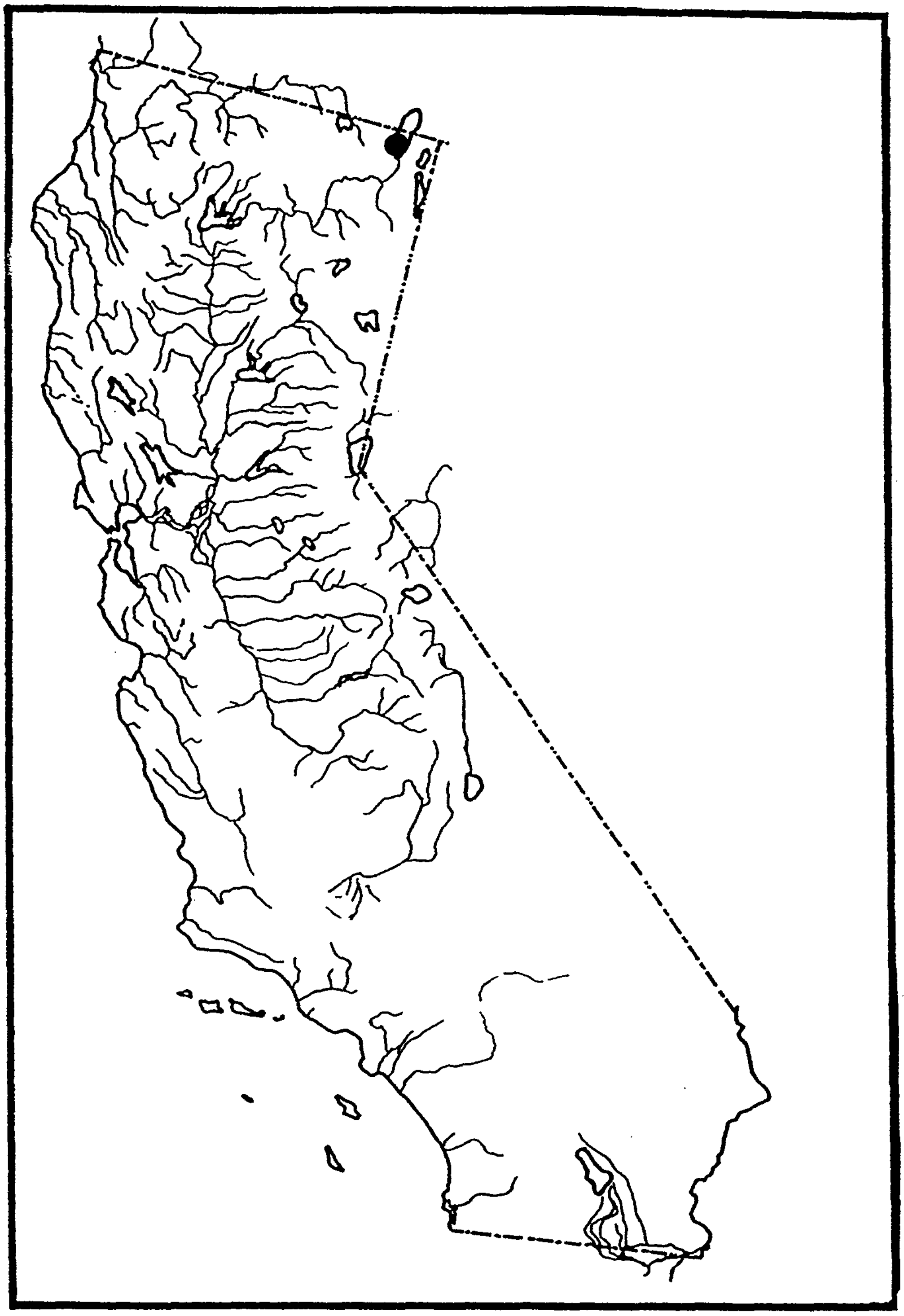


FIGURE 13. Distribution of the Goose Lake redband trout, *Oncorhynchus mykiss* subsp., in California.

C-046003

MCCLOUD RIVER REDBAND TROUT
Oncorhynchus mykiss subsp.

Description: The following description (from Hoopaugh 1974 and Gold 1977) is based on the Sheepheaven Creek population in the McCloud River drainage that may not be typical of the entire subspecies. Overall body shape of this redband trout is similar to the "typical" trout shape as exemplified by rainbow trout. It has a yellowish to orange body color with a brick-red lateral stripe. The dorsal, anal, and pelvic fins are white tipped. Adults retain parr marks. Gill rakers number from 14-18 and pyloric caeca from 29-42, both counts normally being less than those for rainbow trout. However, the number of scales along the lateral line (153-174) and above the lateral line (33-40) are greater than in rainbow trout. Pelvic fin rays are 9-10 and branchiostegal rays range from 8-11.

Taxonomic Relationships: The taxonomic status has been under much debate. Legendre et al. (1972) suggested that redband trout are interior rainbow trout closely related to the group of trout that includes Arizona trout (*O. apache*), Gila trout (*O. gilae*), Kern River rainbow trout (*O. m. gilberti*), golden trout (*O. m. aguabonita*), and Mexican golden trout (*O. chrysogaster*). However, Miller (1972) disputed this relationship, suggesting instead that redband trout represent a derivative of an ancestral form which gave rise to the California golden trout. Recent electrophoretic studies by Berg (1987) suggest that the three known redband lineages, inland redband, Goose Lake redband, and McCloud redband, were independently derived from a "coastal rainbow trout-like" common ancestor and are now genetically distinct lineages that warrant recognition as subspecies of rainbow trout.

Distribution: McCloud River redband trout have been reported from creeks tributary to the McCloud River such as Sheepheaven, Tate, Edson, and Moosehead Creeks (Miller 1972, Hoopaugh 1974, Moyle 1976, Berg 1987) and from the McCloud River above Middle Falls (Fig. 14). Redband trout from Sheepheaven Creek were transplanted into Swamp Creek in 1972 and 1974 and into Trout Creek in 1977 (J. M. Hayes, pers. comm.). They are now established in both streams.

Habitat Requirements: Habitat requirements for the McCloud River redband are derived from conditions of Sheepheaven Creek (Hoopaugh 1974, Moyle 1976) and the McCloud River. Sheepheaven Creek is a small, spring-fed stream at an elevation of 1433 m. Water temperature in summer is typically 10°C and the flow is 0.03 m^3/sec (1 cfs). The stream flows for about 2 km from the source and then disappears into the stream bed. The portion of McCloud River inhabited by redband trout flows at 1.2 m^3/sec (40 cfs) through a steep canyon. It is extremely clear and cold (<15°C).

Life History: Little is known about the life history of this fish. Redband trout caught from Sheepheaven Creek were in reproductive condition in June, suggesting that they spawn in late spring. The largest fish caught during a 1973 survey (Hoopaugh 1974) was 208 mm FL and the population was then estimated at 250 fish over 80 mm FL. Four size classes were found in the stream. The life history of redband trout in the upper McCloud River is presumably similar to that of rainbow trout in comparable waters (see Moyle 1976 for details).

Status: Class 3.

Long-term survival of populations of redband trout in small creeks like Sheepsheaven Creek poses problems because the streams may be largely dry during drought years. Many such streams are located on private or National Forest land managed for timber harvest, so minimal attention is paid to managing the streams for native trout. The populations are more secure in the main river, although much of the river flows through private land that has been heavily logged. Because of its size and the high water quality of the springs that feed it, the river seems to be in good condition. However, the river has been proposed as a site for hydroelectric dams, and poor watershed management from road construction, logging, and grazing could degrade water quality. Thus the combination of heavy use of the drainage with several years of drought could cause a major decline in populations of this trout.

The McCloud River receives substantial numbers of stocked hatchery rainbow trout during the summer. CDFG studies (John M. Hayes, pers. comm.) indicate that the hatchery fish apparently do not survive to spawn. Studies by Gall et al. (1981) confirmed that the McCloud River redband trout has maintained its distinct genetic character despite the stockings of rainbow trout. Reproducing populations of brown (*Salmo trutta*) and brook trout (*Salvelinius fontinalis*) are present in the McCloud River as well.

Management: We recommend the following:

1. Have all waters containing McCloud River redband trout in Shasta-Trinity National Forest given special management protection so that maintaining redband trout populations is a high priority.

2. Acquire as much of the private land along the upper river above Middle Falls as possible. The river here has both high aesthetic and recreational values that would be compatible with protecting redband trout.

3. Encourage designation of the McCloud River as wild and/or scenic river under State and/or Federal laws.

4. Evaluate effects of angling regulations and hatchery stocking procedures on redband trout waters. If redband trout populations are low, minimize harvest of this trout. So far, the redband trout have maintained their integrity despite frequent stocking of rainbow trout in the river in the last 80-90 years.

5. Continue program of establishing instream barriers to isolate tributary populations of redband trout to prevent contamination by nonnative trout.

6. Repeat electrophoretic studies periodically to determine if any hybridization between redband and rainbow trout is occurring.

7. Conduct a life history investigation, including habitat requirements of various life stages.

8. Monitor populations of redband trout.

9. Acquire private land that contains populations, especially the land around Sheepheaven Creek.

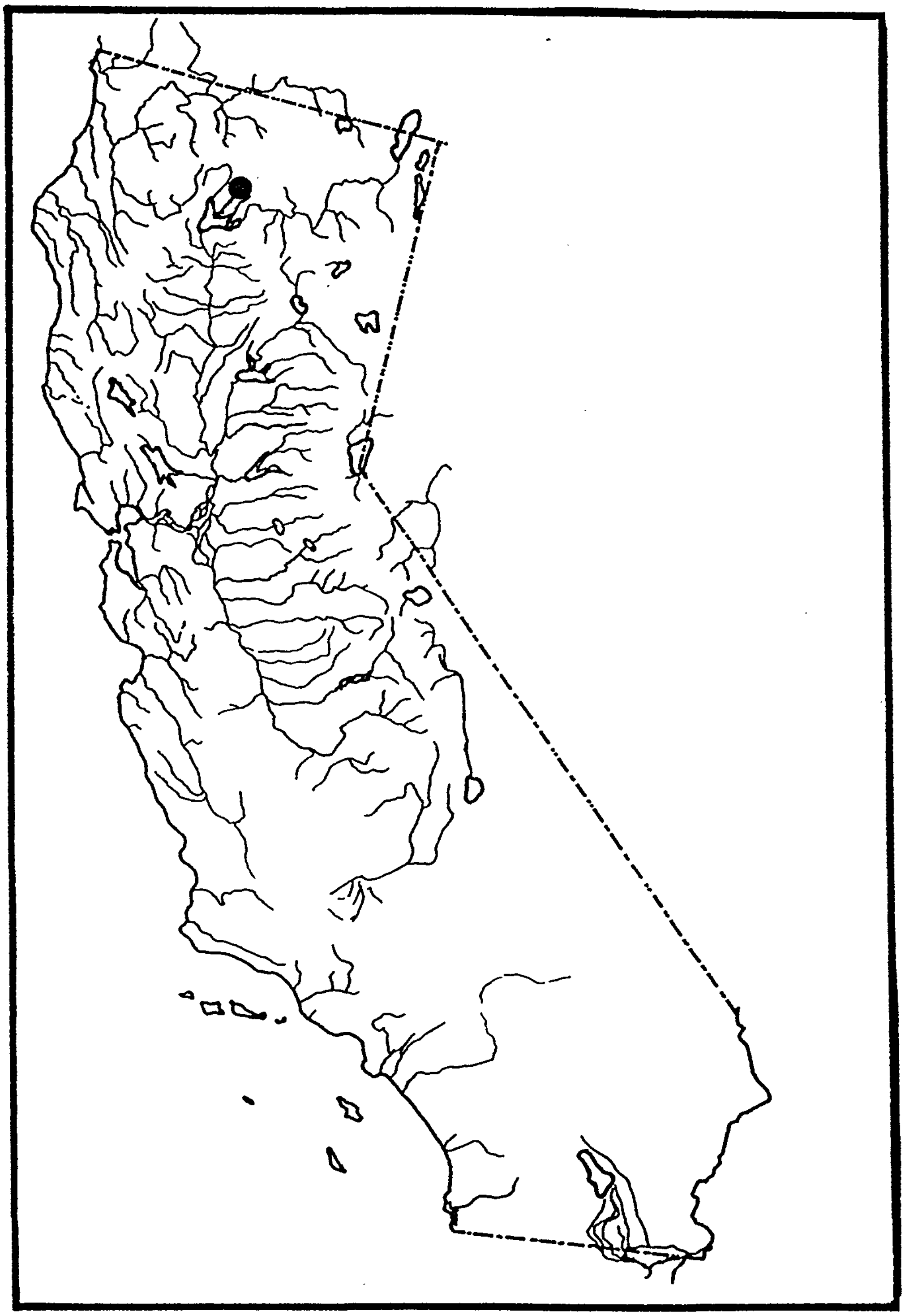


FIGURE 14. Distribution of the McCloud River redband trout, *Oncorhynchus mykiss* subsp., in California.

COASTAL CUTTHROAT TROUT
Oncorhynchus clarki clarki (Richardson)

Distribution: Coastal cutthroat trout reach lengths of 300-380 mm and are similar to rainbow trout (*Oncorhynchus mykiss*) in gross morphology and color. They can, however, be differentiated by the heavier spotting, especially below the lateral line and in the posterior part of the body. Spots also are commonly present on anal and paired fins, which are otherwise uniformly colored. The trout are characterized by "cutthroat" marks, which range from yellow to orange to red, on the skin folds on either side of the lower jaw (Scott and Crossman 1973). Cutthroat marks are seldom visible until the fish become at least 80 mm TL. Overall, however, coloration is extremely variable within the species (DeWitt 1954, Scott and Crossman 1973).

Cutthroat trout also have larger mouths (longer maxillary bones) and more slender bodies than rainbow trout. The teeth are well developed on both jaws, vomer, palatines, tongue, and on the basibranchial bones. The dorsal fin has 9-11 rays, the anal fin 8-12 rays, the pelvic fins 9-10 rays, and the pectoral fins 12-15 rays. The caudal fin is moderately forked. There are 15-28 gill rakers on each arch and 9-12 branchiostegal rays. Scales are smaller than those of rainbow trout and there are 140-200 along the lateral line. Anadromous forms occasionally exceed 4.5 kg (10 lb), but the nonanadromous forms are smaller at 1.5-1.8 kg (3-4 lb) (DeWitt 1954). Parr have 9-10 widely spaced oval-shaped parr marks centered along the lateral line.

Taxonomic Relationships: Despite earlier taxonomic controversy (Needham and Gard 1959, La Rivers 1962, Scott and Crossman 1973), the coastal cutthroat is now recognized as one of three valid California subspecies of *O. clarki* (Moyle 1976). The other two subspecies in California are Lahontan cutthroat (*O. c. henshawi*) and Paiute cutthroat (*O. c. seleniris*).

Distribution: Coastal cutthroat are found in small, coastal streams from the Eel River, Humboldt County, California, north to Seward in southeastern Alaska (Scott and Crossman 1973, Gerstung 1981). In California, their range is restricted in the south to the Eel River drainage and extends north to the Oregon border. The western border is the Pacific coast and in the east the summit of the coast range (Fig. 15) (DeWitt 1954). It has been reported from the California tributaries of the Rogue River, Siskiyou County. In the Eel River, coastal cutthroat trout have been found in the main river and 7 tributaries close (within 16 km) to the coast (DeWitt 1954, Gerstung 1981). However, as the range extends northwards, they tend to be found further inland. Thus, in the Klamath River coastal cutthroat trout are found 30 km inland and in 17 of its tributaries. In the Smith River they are found 70-90 km inland and in 31 tributaries. The Smith River is considered to be the most important coastal cutthroat trout river because the species has been reported from nearly all its tributaries (DeWitt 1954, Gerstung 1984).

Habitat Requirements: Coastal cutthroat require small, low gradient coastal streams and estuarine habitats. Optimal streams are cool (<18°C) and well shaded. Stream sections with small gravel substrates are essential for spawning.

Life History: Coastal cutthroat trout are ecologically similar to rainbow trout but, when sympatric, the cutthroat trout are usually found in the smaller headwater streams whereas rainbow trout are found in the larger, main rivers (Hartman and Gill 1968). Some coastal cutthroat trout may spend their entire lives in freshwater, but most are anadromous, spending the summers in saltwater habitat. Thus most summer fish in the streams are of the first year age class, but a few may be older nonanadromous fish and anadromous forms that have been landlocked by swiftly receding water levels (DeWitt 1954). Scott and Crossman (1973) presented a comprehensive description on their life history, based mostly on coastal cutthroat trout from Canadian waters, and DeWitt (1954) described life history of California populations. The following account is derived from descriptions by these authors.

In northern California, coastal cutthroat trout begin to migrate up spawning streams in September and October following the first substantial rainfall. Redwood Creek and the Mad, Klamath, and Smith rivers are among the significant spawning streams. Ripe or nearly ripe females have been caught from September to April, indicating a prolonged spawning period. Age at first spawning ranges from 2-4 years, and the fish are relatively short lived at 4-7 years.

Females excavate redds in clean gravel with their tails. The completed redd measures approximately 350 mm in diameter by 100-120 mm in depth. After spawning is completed, the female will cover the redd with about 150-200 mm of gravel by displacing the substrate upstream of the redd. Each female will dig a number of redds sequentially. Spawning can take place during the day or at night.

Fecundity ranges from 1100-1700 eggs for females between 200-400 mm TL. Among similar-sized fish, first-time spawners are more fecund than second-year spawners. Embryos are 4-5 mm in diameter, orange-red in color, demersal, and adhesive. They hatch following 6-7 weeks of incubation. The alevins remain among the gravel for an additional 1-2 weeks until the yolk-sac is absorbed. Thus, fry emerge from March to June (DeWitt 1954). Once they emerge, the juveniles move out of the small streams and into the larger rivers (or lakes). Most migrate to sea during their first year, but others will migrate during the second or third years. Once in the sea, they remain close to the coast and most will remain within the estuary. They may spend one or several years at sea, but will migrate upstream each year to spawn.

Adults feed on insects, crustaceans, and other fish. Young and juveniles feed mostly on aquatic and drift insects, microcrustaceans, and occasionally, on smaller fish.

Status: Class 3.

Gerstung (1981) estimated that coastal cutthroat trout occupy 780 stream miles and 4 coastal lagoons of northern California. However, the exact status of coastal cutthroat populations is hard to determine, as juveniles (<50 mm SL) are very difficult to distinguish from the more abundant rainbow trout (steelhead) in the field. Migrating adult cutthroat are probably often mistaken for steelhead as well. Nevertheless, it is likely that their populations have declined in recent years, because they require cold water of high quality and depend on small streams which are vulnerable to damage by logging and other anthropogenic activities. The largest California populations are in the Smith River system (Gerstung 1981). Even within the Smith River numerous streams have been degraded. Gerstung (1981) reported surveys of the Smith River drainage that found 15% of streams severely degraded, 29% moderately degraded, 35% slightly degraded, and 21% pristine. Non-anadromous populations of cutthroat such as in Little Jones Creek, a tributary to the Smith River, may require special management to preserve their genetic integrity.

Management: A thorough survey of coastal cutthroat populations needs to be performed and the results compared to those of Dewitt (1954) and Gerstung (1981). Special attention should be paid to the location and status of non-anadromous populations. Once populations have been located, a status survey of key populations should be conducted every 2 to 5 years. Streams that are important for cutthroat spawning should be given special management designation by state and federal agencies in order to enhance production of cutthroat. Because the Smith River drainage appears to have the largest population of coastal cutthroat in California, special attention should be given to enhancing cutthroat populations in this system. Efforts to enhance coastal cutthroat populations by artificial propagation should be designed to conserve the genetic integrity of wild stocks. Little Jones Creek, with its unique population of non-anadromous cutthroat should be given special management and protection.

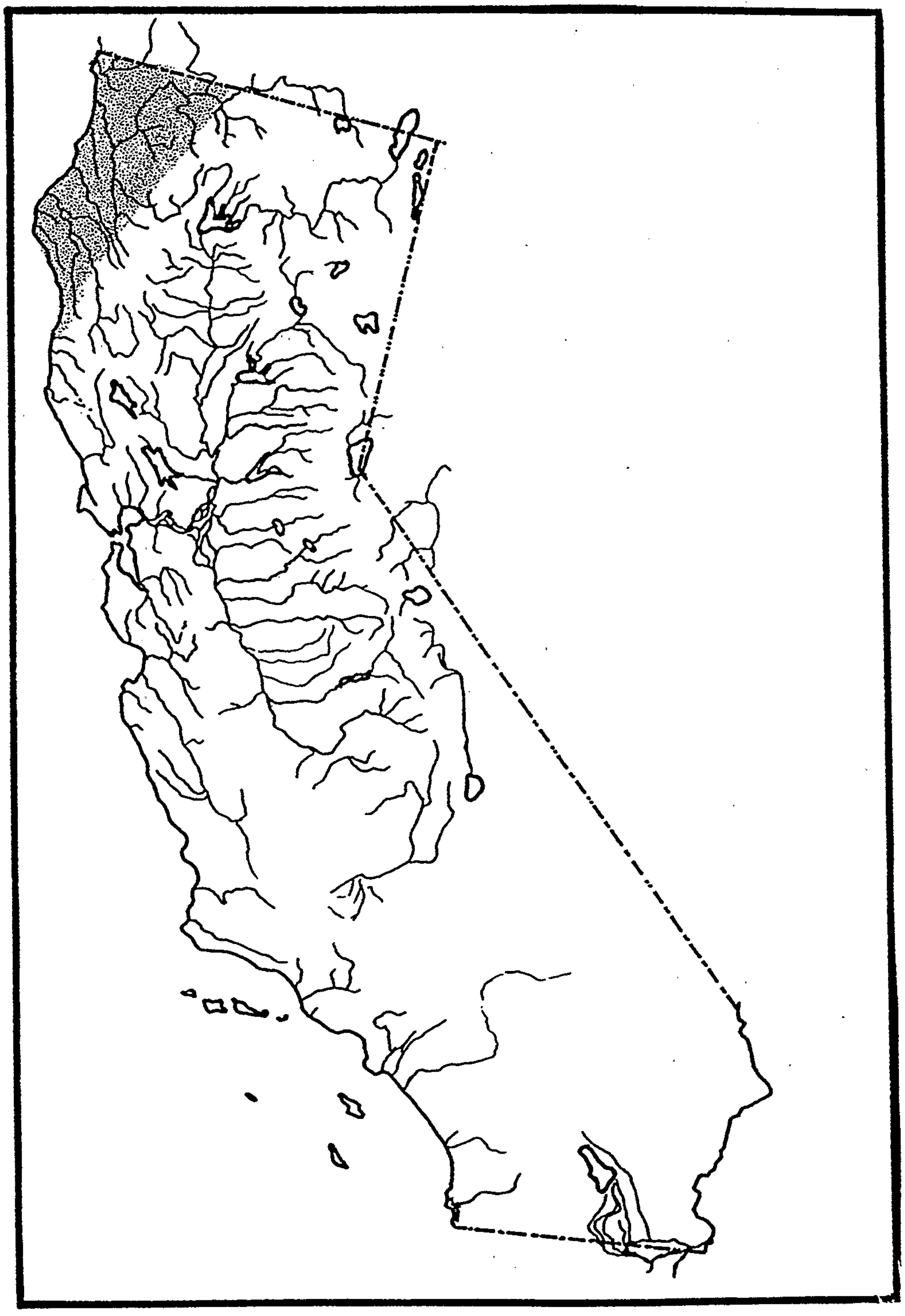


FIGURE 15. Distribution of coastal cutthroat, *Salmo clarki clarki*, in California.

DELTA SMELT
Hypomesus transpacificus (McAllister)

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

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

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

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

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

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

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

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

Status: Class 1.

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

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

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

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

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

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

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

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

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

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

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

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

C-046015

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

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

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

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

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

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

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

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

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

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

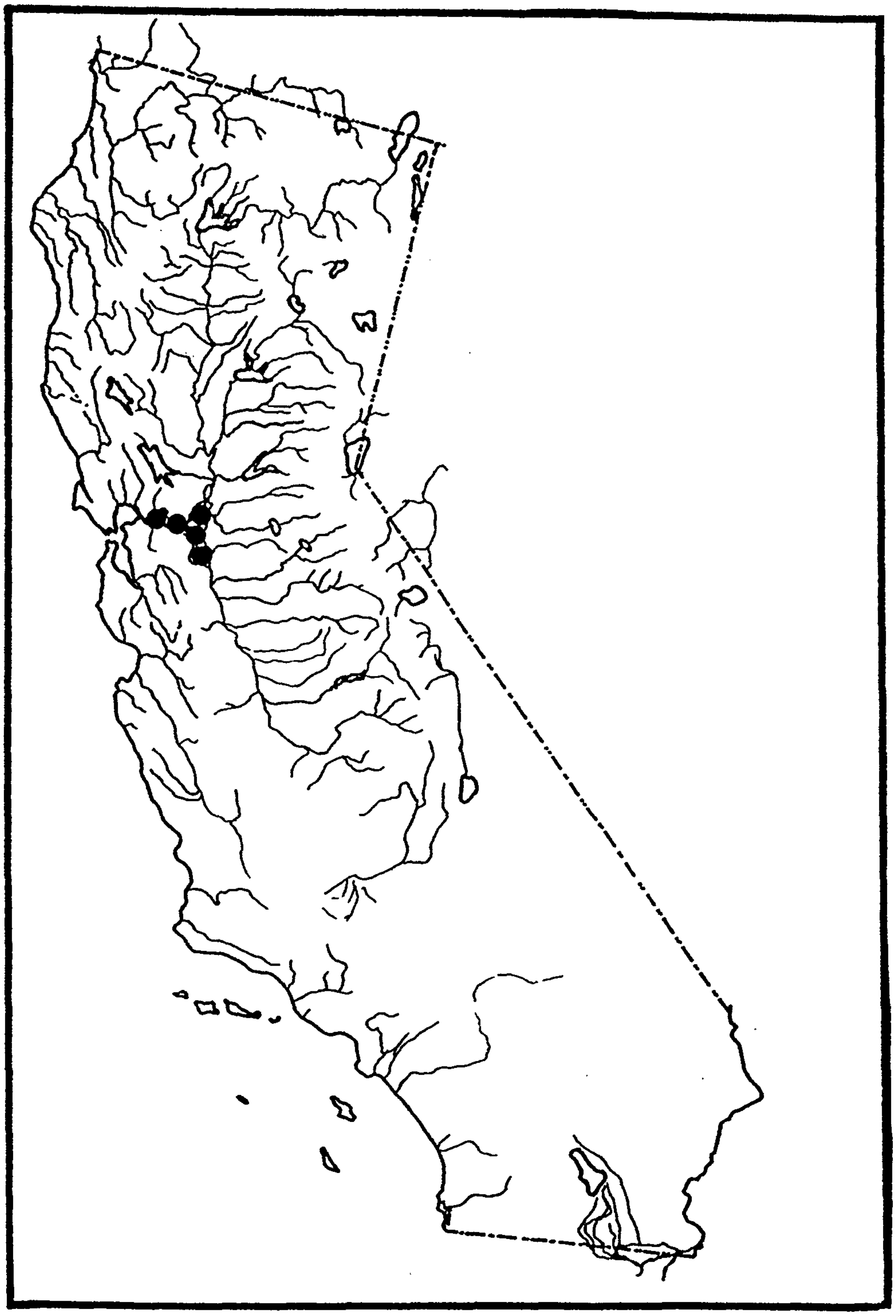


FIGURE 16. Distribution of delta smelt, *Hypomesus transpacificus*, in California.

LAHONTAN LAKE TUI CHUB
Gila bicolor pectinifer (Snyder)

Explanatory Note: The taxonomy of tui chubs is confusing because there are many isolated populations that are morphologically similar. Compounding the confusion is the lack of phenetic and genetic studies and information on life histories and habitat requirements. Presently there are a number of described subspecies of *Gila bicolor*, but most forms remain undescribed. Detailed accounts are given here for five subspecies: Lahontan tui chub (*Gila bicolor pectinifer*), Eagle Lake tui chub, (*G. b.* subsp.), Cowhead Lake tui chub (*G. b. vaccaceps*), High Rock Springs tui chub (*G. b.* subsp.), and Goose Lake tui chub (*G. b. thalassina*). Most tui chub populations are abundant in their limited ranges, but they tend to be very restricted geographically, making them vulnerable to local extinctions.

Description: Lahontan Lake tui chubs are cyprinids that can reach lengths of 35 to 41 cm FL. The mouth is small, terminal, and oblique. There is a single row of hooked, pharyngeal teeth (5-5, 5-4, or 4-4) with narrow grinding surfaces. This subspecies is characterized by numerous (29-40), long, slender gill rakers, the primary characteristic that serves to differentiate it from the sympatric conspecific *G. b. obesa* (Miller 1951, Moyle 1976, Vigg 1985). The inter-gill raker distances are usually less than the width of the gill rakers themselves. Other morphological characteristics that differentiate *pectinifer* from *obesa* are the oblique mouth, the slightly concave profile of the head, and a uniform blackish or silvery body coloration (Miller 1951). Dorsal and anal fin rays usually number 8, but may range from 7-9; fins are short and rounded. Scales are large and there are 44-60 along the lateral line. Spawning males have red fins and develop small, white breeding tubercles on their body surfaces; females have reddish fins, slightly enlarged anal regions, protruding genital papilla, and deeper bodies.

Taxonomic Relationships: This subspecies has a complex taxonomic history. It was first described as *Leuciscus pectinifer* by Snyder (1917) who simultaneously described the sympatric form *Siphateles obesus*. Hubbs and Miller (1943), however, considered *L. pectinifer* to be a subspecies of *Siphateles obesus* and thus called it *Siphateles obesus pectinifer*. Shapovalov and Dill (1950) recognized that both forms were part of the *Siphateles bicolor* complex and renamed them *S. b. pectinifer* and *S. b. obesus*, respectively. Bailey and Uyeno (1964) designated *Siphateles* as a subgenus of *Gila* and designated the fine gill raker tui chub as *Gila bicolor pectinifer*.

Because the zoogeographic range of *G. b. pectinifer* is contained within that of *G. bicolor obesa*, its subspecific status is controversial (Moyle 1976). However, studies in both Lake Tahoe and Pyramid Lake, Nevada, indicate that the two forms segregate ecologically (Miller 1951, Galat and Vucinich 1983) and do not interbreed, which may argue for species status for the fine gill raker form. Hubbs and Miller (1943), Kimsey (1954) and Hubbs et al. (1974) suggested that tui chubs in Eagle Lake, Lassen County, are a hybrid swarm between *G. b. obesa* and *G. b. pectinifer* based on bimodal gill raker counts. However, the lack of other hybrid characters and the isolation of this lake from other parts of the Lahontan Basin suggest a separate evolutionary origin.

Distribution: Unquestionable *G. b pectinifer* occur only in Lake Tahoe and Pyramid Lake, Nevada, which are connected to each other by the Truckee River (Fig. 17), and in nearby Walker Lake, Nevada. A tui chub population of uncertain affinities occurs in Topaz Lake on the

California-Nevada border. Plankton-feeding populations of chubs in Stampede, Boca, and Prosser Reservoirs on the Little Truckee River may also be *G. b. pectinifer* (D. Erman, pers. comm.) although it is more likely they are *G. b. obesa*.

Habitat Requirements: Lahontan Lake tui chub are schooling fish and inhabit large, deep lakes (Moyle 1976). They seem to be able to tolerate a wide range of physico-chemical water conditions because they are found in oligotrophic Lake Tahoe as well as in Pyramid Lake, is a mesotrophic and highly alkaline lake.

In Lake Tahoe, the larger fish (>16 cm TL) exhibit a diel horizontal migration by moving into deeper water (>50 m) during the day and back into shallower habitat at night (Miller 1951). However, they always remain high in the water column. The smaller individuals occupy shallower water. Additionally, there is also a seasonal vertical migration, with fishes located deeper in the water column during winter and moving back into the upper water column during summer (Snyder 1917, Miller 1951). Algal beds in shallow, inshore areas seem necessary for successful spawning, egg hatching, and larval survival.

Life History: Lahontan Lake tui chub feed mostly on zooplankton, especially cladocerans and copepods, but also consume benthic insects such as chironomid larvae, annelid worms, and winged insects such as ants and beetles (Miller 1951). *Pectinifer* are primarily mid-water feeders and their gill raker structure is adapted to feeding on plankton. In contrast, the co-occurring subspecies *obesa* is primarily a benthic feeder (Miller 1951). A comparison of stomach contents of both subspecies captured together in bottom-set gill nets indicated *obesa* had fed on benthic insects such as chironomids and trichopterans; *pectinifer* had only planktonic microcrustacea in their intestines (Miller 1951). There is no significant ontogenetic niche shift diet for *pectinifer*: it feeds on plankton throughout its life (Miller 1951). In Pyramid Lake, Nevada, tui chubs of both subspecies feed primarily on zooplankton (mostly microcrustaceans) when ≤25 mm FL, but the *obesa* subspecies feed increasingly on aquatic and terrestrial macroinvertebrates as they become larger (Galat and Vucinich 1983).

Growth (length increments) of tui chubs is linear until about age 4 when weight increases are more rapid and length increments decrease. There is an ontogenetic change in gill raker numbers in the two forms. When ≤25 mm FL, the *pectinifer* form and the *obesa* form were indistinguishable based on gill raker count, but the gill raker count increased in *pectinifer* until the two forms were readily distinguishable by ≥50 mm FL.

Tui chubs fall prey to large trout and, to a lesser extent, to birds and snakes. Examination of stomachs of rainbow trout and mackinaw trout revealed that 10% and 7%, respectively, of their stomach contents consisted of *G. b. pectinifer* (Miller 1951).

In Lake Tahoe, spawning apparently occurs at night during May and June, and possibly later (Miller 1951). By early August, females do not have mature ova. Lahontan Lake tui chubs spawn by 11 cm SL (Miller 1951). They are probably serial spawners, capable of reproducing several times during a season (Moyle 1976).

Snyder (1917) documented that reproductive adults spawned in near-shore shallow areas over beds of aquatic vegetation and found eggs adhering to the aquatic vegetation. He noted that

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young remained in the near-shore environment until winter when they were 1-2 cm in length and then migrated into deeper water offshore.

The largest Lahontan Lake tui chub caught in Lake Tahoe was 13.7 cm SL (Miller 1951). These fish are considerably smaller than the tui chubs in Walker Lake, Nevada, where they grow to 21 cm SL (Miller 1951).

Status: Class 2.

The Lake Tahoe population is the only one known in California, although it could occur in Honey Lake and/or Topaz Lake. It has not been surveyed in Lake Tahoe since Miller (1951) studied it. Since then the zooplankton in the lake have changed. *Daphnia*, which are an important prey of adult chubs, has been nearly eliminated (Richards et al. 1975) by the introduced Kokanee salmon (*Oncorhynchus nerka*) and opossum shrimp (*Mysis relicta*), both of which feed on zooplankton. Thus it is possible that these competitors have already eliminated *G. b. pectinifer* from Lake Tahoe. The population may also have been stressed by the elimination of marshlands along the lake that may have been used for spawning and as nursery areas. Populations in Pyramid and Walker lakes are, however, large and healthy, but both these lakes are becoming increasingly alkaline due to diversions of inflowing water. If diversions continue at present levels, the lakes could eventually become too alkaline for tui chubs.

Management: Studies on Lake Tahoe are required to determine whether or not *G. b. pectinifer* is still present. Surveys of Honey Lake and Topaz Lake also are necessary to determine the presence of the Lahontan Lake tui chub. If it is present, but only in low numbers, further studies should be made to identify the factors limiting the population and steps taken, if possible, to alleviate them. There is also a need for further taxonomic studies to determine the relationship of the Tahoe population to other pectinifer populations and to the populations in Eagle Lake and Topaz Lake.

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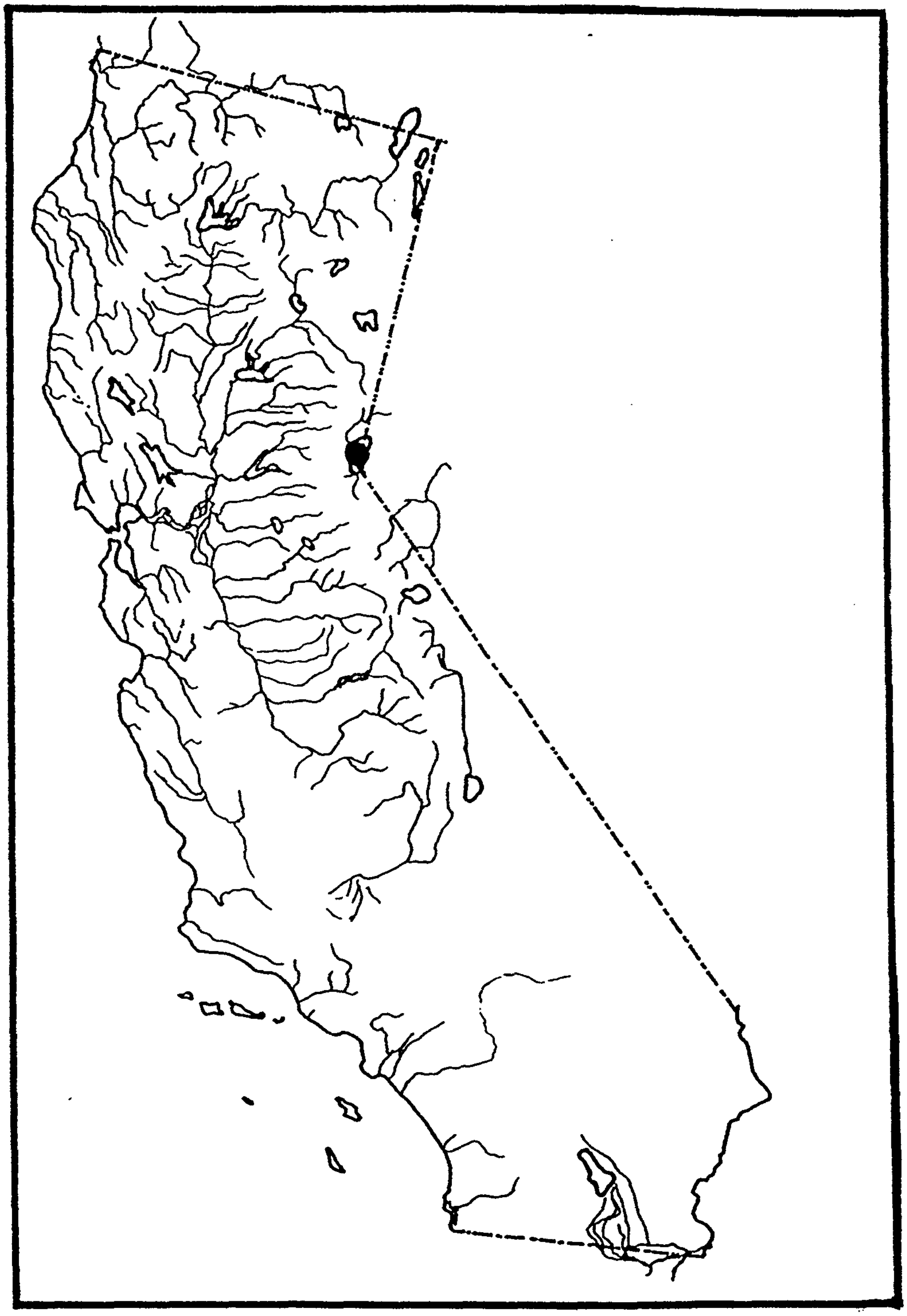

FIGURE 17. Distribution of the Lahontan Lake tui chub, *Gila bicolor pectinifer*, in California.

COWHEAD LAKE TUI CHUB
Gila bicolor vaccaceps (Bills and Bond)

Description: This subspecies was first described by Bills and Bond (1980) and the following is based on their description. The Cowhead Lake tui chub is similar to the species *Gila b. bicolor*, but is differentiated primarily on the basis of more gill rakers. The Cowhead Lake tui chub has 19-25 (mean is 22.49) short, "bluntly rounded" gill rakers, compared with 10-15 gill rakers in *G. b. bicolor*. Other morphological features that characterize this subspecies are: the head is not as deep as in other chubs, is relatively longer, and is convex in profile with a rounded interorbital; a nuchal hump is present, but low; the lower jaw is not overhung by the upper jaw; and the caudal peduncle is relatively deep. Predorsal scales number from 26-35 (mean is 30.97) and there are approximately 57 lateral line scales. The pectoral fin has 15-17 rays and the pelvic fin 8-9 rays. Pharyngeal tooth counts are 0,5-4,0; 0,4-4,0; 0,5-5,0. Coloration is similar to other subspecies, except there is a dark lateral stripe with speckles on the head region, especially the cheek and operculum and lower body. Reproductive males and females develop breeding tubercles, especially on the anterior rays of the pectoral fins. Smaller tubercles develop in rows on the edges of the breast scales. In males, tubercles also develop on the scales above the pectorals and across the nape. The largest individual collected measured 11.6 cm SL (Bills and Bond 1980)

Taxonomic Relationships: This subspecies was first recognized as a distinct form by Hubbs and Miller (1948), but remained undescribed until 1980. Hubbs and Miller (1948) postulated a possible relationship between Cowhead Lake tui chub and chubs from the lakes in Warner Valley, Oregon, because of the connection that existed between Cowhead Lake and the Warner Valley drainage. Bills and Bond (1980) disputed this hypothesis on the basis of differences in gill raker length and fin and head shapes between the two populations.

Distribution: The Cowhead Lake tui chub is confined to about 4 km of slough below Cowhead Lake in the extreme northeastern corner of Modoc Country, California (Fig. 18). The water in the slough is maintained by flows from Eight Mile, Ten Mile, and Twelve Mile creeks, which drain the Warner Mountains. Formerly the chubs probably occupied Cowhead Lake as well during wet years, but the lake was drained to create pasture. About half the slough is on private land, the rest on BLM land.

Habitat Requirements: Cowhead Lake slough is a small muddy creek, consisting, in summer, of a series of pools (95%) and riffles (5%), which meanders through a lava canyon approximately 50 m wide. The pools are fairly large, being approximately 50 m^2, and are interconnected by shallow trickles. In 1974, the average depth of the pools was 0.5 m and maximum depth was at least 1.2 m. Flow was 0.5 CFS. There was considerable vertical stratification of water temperature: 18-19°C on the bottom and 32°C at the surface. Substrate was mostly mud (80%), with some sand (5%) and boulder/bedrock (15%). There was abundant rooted and floating vegetation, but little canopy cover (Moyle, unpubl. data).

Life History: The life history of this subspecies has not been well documented, although Moyle (unpubl. data) found they reached 40-50 mm SL in their first year and 60-80 mm in their second year. They live to at least age 3+, at which time they are around 80 mm SL.

Status: Class 2.

The likelihood of Cowhead Lake tui chubs becoming a Class 1 species is high if active management is not undertaken. The chub is quite abundant in its limited range, but is vulnerable if diversion of the creeks which feed the sloughs, destruction of slough habitats by heavy cattle grazing, and use of pesticides in the area continues.

Management: The following steps should be taken to protect the slough and its fish.

1. Establish a monitoring program whereby the fish are sampled at least once a year. After baseline conditions are established, frequency of monitoring could be lessened. A study of the environmental requirements of these tui chubs is also needed.

2. Have the Bureau of Land Management declare the slough an Area of Critical Environmental Concern and manage it accordingly.

3. Acquire or otherwise protect the habitat on private land in which part of the slough lies.

4. Obtain assurances that there will be a continuous water supply to the slough, either by negotiating with creekside landowners or by acquiring water rights.

5. Fence the slough to prevent further damage by cattle.

6. Require that range improvement or pest control programs (e.g. USDA-APHIS Grasshopper Control Program) stay out of the Cowhead Lake slough drainage.

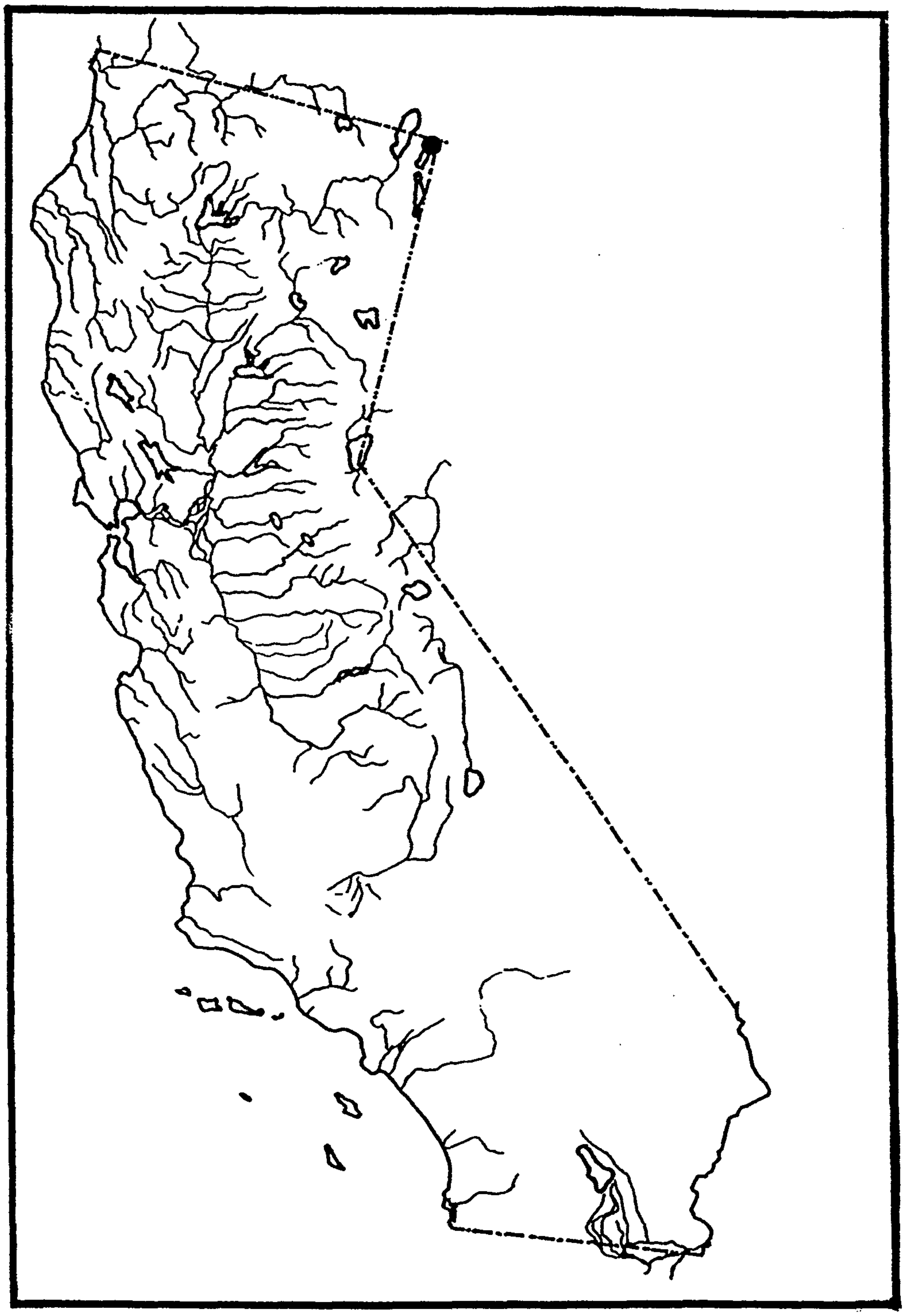

FIGURE 18. Distribution of the Cowhead Lake tui chub, *Gila bicolor vaccaceps*, in California.

EAGLE LAKE TUI CHUB
Gila bicolor subsp.

Description: A thorough description of the Eagle Lake tui chub is lacking, but it seems to be similar in most respects to *G. b. pectinifer*. The most notable difference between the two forms is the number of gill rakers: Eagle Lake tui chubs have 12-28 gill rakers on the first arch, *pectinifer* chubs have 27-40 (Galat and Vucinich 1983, Kennedy 1983). In addition, the Eagle Lake chubs have a bimodal distribution of gill rakers, with a low point at 20-21 rakers (Kimsey 1954; B. Martin, unpubl. data). The chubs can grow to 40 cm SL.

Taxonomic Relationships: This form has been regarded as a hybrid between *G. b. pectinifer* and *G. b. obesa* (Kimsey 1954, Hubbs and Miller 1943, Hubbs et al. 1974). However, the lack of other hybrid characters and the isolation of this lake from other parts of the Lahontan Basin suggest a separate evolutionary origin.

Distribution: This form is confined to Eagle Lake, Lassen County, California (Fig. 19).

Habitat Requirements: Eagle Lake is a large (22000 ha) lake at an elevation of 1557 m. It consists of three distinct basins. Most of the water enters the lake from flows of Pine Creek and a number of smaller creeks, all of which flow only during the winter. Most water loss is through evaporation. There is no outflow of Eagle Lake, except for Blye Tunnel (constructed in the 1920's), which releases several CFS of water into Willow Creek. The lake is highly alkaline (pH about 9 in most years), clear (secchi depth is typically 4-6 m), and cool (summer temperatures rarely exceed 20°C at the surface). Average depth is 5-7 m, with the maximum depth being 30 m (in the lower basin).

The tui chub inhabit deep water during the winter, but migrate to shallower water during summer months when oxygen in the deeper water (>12 m) is depleted (Kimsey 1954). They require beds of aquatic vegetation in shallow, inshore areas for successful spawning, egg hatching, and larval survival (Kimsey 1954).

Life History: Kimsey (1954) conducted the most comprehensive study of the natural history of this subspecies and this account is derived from his study. The fish school in open waters of the lake, with schools consisting of fish from similar year classes. During spawning season, schools break up and mature adults congregate in the near-shore, shallow areas with dense algal beds. At this time the immature 1- to 2-year-old fish remain scattered throughout the lake.

The fish become reproductive at 3 years of age and spawning occurs from mid-May through the beginning of July. Adults in spawning aggregations mill around over dense algal beds in about 1-m deep water and deposit adhesive eggs which stick to aquatic plants (*Myriophyllum spicatum, Ceratophyllum demersum, Potamogeton* sp.). The newly laid eggs are a pale orange-yellow, but color fades to a lighter straw-yellow after some time. Kimsey (1954) estimated the fecundity of a 27-cm female tui chub at 11,200 mature eggs but considered this to be a conservative estimate because not all eggs mature simultaneously. Thus tui chubs are probably serial spawners, capable of reproducing several times during a season (Moyle 1976).

Newly hatched larvae are well developed and immediately begin to feed on rotifers, diatoms, desmids, and other microscopic material. Juveniles remain along the lake shore among the algal beds until about December, at which time they migrate into the open waters of the lake.

Eagle Lake tui chubs are opportunistic omnivores. The bulk of their stomach contents usually consists of detritus, with small quantities of benthic and planktonic invertebrates, algae, and aquatic macrophytes (Kimsey 1954; Martin, unpubl. data). Kimsey (1954) aged Eagle Lake tui chubs at 6-7 years using scales; however, Davis and Moyle (unpubl.) found that if opercular bones are used instead, the ages of adult tui chubs (30-40 cm SL) range from 12-33 years. Such ages appear to be typical of large cyprinids and catostomids of terminal lakes of the Great Basin (G. Scoppetone, pers. comm.).

Status: Class 3.

Eagle Lake tui chubs are included in this report because of their restricted distribution. At present, they are the most abundant fish in Eagle Lake and support large populations of fish-eating birds. Despite the long life span and abundance of these tui chubs, introductions of other species into the lake could cause them problems. In 1986, BLM (with financial assistance of CDFG) blocked the Blye Tunnel that was keeping the lake water levels low. As a result, the lake can now rise. If the water level rises as predicted, the lake will become considerably less alkaline and will be able to support introduced fishes as it did in the early 1900's when largemouth bass and catfish were common. These introduced fishes died out when the lake level dropped during the drought of the 1930's, and the impact these fishes had on the chub populations is not known. However, the effects of introduced diseases, predators, parasites, or competitors from future fish introductions could be disastrous to the lake ecosystem.

Management: Eagle Lake should have special recognition as a refuge for native fishes, which includes the endemic Eagle Lake trout, which feeds in part on tui chubs. Fish introductions into this lake should be prohibited. If a successful introduction is made and natural water quality fluctuations do not eliminate the introduced species, consideration should be given to reopening the tunnel in order to drop the lake level, thus increasing the lake's alkalinity.

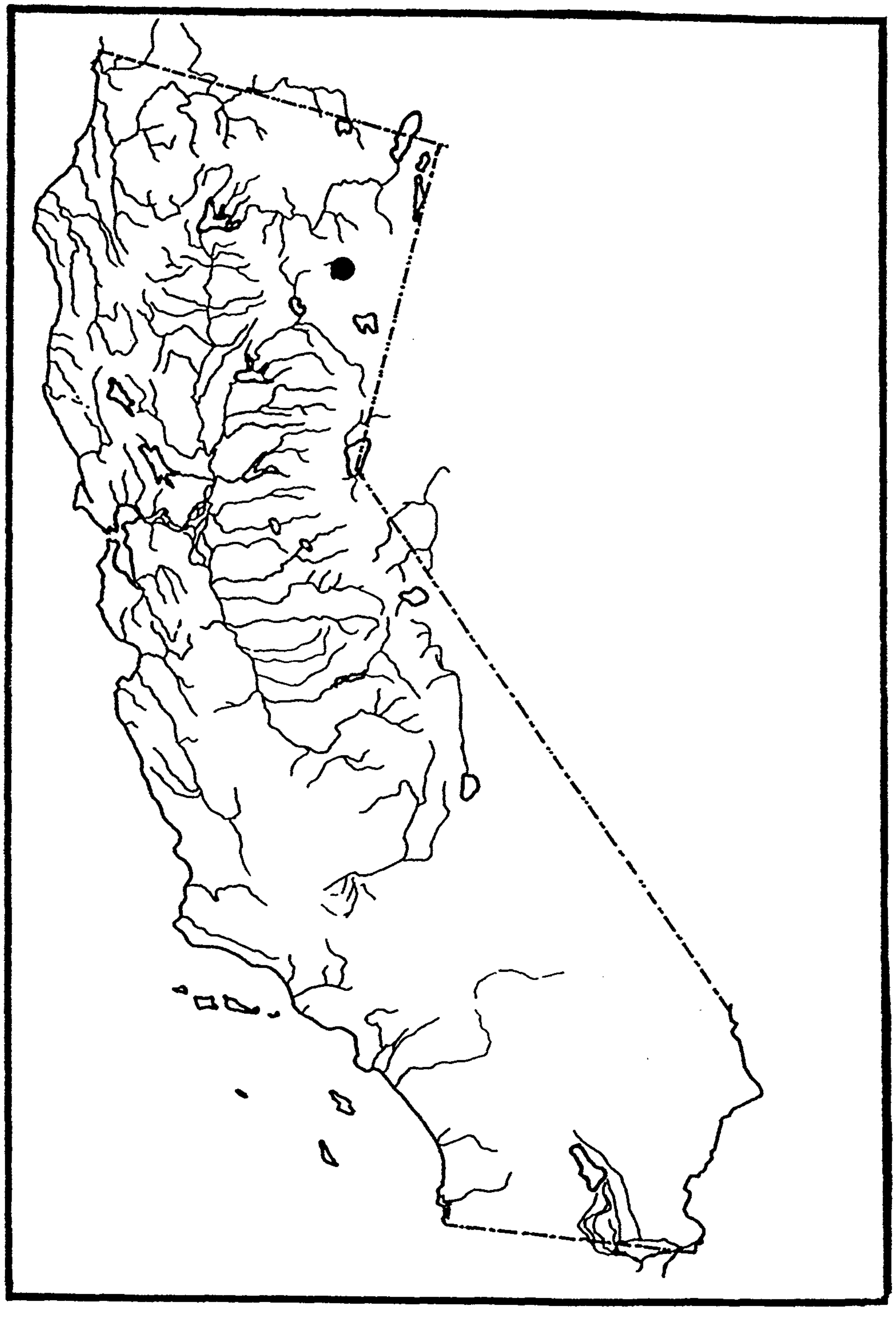

FIGURE 19. Distribution of the Eagle Lake tui chub, *Gila bicolor* subsp., in California.

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GOOSE LAKE TUI CHUB
Gila bicolor thalassina (Cope)

Description: The following account is based primarily on Snyder's (1908) description of this fish. The Goose Lake tui chub is differentiated from other subspecies of *Gila bicolor* by their longer fins, more posterior dorsal fin, longer head, and larger number of dorsal rays (usually 9). Coloration is similar to other subspecies. Larger specimens from Goose Lake are uniformly silver except for a white belly.

Taxonomic Relationships: The Goose Lake tui chub was first described by Cope (1883) as *Myloleucus thalassinus*, but he also recognized another closely related species also from Goose Lake. Snyder (1908) noted that Cope collected numerous fresh and dried chubs that had been dropped by fish-eating birds along the shoreline and hypothesized that the second species recognized by Cope was based on these poorly preserved specimens. Snyder (1908) placed *thalassinus* in the genus *Rutilus* because Jordan and Evermann (1896) synonymized *Myloleucus* with *Rutilus*. North American cyprinids placed in the European genus *Rutilus* eventually were referred to generic names of New World minnows. Snyder (1908) considered *thalassinus* to be native to Goose Lake and the upper Pit River from Big Valley upstream to Goose Lake. Hubbs et al. (1979), however, considered the form in the Pit River to be distinct from the Goose Lake form.

Distribution: The Goose Lake tui chub is confined to the Goose Lake basin of Oregon and California (Fig. 20). It is widely distributed and abundant in Goose Lake. The chub also occurs in low-elevation sections of streams tributary to the lake. In California, the chub is known from portions of Lassen, Willow, Branch, and Corral creeks near Goose Lake (J. Williams, unpubl. data).

Habitat Requirements: Goose Lake is a massive, natural saline lake covering approximately 39,000 surface hectares along the Oregon-California border. The lake is shallow, averaging 2.5 m deep, and is hypereutrophic and very turbid (Johnson et al. 1985). The surface elevation of Goose Lake fluctuates seasonally, but averages 1433 m. In California, no tui chubs have been found in streams above 1441 m in elevation, although tui chubs have been found above 1550 m in Oregon streams (J. Williams, unpubl. data). Chubs prefer pools and are generally not found in swift water, although they have been collected from runs in Battle Creek near the west shore of Goose Lake (J. Williams, unpubl. data). Goose Lake tui chubs have been collected in habitats with a wide range of water temperatures from 9 to 29°C.

Life History: The life history of this subspecies has not been studied. Chubs commonly reach 250 mm FL in the lake and fish as large as 316 mm FL have been collected, indicating that this form may be very long-lived in lake habitats. In streams, however, they rarely exceed 120 mm FL. Most tui chubs are opportunistic omnivores and consume a wide variety of aquatic invertebrates (Moyle 1976).

Status: Class 3.

This tui chub is extremely abundant in the lake. During 1966 gill netting surveys of Goose Lake, it comprised 88% of fishes collected (King and Hanson 1966), in 1984 it comprised nearly 96% of gill net collections (J. Williams, unpubl. data), and in 1989 comprised 100% of the fish caught in a trawl. Potential threats to this fish include the introduction of exotic fishes into Goose

Lake, decreasing water quality in the lake caused by reduced inflows from tributary streams, and increased nutrients from agricultural runoff. In drought years, Goose Lake has naturally been reduced to a few pools. The last time this happened was in the 1930's, but diversions may cause it to happen more frequently.

Management: The following measures should be implemented to protect this tui chub and other endemic fish resources in Goose Lake:

1. Prohibit introduction of exotic fishes into Goose Lake.

2. Prohibit use of live baitfish in the entire Goose Lake basin, including Oregon.

3. Establish instream flow protection for the longer streams in the basin (Oregon: Thomas, Drews, and Cottonwood creeks; California: Lassen and Willow creeks).

Because the lake and its watershed are shared between Oregon and California, close cooperation between CDFG and Oregon Department of Fish and Wildlife is necessary to protect them. At least annual meetings should be held between representatives of both agencies to assess status of fish populations and management strategies.

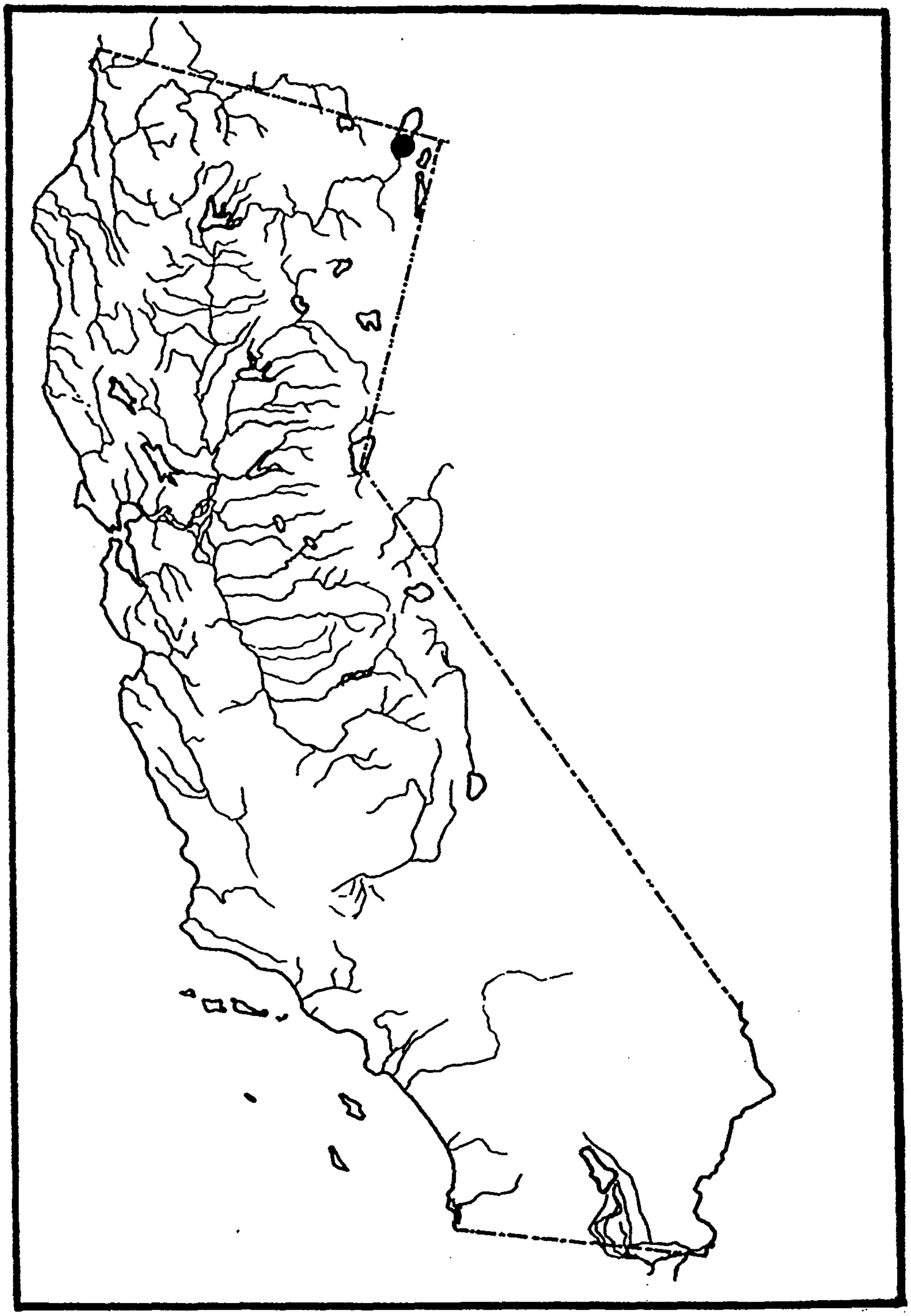


FIGURE 20. Distribution of Goose Lake tui chub, *Gila bicolor thalassina*.

m and 1 m deep. On 23 October 1979, water temperature at the spring was 28.3°C and pH was 6.0.

Life History: The life history of this form has not been studied, and we can only assume that it may be somewhat similar to other tui chubs. For a general description of tui chub life histories, see Moyle (1976).

Status: Class 2.

In December 1982, Mr. Louie Hans, manager of the ranch surrounding High Rock Spring, filed an application to use the water from the springs for aquaculture. California Department of Fish and Game issued an aquaculture permit to Mr. Hans for rearing Mozambique tilapia, *Oreochromis mossambica*, in a screened rearing area 100 m downstream from the spring source. On 27 January 1983, 1,000 tilapia arrived and were stocked into Mr. Hans's rearing facility. One specimen in the shipment, identified as redbelly tilapia, *O. zilli*, was removed. On 17 June 1983, Larry Eng (pers. comm.) reported observations of another shipment of tilapia and freshwater prawns into the rearing facility. He observed tilapia and chubs throughout the spring system. Inadequate screening apparently allowed the tilapia access to the entire system. Channel catfish, *Ictalurus punctatus*, were reported to have been introduced into the spring system, but their occurrence was never documented. The presence of large numbers of exotic fishes provides a hazard for the native tui chub because of predation and/or competition.

A relatively recent concern is unchecked groundwater mining. Officials in Washoe County, Nevada, have identified groundwater in Honey Lake Valley as a primary future water supply for the Reno-Sparks metropolitan area. After Lassen Country officials expressed concern over the fate of groundwater in the interstate valley, the U.S. Geological Survey began a study of the aquifer in 1987. Already the study has identified that a slope from California to Nevada moves the Honey Lake groundwater from west to east (C. Londquist, pers. comm.). Until the study is concluded (scheduled for April 1990), officials from Nevada have agreed not to issue water permits in the Honey Lake Valley. If groundwater mining is expanded in the California or Nevada portion of the valley, the potential exists to reduce or eliminate flow into High Rock Spring.

Management: The following measures should be taken to protect High Rock Spring and its tui chub.

1. A taxonomic and electrophoretic analysis of this population should be conducted and compared with other isolated populations in the region.

2. High Rock Spring should be surveyed and mapped to determine the status of the tui chub, introduced fishes and invertebrates, and recent habitat modifications.

3. CDFG should develop a management plan with the landowner that would insure continued survival of the tui chub.

4. If studies verify the distinctiveness of the endemic tui chub, aquaculture permits should be removed for the entire system. A conservation easement, lease, or purchase should then be negotiated for the spring system.

5. The U.S. Geological Survey should be requested to determine the effects of groundwater mining on quality and quantity of water in High Rock Spring.

6. A Groundwater Management District should be created for the Honey Lake Basin to regulate the use of groundwater. This could help prevent excessive water withdrawals that might reduce the outflow of High Rock Springs.

If studies demonstrate the distinctiveness of this fish, the High Rock Spring tui chub should receive strong consideration for threatened or endangered status.

C-046036

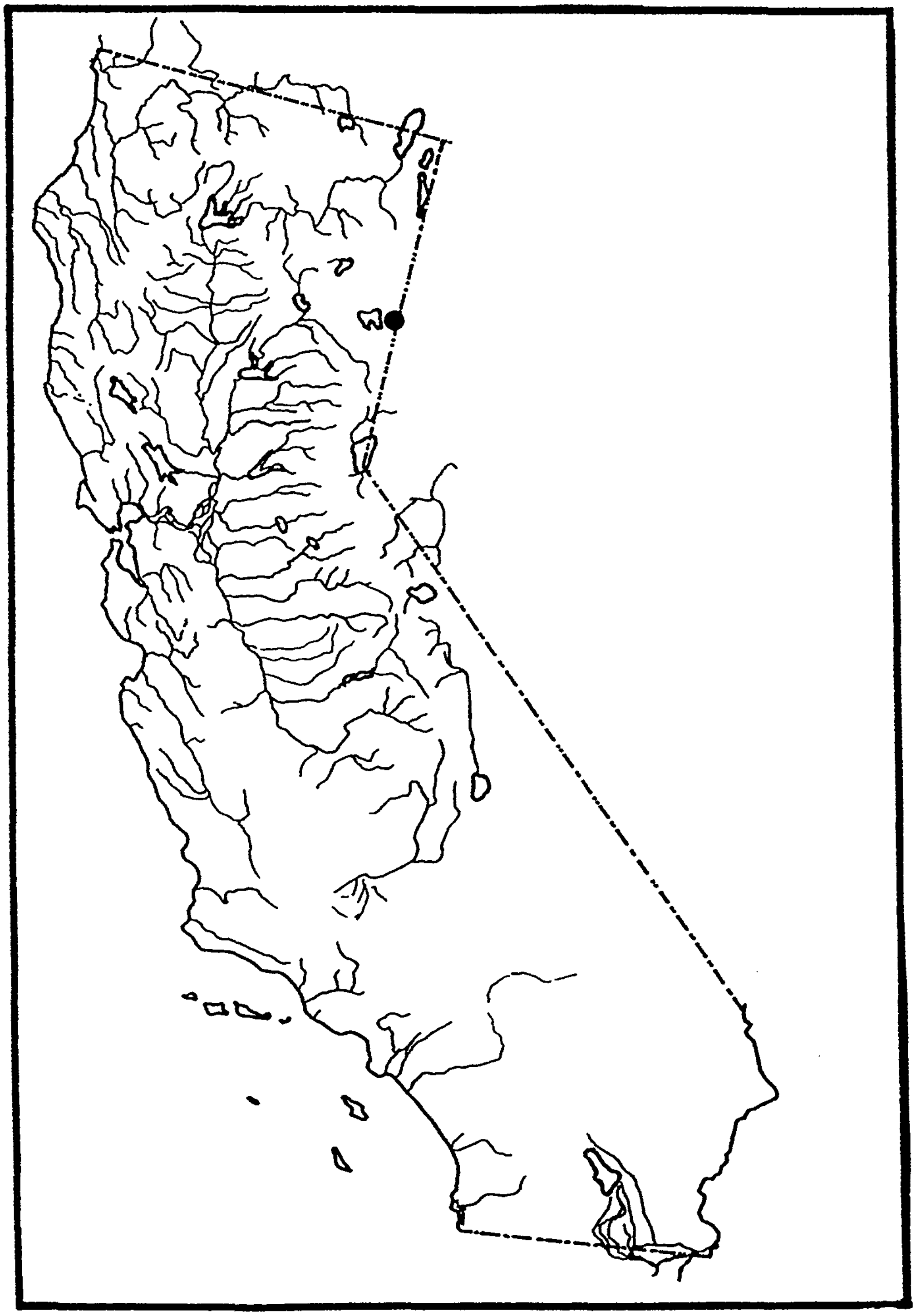


FIGURE 21. Distribution of High Rock Spring tui chub, *Gila bicolor* subsp.

ARROYO CHUB
Gila orcutti (Eigenmann and Eigenmann)

Description: These are small fish that usually reach lengths of 120 mm TL, although rarely they may attain lengths of 300 mm. They have chunky bodies, fairly large eyes, and small mouths. The pharyngeal teeth are hooked and closely spaced with a formula of 2,5-4,2, but may be variable. They have 7 anal fin rays and 8 dorsal rays. Gill rakers range from 5-9. The lateral line is complete with 48-62 scales, extends to the caudal peduncle, and is not decurved. Body color is silver or grey to olive green dorsally, white ventrally, and there usually is a dull grey lateral band (Moyle 1976).

Taxonomic Relationships: Miller (1945) placed both *G. orcutti* and closely related *G. purpurea* in the subgenus *temeculina*. The arroyo chub hybridizes readily with the Mohave tui chub (*G. bicolor mohavensis*) and with the California roach (*Lavinia symmetricus*) (Hubbs and Miller 1942, Greenfield and Greenfield 1972, Greenfield and Deckert 1973).

Distribution: Arroyo chubs are native to the Los Angeles, San Gabriel, San Luis Rey, Santa Ana, and Santa Margarita rivers and Malibu and San Juan creeks (Wells and Diana 1975) (Fig. 22). They have, however, been successfully introduced into the Santa Ynez, Santa Maria, Cuyama, and Mohave river systems and other smaller coastal streams (e.g., Malibu Creek, Arroyo Grande Creek) (Miller 1968, Moyle 1976). The most northern introduced population is in Chorro Creek, San Luis Obispo County (T. Taylor, pers. comm.). They are now absent from much of their native range and are abundant only in the West Fork of the San Gabriel River.

Habitat Requirements: Arroyo chubs are found in slow water sections of streams with mud or sand substrates. Wells and Diana (1975) described physical characteristics of the streams sites where the arroyo chubs were collected.

Life History: Arroyo chubs are known to breed during March and April and spawning occurs in pools. Generally, reproduction is thought to be similar to tui chubs. They readily hybridize with California roach (Greenfield and Greenfield 1972, Greenfield and Deckert 1973) and with Mohave tui chubs (Moyle 1976). Laboratory studies indicate that the arroyo chub is physiologically adapted to survive hypoxic conditions and wide temperature fluctuations common in desert streams (Castleberry and Cech 1986).

They are omnivorous, feeding on algae, insects, and small crustaceans. However, most (60-80%) of the stomach contents consists of algae (Greenfield and Deckert 1973). They are also known to feed extensively on the roots of a floating water fern (*Azolla*) infested with nematodes (Moyle 1976).

Status: Class 4.

If arroyo chubs had not been introduced into a number of waters outside their native range and had they not thrived in these waters, they would be listed as a Class 1 or 2 species. Their native range, like that of the sympatric Santa Ana sucker, is largely coincident with the Los Angeles metropolitan area where most streams are degraded and populations reduced and fragmented. Today, the only large populations remaining are in the West Fork of the San Gabriel River. Even introduced populations, however, should not be regarded as secure. Those in the Cuyama River and Mohave River have hybridized with California roach (*Lavinia symmetricus*) and Mohave chub (*G. bicolor mohavensis*), respectively (Hubbs and Miller 1942, Greenfield and Deckert 1972). Recently, red shiner (*Notropis lutrensis*) have been introduced into arroyo chub streams and may competitively exclude chubs from many areas (C. Swift, pers. comm.). The potential effects of introduced species, combined with the continued degradation of the urbanized streams that constitute much of its habitat, mean that this species is not secure, despite its wide range.

Management: Status surveys should be made annually of this species in its native range and every five years at all known sites. Within its native range, streams should be selected to be managed to favor its survival, along with that of the other native fishes of the region. The strongest candidate for a native fish refuge is the West Fork of the San Gabriel River.

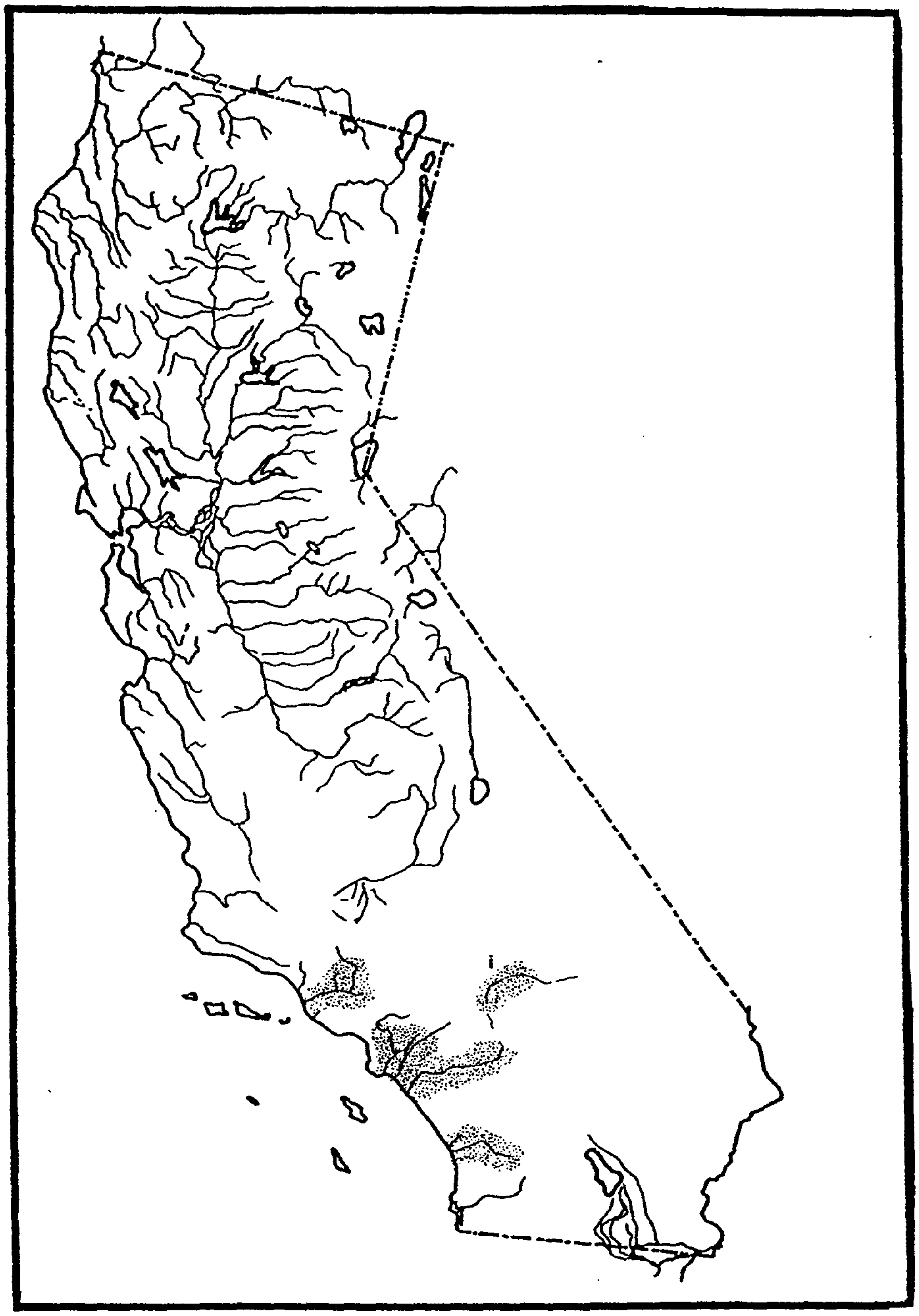


FIGURE 22. Distribution of the Arroyo chub, *Gila orcutti*, in California. (i = introduced population.)

C-046040

CLEAR LAKE HITCH
Lavinia exilicauda chi (Hopkirk)

Description: Hitch are fairly large cyprinids that grow over 350 mm SL. The body is moderately elongated and thick, almost oval shaped in cross section (Moyle 1976, Hopkirk 1973). The head is relatively small and conical. Clear Lake hitch are distinguished from the type subspecies by a deeper body, larger eyes, and more gill rakers. Scales are also larger, with 55 to 64 along the complete, decurved lateral line (Hopkirk 1973). The caudal peduncle is narrow, this feature being responsible for the specific etymology. Clear Lake hitch have 10-12 dorsal fin rays, 11-14 anal fin rays, and usually 26-32 gill rakers. The pharyngeal teeth are long, narrow, and slightly hooked, but the surfaces are relatively broad and adapted for grinding (Moyle 1976).

Young fish are silver and have a dark, triangular blotch on the caudal peduncle extending anteriorly as a black stripe that gradually fades (Hopkirk 1973). As fish age, the dorsal area becomes brownish-yellow (Moyle 1976).

Taxonomic Relationships: Hitch are most closely related to the California roach (*Lavinia symmetricus*), with which some populations are interfertile when they hybridize (Avise et al. 1975). Hitch also hybridize with Sacramento blackfish, although the hybrids are sterile (Moyle and Massingill 1981). The Clear Lake subspecies, *L. e. chi*, was first described by Hopkirk (1968) as a lake-adapted form. Another subspecies *Lavinia exilicauda harengus* from the Pajaro and Salinas rivers was described by Miller (1945) based solely on deeper body depth compared to the type species *Lavinia exilicauda exilicauda*. However, Hopkirk (1973) disputed the validity of *harengus* because *L. e. exilicauda* exhibits sexual dimorphism based on body depth and there is considerable body size and proportional variability among populations.

Distribution: This subspecies is confined to Clear Lake, Lake County, California (Fig. 23) and to associated lakes and ponds such as Thurston Lake and Lampson Pond. It spawns in intermittent tributary streams to Clear Lake, mainly Kelsey, Seigler, Adobe, Middle, Scotts, and Manning creeks.

Habitat Requirements: Adult Clear Lake hitch are usually found in the limnetic zone of Clear Lake. Juveniles are found in the near-shore shallow water habitat and move into the deeper off-shore areas after approximately 80 days when they are between 40-50 mm SL (Geary 1978). While in the near-shore environment, juveniles require vegetation for refuge from predators. During the reproductive season, adults migrate into the tributary streams where they spawn in the lower reaches, mostly in sections that dry up during the summer (Geary 1978, Moyle 1976).

Life History: The deep compressed body, small upturned mouth, and the long slender gill rakers reflect the zooplankton-feeding strategy of an open-water feeder (Moyle 1976). Hitch >50 mm SL feed almost exclusively on *Daphnia* (Geary 1978, Geary and Moyle 1980). Juveniles (<50 mm SL) in the shallower, near-shore environment feed primarily on the larvae and pupae of chironomid midges; planktonic crustaceans including *Bosmina* and *Daphnia* (Geary 1978); and the eggs, larvae, and adults of the Clear Lake gnat (*Chaoborus astictopus*) (Lindquist et al. 1943). They switch to feeding on *Daphnia* after they move into the off-shore limnetic habitat. Geary

(1978) found that stomachs of hitch caught early in the morning were empty, but fish caught in the afternoon had fed, indicating that hitch feed primarily during the daylight hours.

Clear Lake hitch grow much more rapidly than lacustrine Sacramento hitch (*L. e. exilicauda*) from high-elevation Beardsley Reservoir (Murphy 1948, Geary 1978). In Clear Lake, hitch reached 44 mm SL within 3 months and were 80-120 mm SL by the end of their first year (Geary 1978). Hitch in Beardsley Reservoir, in contrast, were only 40-50 mm by the end of the first year (Nicola 1974). Geary (1978) attributes this rapid growth rate in Clear Lake hitch to the high productivity and warm water temperatures of the lake.

Females become mature by their 2nd or 3rd year, whereas males tend to mature earlier (1-2rd yrs) (Kimsey 1960). Mature females are also larger than males (Geary 1978). Females are quite fecund, producing up to 26,000 eggs (Moyle 1976). Spawning occurs in tributary streams and migrations take place from March through July (Moyle 1976). The important spawning streams are Kelsey, Scotts, and Middle creeks (Geary 1978). Other smaller streams also used for spawning are Manning, Adobe, Cole, and Seigler creeks. Usually Clear Lake hitch spawn after heavy rains. They require clean, fine-to-medium gravel, and water temperatures from 14-18°C for spawning (Murphy 1948, Kimsey 1960). When spawning, each female is pursued by 1-5 males that fertilize the eggs as they are released (Moyle 1976). Eggs sink to the bottom after fertilization where they become lodged among the interstices in the gravel. The eggs hatch after approximately 7 days and the larvae become free-swimming after another 7 days (Swift 1965). They then move downstream quickly before the streams dry up (Moyle 1976).

Status: Class 3.

The Clear Lake hitch still seems to be common in Clear Lake, but its populations are undoubtedly diminished. The principal causes of this population decline are loss of spawning habitat and loss of nursery areas. The lower reaches of all their spawning streams dry up annually and probably did so naturally. However, now these streams go dry earlier in the season due to stream diversions and the result is spawning failures, especially during dry years. In streams such as Adobe and Kelsey creeks, upstream areas that were once used for spawning are now blocked by roads and other obstructions. The fish that do get to spawning areas are unprotected and are vulnerable in shallow water where they are destroyed by local people by various means (the "sport" is called "hitching"). Furthermore, many of the marshy areas that once ringed the lake are now gone, limiting habitat available to larval hitch. Such habitat loss is ongoing. A more recent problem is the introduction of planktivorous threadfin shad (*Dorosoma cepedianum*) into the lake, which may compete with hitch for food.

Management: Annual surveys of spawning runs should be made to determine the abundance of fish. Critical areas that require protection should be identified and designated. Human-made barriers across spawning streams that are presently insurmountable to hitch should be modified so as to facilitate the passage of hitch during spawning migrations. Marshy areas near the mouths of streams should receive special protection as hitch nursery areas. An effort should be made to educate the local people about the hitch, their importance as a California native and Clear Lake endemic and their role in local food chains (such as their probable importance as forage for breeding osprey).

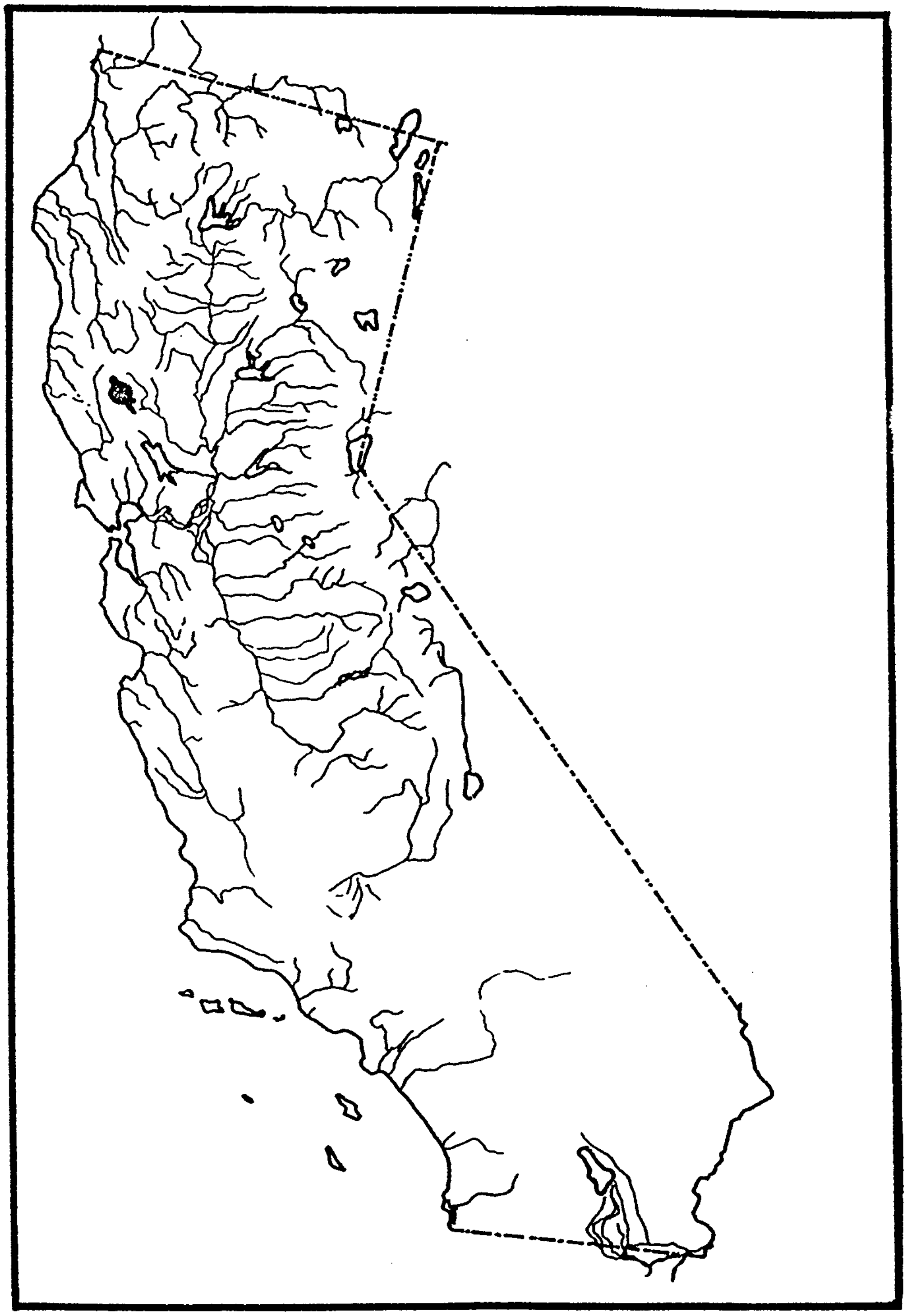


FIGURE 23. Distribution of Clear Lake hitch, *Lavinia exilicauda chi*, in California.

C-046044

C-046045

CALIFORNIA ROACH
Lavinia symmetricus (Baird and Girard)

Description: Adults of California roach are usually <10 cm SL. The body of a typical roach is elongate and rounded in cross section. The head is relatively large and conical. The mouth is small and sub-terminal. Some populations develop a distinctive "chisel lip," with a cartilaginous plate on the lower jaw. The short dorsal fin has 7-10 rays; the anal fin 6-9 rays. Scales are small, with 47-63 along the lateral line, 32-38 of these being anterior to the dorsal fin. Roach have 4-5 pharyngeal teeth which are adapted for grinding. Coloration is grey-steel blue dorsally and dull silver ventrally. Red-orange patches appear on the chin, opercula, and at the bases of the paired and anal fins of reproductive adults. Like most minnows, reproductive males develop cephalic breeding tubercles (description mostly from Hopkirk 1973 and Moyle 1976).

Taxonomic Relationships: The California roach was first described as *Rutilus symmetricus* (Baird and Girard) and collected from the San-Joaquin River near Friant (Murphy 1943). They were subsequently reassigned to the genus *Hesperoleucus* by Snyder (1912) who described the following 6 species based on locality and morphological differences:

1. *Hesperoleucus symmetricus* from the Sacramento-San Joaquin Valley.
2. *Hesperoleucus subditus* from the Pajaro River system.
3. *Hesperoleucus venustus* from the San Francisco Bay system and the Russian River and Tomales Bay drainages.
4. *Hesperoleucus parvipinnis* from the Gualala River system in Mendocino County.
5. *Hesperoleucus navarroensis* from the Navarro River system, Sonoma County.
6. Hesperoleucus mitrulus from the Pit River system and Goose Lake, Modoc County.

Murphy (1948) reanalyzed Snyder's data along with his own from coastal streams and concluded that the species should be relegated to subspecies. This diagnosis was accepted by the American Fisheries Society even though Murphy's study was never formally published. It has also been accepted by most subsequent workers (e.g. Moyle 1976, Hubbs et al. 1979), mostly as a matter of convenience. Hopkirk (1973) also examined roach from coastal drainages and concluded that Murphy was correct in placing all roach species together. However, he differed in his conclusions as to what populations should be recognized as subspecies. Hopkirk (1973) considered *H. s. symmetricus, H. s. subditis*, and *H. s. parvipinnis* to be morphologically distinct subspecies, whereas *H. s. venustus* was not different from *H. s. symmetricus*. *Hesperoleucus s. navarroensis* was considered distinct, but also included roach from the Russian River and perhaps the tributaries to Tomales Bay. The Tomales roach populations may, however, be distinct enough to be recognized as a separate subspecies. Hopkirk (1973) warned that *H. s. symmetricus* possibly consisted of several distinct subspecies, noting that a collection he examined from the Consumnes River was quite distinct. Brown and Moyle (1988) examined roach populations from throughout the San Joaquin River drainage and found that populations from the more isolated tributary basins (e.g., Kaweah and Tule Rivers) could be distinguished by using multivariate analyses of morphometric data. The Kaweah River population was particularly distinctive because a high percentage had a "chisel lip," with the lower jaw having a projecting cartilaginous plate. B. Quelvog (CDFG, pers. comm.) has noted similarly distinctive roach in streams near Sonora. The California roach "complex" needs to be taxonomically reevaluated. Such an evaluation may turn up new subspecies or even species and perhaps merge presently recognized forms. For the present, we recognize the following forms:

1. Sacramento roach, *L. s. symmetricus*. Sacramento River drainage, except the Pit River, as well as tributaries to San Francisco bay.
2. San Joaquin Roach, *L. s.* subspp. This form is either several subspecies or part of *L. s. symmetricus*. Tributaries to the San Joaquin River from the Consumnes River south.
3. Monterey roach, *L. s. subditus*. Tributaries to Monterey Bay, specifically the Salinas, Pajaro, and San Lorenzo drainages.
4. Navarro roach, *L. s. navarroensis*. From the Russian and Navarro Rivers.
5. Tomales roach, *L. s.* subsp. From Walker Creek and other tributaries to Tomales Bay.
6. Gualala roach, *L. s. parvipinnis*. Gualala River.
7. Pit Roach, *L. s. mitrulus*. From the upper Pit River and tributaries, and tributaries to Goose Lake. The roach found in Oregon may also belong to this subspecies.

The generic name Lavinia is preferred to *Hesperoleucus* because studies have shown little basis for separation of the two genera (Hopkirk 1973, Avise et al. 1975, Moyle and Massingill 1981).

Distribution: The overall distribution of California roach is shown in Fig. 24. At least two populations have resulted from introductions: the Eel (Fite 1973) and Cuyama rivers, San Luis Obispo and Santa Barbara Counties, respectively (Moyle 1976). The sources of the introductions are not known.

Habitat Requirements: California roach are generally found in small, warm intermittent streams, and dense populations are frequently found in isolated pools (Moyle 1976, Moyle et al. 1982). They are most abundant in mid-elevation streams in the Sierra foothills (Moyle 1976). Roach are tolerant of relatively high temperatures (30-35°C) and low oxygen levels (1-2 ppm) (Taylor et al. 1982). However, they are habitat generalists, being also found in cold, well aerated clear "trout" streams (Taylor et al. 1982), in human-modified habitat (Moyle 1976, Moyle and Daniels 1982), and in the main channels of rivers, as in the Russian and Tuolumne Rivers.

In the Clear Lake region, roach abundance was positively correlated with such environmental variables as temperature, conductivity, gradient, and coarse substrates and negatively correlated with depth, cover, canopy, and fast water habitat (Taylor et al. 1982). In the Pit River system, however, roach were found in deep mud/rock bottomed pools in 2-3 order streams and in the Pit River itself (Moyle and Daniels 1982). Most such habitat was characterized by low flows, moderate gradients, warm temperatures, and edge vegetational mats of duckweed and water ferns. Furthermore, unlike in the Sierra foothill streams where roach abundance was negatively correlated with other species (Moyle and Nichols 1974), in the Pit River there was a positive correlation between the abundance of roach and that of other native fishes.

Roach have disappeared from 4 sites sampled since the 1908 collections of Snyder (1913) in the Pajaro River system (Smith 1982). Smith attributes this to habitat alteration. Alkalinity and conductivity is thought to depress juvenile populations; low dissolved oxygen availability also affects adult survival (Smith 1982). In the Clear Lake region, roach were found in a wide variety of habitats, from cool headwater streams to the warmwater lower reaches (Taylor et al. 1982). They were most abundant in the low-mid elevational streams with high pH, conductivity, and temperature and with little cover or canopy. Stream width and depth, however, had little influence on abundance although roach preferred pools or slow water sections in the streams.

Life History: Roach feed primarily on filamentous algae, but they ingest lesser quantities of crustaceans and insects (Greenfield and Deckert 1973, Moyle 1976). However, during the winter their diet consists of diatoms and other unicellular algae. Being bottom feeders, their intestines also contained a high proportion of detritus.

Growth is seasonal, with rapid growth during the early summer (Fry 1936). This could be related to food abundance and availability during this time. Roach reach sexual maturity by about the second year (approximately 45 mm SL). Studies also indicate that roach in the Russian and Navarro Rivers grow much faster and attain in excess of 45 mm SL by the first year, 69-70 mm by the second year, and 80-90 mm by the third (Moyle 1976).

Reproduction occurs from March to June, but may be extended through late July (Moyle 1976). Murphy (1943) states that spawning is determined by water temperature, which must be approximately 16°C (60°F) for spawning to be initiated. During the spawning season, schools of fish move into shallow areas with moderate flow and gravel/rubble substrate (Moyle 1976). Females deposit adhesive eggs in the substrate interstices and the eggs are fertilized by attendant males. Typically 250-900 eggs are produced by a female and eggs hatch within 2-3 days. The fry remain in the substrate interstices until they are free-swimming.

Status

1. Sacramento roach. Class 5.

   Assuming this widely distributed form is indeed just one subspecies, it appears to be abundant in a large number of streams. Nevertheless, it is absent from many streams and stream reaches where it once occurred (e.g. Leidy 1982), and most populations are probably isolated by downstream barriers such as dams, diversions, or polluted water containing predatory introduced fishes.

2. San Joaquin roach. Class 3.

   Surveys by Moyle and Nichols (1973) and Brown and Moyle (1988) indicate that this form is abundant in many areas, yet it has been eliminated from many others. It is possible that a number of the more isolated populations deserve subspecific recognition and perhaps Class 2 listing.

3. Monterey roach. Class 3.

   Smith (1982) found this roach to be widespread in the Pajaro and San Benito drainages, but probably less widely distributed than formerly. Since Snyder's (1913) collections in 1908, they have disappeared from four sites. They have also hybridized with, or have been competitively excluded by, hitch (*Lavinia exilicauda*) in some areas (Smith 1982).

4. Navarro roach. Class 3.

This form appears to be abundant in both the Russian and Navarro rivers, but given the effects of dams on the Russian River and the logging and agricultural practices on the Navarro River drainage, their populations should be monitored.

5. Tomales roach. Class 3.

Most of the streams in the Tomales drainage have been heavily modified by dams and erosion caused by grazing. The roach are nevertheless abundant in many areas such as the middle reaches of Walker Creek (P. Moyle, unpubl. data). Because of their limited distribution and their competition with humans for the water in the streams, the populations should be monitored.

6. Gualala roach. Class 2.

This form is given high priority because we do not have any recent records of its status. The Gualala River needs to be surveyed.

7. Pit roach. Class 2.

This roach has apparently disappeared from much of its former range in the upper Pit River drainage (Moyle and Daniels 1982) and is confined to a few scattered populations.

Management: The California roach needs a comprehensive study that looks at both systematics and distribution. An immediate need is to find streams in the Pit River drainage that can be managed for roach. The recommendations made for hardhead management can also be applied to California roach.

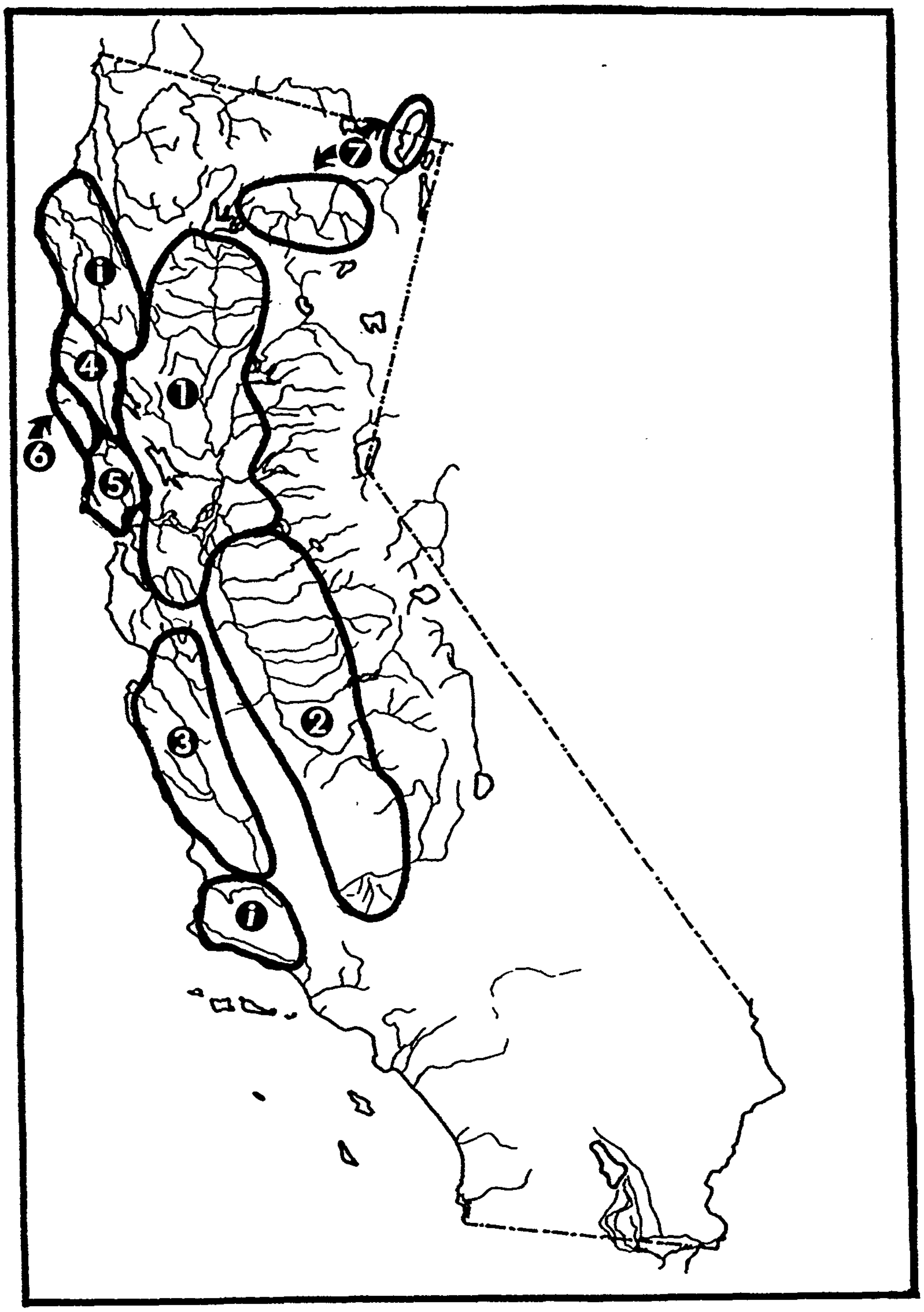


FIGURE 24. Distribution of the California roach, *Lavinia symmetricus*. The numbers correspond to the distributions of the following subspecies: 1 = Sacramento roach, 2 = San Joaquin roach, 3 = Monterey roach, 4 = Navarro roach, 5 = Tomales roach, 6 = Gualala roach, 7 = Pit roach, i = introduced populations.

SACRAMENTO SPLITTAIL
Pogonichthys macrolepidotus (Ayres)

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

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

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

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

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

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

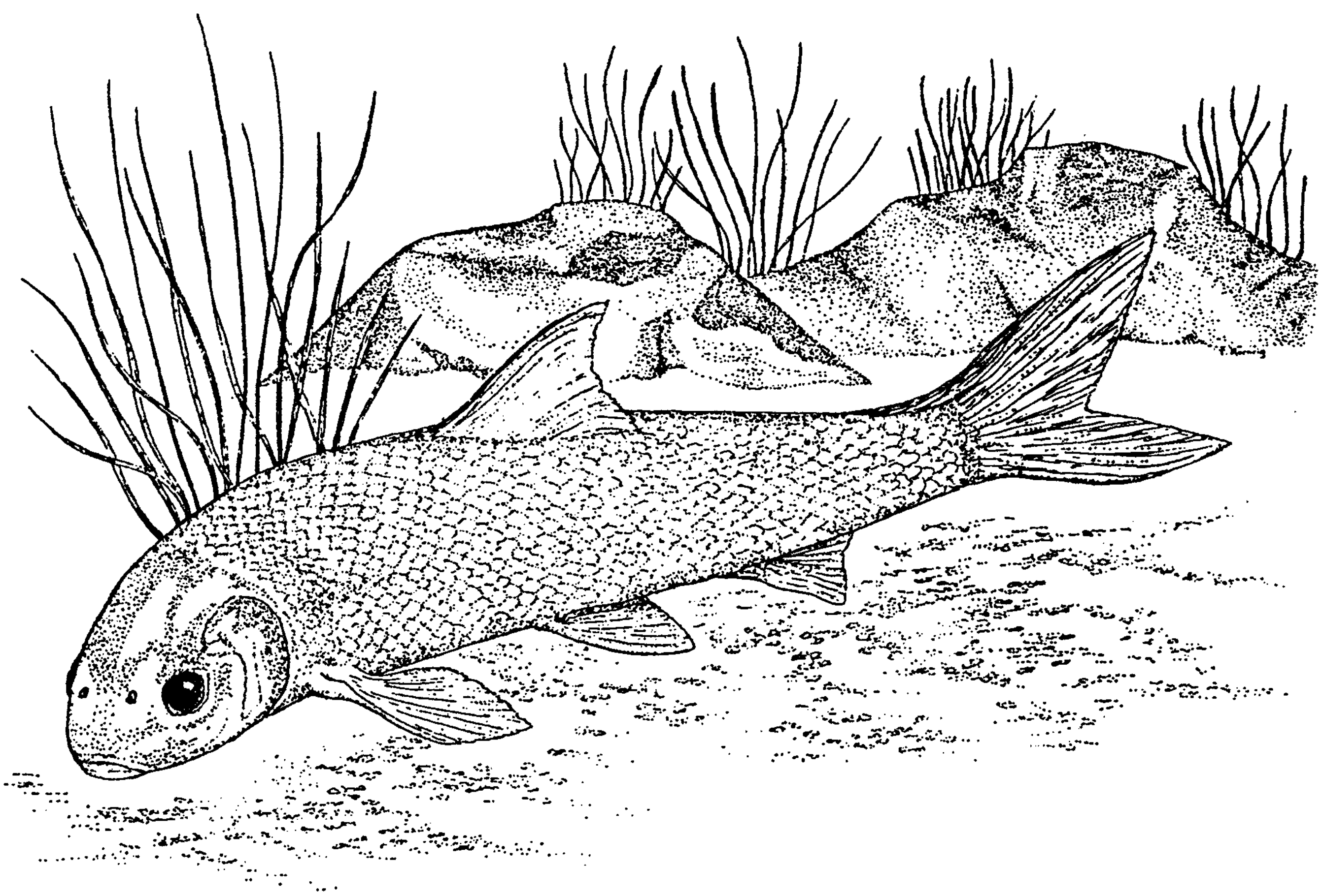
There is some variability in the reproductive period, with older fish reproducing first, followed by younger fish which tend to reproduce later in the season (Caywood 1974). Generally, gonadal development is initiated by fall, with a concomitant decrease in somatic growth (Daniels and Moyle 1983). By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

Status: Class 2.

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

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

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



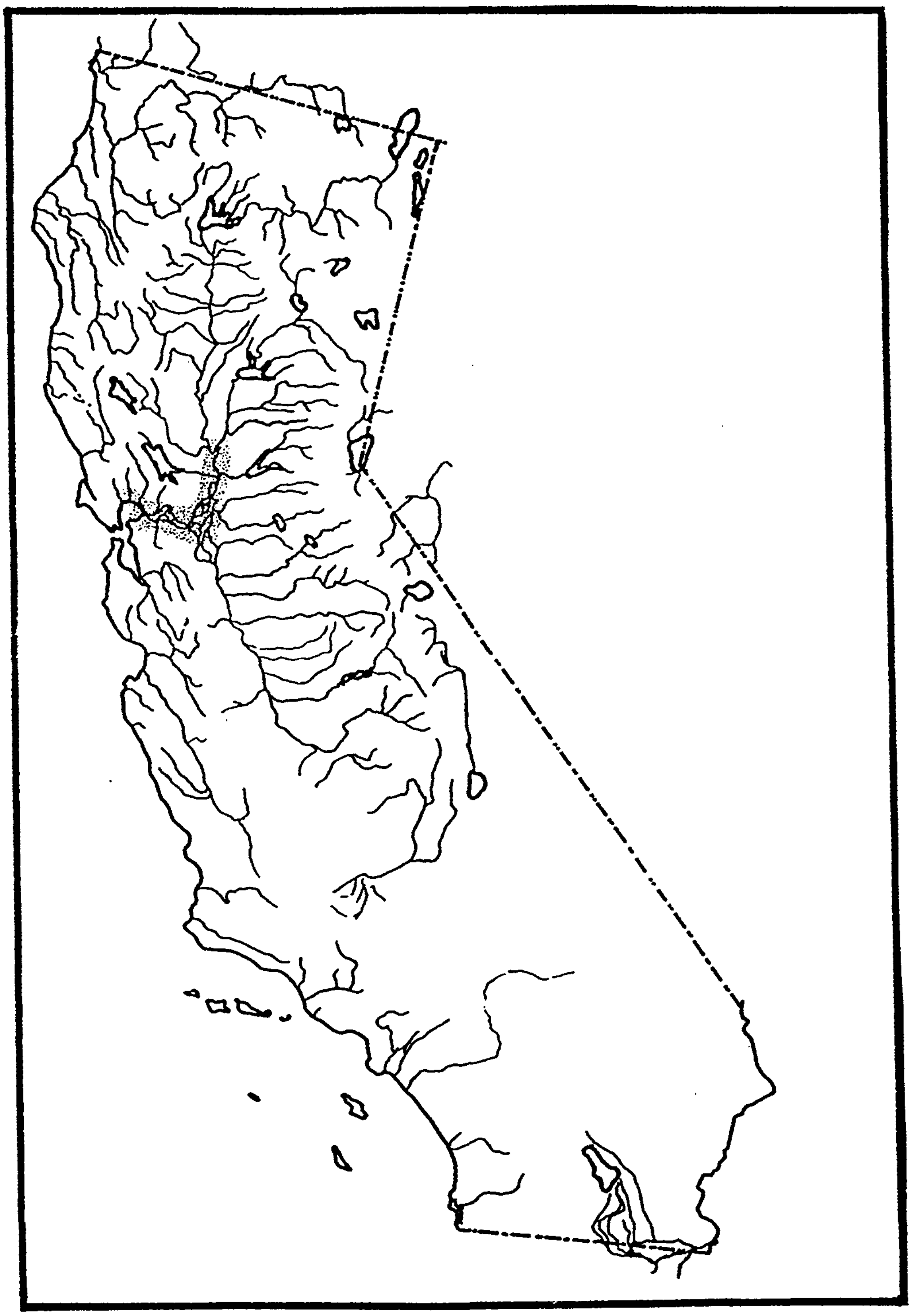


FIGURE 25. Distribution of Sacramento splittail, *Pogonichthys macrolepidotus*, in California.

HARDHEAD
Mylopharodon conocephalus (Baird and Girard)

Description: Hardhead are large cyprinids, reaching lengths in excess of 60 cm SL. The shape is similar to that of Sacramento squawfish (*Ptychocheilus grandis*), with which they co-occur, but the body is deeper and heavier and the head is less pointed. Hardhead also differ from squawfish in that their maxilla do not extend beyond the anterior margin of the eye and they possess a frenum connecting the premaxilla to the head. Hardhead have 8 dorsal rays, 8-9 anal rays, and 69-81 lateral line scales. Adults have large molariform pharyngeal teeth, but juvenile teeth are hooklike. Juveniles are silver; adults are brown-bronze dorsally. During the spawning season adult males develop fine nuptial tubercles in the head region (Moyle 1976).

Taxonomic Relationships: *Mylopharodon conocephalus* was first described as *Gila conocephala* Baird and Girard (Girard 1854) from one specimen collected from the "Rio San Joaquin." Ayres (1856) redescribed the species as *Mylopharodon robustus*. Girard (1856) recognized the generic designation and reclassified *G. conocephala* as *Mylopharodon conocephalus* and recognized *M. robustus* as a closely allied species. Jordan (1879), however, considered the genus monotypic and united both forms as *Mylopharodon conocephalus* (Jordan and Gilbert 1882) and attributed the generic nomenclature to Ayres and the specific nomenclature to Girard and Baird. Electrophoretic studies by Avise and Ayala (1976) indicated it to be most closely allied to Sacramento squawfish in the California fauna.

Distribution: Hardhead are widely distributed in low to mid-elevation streams in the main Sacramento-San Joaquin drainage as well as in the Russian River drainage. Their range extends from the Kern River, Kern County, in the south to the Pit River (south of the Goose Lake drainage), Modoc County, in the north. In the San Joaquin drainage, populations are scattered in the tributary streams, but are absent from the valley reaches of the San Joaquin River (Moyle and Nichols 1973, Saiki 1984, Brown and Moyle 1988). In the Sacramento River drainage, hardhead are present in most of the larger tributary streams as well as in the Sacramento River. They are widely, if spottily, distributed in the Pit River drainage (Moyle and Daniels 1982, Cooper 1982), including the main Pit River and its series of hydroelectric reservoirs.

Habitat Requirements: Hardhead are typically found in undisturbed areas of larger middle and low elevational streams (Fig. 26; Moyle 1976, Moyle and Nichols 1973). The elevational range of hardhead is 10 to 1450 m (Reeves 1964). They seem to prefer clear, deep pools with sand-gravel-boulder substrates and slow water velocities (<15 cm $\cdot$ sec^{-1}) (Moyle and Nichols 1973, Knight 1985). In streams, hardhead tend to remain in the lower half of the water column, rarely moving into the upper water column, and adults are associated with deeper water than juveniles (Knight 1985). However, in Britton Reservoir (Vondracek et al. 1988) and in large pools of the Pit River down from the reservoir (Hunt et al. 1988), they were found close to the surface where the water was warm. Hardhead are always found in association with Sacramento squawfish and usually with Sacramento suckers. They tend to be absent from streams where introduced species, especially centrarchids, predominate (Moyle and Nichols 1973).

Hardhead populations are well established in mid-elevation reservoirs used exclusively for hydroelectric power generation such as the Redinger and Kerkhoff Reservoirs on the San Joaquin River, Fresno County, and Britton Reservoir on the Pit River, Shasta County. In other types of reservoirs they usually establish only temporary populations. Populations in Shasta Reservoir, Shasta County, declined dramatically within two years (Reeves 1964), although they are still present there (J. M. Hayes, pers. comm.). Similar crashes of large reservoir populations have been reported from Pardee Reservoir on the Mokelumne River, Amador/Calaveras County (Kimsey et al. 1956); Millerton Reservoir on the San Joaquin River, Fresno County (Bell and Kimsey 1955); Berryessa Reservoir, Napa County (Moyle 1976); Don Pedro Reservoir, Tuolumne County; and Folsom Reservoir, El Dorado County (Kimsey et al. 1956). In the Pit River, hardhead are most abundant in Upper Lake Britton where habitat is more riverine and less abundant in the lacustrine habitat of Lower Lake Britton where centrarchids are more abundant (PG&E Rept. 1985). The initial establishment of hardhead in recently impounded reservoirs is probably the result of residual populations of juvenile fish growing to large sizes before populations of predatory centrarchid basses are established.

Life History: Hardhead are bottom feeders that forage for benthic invertebrates and aquatic plant material in quiet water. Occasionally they will also feed on plankton and surface insects and in Shasta Reservoir they were known to feed on cladocerans (Wales 1946). Smaller fish (<20 cm SL) feed primarily on mayfly larvae, caddisfly larvae, and small snails (Reeves 1964), whereas the larger fish feed more on aquatic plants, especially filamentous algae, as well as crayfish and other large invertebrates (Moyle, unpubl. data). The ontogenetic changes in teeth structure seems to fit this dietary switch. Reeves (1964) stressed that no fish remains have been found in the stomachs of large hardhead.

Hardhead reach 70-80 mm by their first year, but growth slows in subsequent years. In the American River hardhead reach 300 mm SL in 4 yrs; in the Pit and Feather rivers, it typically takes six years to reach that length (Moyle et al. 1983, PG&E 1985). The Feather River fish in the 440-460 mm SL range were aged at 9-10 years, but older and larger fish probably exist in the Sacramento River.

Hardhead mature following their second year and presumably spawn in the spring (Reeves 1964), judging by the upstream migrations of adults into smaller tributary streams during this time of the year (Wales 1946, Murphy 1947, Bell and Kimsey 1955, Rowley 1955). Shapovalov (1932) reported the presence of mature eggs in females during March, but gonads of males and females caught in July and August were spent (Reeves 1964). Estimates based on juvenile recruitment suggests that hardhead spawn by May and June in the Valley streams and the spawning season may extend into August in the foothill streams of the Sacramento-San Joaquin River (Wang 1986).

Spawning activity has not been documented, but reproductive behavior may involve mass spawning in upstream gravel bed riffles (Moyle 1976). Females are highly fecund, producing over 20,000 eggs (Burns 1966) although Reeves (1964) reported fewer (9,500-10,700) eggs.

Status: Class 3.

Historically, hardhead have been regarded as a widespread species that was locally abundant (Ayres 1855, Jordan and Evermann 1896, Evermann 1905, Rutter 1908, Follett 1937, Murphy 1947, Soule 1951, Reeves 1964). Hardhead are still widespread in the foothill streams, but their specialized habitat requirements, combined with widespread alteration of downstream habitats, has resulted in localized populations that are isolated. This makes them vulnerable to localized extinctions.

Hardhead are much less abundant than they once were, especially in the southern half of their range. Reeves (1964) summarized the historical records and noted they were found in most streams in the San Joaquin drainage, but Moyle and Nichols (1973) found them in only 9% of the streams they sampled. Brown and Moyle (1988) resampled most of the sites of Moyle and Nichols (1973) and found that a number of hardhead populations had disappeared during the 15-year period. Moyle (unpubl. data) collected hardhead from the Napa River during 1973, but Leidy (1986) failed to find any in an extensive sampling program.

Populations established in a few reservoirs used for hydroelectric power generation should not be regarded as "safe" populations because reservoir management can change. Either stabilization of water levels or increasing the amount of seasonal fluctuation of these reservoirs can result in increased populations of centrarchid basses and decreased hardhead populations.

Management: The best way to protect hardhead is to have a number of stream preserves established in mid-elevation canyon areas in which normal flow regimes and high water quality are maintained. Because hardhead are good indicator species of relatively undisturbed conditions, a system of such preserves would not only protect the species, but the entire biotic community of which they are part. In the meantime, stream populations should be monitored to ascertain that the species is holding its own. Particular attention should be paid to the Russian River population which may have declined in recent years.

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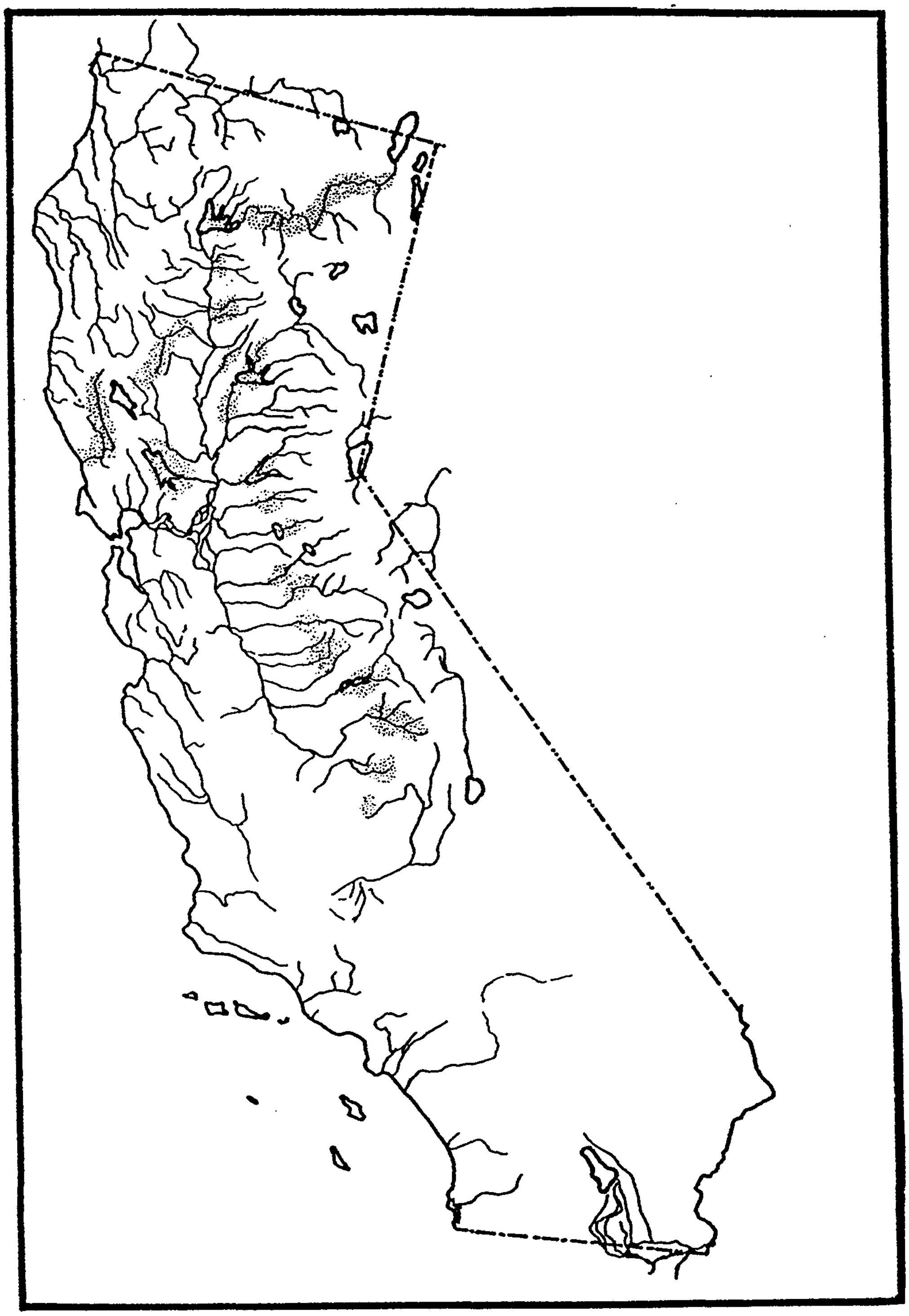

FIGURE 26. Distribution of hardhead, *Mylopharodon conocephalus*, in California.

AMARGOSA CANYON SPECKLED DACE
Rhinichthys osculus subsp.

Explanatory Note: We consider three forms of this widely distributed species to warrant status as sensitive subspecies. These are the Amargosa Canyon speckled dace (R. o. subsp.) from Willow Creek and the Amargosa river, the Owens River speckled dace (R. o. subsp.), and the Santa Ana speckled dace (R. o. subsp.). Little information is available on these forms; therefore, their life histories are necessarily generalized from other populations. There are undoubtedly other forms that deserve protection as well, but the species is so variable that few attempts have been made to work out their systematics.

Description: Speckled dace are small cyprinids that are usually <90 mm TL. They have small, subterminal mouths, a pointed snout, thick caudal peduncle, and a slender body. The dorsal fin is set distal to the origin of the pelvic fins. There are 6-9 dorsal fin rays (usually 8) and 6-7 anal fin rays (occasionally 8). Scales are small and there are 47-89 along the lateral line. The pharyngeal teeth are hooked with slight grinding surfaces. The dental formula is 1,4-4,1 or 2,4-4,2. They possess small barbels and a frenum that may or may not be attached to the premaxilla. Coloration is highly variable, but consists of a series of dark blotches on a lighter background. In reproductive individuals of both sexes, the bases of the fins become orange to red and males may develop tubercles on the pectoral fins (Moyle 1976).

Taxonomic Relationships: Williams et al. (1982) compared speckled dace from the Amargosa Canyon region in California with speckled dace from Ash Meadows in Nevada and found that the two populations were morphologically distinct. The former were characterized by a comparatively smaller head depth, shorter snout to nostril length, longer anal to caudal length, more pectoral fin rays, and fewer vertebrae.

Distribution: This population is confined to the Amargosa River in Amargosa Canyon (Fig. 27) and tributaries to it, especially Willow Creek and Willow Creek Reservoir (Williams et al. 1982).

Habitat Requirements: Unlike other speckled dace, the Amargosa Canyon form prefers pool-like habitat with deep (0.45-0.75 m), slow (<0.01 m^3 sec^{-1}) water. They are rare in the Amargosa River itself (Williams et al. 1982), but have probably never been very abundant there (Soltz and Naiman 1981). Dace are, however, abundant in Willow Creek and Willow Creek Reservoir (Williams et al. 1982). Willow Creek is a small, clear stream with low flow (1 cfs) and fine sand/silt substrates. It is characterized by a pH of 7.7, dissolved oxygen of 5-6 mg l^{-1}, total dissolved solids of 700 ppm, and water temperatures of 21-28°C. The reservoir, however, is turbid, with a substrate of easily roiled fines. The periphery of the reservoir has dense stands of salt-cedar and cattails (Williams et al. 1982).

Life History: Speckled dace typically form small feeding aggregations (Moyle 1976). In stream systems they may be active throughout the year, including the winter months, and as a consequence are hard to age by scale analysis because growth is continuous year-round (Moyle 1976). However, length-frequency analysis of dace from various localities suggests that they may live for five to six years (Moyle 1976). They usually mature by the second year and most spawning occurs during June and July, probably induced by increasing temperatures (Jhingran 1948).

In Amargosa Canyon, the most frequent size class in May was 52-54 mm TL, but in July smaller fish averaging 31-33 mm were more common (Williams et al. 1982). However, in May there were many small fish (<30 mm TL), suggesting that peak spawning occurs in early spring (March) and spawning activity is reduced or absent in late spring and summer. Speckled dace are reproductive at age 1+ (<70 mm SL) (Costantz 1981) and the 52-54 mm TL size class, common in May, are probably first year fish (Williams et al. 1982).

Speckled dace are omnivorous; their diet ranges from aquatic and terrestrial insects and other invertebrates such as snails and microcrustaceans to filamentous algae (Moyle 1976).

Status: Class 2.

This fish occupies an extremely limited range. It was found in 1937 in a warm spring just north of Tecopa (Miller 1938), but this population is no longer present. During a 1981 survey of the Amargosa Canyon that included the river and Willow Creek, speckled dace comprised 1.3% of the fishes collected (Williams et al. 1982). Introduced mosquitofish comprised 40.2% of the fish fauna.

Most of the land in the Amargosa Canyon is owned by The Nature Conservancy or BLM. The largest tract of privately owned land is China Ranch, which includes the headwater area of Willow Creek. Diversion of water from the creek or other alterations affecting water quality could cause dace populations to decline.

Management: The small population in the Amargosa River may be dependant upon recruitment of dace from Willow Creek. If this is so, maintenance of adequate flows from China Ranch are critical to the survival of this subspecies. Efforts also should be made to locate the spring occupied by dace in 1937 (Miller 1938) to determine if this spring, or another nearby spring, could again support a dace population. As discussed for the Amargosa pupfish, frequent surveys of the Amargosa Canyon are necessary to monitor habitat conditions and the presence of introduced fishes.

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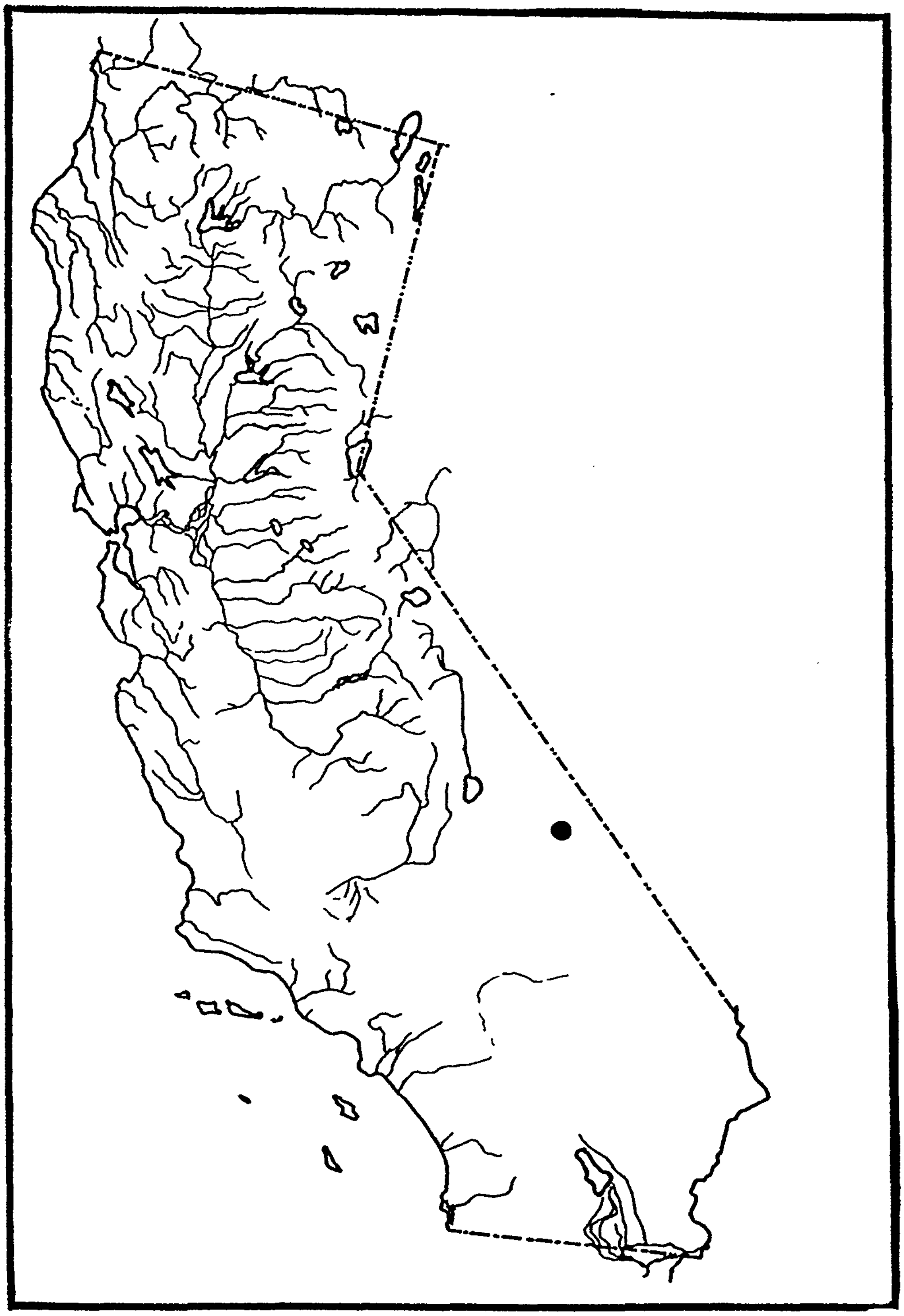

FIGURE 27. Distribution of Amargosa Canyon speckled dace, *Rhinichthys osculus* subsp., in the Amargosa Canyon area of the Amargosa River, California.

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C-046063

SANTA ANA SPECKLED DACE
Rhinichthys osculus subsp.

Description: This is a small (<80 mm SL) cyprinid, with basic characteristics similar to those of Amargosa Canyon speckled dace. Cornelius (1969) presented evidence that the Santa Ana dace differs from other speckled dace in some of its meristic and morphometric characteristics. Santa Ana speckled dace have finer scales (69-82 scales in lateral line), a better developed frenum on the upper lip, a longer head, and smaller eggs than other California dace.

Taxonomic Relationships: The Santa Ana speckled dace has not been formally described as a subspecies, but the data of Cornelius (1969) suggest that it warrants this status. Hubbs et al. (1979) list it as an undescribed subspecies. This dace appears to be most closely related to dace of the Colorado River drainage (Cornelius 1969).

Distribution: This dace was apparently once widely distributed in the Santa Ana, San Gabriel, and Los Angeles river systems of southern California (Los Angeles and Orange counties). Today it has a very limited distribution in the headwaters of all three drainages (C. Swift, pers. comm.). In the Los Angeles River drainage, it is found only in 6-14 km of stream in Big Tijunga wash and possibly in Pacoina Canyon. In the Santa Ana drainage, it is confined to less than 1 km of stream during the dry season in Silverado Canyon in and below Shrewsberry Spring. There are unconfirmed reports (early 1980's) from USFS biologists that dace may also be present in Cajon Creek, West Fork of City Creek, and North Fork of Listle Creek above its junction with the Middle Fork. In the San Gabriel River, it is known from about 13 km of the West Fork below Cogswell Dam (Deinstadt et al. 1988) and from an undetermined length of the East Fork. They should be present in the North Fork as well. On 15 February 1988 only five fish were seen during a survey of Fish Canyon, a lower tributary of the main San Gabriel River. In 1986, dace were abundant in this stream (C. Swift, pers. comm.)

Habitat Requirements: The Santa Ana speckled dace requires permanent flowing streams with summer water temperatures of 17-20°C. It inhabits shallow cobble and gravel riffles (Wells and Diana 1975). The best description of its habitat is provided by Deinstadt et al. (1988) for the West Fork of the San Gabriel River. The West Fork is a small (typical summer flow of 4 CFS, 5-8 m wide, depths mostly 15-30 cm), permanent stream that flows through a steep, rocky canyon with chaparral-covered walls. Overhanging riparian plants, mainly alders and sedges, provide cover for fish. Even though Deinstadt et al. (1988) found dace throughout the 14 km of stream they sampled, the dace were common only in the lower reaches of the stream where the dominant habitat types were runs and riffles with gravel and cobble substrates. In the West Fork, Santa Ana speckled dace are most common where other native fishes (rainbow trout, arroyo chub, and Santa Ana sucker) are common as well. Introduced species (largemouth bass, green sunfish) may be present, but only in low numbers.

Life History: No specific information is available on the life history of this subspecies, although length data in Deinstadt et al. (1988) indicates it probably lives three years. Other aspects of its life history are presumably similar to those described for the Amargosa Canyon speckled dace.

Status: Class 1.

The Santa Ana speckled dace occupies only remnants of its native range because of water diversions, urbanization of watersheds, introduction of nonnative species, and a myriad of other factors associated with expanding human populations in the Los Angeles region. The three populations are disjunct and each is threatened by these factors, especially when combined with natural drought conditions.

Big Tijunga Wash. The dace are already scarce in this stream due to habitat degradation. Recently, red shiners were introduced into the drainage and have invaded the lower reaches of the wash (C. Swift, pers. comm.). Red shiners may further deplete dace populations through competition for food and space or by preying on dace eggs.

Silverado Canyon. Dace were uncommon or absent in all sections of stream sampled in the winter of 1987-1988 (C. Swift, pers. comm.), so their extirpation from the Santa Ana drainage could be imminent.

San Gabriel River. Dace are common in the West and East Forks, but their total populations are small. The population estimates of Deinstadt et al. (1988) indicate that probably less than 2000 dace exist in the West Fork. This population may be low, however, because the stream was recovering from a release of sediments from Cogswell Dam in 1981. These sediments smothered most of the dace's habitat and were not flushed out until 1988 through a combination of high rainfall and releases from the dam. Cogswell Dam was constructed for flood control, so the water stored in it is normally released after storms have passed. Often there is little water in the reservoir during the summer and the stream is maintained only by seepage from below the dam and from springs. This water is reliable enough, however, so that CDFG manages much of the stream below the dam as a wild trout fishery (Deinstadt et al. 1988).

The status of dace populations in the East Fork is not known although they were reported to be common there in the early 1980's (C. Swift, pers. comm.).

Overall, it appears that the remaining populations of Santa Ana speckled dace in the Santa Ana and Los Angeles river systems are in imminent danger of extinction. The populations in the San Gabriel River are less obviously threatened, but their very limited range means that they could be eliminated from either or both forks by major floods, debris torrents, and/or landslides. Such events can occur if heavy rains follow a season of heavy fires that eliminate stabilizing vegetation on the slopes of the drainages. The problems with Cogswell Dam in the past indicate that its presence is no guarantee of the safety of the fish that live in the stream below it.

Management: Thorough surveys are needed of all reaches of stream suspected to contain the dace to determine population sizes and factors threatening their continued existence. Immediate steps should then be taken to protect their habitats in all three drainages, including assuring that they will have enough water to live in. Studies on their systematics and life history should also be undertaken. As an immediate conservation measure, the East and West Forks of the San Gabriel River should be given the status of native fish management areas or refuges to protect not only dace but other native fishes as well.

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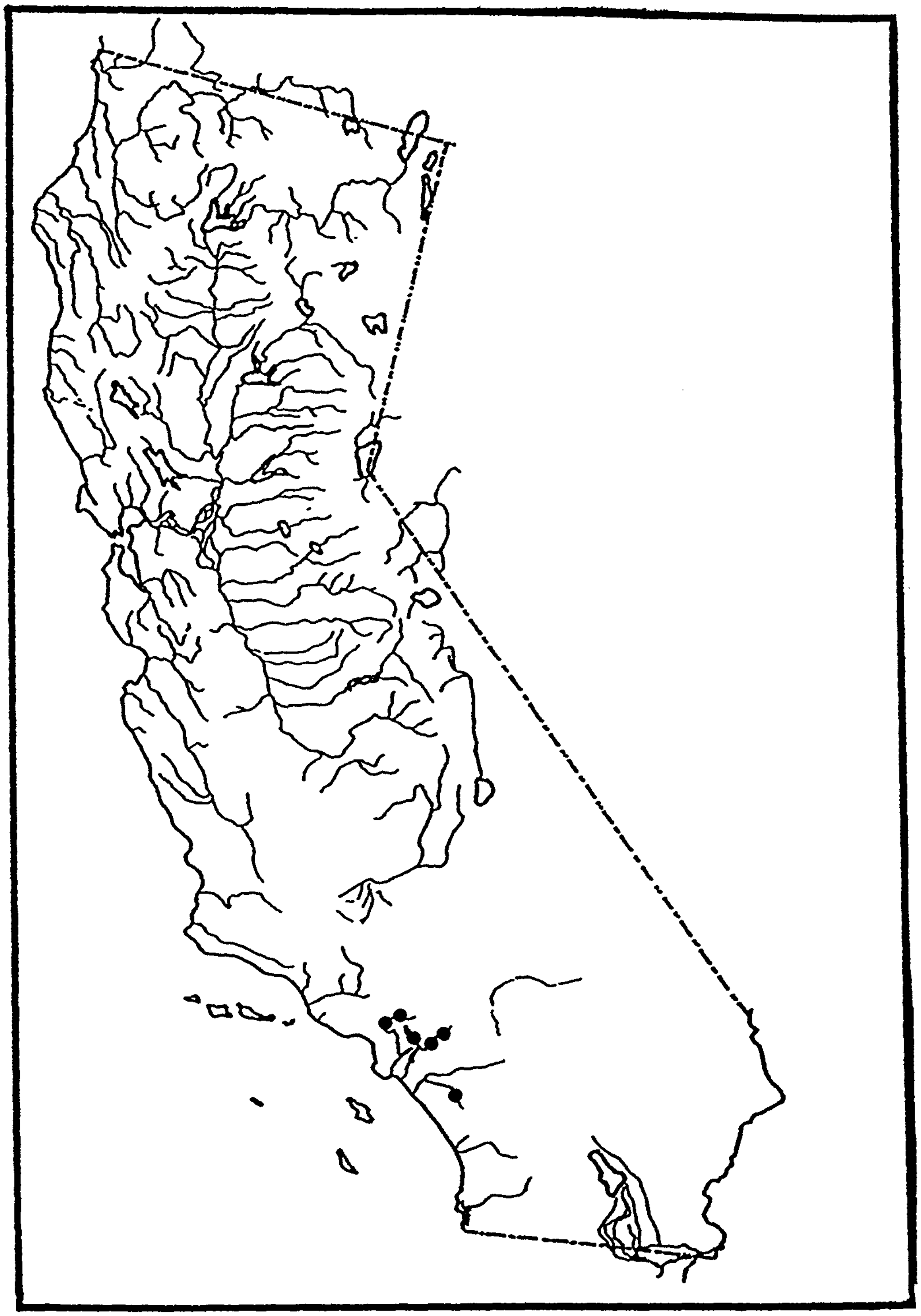

FIGURE 28. Distribution of the Santa Ana speckled dace, *Rhinichthys osculus* subsp., in California.

C-046067

OWENS SPECKLED DACE
Rhinichthys osculus subsp.

Description: Description of speckled dace from the Owens Basin are underway (D. Sada, pers. comm.) but are not available for this report. The following general description of speckled dace is from Moyle (1976), with notes on a presumably related form, *Rhinichthys osculus nevadensis*.

Speckled dace are highly variable in morphology but are generally distinguished by small, subterminal mouths; pointed snout; small, irregularly-placed scales; and torpedo-shaped body. Total body length is usually less than 90 mm. Typical dorsal fin ray number is 8 (range 6-9) and anal fin rays number 7 (range 6-8). As their common name indicates, numerous black speckles cover the body, except in turbid waters where fish may lack them. Gilbert's (1893) description of *nevadensis* generally fits the above with additional characters as follows: (1) lateral line incomplete and with 65 scales, (2) mouth terminal (rather than subterminal), and (3) maxillary barbel well developed.

Taxonomic Relationships: Although Gilbert (1893) described *nevadensis* from Ash Meadows, Nevada, this subspecific name has been assigned to speckled dace in the Amargosa River system and Owens Valley (La Rivers 1962, Moyle 1976). Recent investigators have placed dace in Ash Meadows, Amargosa River, and Owens Basin in separate subspecies (Williams et al. 1982, Deacon and Williams 1984). More recent studies by Don Sada (unpubl. data) suggest that the following four distinct forms are present in the Owens Basin: (1) Long Valley, (2) fluvial East Fork Owens River drainage, (3) northern Owens Valley, and (4) Little Lake. Each of these forms has distinctive characteristics; studies by D. Sada indicate that fluvial populations have more scales on the lateral line, more lateral line pores, more slender bodies, and longer fins than populations living in springs.

Distribution: Museum records from the 1930's and 1940's indicate that speckled dace occupied most small streams and springs in the Owens Valley. D. Sada (pers. comm.) reported 17 different sites are represented in collections at the University of Michigan Museum of Zoology, California Academy of Sciences, and files of CDFG. Surveys conducted by D. Sada in 1988 (unpubl. data) found speckled dace at two Long Valley sites (Whitmore Hot Springs and an unnamed thermal spring), one East Fork Owens River site (springs or Harris Ranch/Lower Marble Creek), and five sites in Owens Valley (N. McNally Ditch, Lower Bishop Creek, irrigation ditch in north Bishop, Lower Horton Creek, and Lower Pine and Rock Creeks). Because these investigations are still underway, no map is presented here.

Habitat Requirements: Speckled dace from the Owens Basin are known to occupy a variety of habitats, including small streams and spring systems. They also have been found in irrigation ditches near Bishop. Despite the large variety of habitats apparently suitable to speckled dace of the Owens Basin, their disappearance from numerous localities since the 1930's and 1940's suggests their vulnerability to habitat modifications and/or invasion by exotic fishes.

Life History: Particular life history adaptations of speckled dace from the Owens Basin have yet to be determined. In general, speckled dace feed on small aquatic insects and algae

(Moyle 1976). They typically live three years and attain a maximum total length of 90 mm (Moyle 1976).

Status: Class 2.

If the native speckled dace of the Owens Basin are considered to be a single undescribed subspecies, as they are provisionally treated here, the subspecies warrants a Class 2 status.

D. Sada (unpubl. data) reported speckled dace from eight localities in the Owens Basin during 1988 surveys. This represents a substantial reduction in known populations and range. For example, speckled dace are now restricted to one site (Benton) in the East Fork Owens River subbasin and two sites in Long Valley. If further taxonomic analysis shows that dace in the East Fork Owens River or Long Valley are worthy of subspecific descriptions, these forms warrant listing as endangered.

Management: The most critical need for Owens speckled dace is protection of existing habitat (especially at Benton). A taxonomic review of the forms from various localities is needed to determine if some populations warrant endangered status. Even if these forms do not warrant separate subspecies status, they may represent regions of more limited genetic differentiation within the basin. Such isolated populations of dace are susceptible to habitat changes and to the establishment of exotic fishes (Williams and Sada 1985). Remaining populations of Owens speckled dace should be monitored annually.

GOOSE LAKE SUCKER

***Catostomus occidentalis lacusanserinus* (Fowler)**

Description: This is a large catostomid that reaches 350 mm SL. Its gross morphology is similar to other subspecies of Sacramento sucker (Moyle 1976), but the subspecies is distinguished by 2-3 rows of large papillae on large upper lips and 8-10 rows on the lower lip that is deeply cleft almost to the symphysis. There are no lateral notches on the lips. The anterior medial papillae are enlarged; a frontoparietal fontanelle is present. There are 60-77 (mean = 65.5) lateral line scales, 11-15 scales (mean = 12.99) above the lateral line and 7-11 (mean = 11.6) below. There are 7 anal rays and 21-27 gill rakers. The number of post-Weberian vertebrae ranges from 42-44. The caudal peduncle is 8-10% standard length. There are no pelvic axillary processes. The peritoneum is black. External body coloration is dark grey to black dorsally and light grey-dull brown ventrally. The head is steel grey-brown dorsally, but is lighter ventrally. A darker lateral streak is present in larger fish. The caudal, pelvic, and pectoral fins are light grey to cream. Males also develop sexual tubercles on branched and unbranched anal rays and on lower caudal rays. Females have no tubercles (Martin 1967.)

In reproductive males, the pelvic fins become extremely enlarged, elongated, and cupped, presumably to aid in dispersal of sperm during reproduction (Martin 1967). Similar hyperdevelopment and cupped pelvic fins have been observed in other catostomids which reproduce in swift water (Reighard 1920).

Taxonomic Relationships: Goose Lake sucker were first described as a subspecies of *Catostomus occidentalis* by Fowler (1913) from a single specimen. Since then the original subspecific nomen, *lacus-anserinus*, has been modified to eliminate the hyphen, and the present name is *C. o. lacusanserinus* (Shapovalov et al. 1959, Kimsey and Fisk 1960, Hubbs et al. 1979). Based on morphological evidence, this subspecies is thought to have evolved in the Goose Lake basin (Martin 1967). However, a detailed phenetic and genetic reanalysis is needed.

Distribution: The subspecies is restricted to the Goose Lake basin (Martin 1967) (Fig. 27) and has been reported from Goose Lake and Willow, Lassen, and Canal creeks, Modoc County, California; and Dog, Drews, Cottonwood, Dry, Thomas, Cox, and Warner creeks, Lake County, Oregon (Williams et al. unpubl. ms.). It is also known from Drews and Cottonwood reservoirs in Oregon.

Spawning runs have been observed in Willow Creek (Martin 1967, Williams et al. unpubl. ms.) and other tributaries to Goose lake, as well as Dog Creek (spawning runs from Drews Reservoir) and Cottonwood Creek (spawning runs from Cottonwood Reservoir).

Habitat Requirements: Relatively little information is available on this subspecies. In streams, *Catostomus o. lacusanserinus* is typically found in water depths of 15 to 150 cm and in moderate to slow water velocities (Martin 1967). The streams in which they are found are up to 4.5 m wide, with summer water temperatures of 15-19°C. Little vegetation is present in the streams. Substrates consist primarily of rock and gravel in headwater sections and mud, silt, and gravel in lower sections. (Goose Lake is described in the Goose Lake tui chub section.)

Life History: Little is known about the life history of Goose Lake sucker, except that they spawn during spring in the streams tributary to Goose Lake (Martin 1967). Adults can be found in the streams and lake throughout the year.

Fish become sexually mature by the second year when they are 80-90 mm SL. Martin (1967) found several fish (141-216 mm SL), both male and female, with mature gonads at the beginning of April and concluded that *lacusanserinus* breeds during April or May, depending on water temperature. J. Williams (unpubl. observ.) observed 246-430 mm FL fish on a spawning migration in Willow Creek during 14-16 May 1984.

This subspecies feeds primarily on algae and diatoms (Martin 1967). Like other suckers, it has a long intestine and ventral mouth adapting it to this diet.

Status: Class 3.
The species is abundant in its limited range. It is listed because most of its stream habitats are subject to degeneration by diversions, over-grazing, and other agricultural practices.

Management: The systematic position of this form needs re-evaluation. Meanwhile the subspecies can maintain itself if there is adequate spawning and rearing habitat in the streams tributary to Goose Lake. It is likely that measures taken to conserve Goose Lake redband trout will also benefit this species.

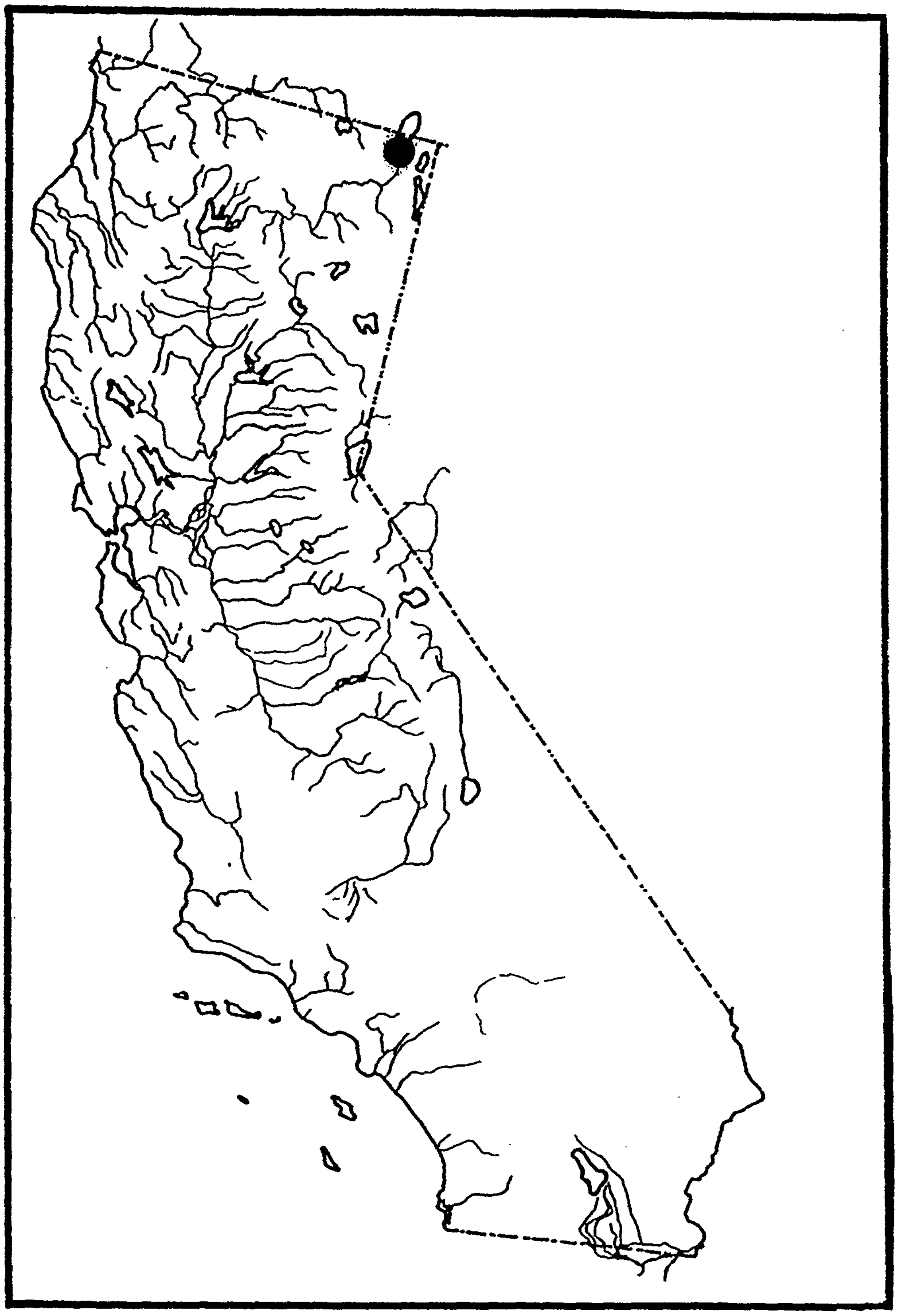

FIGURE 27. Distribution of the Goose Lake sucker, *Catostomus occidentalis lacusanserinus*, in California.

C-046073

OWENS SUCKER
Catostomus fumeiventris (Miller)

Description: The Owens sucker is most closely related to the Tahoe sucker (*Catostomus tahoensis*) and the external morphology of the two species is quite similar (Miller 1973). Adults are from 115 to 212 mm SL (Miller 1973). They have large heads, long snouts, and coarse scales (Moyle 1976). The sub-terminal mouth is large and the papillose lower lip is deeply incised. The cephalic fontanelle is well developed. The caudal peduncle is thick. There are 75-78 lateral line scales, with usually 13-16 scale rows above and 9-11 scale rows below the lateral line. Pectoral fins have 16-19 rays, dorsal fin 10 rays, and pelvic fins 9-10 rays.

Adults are slate dorsally, which occasionally becomes very dark, and can have weak, blue iridescence on their sides. The ventrum is a dusky/smokey color, giving rise to the specific name. Unlike most other species of sucker, reproductive adults of this species do not develop the characteristic red lateral stripe, and this characteristic distinguishes it from the Tahoe sucker (*C. tahoensis*). However, the paired fins may be faintly tinged with a dull reddish-amber.

Taxonomic Relationships: *Catostomus fumeiventris* was first diagnosed by Snyder (1919) as *Catostomus arenaris*, but was later included with *Catostomus tahoensis*. However, *Catostomus fumeiventris* was subsequently recognized as distinct and described by Miller (1973).

Distribution: The Owens sucker is endemic to the Owens River drainage (Fig. 28) and is widely distributed throughout the Owens Valley. It is most abundant in Crowley Lake in Mono County (P. Pister, pers. comm). Other populations exist in Convict Lake in Mono County and Lake Sabrina in Inyo County (P. Pister, pers. comm). There is also an introduced population in June Lake of the Mono Lake Basin. A population is apparently established in the Santa Clara River, Los Angeles County, presumably via the Owens Aqueduct. Although Bell (1978) did not record it from the Santa Clara River during his survey, Wells and Diana (1975) found it in Sespe Creek of this drainage.

Habitat Requirements: In the lower Owens River and two of its tributaries, lower Rock Creek and lower Hot Creek, Owens suckers were most abundant in sections with long runs and few riffles (Dienstadt et al. 1986). The substrate in these sections consisted mostly of fine material, with lesser amounts of gravel and rubble. Water temperature was 7-13°C and pH 7.9-8.0. Adults can thrive in lakes and reservoirs, but they presumably need gravelly riffles in tributary streams for spawning.

Life History: The life history of Owens suckers is thought to be similar to the closely related Tahoe sucker (Miller 1973); they are probably nocturnal feeders that ingest aquatic insects, algae, detritus, and inorganic matter picked off the bottom. They spawn from late May to early July, and larval to juvenile suckers have been collected in late June near mouth of Whiskey Creek, a tributary to the southwestern arm of Crowley Lake (Miller 1973). Larvae transform into juveniles when 19-22 mm and are usually found in quiet, sedge-dominated margins and backwater areas (Miller 1973).

Status: Class 3.

Owens suckers have adapted well to the damming of the Owens River and creation of Crowley Reservoir so they still have large populations in a good portion of their native range. Successful introductions of Owens suckers into June Lake, outside their native range, and into the Owens Native Fish Sanctuary have also been made. However, their total range is limited and the bulk of their population seems to depend on reservoirs that are dominated by introduced game fishes.

Management: No special management is needed at this time, but their status should be assessed every five to ten years to see if their numbers are declining.

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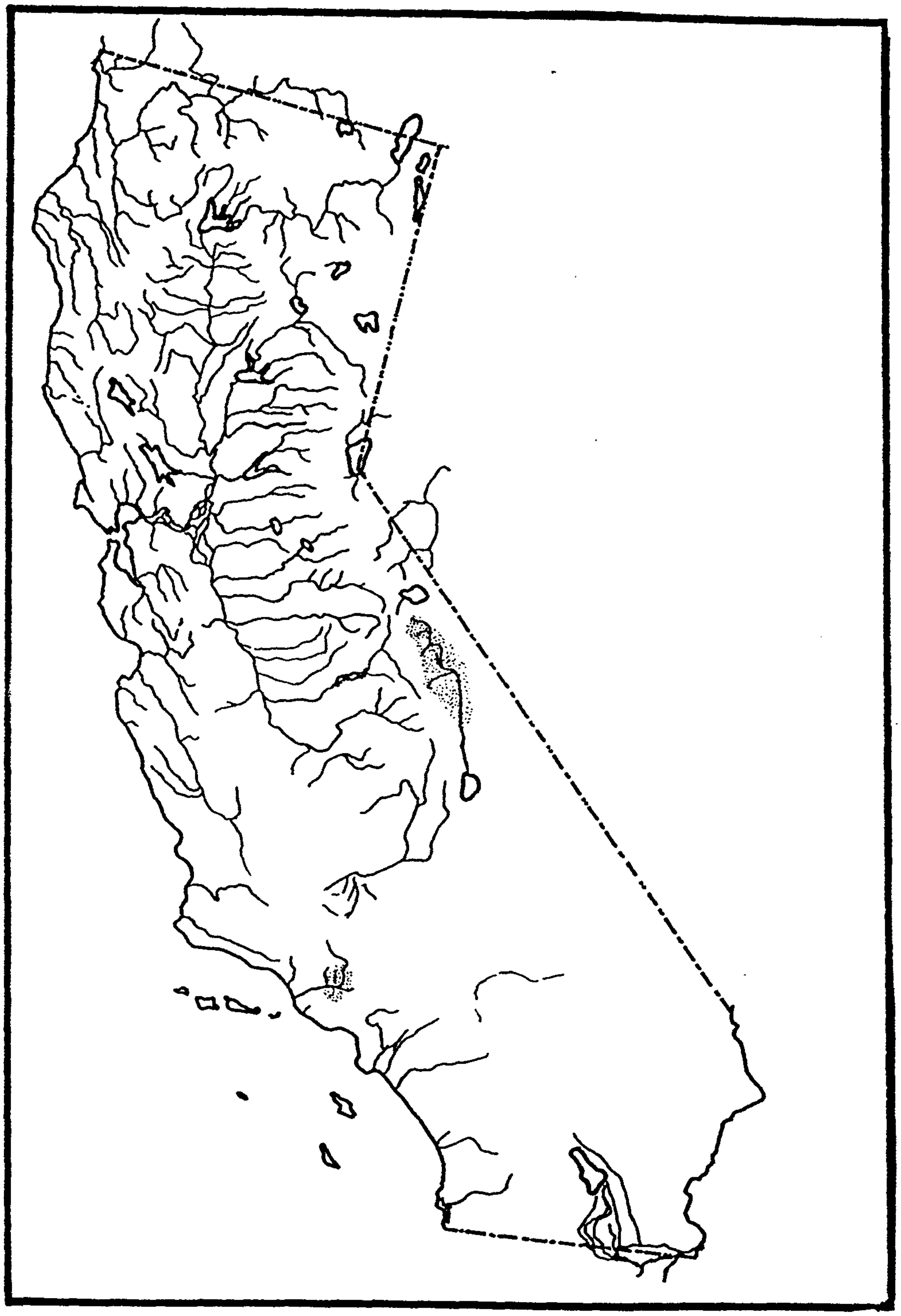


FIGURE 28. Distribution of the Owens sucker, *Catostomus fumeiventris*, in California. An introduced population (i) is shown in the Santa Clara River basin.

C-046077

KLAMATH LARGESCALE SUCKER
Catostomus snyderi (Gilbert)

Description: The Klamath largescale sucker is similar to the Sacramento sucker (*Catostomus occidentalis*) in gross morphology. Andreasen (1975) described this species as being a generalized sucker, intermediate in most morphological characteristics, especially between *Deltistes luxatus* and *Chasmistes brevirostris* with which it co-occurs. The inferior mouth of this sucker is smaller than the Sacramento sucker's. The lips are papillose and there is a medial incision on the lower lip resulting in only one row of papillae extending across the lip. The upper lip is narrow and has 4-5 complete rows of papillae. It also differs from the Sacramento sucker in having a shorter dorsal fin, with a basal length equal or shorter than the longest dorsal ray. The dorsal fin insertion is more proximal to the snout than to the caudal fin. There are 11 dorsal fin rays (may range from 11-12) and 7 anal fin rays. Scales are large and there are 69-77 along the lateral line, 13-14 rows above and 10-11 below. Gill rakers number from 31-33, but usually there are 32. Adult body coloration is similar to Sacramento sucker. Dorsal surface is greenish and ventral surface is a yellow-gold (Moyle 1976). Coloration of reproductive adults has not been described.

Taxonomic Relationships: *Catostomus snyderi* from upper Klamath Lake was first described by Gilbert (1897). It is presumably closely related to *C. macrocheilus* of the Columbia River drainage to the north and to *C. occidentalis* of the Sacramento drainage to the south.

Distribution: The Klamath largescale sucker is native to the Klamath River and Lost River-Clear Lake systems of Oregon and California (Fig. 29). Although it is found in the Klamath River below Klamath Falls, most are found in the river above the falls. Andreasen (1975) reported them from Upper Klamath Lake, the Clear Lake-Lost River system, the entire Sprague River, the lower 20 km of the Sycan River, lower Williamson River, and the Williamson River above Klamath Marsh. However, Contreras (1973) failed to find any in the Lost River drainage. This may be because Klamath largescale suckers have never been very abundant anywhere. In California they are found mainly in the Lost River drainage and in the Klamath River above Iron Gate Reservoir.

Habitat Requirements: It is known to inhabit both lentic and lotic habitats, but is primarily adapted to a riverine existence (Andreasen 1975). However, little additional information on its ecology is available.

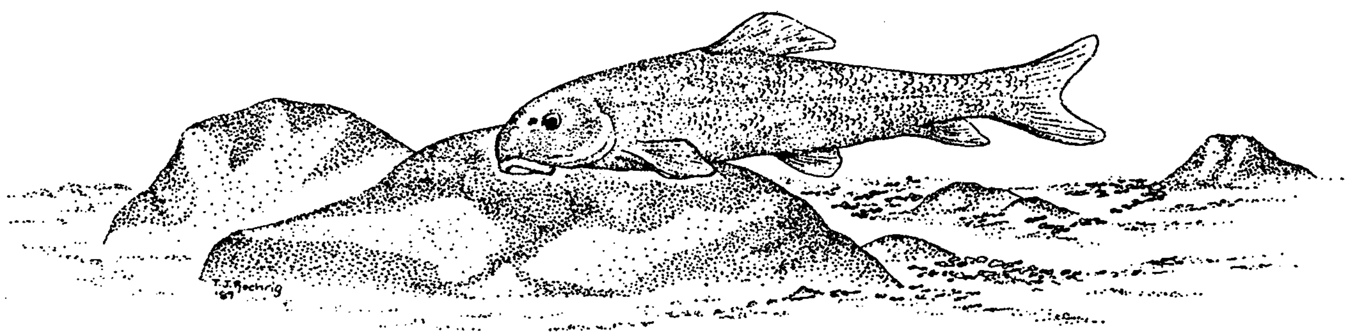
Life History: Detailed information is scant on the biology and life history of this species. Mature suckers collected during a spawning migration were aged at 5-8 yrs (Andreasen 1975), but this is probably an underestimate. In Upper Klamath Lake, these spawning migrations occurred during March and peaked by the end of March when individuals of both sexes were ripe and migrating in large numbers. Earlier in the month Andreasen (1975) found lesser numbers migrating, although most of the males were ripe, the few females observed were not. Initiation of reproduction was attributed to temperature. Fecundity was estimated for three females at 39,697 (353 mm SL), 64,477 (405 mm SL), and 63,905 eggs (421 mm SL).

Extensive hybridization and introgression with *Chasmistes brevirostris* has been reported, especially in the Clear Lake and Lost River populations (Andreasen 1975). Although the Klamath largescale sucker has also hybridized with *Deltistes luxatus* and *Chasmistes brevirostris* in Upper Klamath Lake, no introgression has occurred and distinct species are still present.

Status: Class 2.

The Klamath largescale sucker is a poorly known species that is native to waters that have been highly modified by dams, diversions, and pollution. California populations are on the edge of its range, but its range is rather limited in any case. The Lost River drainage in California has been especially altered by human activity and contains large populations of introduced predatory fishes, such as yellow perch (*Perca flavescens*) and Sacramento perch (*Archoplites interruptus*). The largescale sucker occurs with and occasionally hybridizes with two other native catostomids, the Lost River sucker, *Deltistes luxatus*, and the shortnose sucker, *Chasmistes brevirostris*, both of which have been formally listed as endangered by both the USFWS and CDFG. All this evidence indicates that Klamath largescale sucker may be on its way to becoming a threatened species.

Management: The first step is to find out more about the distribution, habitat requirements, and life history of this species in both Oregon and California. There is also a need to find ways to manage at least part of the Klamath River drainage as a refuge for it and other native fishes. It is quite likely that steps taken to benefit the two endangered suckers of the upper Klamath basin will also benefit Klamath largescale sucker, but several measures such as protection of spawning grounds may also be needed to specifically protect it.



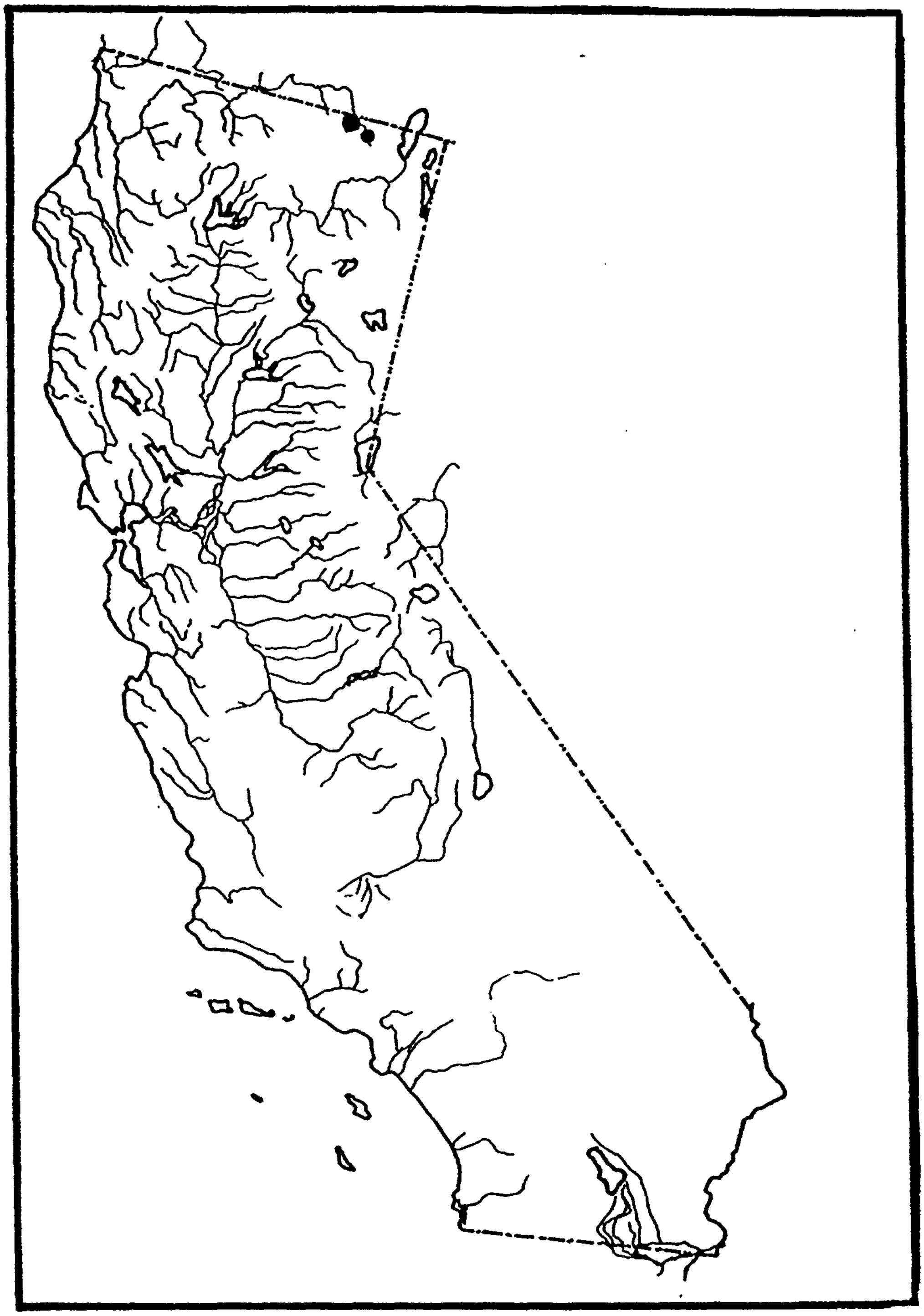


FIGURE 29. Distribution of the Klamath largescale sucker, *Catostomus snyderi*, in the Lost and Klamath rivers in California.

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C-046081

MOUNTAIN SUCKER
Catostomus platyrhynchus (Cope)

Description: Mountain suckers are small catostomids that are from 80 to 120 mm TL when adult and seldom exceed 180 mm TL (Smith 1966, Moyle 1976). Like other catostomids, they have sub-terminal mouths with prominent, fleshy, protrusible lips. Adult and juvenile mountain sucker, however, have deep lateral notches at the juncture of the upper and lower lips and a shallow, median cleft on the lower lip that serve to distinguish them from other species (Smith 1966, Snyder 1983). The lips have numerous large papillae, except on the anterolateral corners of the lower lip and the anterior area of the upper lip. Jaws are modified with cartilaginous plates for scraping food from rocks.

Mountain suckers have 23-37 gill rakers on the external row and 31-51 gill rakers on the internal row of the first gill arch. Lateral line scales typically number from 75 to 92. The dorsal fin has 8-13 rays (mean = 10); the pelvic fins have 9 rays. The intestine is long (4.5 to 6 times body length), reflecting its herbivorous trophic status. The peritoneum is black.

Fish are brown to olive green dorsally and laterally and white to yellow ventrally. A lateral band, or a series of blotches, along the sides is usually present (Smith 1966, Moyle 1976). Reproductively mature fish have a dark, red-orange lateral band. Fins also take on a red-orange color in reproductive specimens. Reproductive adults exhibit secondary sexual dimorphic characteristics (Hauser 1969). In mature males, large conical tubercles are present on rays of the enlarged anal fin and smaller tubercles are present in the lower caudal fin. Males develop breeding tubercles over the entire body and all fins, except for the dorsal. In females, tubercles are restricted to the dorsal and lateral areas of the head and body.

Taxonomic Relationships: *Catostomus (Pantosteus) platyrhynchus* was first described by Cope (1874) as *Minomus platyrhynchus* from specimens collected from Provo, Utah. The generic designation was subsequently changed to *Pantosteus* by Cope and Yarrow (1875). However, Smith (1966), in an extensive review of the taxonomy of Catostomidae, combined *Pantosteus platyrhynchus* with two other species, *Pantosteus lahontan* (Rutter 1903) and *Pantosteus jordani* (Evermann 1893), and reclassified all three as one species under the genus *Catostomus* while retaining *platyrhynchus* as the specific name. The former genus *Pantosteus* was reduced to a subgeneric status. The three former species, however, may deserve subspecific recognition.

Distribution: Although this species is widely distributed in the western United States (Smith 1966, Snyder 1983), in California it is restricted to the Lahontan system (Fig. 30) and possibly the North Fork of the Feather River (Smith 1966), although there are no recent records from the latter stream. In any case, the Feather River population presumably resulted from an irrigation diversion into the basin from the Truckee River (E. Erman, pers. comm.). Scattered populations are found in the Truckee, Walker, and Carson River drainages (Decker 1984, Moyle unpubl. data). It has been studied extensively in the Little Truckee River and associated streams such as Alder, Prosser, and Sagehen creeks (Flittner 1953, Gard and Flittner 1974, Decker 1984, Olson and Erman 1987).

Habitat Requirements: In the Little Truckee stream system, Olson and Erman (1987) found that most mountain suckers were in stream sections distal to the reservoirs. However, within this distribution, there was some spatial separation between adults and juveniles, with juveniles in stream habitat closer to the reservoirs.

Contrary to descriptions of habitat requirements elsewhere (Smith 1966, Snyder 1893), mountain suckers in California streams generally occupy pool-like habitats. Olson and Erman (1987) found that mountain sucker abundance was positively correlated with pools, but negatively correlated with riffles. Decker (1984) observed that mountain suckers were never found in riffles and swift currents despite presumed morphological adaptations for inhabiting fast water. Decker (1984) also found that mountain sucker abundance was greatest in areas with cover, especially where abundant instream root-wads were present. Suckers presumably require such cover as refuge, and fish were often observed resting on the bottom in close proximity to some form of cover during daylight hours.

Mountain suckers in Montana streams tended to form exclusive schools and thus were separated from other catostomids (Hauser 1969). However, in California streams they form mixed schools with Tahoe sucker (*Catostomus tahoensis*) (Decker 1984), and there is a positive correlation between mountain sucker abundance, Tahoe sucker abundance, and speckled dace (*Rhinichthys osculus*) abundance (Olson and Erman 1987).

Life History: Mountain sucker feed mostly on algae and diatoms as well as on small quantities of aquatic insects and other invertebrates (Smith 1966). The mode of feeding that involves scraping food off the substrate also results in a high proportion of sand and grit being ingested. The diet of juveniles (<30 mm TL) contains a higher proportion of insects (Hauser 1969).

Hauser (1969) documented growth rates of mountain sucker from streams in Montana and found that by the first year they reached 60-65 mm TL and by the second year, 90-100 mm TL. Average growth rates are greatest during the first year and decrease gradually through the third year, after which growth is slow and constant. This pattern is probably true of the California population as well.

Males mature earlier than females (Hauser 1969). However, females are larger than males and seem to live longer (7 yrs for males and 7-9 yrs for females). Males become reproductive by the third year when approximately 127 mm TL, whereas females mature by the fourth year at approximately 175 mm TL (Smith 1966). Fecundity is variable, females producing between 990 (for a 131 mm TL specimen) and 3710 (for a 184 mm TL specimen) eggs.

Upstream migrations during the early summer have been associated with spawning (Decker 1984). Spawning is thought to occur between the last week of June and the first two weeks of July when water temperature is between 11-19°C (Smith 1966, Hauser 1969, Snyder 1983), and takes place in gravel riffles (Moyle 1976). Spawning behavior has not been described in detail, but Decker (1984) observed mountain suckers spawning in an open gravel riffle on 22 June 1983 in Sagehen Creek, California.

Status: Class 3.

Although the Lahontan mountain sucker is still widespread in California and Nevada, its populations in California seem to be in a general decline (Decker 1984, Olson and Erman 1987).

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This decline is tied to stream alterations and modifications, especially the construction of dams and reservoirs that isolates populations. Such populations apparently do not persist in reservoirs, and so the species becomes confined to tributary streams. Furthermore, because their favored habitats are the lower reaches of streams, now flooded by reservoirs, the remaining habitat supports only small populations that are vulnerable to extirpation.

Management: Olson (1988) noted that streams in which mountain suckers had sharp declines were also characterized by declines of Lahontan speckled dace and mountain whitefish. Thus the decline of mountain sucker is probably a good indicator that native fish and invertebrate assemblages of the Lahontan drainage of California are in some trouble. It is therefore important that a number of streams in the basin are identified in order to manage them specifically for maintaining the integrity of the native biotic community, which includes the sucker.

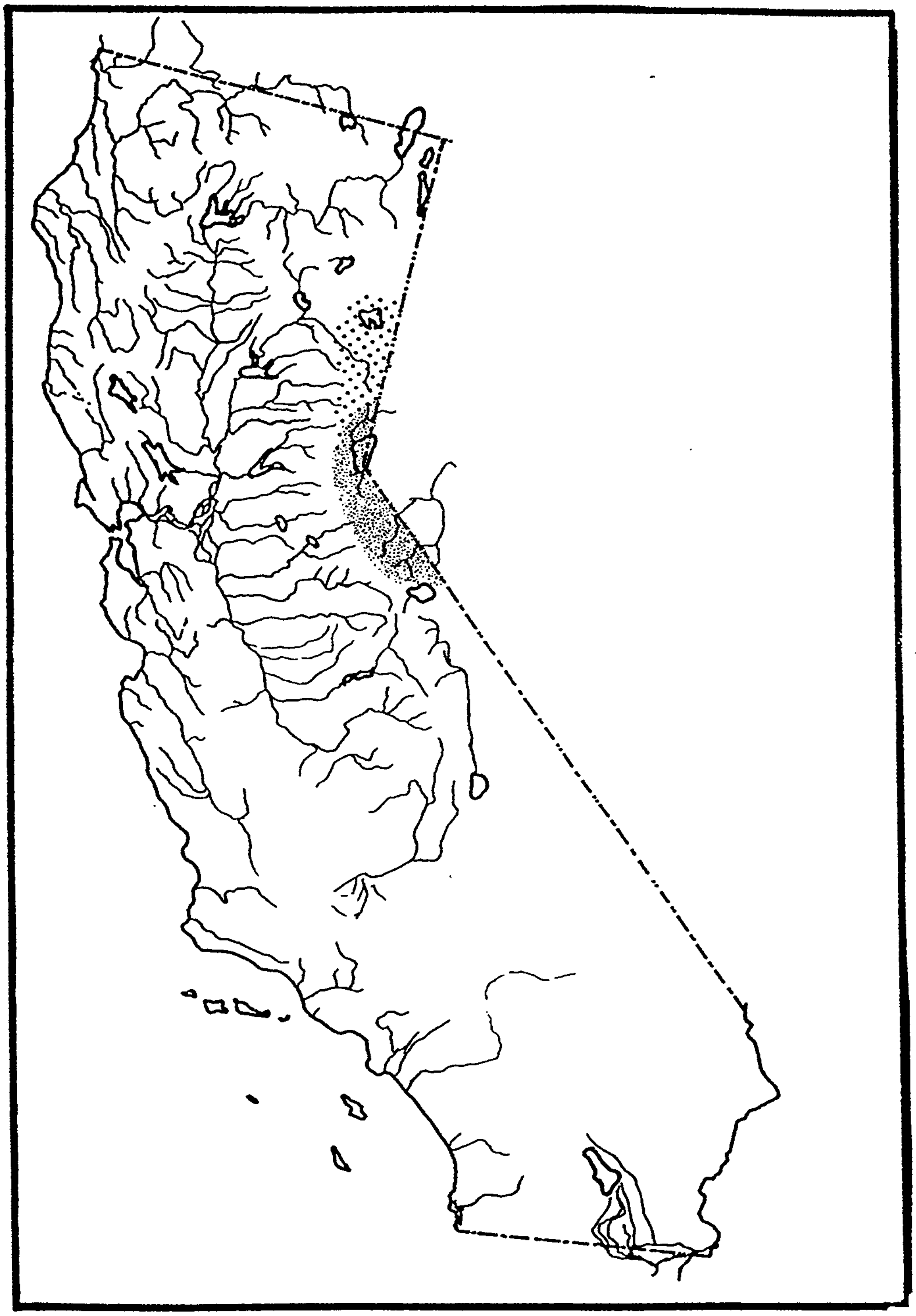

FIGURE 30. Distribution of the mountain sucker, *Catostomus platyrhynchus*, in California. Fine stippling indicates recent distributions and larger stippling indicates past records.

SANTA ANA SUCKER
Catostomus santaanae (Snyder)

Description: Adult Santa Ana suckers are usually less than 175 mm SL and resemble mountain suckers (*Catostomus platyrhynchus*) in gross morphology. Santa Ana suckers also possess notches at the junctions of upper and lower lips (as do mountain suckers), but the median notch on the lower lip is less well defined. Large papillae are distributed in a convex arc on the anterior lower lip. Papillae are poorly developed on the upper lip. Cartilaginous plates are present on the inside of the lips. In fish >70 mm SL, the fontanelle on the head is closed.

There are 21-28 gill rakers on the external row of the first gill arch and 27-36 gill rakers on the internal row. The lateral line has 67-86 scales and there are 27-41 predorsal scales. The short dorsal fin has 10 fin rays (may range from 9-11) and the pelvic fins have 8-10 rays. The axillary process at the base of the pelvic fins is a simple fold. The caudal peduncle is deep, being 8-11% SL. The intestine is long, with up to 8 coils adapting Santa Ana suckers to a herbivorous trophic status. The peritoneum is black.

Body coloration of fish is silver on the ventral surface and darker with irregular blotches on the dorsal surface. The melanophore pattern of the scales resembles longitudinal lateral striping. The interradial membrane of the caudal fin is pigmented. Reproductive males develop breeding tubercles over most of the body, but tubercles are most dense on the caudal and anal fins and the caudal peduncle. Reproductive females possess tubercles only on the caudal fin and the peduncle.

Taxonomic Relationships: *Catostomus santaanae* was originally described as *Pantosteus santa-anae* by Snyder (1908) who collected the fish from the Santa Ana River, Riverside, California. The hyphen was then omitted from the specific name and the genus assigned to *Catostomus* in a subsequent revision of the nomenclature (Smith 1966).

Santa Ana suckers exhibit variability in certain anatomical characteristics that among other members of the subgenus *Pantosteus* are more homogeneous (Smith 1966). The characters that commonly show variability are the degree of papillation of the anterolateral corners of the lower lip, the degree of pigmentation of the caudal interradial membrane, and the development of the pelvic axillary process. Within the species, however, there is little differentiation among populations from the four adjacent, but isolated, rivers (Smith 1966).

Distribution: Santa Ana suckers are endemic to southern California and the native range consisted of the Santa Ana, Los Angeles, San Gabriel, and Santa Clara river drainages (Fig. 31, Smith 1966). Today, native populations are confined to the middle reaches of the Santa Ana River and Big Tajunga Wash in the Los Angeles River drainage (C. Swift pers. comm.). The only large, population is in the East, West, and North Forks of the San Gabriel River (Wells and Diana 1975).

There is also a population in the Santa Clara River, but it may have been derived from a relatively recent introduction (Miller 1968, Greenfield et al. 1970, Swift 1980). Buth and Crabtree (1982), in an effort to substantiate this idea, conducted electrophoretic investigations on the genetic variability in the Santa Ana sucker population of the Santa Clara River. However, the results could not resolve whether or not the population was the result of a recent introduction. There is some evidence to suggest that the Santa Ana suckers in the Santa Clara River drainage may be hybridizing with Owens suckers (*C. fumeiventris*) that were accidentally introduced from the Owens River (Bell 1978).

Habitat Requirements: Santa Ana suckers are generally found in small to medium sized (<7 m wide) streams in water ranging in depth from a few centimeters to a meter or more (Smith 1966, Deinstadt 1988). Flow is described as ranging from slight to swift. Although Santa Ana suckers are usually found in clear water, they can tolerate seasonal turbidity. Preferred substrates are generally coarse, consisting of sand, rubble, and boulder, but occasionally Santa Ana suckers are found on sand/mud substrates. Santa Ana suckers are associated with algae but not with macrophytes. Greenfield et al. (1970) recorded that Santa Ana suckers were washed down into the Santa Clara River from a recreational lake, indicating that Santa Ana suckers are capable of inhabiting reservoirs. Even though Santa Ana suckers seem to be quite generalized in their habitat requirements, they are intolerant of polluted or highly modified streams.

Life History: The only extensive study documenting the life history of the Santa Ana sucker is by Greenfield et al. (1970). They found 97% of the stomach content of Santa Ana sucker consisted of detritus, algae, and diatoms; aquatic insect larvae, fish scales, and fish eggs constituted three percent. They also found that larger fish usually had a higher percentage of insect material in their diets. Growth rates indicate that by the first year Santa Ana suckers are 61 mm, by the second year 77-83 mm, and by the third 141-153 mm SL.

Santa Ana suckers are relatively short-lived. They become reproductively mature by the first year and spawn during the first and second years. Few suckers survive beyond the second year and none beyond the third year. There is no sexual dimorphism and the sex ratio is 1:1. Females are highly fecund and produce between 4,423 (for a 78 mm SL female) and 16,151 (for a 158 mm SL female) eggs. Santa Ana suckers are more fecund than most other catostomids. There is also a linear relationship between size and number of eggs produced. Eggs hatch within 360 hr (at 13°C) and are demersal and adhesive. Spawning occurs from April until early July, but peaks from late May through early June.

The streams in which Santa Ana suckers are found are subject to periodic, severe flooding resulting in drastic decreases in sucker population densities. Greenfield et al. (1970) sampled the Santa Clara River one week following a flood in late January 1969 and collected only 120 Santa Ana suckers, compared to 225 collected the previous December. Santa Ana suckers, however, are adapted for living in such unpredictable environments and are able to repopulate the rivers following floods. Such adaptations include short generation time (early maturity), high fecundity, and relatively prolonged spawning period. These characteristics enable Santa Ana suckers to rapidly recolonize rivers following a flood by producing more young over a longer time span. The short generation time allows Santa Ana suckers to reproduce early in life, as the probability of adult mortality is high. The small size also probably enables individuals to utilize a greater range of instream refuges that would be unavailable to larger fish during high flows. The greater dependence on detritus, algae, and diatoms by juveniles has been viewed as another adaptation for survival in stochastic environments (Greenfield et al. 1970).

Status: Class 2.

The range of the Santa Ana sucker is largely coincident with the Los Angeles metropolitan area, so it is not surprising that its populations have declined in recent years. It is nearly gone from the Santa Ana and Los Angeles river drainages where it was presumably once widespread. Even streams in which it seems to be fairly secure (e.g., the San Gabriel River system) can be affected by factors related to urbanization such as pollutants carried by air, heavy recreational use, or frequent forest fires. Fortunately the sucker is adapted for surviving extreme environmental perturbations so populations can recover from disasters, providing there is a source of colonists and provided the habitat is suitable. However, if several streams are not managed to maintain its populations, Santa Ana sucker will soon be a candidate for endangered status.

Management: As much of the San Gabriel River system as possible should be managed as a native fish sanctuary. The reaches on USFS land should be given special management designation by USFS to protect native fishes. The Santa Ana, Los Angeles, and Santa Clara river drainages should be thoroughly surveyed to find possible sites to manage as native fish sanctuaries. Studies of reservoirs in the range of the sucker are needed to see if they are used by significant portions of the sucker populations. Annual or biennial surveys of existing populations should be conducted to determine long-term population trends. However, surveys should be conducted with seines or by snorkeling because electrofishing may cause high mortalities of suckers.

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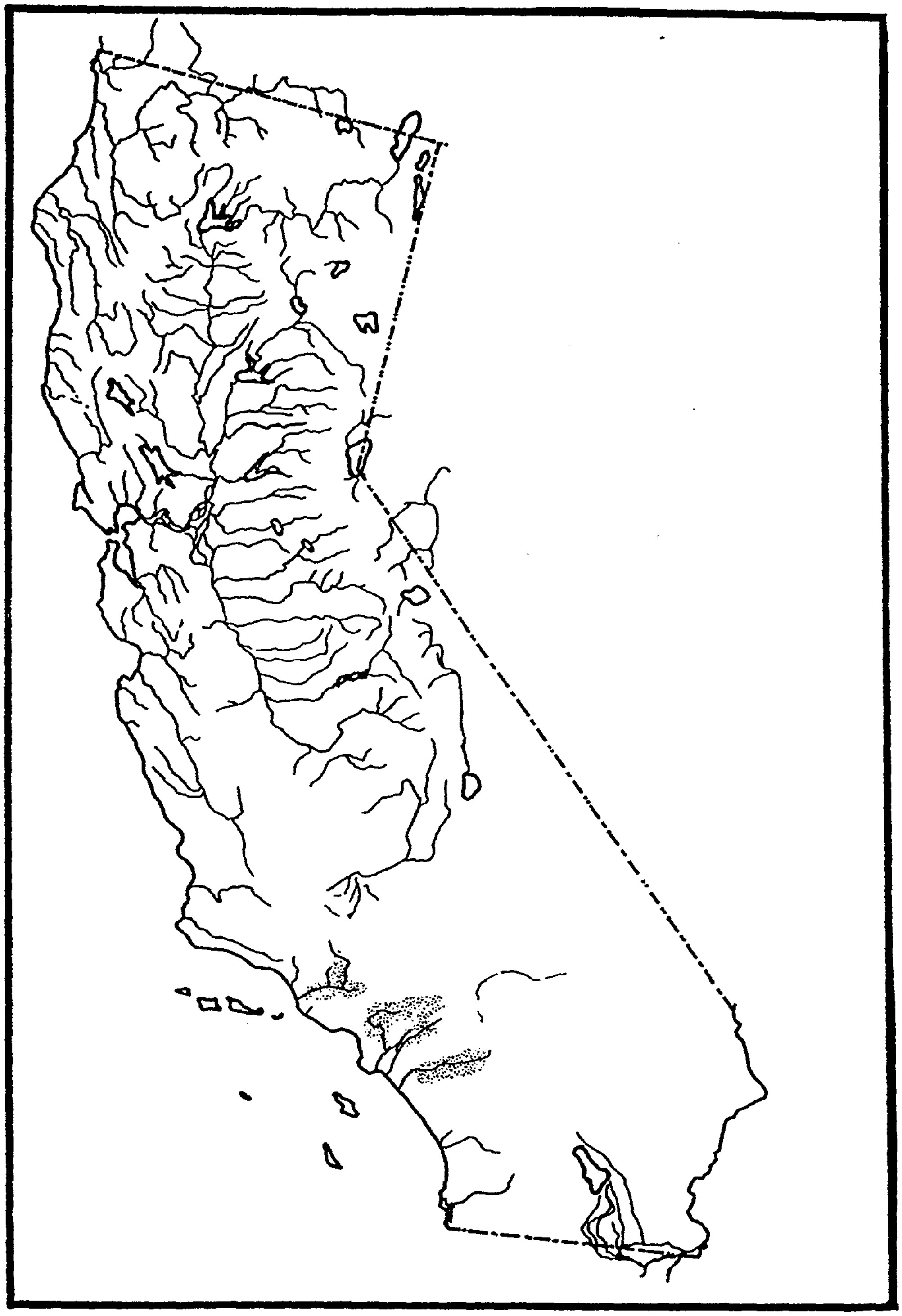

FIGURE 31. Distribution of the Santa Ana sucker, *Catostomus santaanae*, in California.

SARATOGA SPRINGS PUPFISH
Cyprinodon nevadensis nevadensis (Eigenmann and Eigenmann)

Description: These are small fish that rarely exceed 5 cm in length. The body is deep, especially in reproductive males. The head is blunt and slopes steeply in front to a small, terminal, oblique mouth. There is one row of tricuspid teeth on each jaw, with the central cusps being truncated or pointed.

C. nevadensis is an extremely variable species, but can be distinguished from other pupfish by the following characteristics: (1) the scales are large, the circuli lack spine-like projections, and the interspaces are reticulated; (2) there are 23 to 28 scales (usually 25 to 26) along the lateral line and 15 to 24 scales (usually 16 to 18) anterior to the dorsal fin; (3) the pelvic fins are reduced and may even be absent; (4) there are 8 to 11 anal fin rays (usually 10), 11 to 18 pectoral fin rays (usually 15 to 17), 0 to 9 pelvic fin rays (usually 6), and 14 to 22 caudal fin rays (usually 16 to 19); gill rakers range from 14 to 22 (usually 15 to 17) and preopercular pores from 7 to 17 (usually 12 to 14).

Reproductive males in nuptial coloration are bright blue with a black band at the posterior edge of the caudal fin. Reproductive females are drab olive brown and develop 6 to 10 lateral vertical bars which may be distinct or faint. An ocellus is typically present on the posterior base of the dorsal fin of females.

The subspecies *C. n. nevadensis* can be distinguished from the other subspecies by the deeper, broader body, anteriorly placed pelvic fins, and a greater than average number of fin rays and scales (Table 10). Scales are narrow and larger, with very dense and extensive reticulations and a high number of scale radii. Males of this subspecies have an intense blue coloration (Soltz and Naiman 1978).

Taxonomic Relationships: The fossil record and past geologic events suggest that the *Cyprinodon* species differentiated relatively recently, with most differentiation occurring during the pluvial-interpluvial fluctuations of the early to mid-Pleistocene (Miller 1981). Some differentiation may have even occurred in the last 10,000 years, following the final recession of the pluvial waters. As the numerous lakes and streams scattered throughout the Great Basin shrank during the Pleistocene, remnant populations of pupfish survived in isolation, leading to speciation of *C. nevadensis.*

Cyprinodon nevadensis from Saratoga Springs in the southern arm of Death Valley, San Bernadino County, California, was first described by Eigenmann and Eigenmann (1889). Following the initial description, the species was lumped with *Cyprinodon macularius* until Miller (1943) resurrected the species by extensive analysis of collections. In subsequent studies of *C. nevadensis*, Miller (1948) recognized and described six subspecies, of which four occur in California (*C. n nevadensis*, *C. n. amargosae*, *C. n. shoshone*, and *C. n. calidae*) and two in Nevada (*C. n. mionectes* and *C. n. pectoralis*). *Cyprinodon n. calidae* is now extinct (Moyle 1976).

TABLE 10. Comparative morphometrics and meristics of *Cyprinodon nevadensis* subspp. Adapted from Miller (1948).

Measure/Count	*C. n. amargosae* male	*C. n. amargosae* female	*C. n. nevadensis* male	*C. n. nevadensis* female	*C. n. shoshone* male	*C. n. shoshone* female
Standard length (mm)	36		40		34	
*Body width	256	265	274	269	231	229
*Head length	305		312		307	
*Head depth	330	304	367	343	331	311
*Head width	240	259	257	256	233	231
*Snout length	101		97		89	
*Mouth width	117		115		114	
*Mandible length	98		95		93	
*Anal origin to caudal base	338	346	394	362	371	355
*Caudal peduncle length	264	237	277	253	263	251
*Anal fin base length	116	105	111	105	108	101
*Anal fin length	233	199	227	195	217	190
*Pelvic fin length	98	89	95	87	90	77
Anal fin ray count	10		10		10	
Dorsal fin ray count	10		10		10	
Pelvic fin ray count	6		6		4	
Pectoral fin ray count	16		16		16	
Caudal fin ray count	18		17		18	
Lateral line scales	26		26		26	
Predorsal scale count	19		18		18	
Dorsal fin to pelvic fin scale count	11		10		9	
Caudal peduncle circumference scale count	16		16		15	
Body circumference scale count	27		25		23	

*Expressed as % standard length X 1000.

Distribution: *Cyprinodon n. nevadensis* is found only in Saratoga Springs and its outflow in Death Valley, San Bernadino County, California (Fig. 32). This spring is one of four adjacent springs that are among the largest in the California desert. They are located at an elevation of

70 m and are tributary to the Amargosa River (Miller 1948). The overflow from the springs forms a series of marshes and shallow lakes.

Habitat Requirements: Saratoga Springs is circular in shape, approximately 10 m in diameter and 1 to 2 m deep (Miller 1948). The water is clear with some algal material and detritus on the quicksand bottom. Water temperature is rather constant at 28 to 29°C. The spring overflows to the north into a larger pond that in turn drains into a number of shallow lakes approximately 4 to 6 hectares in area. Lake bottoms are grassy and the substrate consists of mud and sand. Water temperatures fluctuate considerably with ambient temperature and may vary from 10 to 49°C on a seasonal basis. Depth along the shores ranges up to 50 cm. Fish remain along the shores but move into the marshy meadows when disturbed. Juvenile fish abound in the lakes but are absent from the main spring, suggesting that spawning occurs only in the lakes.

Life History: As a species, these pupfish exhibit many characteristics that adapt them to live in habitat with thermal and osmotic extremes (Miller 1981). Their growth is extremely rapid and they become sexually mature within four to six weeks (Miller 1948). Such short generation times enables the pupfish to maintain small but viable populations (Moyle 1976). Among the subspecies, however, there are minor differences in generation times, with pupfish in habitats with widely fluctuating environmental conditions exhibiting shorter generation times (Moyle 1976).

Young adults (15-30 mm SL) of *C. nevadensis* usually contribute to most of the biomass throughout the year (Naiman 1976). Highest densities and peak breeding season occur during summer when water temperatures are higher and food is abundant (Kodric-Brown 1977). However, in the thermally stable habitats of the springs, the breeding season is continuous year-round. In the river where thermal conditions are more variable, the breeding season extends throughout spring and summer (Kodric-Brown 1981).

Cyprinodon n. nevadensis, like other spring-dwelling subspecies, exhibits a different reproductive behavior than riverine forms (Kodric-Brown 1981). The males of spring-dwelling subspecies establish territories over substrate with a topographic complexity suited for oviposition. Both sexes are promiscuous, and a single female may lay eggs in a number of different territories. The demersal eggs are sticky and thus adhere to the substrate. Females may lay a few eggs each day (not necessarily on consecutive days) throughout the year. Territorial defense by the males confers some protection of the eggs from predators, but otherwise parental investment is limited to gamete production (Kodric-Brown 1981). However, such territorial behavior is dependent on space availability and substrate complexity.

Pupfishes are capable of precise thermoregulation and usually exploit habitat close to their thermal maxima (Gerking 1981). The most sensitive phase of the life history of pupfishes to thermal stress is during reproduction (Gerking 1981). Although the adults have wide temperature tolerances (2-44°C), their reproductive tolerance limits are narrow, ranging from only 24 to 30°C. Extreme temperatures affect egg production and egg viability (Shrode and Gerking 1977, Gerking 1981). Furthermore, reproductive performance does not improve despite generation-long acclimation to sub-optimal temperatures (Gerking et al. 1979). Thus, any alterations to their habitat that would result in temperature changes outside of the range of their reproductive temperature optima would be potentially deleterious. Eggs, however, become resistant to environmental stresses within hours of being laid.

Pupfishes feed primarily on blue-green algae. They feed seasonally on small invertebrates, mostly chironomid larvae, ostracods, and copepods (Naiman 1975, 1976). They forage continuously from sunrise to sunset and become inactive during the night. Their guts are extremely long and convoluted, an adaptation that enables them to digest blue-green algae. Their teeth are also adapted for feeding behavior which involves nipping (Moyle 1976).

Status: Class 3.

Historic distribution is restricted to Saratoga Springs and outflows which lie entirely within Death Valley National Monument. No exotic species have been collected from the habitat. Periodic surveys have found this pupfish population to be stable and occupying all available habitat. Although protected, disturbances to the limited habitat could quickly cause extinction. *Cyprinodon n. nevadensis* has been introduced and become established in Lake Tuendae, San Bernardino County (Turner and Liu 1976).

Management: Saratoga Springs and the habitat created by their outflow are protected by the National Park Service. Because of restricted range and vulnerability of the pupfish to introduction of exotic species, however, annual population monitoring should be conducted. A contingency plan should include the identification of habitats or facilities to temporarily hold pupfish from Saratoga Springs in the event population loss appears imminent. Management of Ft. Soda (Lake Tuendae) and the Mohave tui chub should encourage conservation of the introduced population of Saratoga Springs pupfish. Further introductions of this pupfish into nonnative habitats are not warranted at this time.

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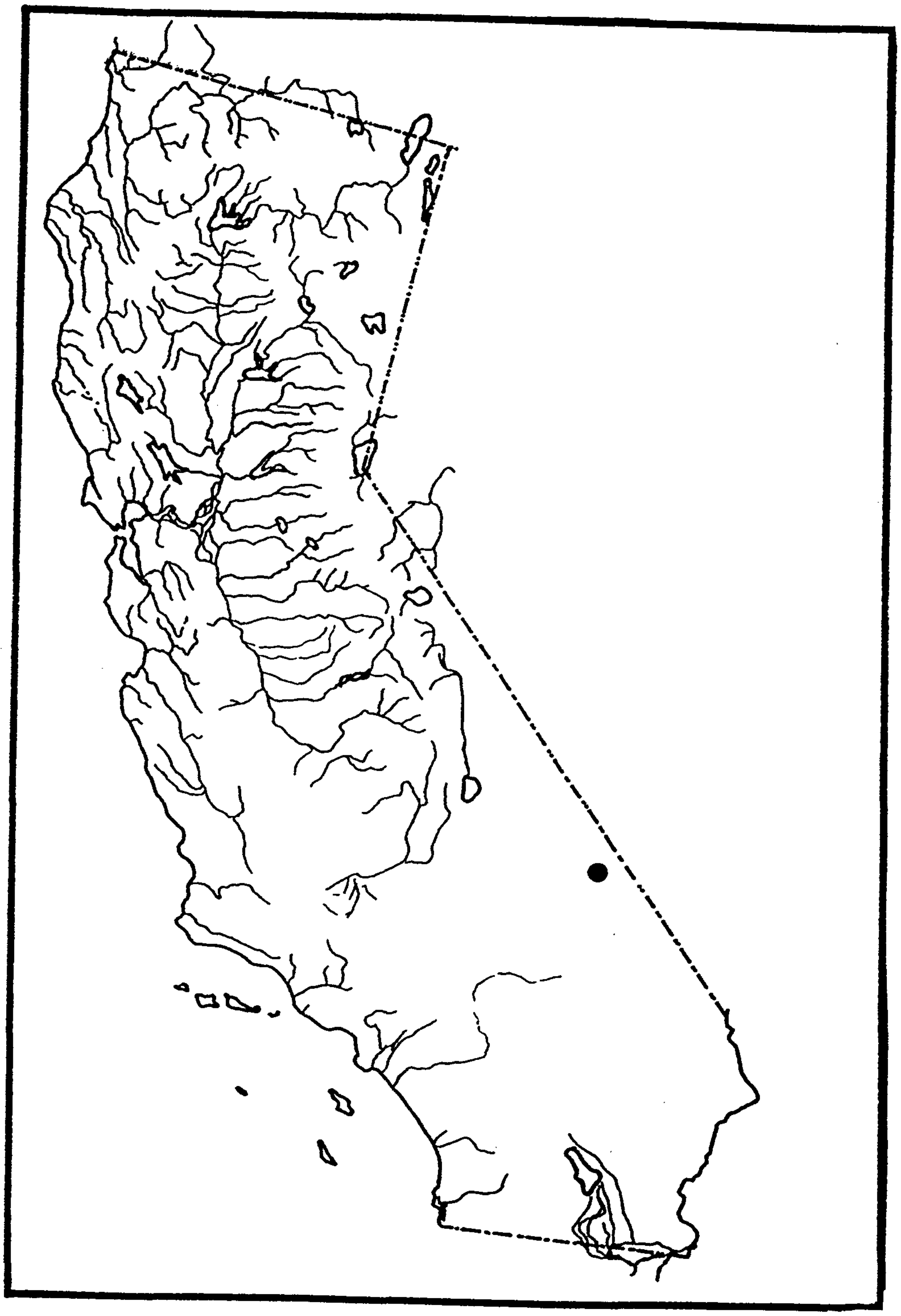
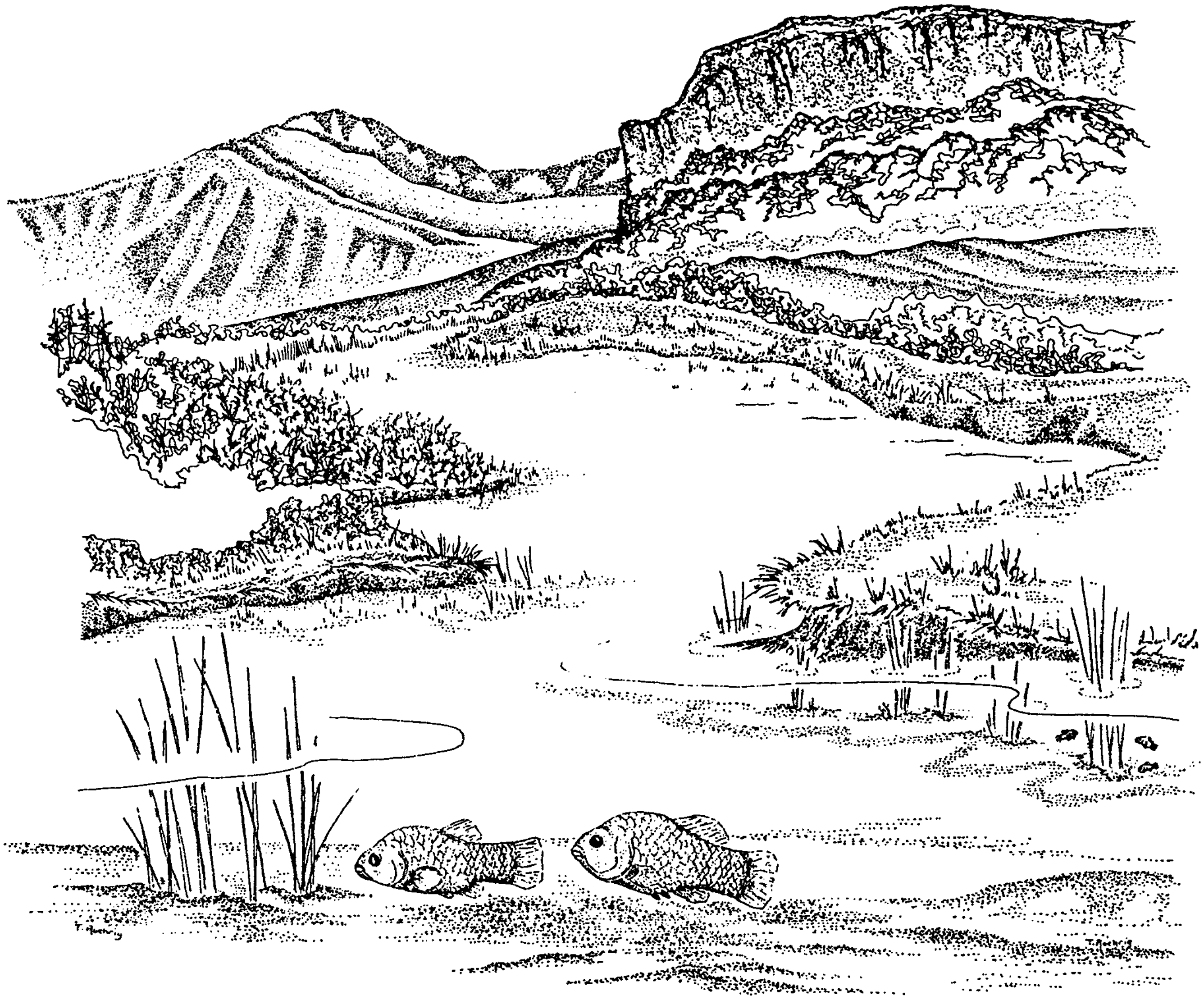


FIGURE 32. Distribution of the Saratoga Springs pupfish, *Cyprinodon nevadensis nevadensis*, in Saratoga Springs, San Bernadino County, California.



AMARGOSA PUPFISH
Cyprinodon nevadensis amargosae (Miller)

Description: This subspecies is similar to *C. n. nevadensis* but has more scales around the body and fewer scale radii than other subspecies (Table 10).

Taxonomic Relationships: *Cyprinodon nevadensis amargosae* is one of three extant subspecies of *C. nevadensis* found in California. Their relationships are discussed under *C. n. nevadensis* (preceding chapter).

Distribution: *Cyprinodon n. amargosae* is the most widely distributed subspecies of this species, inhabiting two sections with permanent flows of the lower Amargosa River (Fig. 33). The upper section begins above Tecopa and flows through Amargosa Canyon for about 11 km until it approaches Sperry. The second, lower section flows through Death Valley northeast of Saratoga Springs and approximately 32 km below Sperry and continues for about 3 km. Differences in meristic characteristics between the two populations suggest that they are effectively isolated from each other (Miller 1948), except perhaps in times of floods.

Habitat Requirements: The upper section of the lower Amargosa River is divided into two distinct areas. The upstream area near Tecopa is characterized by broad marshes fed by hot springs. The second area is immediately downstream where the river flows through a narrow, steep-sided canyon. The river there is less than 2 m wide and up to 2.5 m deep. The flows are swift in the runs between pools and the substrate consists mostly of gravel and sand, with some boulder and rubble (Miller 1948, Williams et al. 1982). The water is clear and saline, with pH ranging from 8.2-8.7. Total dissolved solids are fairly high and variable at 1390-3890 ppm and dissolved oxygen is 7.3-11.6 mg l^{-1}. Shoreline vegetation is abundant. Pools are numerous, both in the river and in the flood plain, the largest being about 8 x 5 m. Substrate in the pools is mostly mud and clay. Water temperature in habitat where fish are found is 20-21°C (Miller 1948) and preferred depth and velocity range from 10-35 cm and 0.05 m^3 sec^{-1} respectively (Williams et al. 1982).

The downstream section in Death Valley is at an elevation of 33 m (Miller 1948). The river bottom consists of fine silt, clay, mud, and sand and there is no instream vegetation. The current is moderate to swift between pools that are 0.75-1.25 m deep. Water temperature varies seasonally from 10 to 38°C. During severe winters, temperatures may approach freezing. Diel variation in water temperature is also present and there is a tendency for longitudinal and vertical temperature stratification. Younger fish tolerate higher water temperatures than adults (Shrode 1975) and are commonly found in warmer water (Miller 1948) that may serve as a refuge from predation or competition for food.

Life History: The life history of this subspecies is similar to *C. n. nevadensis*. Being a riverine fish, however, its reproductive strategies differ from many spring-dwelling pupfishes. *Cyprinodon n. amargosae* is a group spawner (Kodric-Brown 1981). The male usually directs a receptive female to the periphery of the group where spawning occurs. However, spawning may even take place in the center of the group. In the Tecopa area, this subspecies also inhabits torrid outflows of hot springs, habitats formerly occupied by *C. n. calidae*. Males do not establish and defend territories as do males of spring-dwelling subspecies.

The pupfish feed primarily on blue-green algae but also ingest lesser quantities of small invertebrates (mostly chironomid larvae, ostracods, and copepods) (Naiman 1975, 1976). They forage continuously during the day but become inactive during the night.

Status: Class 3.

This pupfish appears to be the most widespread of any *Cyprinodon nevadensis* subspecies and is common in the lower Amargosa River, particularly around Tecopa and in the Amargosa Canyon. It also occurs in an isolated downstream reach of river in Death Valley National Monument. Diversions of springs and outflows on private land in the Tecopa area have reduced the local population. Mosquitofish that are associated with declines of other pupfish species often are abundant in Amargosa Canyon yet Amargosa pupfish seem to be able to coexist with them (Williams et al. 1982). Flash floods periodically reduce mosquitofish populations, to the advantage of pupfish. The possibility of additional introductions of exotic fishes into Amargosa River exists. A catfish farm located upstream in Shoshone will require careful management to prevent escape and subsequent establishment of unwanted species in the river. With an increasing human population in Tecopa and the upper Amargosa Valley, demand for water and protection from floods will increase. The pupfish populations, therefore, should not be regarded as secure.

Management: Populations should be monitored annually. Efforts should be made to insure a natural flow of water in the Amargosa River, including flood flows which reduce populations of introduced fishes. Management strategies should protect populations in both the upstream segment (Tecopa area and Amargosa canyon) and the downstream segment (in Death Valley) to maintain genetic diversity. Fortunately, most of the Canyon area is now owned by The Nature Conservancy and BLM. Amargosa Canyon is part of an Area of Critical Environmental Concern and is closed to off-road vehicle use. Fences and barriers need to be properly maintained, however, as vehicle trespass is a common problem. The downstream section in Death Valley is managed by the National Park Service but is dependent on water availability from upstream, unprotected areas.

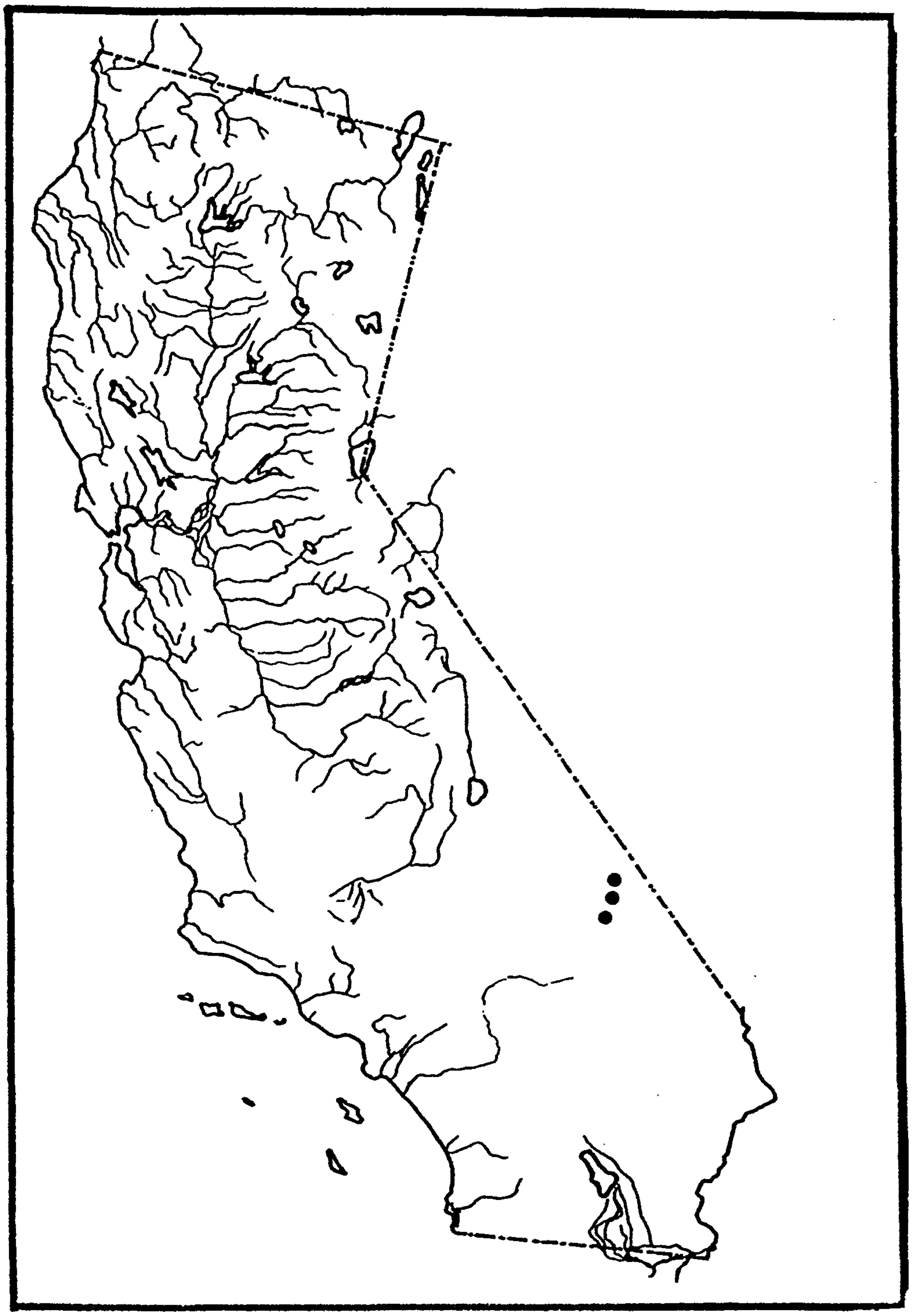


FIGURE 33. Distribution of the Amargosa pupfish, *Cyprinodon nevadensis amargosae*, in the lower Amargosa River, California.

C-046099

SHOSHONE PUPFISH

Cyprinodon nevadensis shoshone (Miller)

Description: The morphology of this subspecies is similar to *C. n. nevadensis*. However, it is characterized by large scales and a "slab-sided," narrow, slender body, with the arch of the ventral contour much less pronounced than the dorsal. It also has fewer fin rays and scales than the other subspecies (Table 10).

Taxonomic Relationships: See discussion under *C. n. nevadensis*.

Distribution: *Cyprinodon n. shoshone* is found in the Shoshone Spring (Fig. 34) and throughout its outlet creek (Miller 1948, Taylor et al. 1988). Taylor et al. (1988) also considered pupfish in the Amargosa River near the Shoshone Spring outlet creek to be *C. n. shoshone*, but this finding remains tentative pending a detailed examination of the fish. The spring is located in Shoshone, Inyo County, California. The spring source is at an elevation of 518 m, about 170 m above State Highway 127 on the east slope of a rocky lava hill. The outlet creek flows under the Old State Highway and becomes confluent with the Amargosa River approximately 400-500 m downstream.

Habitat Requirements: In Shoshone Spring and its outlet creek there were two holes well above the Old State Highway that provided the Shoshone pupfish refuge from the swifter flows in the main channel (Miller 1948). The larger, upper hole (known as "Squaw Hole") was about 1 m in diameter and 0.75 m deep. The water was clear, the bottom muddy. There were overhanging banks. Shoshone Spring was less saline than the other springs and had less boron content but more calcium. Since then the habitat has been subjected to considerable anthropogenic changes (Taylor et al. 1988, Castleberry et al. unpubl. ms.). The spring source has been enclosed by a series of concrete boxes for the past 45 years or so. These boxes direct the water supply to the town of Shoshone, a swimming pool, and a catfish rearing pond. Once the outlet creek emerges from under the Old State Highway, it is augmented with chlorinated outflow water from the swimming pool. The spring outflow between the Old State Highway and State Highway 127 is confined to a concrete ditch. The stream then flows through a dense cattail marsh and an impenetrable tamarisk thicket prior to becoming confluent with the Amargosa River. The depth of the channel during the 1986 collections of Taylor et al. (1988) varied from 8 to 50 cm, width from 8 cm to 1.5 m. Conductivity was 2959 $\mu m\ cm^{-1}$, pH 8.2, and water temperature varied from 28-34°C.

Life History: The life history characteristics of this subspecies have not been studied in detail but is thought to be similar to *C. n. nevadensis*.

Status: Class 1

The Shoshone pupfish was recently considered to be extinct (Selby 1977, CDFG 1980) but was rediscovered in 1986 (Taylor et al. 1988). Although the pupfish was found in "large numbers" through the outflow creek in the summer of 1986 (Taylor et al. 1988), its numbers had dwindled to perhaps less than about 20 individuals by 1988 (J. Williams, unpubl. data). The decline may have been precipitated by the vast numbers of mosquitofish (*Gambusia affinis*) in the outflow creek. Taylor et al. (1988) hypothesized that the Shoshone pupfish survived in very low numbers until conditions became more favorable, when the population expanded. Evidence was presented that the pupfish passed through a genetic bottleneck during the period of a reduced population.

Because of the lack of suitable habitat and the abundance of mosquitofish, most Shoshone pupfish have been removed from the wild. Small stocks of approximately 12 fish each exist at the University of Nevada, Las Vegas, and the University of California, Davis.

The taxonomic status of pupfish in the Amargosa River near Shoshone is uncertain. They may be pure *C. n. shoshone* as hypothesized by Taylor et al. (1988), or *C. n. amargosae* from downstream sources, or some combination thereof.

Management: One or more preserves for pupfish should be established in the headsprings area of Shoshone Spring. Two pools were created in the headsprings area during 1988 and stocked. Fish for reintroduction should eventually be available from stocks at the University of Nevada, Las Vegas and/or University of California, Davis. Until sufficient pupfish are available for stocking, the preserves should be monitored to establish baseline water conditions and checked for presence of introduced mosquitofish.

The cement ditch between the Old State Highway and State Highway 127 should be managed to enhance conditions for the pupfish. This would include maintaining a slight to moderate flow through the channel because a slight flow will be unfavorable to mosquitofish. Conditions in the outflow creek between State Highway 127 and the Amargosa River will have to be monitored to determine if desirable habitat can be restored.

Several studies are needed to enable proper management of this subspecies. A taxonomic evaluation of pupfish in the Amargosa River is needed to determine the presence of *C. n. shoshone* and *C. n. amargosae* genotypes. Because of the similar morphology, electrophoretic and traditional taxonomic studies should be conducted simultaneously. A hydrologic study is also needed to establish the amount of available water and water losses through evaporation from open water and municipal uses.

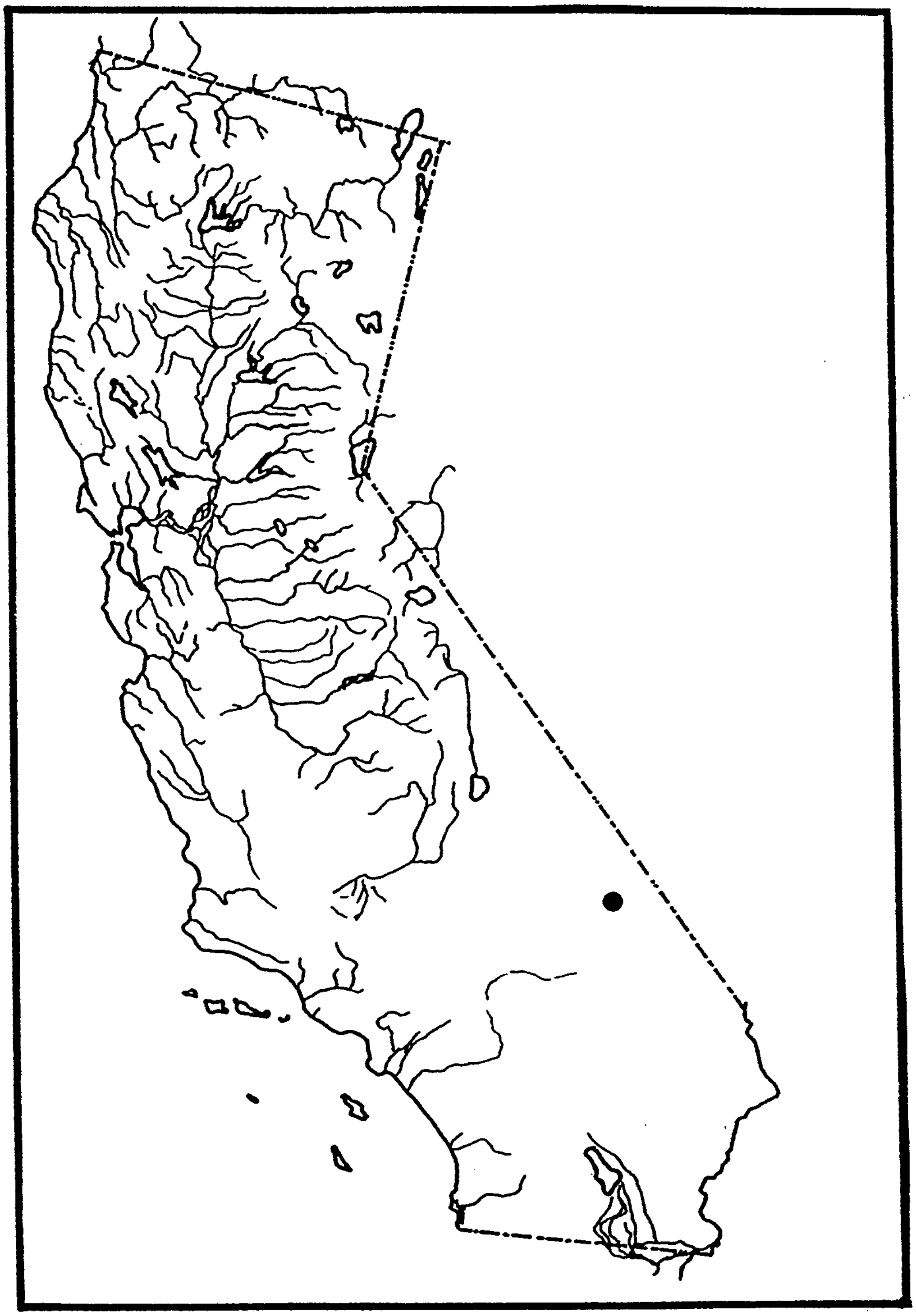


FIGURE 34. Distribution of the Shoshone pupfish, *Cyprinodon nevadensis shoshone*, in Shoshone, Inyo County, California.

C-046103

SALT CREEK PUPFISH
Cyprinodon salinus salinus (Miller)

Description: These are small fish reaching approximately 6.5 cm TL and, of all the species of Death Valley pupfishes, these are the most slender bodied. They have small scales, crowded together, with reticulated interspaces between the circuli. Scales are oval to nearly circular in outline, being intermediate to *C. nevadensis* and *C. macularius* in the number of radii (15-22, usually 18). There are 28 to 29 scales along the lateral line and a high number of predorsal scales; these scales serve to distinguish this species from other western *Cyprinodon* species.

The preorbital region of the head lacks scales. Lateral line pores, especially the preopercular pores, are well developed. The mouth is slightly supra-terminal and has tricuspid teeth with prominent median ridges.

The dorsal fin is set distal to the mid point of the body. The pelvic fins are reduced and may even be absent.

There are 8 to 11 dorsal fin rays (usually 9-10); 9 to 11 anal fin rays (usually 10); 14 to 17 pectoral fin rays (usually 15-16); 15 to 19 caudal fin rays (usually 16-17); and 6 (or no) pelvic fin rays. Gill rakers range from 18 to 22 (usually 19-21) and are shorter and more compressed than in other pupfishes.

Reproductive males are deep blue on the sides and iridescent purple dorsally (Miller 1943). Caudal fins of males have a prominent black terminal band. The sides have 5 to 8 broad black bands that may be continuous or interrupted ventrally. Females have less conspicuous coloration, being brownish with a silvery sheen (Miller 1943). They do, however, have 4 to 8 vertical lateral bars that are less intense than the barring pattern of males except during spawning. Females are also more slender than males, the latter being more deep bodied, with a noticeable arch to their profile anteriorly.

Taxonomic Relationships: *Cyprinodon salinus* was first described by Miller (1943) from Salt Creek in Death Valley. In scale structure, *C. salinus* agrees with the other species of *Cyprinodon* in the Death Valley system. However, other characteristics such as reduced or absent pelvic fins, posterior position of the dorsal fin, short head, small eyes, low mean fin-ray counts, and inconspicuous humeral process, suggest that it is closely related to *C. nevadensis* (Miller 1943). Thus, *C. salinus* probably either shared a common ancestral stock with *C. nevadensis* or became differentiated from *C. nevadensis* during the late Pleistocene when most of Lake Manly, which was contiguous with the Amargosa River, receded and dried up, isolating *C. salinus* in its present habitat (Miller 1981). *Cyprinodon salinus* has subsequently been divided into two subspecies, *C. s. salinus* from Salt Creek and *C. s. milleri* from Cottonball Marsh, into which Salt Creek overflows.

Distribution: Salt Creek pupfish are restricted to Salt Creek, Inyo County, in the Death Valley National Monument (Fig. 35). However, Salt Creek pupfish were introduced in Soda Lake, San Bernadino County, and in River Springs, Mono County (Miller, 1968). The Soda Lake population no longer exists and the pupfish in River Springs have been mixed with *Cyprinodon nevadensis*. Thus, genetically pure *C. s. salinus* apparently are restricted to Salt Creek.

Habitat Requirements: Salt Creek begins from seepages, which collect to form the meandering, mud-bottomed creek. The upper reaches of the creek contains surface water only during the winter and spring. This section, which originates at 60 m below sea level, traverses Mesquite Flat for 1 to 2 km before abruptly entering a narrow, shallow canyon. The flow within the canyon is permanent and provides year-round habitat for the pupfish. The stream channel in the canyon is carved 3 to 7 m deep into the alkaline mud and has a series of large (10 x 25 m by 2 m deep) interconnected pools. These pools provide shelter and refuge for the pupfish. Overhanging salt grass, pickleweed, and saltbush form a protective canopy over the pool edges. The pools also contain heavy growths of aquatic plants that provide instream refuge for the fish.

Below the pool area, the stream is shallow and exposed. Shortly afterwards it emerges from the canyon and disappears into the floor of Death Valley. When flows are high, pupfish may also inhabit this stream section.

Water temperatures in Salt Creek fluctuate from near freezing during the winter to >40°C during the summer. However, the deeper water in the pools seldom exceeds 28°C and may provide temperature refuges, especially for reproduction. Salinity is also high, approaching that of sea water, but the levels of boron (39 ppm) and total dissolved solids (23,600 ppm) are considerably higher.

Life History: These fish are physiologically adapted to tolerate wide temperature and salinity fluctuations. Brown and Feldmeth (1971) found that under experimental conditions *salinus* survived temperatures up to 42°C, and tolerated a wide temperature range. They also survived salinities of up to 67 ppt, but died at 79 ppt (LaBounty and Deacon 1972).

They usually live one year or less (Sigler and Sigler 1987), and have generation times of 2 to 3 months, enabling them to reproduce several times a year. Thus, high populations are built up during favorable conditions of high water and colonization of areas beyond the permanent water takes place. During these periods their numbers have been estimated to be in the millions (Miller 1943). However, when the waters recede, most of these fish get trapped in side pools and in the flood plain and perish. Also, the habitat is vulnerable to flash flooding, which may result in population losses as young fish are washed downstream and adults are isolated in pools that eventually dry (Williams and Bolster 1989).

Status: Class 3.

Salt Creek pupfish are reasonably secure as their native habitat is entirely in the Death Valley National Monument. Two introduced populations of *C. s. salinus* at Lake Tuendee and Adobe Valley have failed (Turner and Liu 1976).

Management: Present management by the Death Valley National Monument is maintaining the native population well. Any future changes should be approved by fish biologists familiar with the pupfish and its habitat.

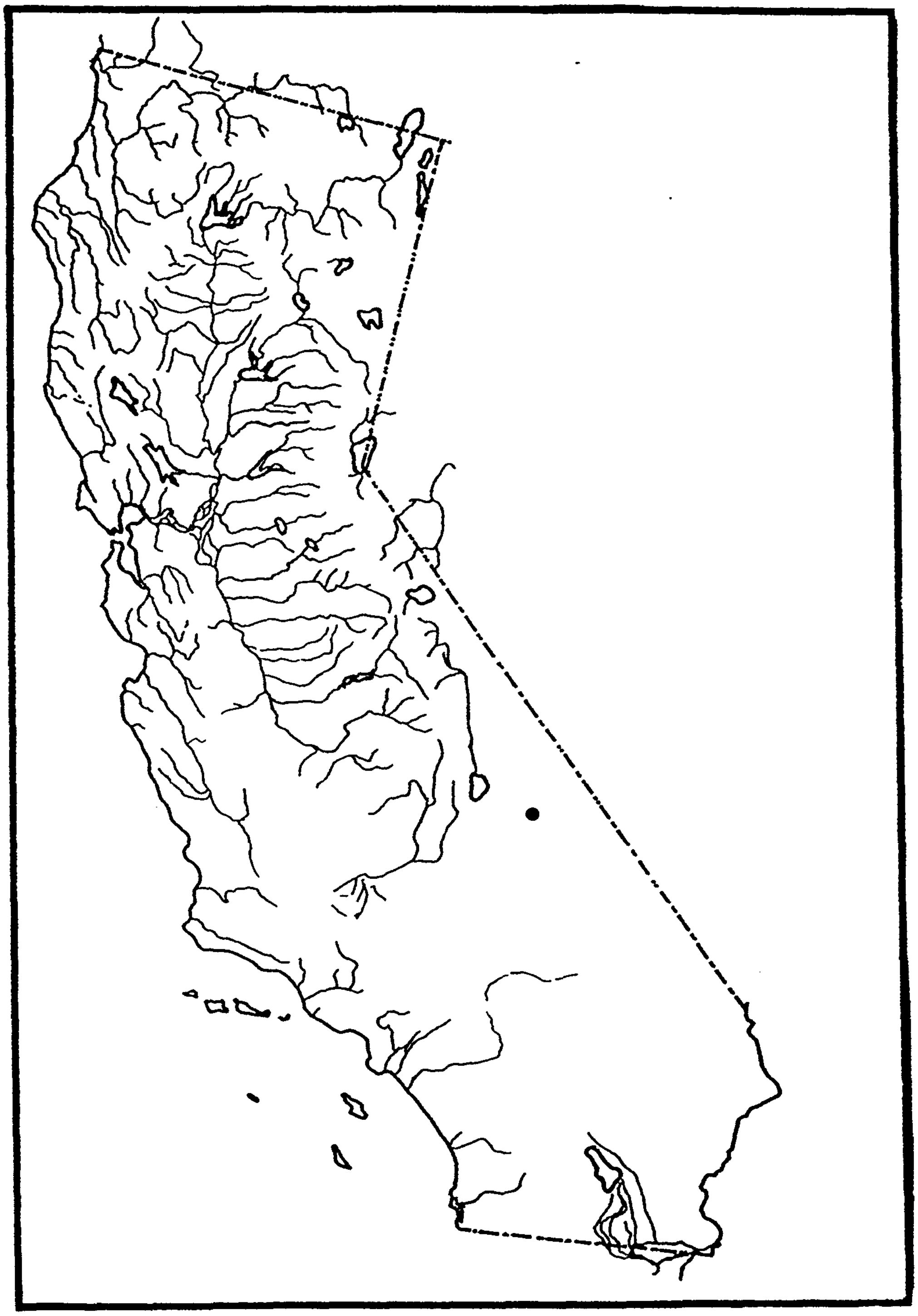
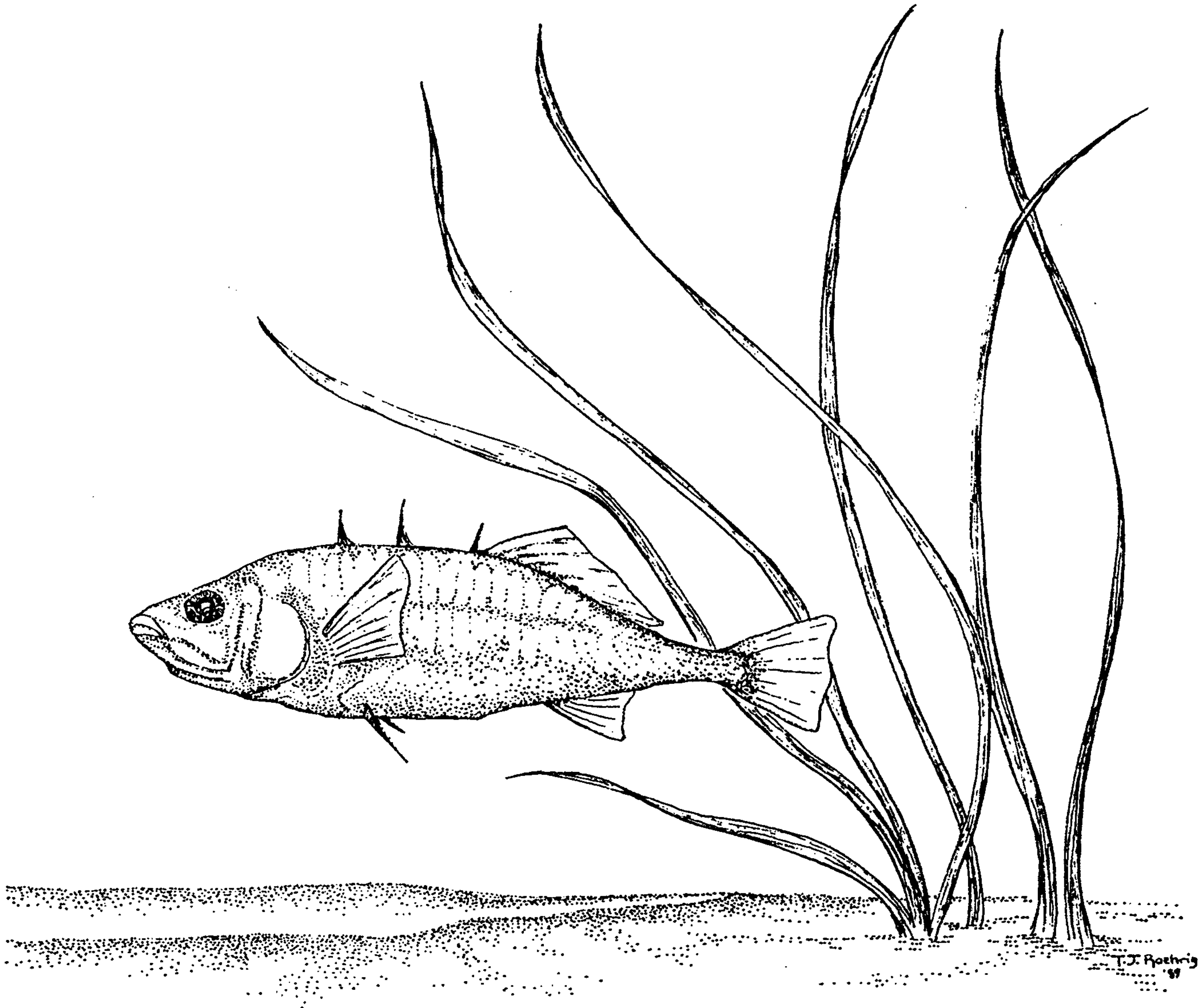


FIGURE 35. Distribution of the Salt Creek pupfish, *Cyprinodon salinus salinus*, in Salt Creek, Inyo County, California.


T.J. Roethig '89

SANTA ANA THREESPINE STICKLEBACK
Gasterosteus aculeatus santannae (Regan)

Description: The Santa Ana threespine stickleback is morphologically similar to the unarmored stickleback, *G. a. williamsoni* (Haglund and Buth 1988, Haglund pers. comm): both lack plates (Haglund and Buth 1988). They are small (maximum size is about 80 mm TL) and have three sharp dorsal spines anterior to the dorsal fin and a short, stout spine derived from modified pelvic fins on each side. The mouth is terminal and oblique and the eyes are large. The caudal peduncle is narrow. Gill rakers number 17-26, dorsal fin rays 10-24, anal fin rays 6-10, and pectoral fin rays from 9-11. There is only one pelvic fin ray.

Adult coloration is usually olive to dark green on the sides and back, and white to golden ventrally. The fins are colorless. Reproductive males acquire a blue nuptial coloration on their sides, iridescent blue or green eyes, and a characteristic bright red throat and anterior ventral area. Females are generally larger than males at maturity.

Taxonomic Relationships: Evidence from electrophoretic studies by R. Haglund and D. Buth (pers. comm.) suggests that even though this population is phenotypically similar to *G. a. williamsoni*, the genetic differences are sufficient enough to warrant subspecific or maybe even species status. Regan (1909) described *G. santa-annae*, an unplated stickleback from the Santa Ana River, but Miller (1960) considered this species to be synonymous with *G. a. williamsoni* because Shay Creek is a headwater tributary of the Santa Ana River. *Santa-annae* (or *santannae*) is the appropriate name for the sticklebacks from this creek.

Distribution: The Santa Ana threespine stickleback is presently known only from Shay Creek, a tributary to Baldwin Reservoir, San Bernadino County, California (Fig. 36). Presumably, the historic distribution of this stickleback included much of the Santa Ana River drainage.

Habitat Requirements: Sticklebacks prefer quiet water habitat such as pools with abundant aquatic vegetation, backwaters areas, and stream margins where water velocity is low. They usually require cool water temperatures below 23-24°C and clear water as they are sight feeders (Moyle 1976).

Life History: Although no information on the life history of the Shay Creek population is available, there is much information on other sticklebacks whose life history is presumably similar (Wootton 1976). Freshwater sticklebacks feed primarily on benthic organisms and organisms found on the surfaces of aquatic plants (Hynes 1950, Hagen 1967). Anadromous populations also feed on pelagic, free-swimming microcrustaceans. Except during the breeding season, they form loose schools, especially while feeding (Moyle 1976). The small size and slow movements of stickleback make them susceptible to piscine predators, but the spines and lateral plates provide some protection against predation (Hoogland et al. 1957, Moodie 1972, Moodie and Reimchen 1976).

Sticklebacks are mostly an annual species but occasionally individuals may survive for 2 to 3 years (Moyle 1976). During the breeding season (April-July) males assume nuptial coloration, move away from the schools, and set up territories among beds of aquatic plants. They then construct nests by excavating shallow pits in the substrate and placing strands of algae, pieces of aquatic plants, and other material in it. These are then glued together with sticky kidney secretions. When the pile is large enough, the male wriggles through it to create a tunnel. He then approaches the females, engages in the characteristic zig-zag dance of sticklebacks, and leads a responding female into the nest. The female lays her eggs in the nest and the male fertilizes them. Several females may lay eggs in one nest and each female may lay between 50-300 eggs in several spawnings. The male then guards and incubates the eggs until they hatch 6-8 days later (at 18-20°C). The fry remain in the nest for the first couple of days. During this time the male continues to guard and shepherd the fry. Upon leaving the nest, the free-swimming juveniles form schools.

Status: Class 1.

Santa Ana threespine stickleback are restricted to one small creek in a water-short area. Presumably they were much more widely distributed in the past. They are likely to disappear completely if Shay Creek is not managed to maintain their populations.

Management: Shay Creek and its drainage should be managed to protect and improve habitat for this fish. There is an immediate need to learn more about its biology so a proper management plan can be devised. If possible, additional populations should be reestablished in its native range.

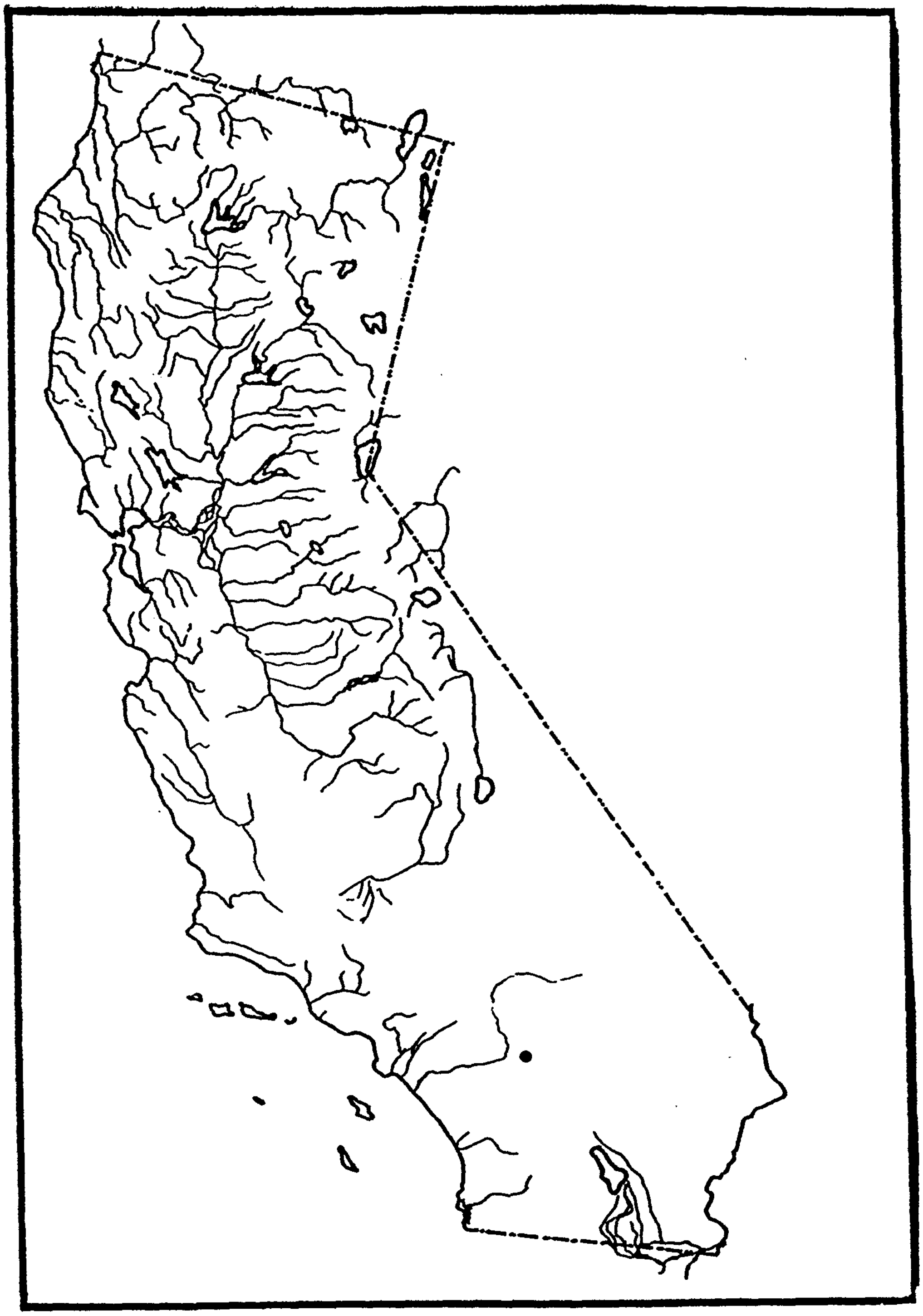


FIGURE 36. Distribution of the Santa Ana threespine stickleback, *Gasterosteus aculeatus* subsp., in California.

C-046110

TABLE 11. Major localities of Sacramento perch in California. Data mostly from Aceituno and Nicola (1976), based on CDFG and Moyle (unpubl. data). This record is by no means comprehensive in that it does not take into account small farm ponds, etc.

Location	County	Source
Alameda Creek	Alameda	Introduced
Alamo River	Imperial	Introduced
Lake Greenhaven (Brickyard Pond)	Sacramento	Native (EXTINCT)
Calaveras Reservoir	Alameda/Contra Costa	Introduced
Clear Lake	Lake	Native
Duncan Pond	Mendocino	Introduced
Gravel Pit Ponds near Niles	Alameda	Introduced
Lake Anza	Contra Costa	Introduced
Lassotovich Pond	Fresno	Introduced
Middle Lake	San Francisco	Introduced
Ramer Lake	Imperial	Introduced
Tevis Ponds	Marin	Introduced
Abbott's Lagoon	Marin	Introduced
Van Vleck Ponds	Sacramento	Introduced
Washington Lake	Yolo	Native (EXTINCT)
West Valley Reservoir	Modoc	Introduced
Moon Reservoir	Lassen	Introduced
Clear Lake Reservoir	Modoc	Introduced
Lost River	Modoc	Introduced
Crowley Reservoir	Inyo	Introduced
Almanor Reservoir	Plumas	Introduced
Pyramid Reservoir	Los Angeles	Introduced
Owens River	Inyo	Introduced
Gull Lake	Mono	Introduced
Bridgeport Reservoir	Mono	Introduced
East Walker River	Mono	Introduced
West Walker River	Mono	Introduced
Topaz Lake	Mono	Introduced

Habitat Requirements: Sacramento perch are warm water, lacustrine fish; they formerly inhabited sloughs, slow-moving rivers, and lakes of the Central Valley, but are now mostly found in reservoirs and farm ponds. They are often associated with beds of rooted, submerged, and emergent vegetation and other submerged objects. Aquatic vegetation is especially essential for the young-of-year which remain close to such vegetation and/or in shallow areas.

Sacramento perch are able to tolerate a wide range of physicochemical water conditions. This tolerance is thought to be an adaptation to fluctuating environmental conditions resulting from floods and droughts. Thus they do well in highly alkaline water with salinities of up to 17,000 ppm (McCarraher and Gregory 1970, Moyle 1976). Most populations today are established in warm (summer temperatures >25°C), turbid, moderately alkaline reservoirs or farm ponds.

Life History: Growth rates in Sacramento perch are variable and are affected by both biotic and abiotic environmental factors (Aceituno and Vanicek 1976, Mathews 1962, McCarraher and Gregory 1970, Moyle et al. 1974, Vanicek 1980). Although the largest recorded Sacramento perch was 610 mm TL (Jordan and Everman 1896), more recent records indicate that Sacramento perch reach approximately 300 mm TL in about 4 years. Length increments typically decrease as the fish gets older, but the weight tends to increase more rapidly (McCarraher and Gregory 1970, Moyle 1976). Recent longevity records in California for Sacramento perch indicate life spans of 4-5 yrs, but Mathews (1962) reported 9-year-old Sacramento perch from Pyramid Lake, Nevada, that ranged from 350-420 cm total length. Growth of Sacramento perch in Clear Lake appears to be slower than in other populations (Moyle, unpubl. data)

Vanicek (1980) monitored the Sacramento perch populations in Greenhaven Lake each year between 1973-1978 and found that the population underwent a decline during this period. In addition to a decrease in fish abundance, he also reported a decrease in growth rates. These declines coincided with the establishment of a large housing development on the shores of the lake.

The diet of Sacramento perch consists primarily of benthic insect larvae, snails, mid-water insects, zooplankton, and fish (Moyle et al. 1974). There is a tendency for the diet to vary with size of the fish as well as season, but no diel variation was observed (Moyle et al. 1974). Usually larger Sacramento perch included more fish in their diet (McCarraher and Gregory 1970). Sacramento perch in Clear Lake had a high proportion of zooplankton, especially *Hyelella azteca* (a freshwater amphipod), in its diet (McCarraher and Gregory 1970).

Fecundity is greater in this species than in other centrarchids and increases with size (Moyle 1976). Females in Lake Anza (120-157 mm TL) and Pyramid Lake (196-337 mm TL) produced between 8,370-16,219 and 9,666-124,720 eggs, respectively (Mathews 1962). Sacramento perch can become reproductive by the first year (Murphy 1948), but second year and older females spawn earlier than the first year females (McCarraher and Gregory 1970). Spawning occurs during spring and early summer and usually begins by the end of March and continues through the first week of August (Mathews 1965, Moyle 1976). The timing of the spawning period is thought to be dependent on the water temperature which, during this period, is usually between 21.7-23.9°C (Mathews 1965, Murphy 1948). Specifically, Mathews (1965) observed spawning Sacramento perch in Kingfish Lake, San Joaquin County, in April 1962 and in Lake Anza, Contra Costa County, in early May. Gravid females were also observed during mid-May in the latter lake. Murphy (1948) observed spawning Sacramento perch in Clear Lake, Lake County, during May-June. In Pyramid Lake, however, spawning begins much later in mid-June and August (Johnson 1958, cited in Mathews 1965). This lake is much deeper and presumably takes longer to warm up to the required temperature.

Spawning behavior has been extensively described by Murphy (1948) and Mathews (1965). Murphy reports that Sacramento perch school prior to spawning and maintain the aggregations during spawning. Such aggregations are unique to this species within the Family. Furthermore, unlike other centrarchids, Sacramento perch do not build distinctive nests. However, the male establishes and guards a territory during the spawning period (Murphy 1948, Mathews 1965). The territories are approximately 40 cm in diameter (Aceituno and Vanicek 1976) and are located in a wide variety of substrate types ranging from clay and mud to among rocks (Aceituno and Vanicek 1976, Mathews 1965, Murphy 1948). Depth of the nests ranges from 20-75 cm (Murphy 1948, Mathews 1965).

The females indicate reproductive readiness by increased activity and approaching the territory. During the first few approaches she is chased away by the male but, after repeated attempts, is accepted. Both fish then spend about 30 minutes at the nest prior to spawning. Once the eggs are laid and fertilized the female leaves, but the male remains at the nest until the eggs hatch following an incubation period of approximately 50 hours (at 21.7°C) and for about two more days following hatching (i.e. during the initial period of larval development). Observations in Clear Lake indicate that the larvae remain in the shallow areas among aquatic and emergent vegetation and move into the offshore environments when 5 cm in length (Murphy 1948).

Status: Class 4.

The Clear Lake population is the last native population in the natural range of the species and is probably distinct genetically, given its long isolation from other populations. The perch is very rare in the lake and may only be able to reproduce successfully when black crappie populations are low (P. Moyle, unpubl. observ.), presumably because of competition for breeding sites.

Other populations are scattered throughout California and the western United States, but most are in isolated reservoirs or ponds. The isolated nature of these populations and their occurrence in human-created habitats makes them vulnerable to extinction, although the perch are now the most abundant fish in a number of reservoirs.

Management: Attempts should be made to propagate the Clear Lake Sacramento perch in ponds in the Clear Lake Basin to back up populations in the lake. Once pond populations are established, Clear Lake could be stocked with Sacramento Perch on a regular basis. This would add a native fish to a fishery dominated by introduced species. Outside the Clear Lake Basin, efforts should be made to establish this fish in as many suitable habitats as possible to promote its value as a sport and food fish and to encourage its use in farm ponds.

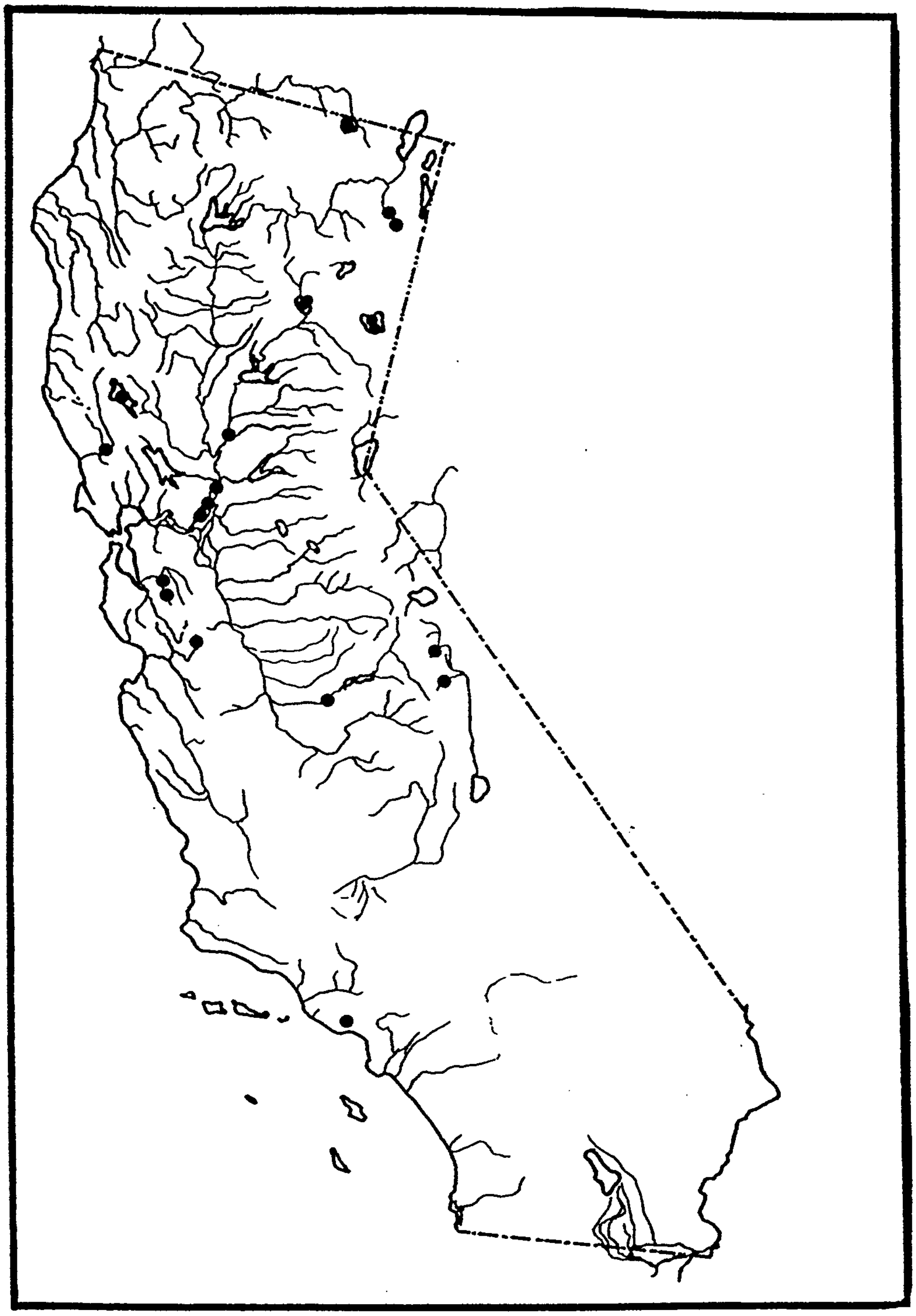


FIGURE 37. Distribution of Sacramento perch, *Archoplites interruptus*, in California.

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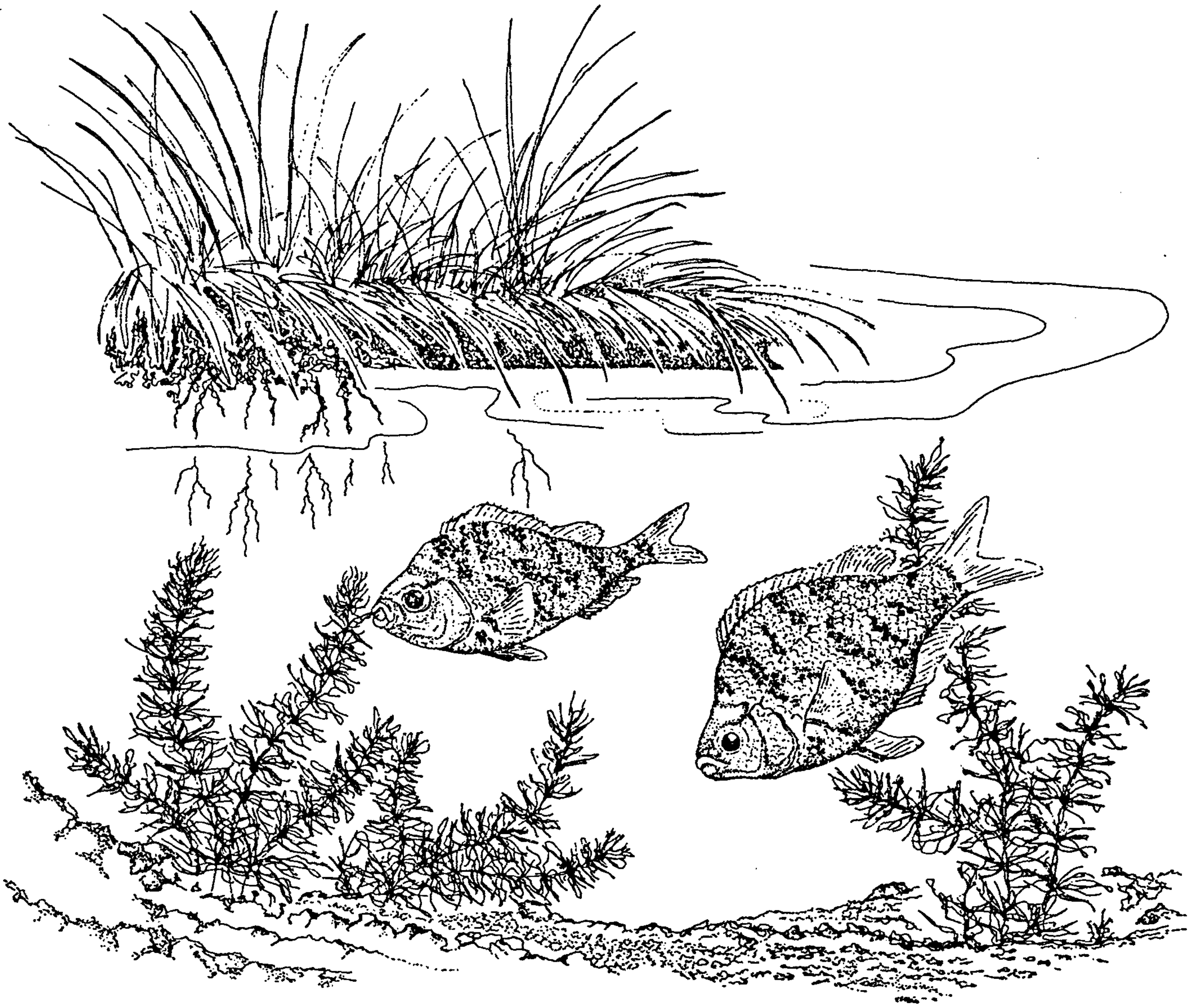


C-046115

RUSSIAN RIVER TULE PERCH
Hysterocarpus traskii pomo (Hopkirk)

Description: Tule perch are small (up to 150 mm SL), deep-bodied fish, bluish to purple dorsally, and white to yellow ventrally. Three color variants are described based on their lateral barring patterns: wide barred, narrow barred, and bars absent. Adults have a pronounced hump (nuchal concavity) immediately anterior to the dorsal fin. The dorsal fin has 15-19 spines, 9-15 rays; the anal fin 3 spines, 20-26 rays; the pectoral fins 17-19 rays. There are 34-43 scales along the lateral line (Moyle 1976).

Body proportions and gill raker morphology of the Russian River subspecies, *H. t. pomo*, differ from the other two subspecies, *H. t. traskii* and *H. t. lagunae* (Hopkirk 1973, Moyle and Baltz 1981, Table 12). The narrow barred color variant (98.7%) predominates in the Russian River population, with few broad barred (1.3%) fish (Hopkirk 1973). The unbarred variant is absent from this system.

Taxonomic Relationships: The tule perch, *Hysterocarpus traskii*, is the only freshwater species in the marine family Embiotocidae. *Hysterocarpus traskii pomo* was described by Hopkirk (1968) as one of three subspecies. Although this designation was disputed by Hubbs (1974), Baltz and Moyle (1981), using morphometric analyses, showed that *H. t. pomo* is different from *H. t. lacunae* (from the Clear Lake drainage basin) and *H. t. traskii* (from the main Sacramento-San Joaquin drainage), thus supporting Hopkirk's contention. These three subspecies also show some genetic divergence (Baltz and Loudenslager 1984) as well as striking differences in life history patterns (Baltz and Moyle 1982).

Distribution: This subspecies is confined to the Russian River and its tributaries in Sonoma and Mendocino Counties, California (Hopkirk 1973, Fig. 38). A. Phelps (pers. comm. 1988) found them to be present in the Russian River from Ukiah downstream to Monte Rio, but they were generally uncommon compared with the abundance of other native fishes.

Habitat Requirements: This subspecies requires clear, flowing water and abundant cover, such as beds of aquatic macrophytes, submerged tree branches, and overhanging plants (Moyle 1976). Cover is especially essential for near-term females and young as it serves as refuge from predators. Although Russian River tule perch sometimes feed in riffles, they require deep (>1 m) pool habitat and will use rip-rapped habitat in deep water. For a number of years, a population of tule perch maintained itself in a pond on the campus of Sonoma State University, but this population is now gone (J. Hopkirk, pers. comm.) They are usually absent from polluted water with reduced flows, high turbidity, and lack of cover (Moyle 1976).

Life History: The life history of Russian River tule perch is adapted to the unpredictable flow conditions of the Russian River system (Baltz and Moyle 1982). Flow variations in streams and rivers affect aquatic macrophytes, riparian vegetation (Westlake 1975), and water column turbidity. As these tule perch require cover provided by aquatic vegetation and are intolerant of turbid conditions, they are susceptible to extreme flow variations. Thus, mortality is high among Russian River tule perch. Baltz and Moyle (1982) also found that these perch are relatively short-lived (maximum 3-4 yrs) compared with the two other subspecies.

TABLE 12. Measurements (mm) and counts of the three subspecies of *Hysterocarpus traskii*. Standard deviations are given in parenthesis below means. (Table adapted from Baltz and Moyle 1981.)

	H. t. lagunae		*H. t. pomo*	*H. t. traskii*	
	Clear Lake	Upper Blue L.	Russian River	Deer Creek	Sac.-San J. Estuary
Standard length	105.5 (13.22)	94.4 (11.37)	75.8 (8.9)	79.3 (10.54)	90.6 (22.31)
Body depth	51.8 (8.44)	38.1 (4.88)	36.5 (5.26)	38.1 (6.63)	41.9 (11.07)
Lateral line scales	40.6 (1.94)	40.7 (1.28)	39.0 (0.91)	37.8 (1.61)	39.2 (1.30)
Scales					
above lateral line	7.3 (0.59)	7.0 (0.57)	6.9 (0.60)	6.9 (0.60)	6.8 (0.44)
below lateral line	13.1 (0.66)	13.2 (0.83)	12.0 (0.56)	12.6 (0.83)	11.7 (0.61)
dorsal spines	16.3 (0.68)	17.4 (0.57)	17.7 (0.61)	17.2 (0.66)	16.9 (0.59)
Gill rakers					
upper limb	6.9 (0.83)	7.5 (0.61)	6.5 (0.85)	6.0 (0.86)	6.4 (0.65)
lower limb	15.7 (1.16)	16.3 (1.19)	13.9 (0.64)	11.6 (1.20)	12.7 (0.88)
Longest gill raker	2.6 (0.47)	2.5 (0.48)	1.8 (0.29)	1.3 (0.17)	1.4 (0.39)
Depth muchal concav.	1.2 (0.51)	0.7 (0.30)	0.3 (0.59)	0.1 (0.21)	0.4 (0.54)
Sample size	50	50	36	41	102

The reproductive strategy of Russian River tule perch reflects its adaptations to this unpredictable environment (Baltz and Moyle 1982). The viviparous females produce more young per brood and reproduce at smaller sizes than those of other subspecies. Mating occurs from July through September and sperm is stored within the female until January when fertilization takes place. Young are born during May-June when food is abundant (Moyle 1976). During the mating season, males apparently hold and defend territories, usually under overhanging branches and among plants close to shore. Courtship and mating can, however, occur away from territories (Moyle 1976).

Except when breeding, tule perch are gregarious, feeding and swimming in schools. The terminal mouth of Russian River tule perch with its protrusible upper jaw and the number and length of gill rakers are adaptations for feeding on benthic and "plant-dwelling" aquatic invertebrates (Moyle 1976, Baltz and Moyle 1981). The number and length of gill rakers of this subspecies are intermediate to the two other subspecies (Table 12). The lake dwelling *H. t. lacunae* with a greater number of longer gill rakers feeds on zooplankton; *H. t. traskii* feed on larger invertebrates (Baltz and Moyle 1981).

Status: Class 2.

The limited distribution and low numbers of this subspecies makes it susceptible to extinction from localized threats to habitat. Tule perch are extremely sensitive and susceptible to stream pollution and tend to disappear from polluted, low flow, turbid streams. The Coyote and Warm Springs dams now control flows in the Russian River, resulting in increased turbidity and decreased water quality. Other pond and dam construction has also resulted in habitat alterations detrimental to *H. t. pomo*. Introduced fish predators such as smallmouth bass (*Micropterus dolomieui*) also may contribute to population declines of this tule perch. Russian River tule perch seem to be less abundant then they were in the early 1970's when they were the subject of studies by students on UCD field courses.

Management

1. A thorough survey should be conducted to accurately determine the status and range of *H. t. pomo* and to identify critical and suitable habitat. Such habitat should then be managed for conservation of *H. t. pomo*. If higher water quality is needed (e.g. increased clarity), alternate flow regimes may be needed from the dams on the river.

2. A survey should also be conducted of the Mendocino Reservoir to determine whether *H. t. pomo* is present there and, if it is, the status of the population should be evaluated.

3. Populations of Russian River tule perch should be restored to the Sonoma State University ponds or a similar refuge should be constructed for them.

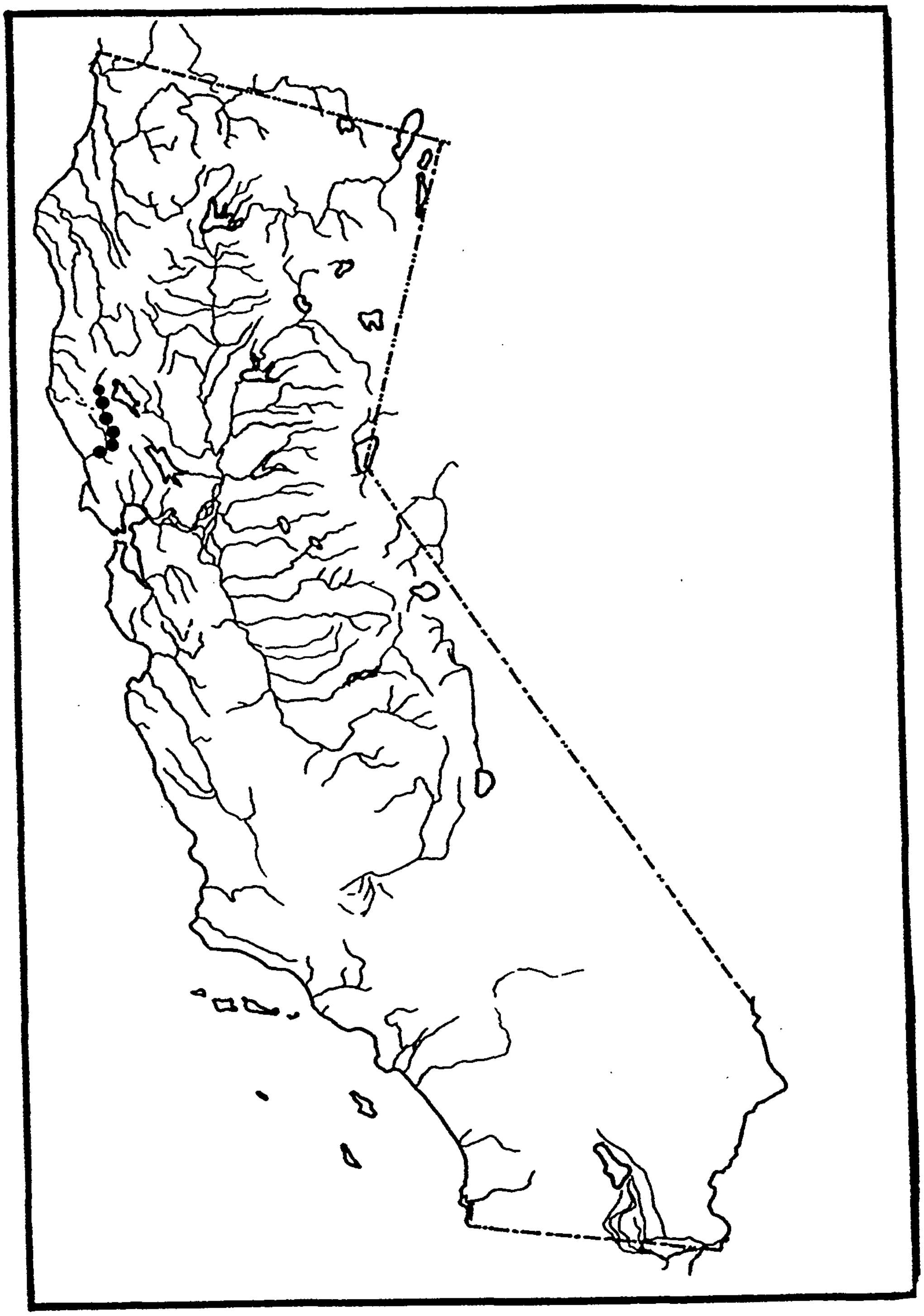


FIGURE 38. Distribution of Russian River tule perch, *Hysterocarpus traskii pomo*, in California.

TIDEWATER GOBY
Eucyclogobius newberryi (Girard)

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

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

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

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

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

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

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

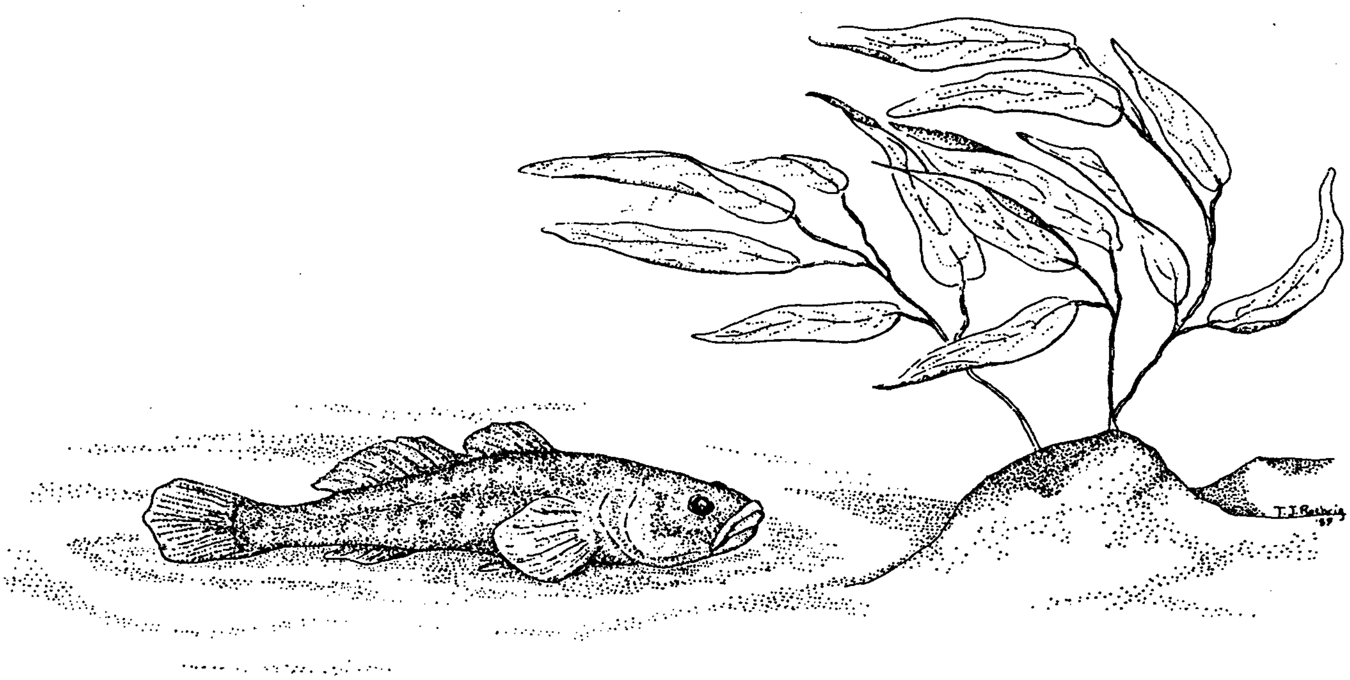
Goldberg (1977) found that in tidewater gobies of southern California, ovarian maturation is asynchronous, i.e. females with various stages of ovarian development are found throughout the year. The occurrence of larvae throughout the year, albeit in small numbers, supports the theory for year-round reproduction.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

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

Status: Class 2.

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

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



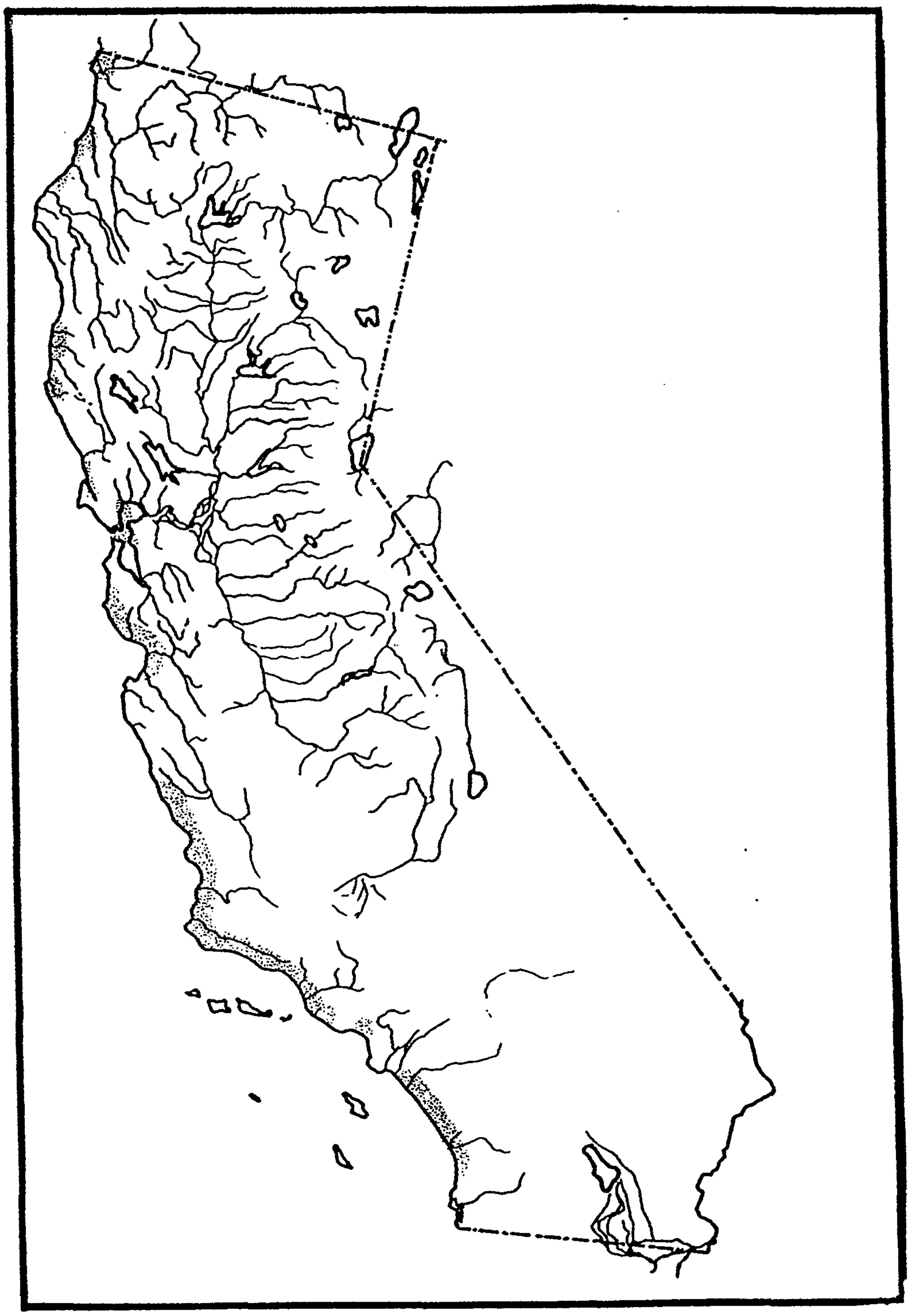


FIGURE 39. Distribution of the tidewater goby, *Eucyclogobius newberryi*, in California.

RETICULATE SCULPIN
Cottus perplexus (Gilbert and Evermann)

Description: This species is similar to the marbled sculpin in overall shape, but is considerably smaller, being no more than 85 mm TL. They are distinguished from other sculpins by a complex of characters that consist of a mouth that is narrower than the body posterior to the pectoral fins; absence of palatine teeth; a maxilla that extends to the anterior margin of the eye; broadly joined dorsal fins with 7-8 spines on the anterior dorsal fin and 18-20 on the posterior dorsal fin; 14-15 unbranched pectoral fin rays (range from 13-16); 13-16 anal fin rays; 22-23 pores along the lateral line that may or may not be complete; 1-2 median chin pores; 1-4 preopercular spines, of which only 2 are usually visible; and variable body prickling, although axillary prickling is always present.

Body coloration of live fish consists of faint vermiculate markings and some darker mottling. The pectoral fins have a checkerboard pattern that is similar to the marbled sculpin. A dark blotch is present on the posterior margin of the anterior dorsal fin.

Taxonomic Relationships: This species was first described by Gilbert and Evermann (1894), but was synonymized with *Cottus gulosus* by Shultz (1930). However, in a subsequent reanalysis of the type material, Robins and Miller (1957) redesignated *Cottus perplexus* as a species because, based on morphological characteristics, it is more closely allied to *Cottus klamathensis* than to *C. gulosus*.

Distribution: This sculpin is common in Oregon and Washington. Its range extends from the Columbia River drainage, Washington, south to the Rogue River drainage, Oregon, and includes the Williamette and Upper Deschutes River drainages in between (Bond 1963, Reimers and Bond 1967). A few have been recorded in California, one from the Middle Fork of the Applegate River on the California side of the border (Bond 1973) and others from creeks that drain north into the Rogue River, especially Elliot Creek (Moyle 1976) (Fig. 40).

Habitat Requirements: This species has been extensively studied in Oregon where it primarily occupies slower water habitat in small coastal and headwater streams. It seems to be excluded by *C. gulosus* from fast water. In sympatry, *C. perplexus* is found in quiet water; in allopatry it tends to occupy faster water with rubble and gravel substrates (Bond 1963).

It is tolerant of fairly high fluctuations of water temperatures and is able to withstand temperatures up to 30°C and salinities up to 18 ppt (Bond 1963). The fish feed mostly on aquatic insect larvae, especially mayfly, stonefly, chironomid, and caddisfly larvae (Moyle 1976).

Growth is slow, with fish reaching only 27 mm SL by age one, 42 mm by age two, 56 mm by age three, and 64 mm by age four. They live for about 6 years and are sexually mature by their second year. Fecundity is low and increases with size. In Oregon, fecundity has been determined as 35 to 315 eggs for fish ranging from 30 to 69 mm SL (Bond 1963) and in Washington state 84 to 432 eggs for fish ranging from 60 to 97 mm TL (Patten 1971). Mean fecundity in these latter fish was 172 eggs for two-year-old fish and 283 eggs for 3-year-old fish.

C-046124

Spawning occurs from March to May when water temperature exceeds 6-7°C (Moyle 1976). Eggs are laid on the underside of rocks (10 to 45 cm in diameter), with numerous females contributing to the nest. When other sculpins are rare or absent, *C. perplexus* spawn in riffle habitat; however, in the presence of other sculpins, they spawn in areas of slower water. Males guard the nest and fry from predators. Fry assume a benthic life style in quiet water immediately after leaving the nest (Bond 1963).

Status: Class 3

California populations of reticulate sculpin are on the periphery of its range. As a species, it is not threatened, but the California populations could disappear if the water quality of the few California streams in which they occur should be degraded. The presence of dams on the streams indicates the California populations are now isolated from other populations downstream.

Management: A survey of all California tributaries to the Rogue River is needed to determine the extent of the distribution of this sculpin. Agencies with responsibilities for land around the reticulate sculpin streams should be alerted of the presence of the species so the streams can be managed to maintain its populations in California.

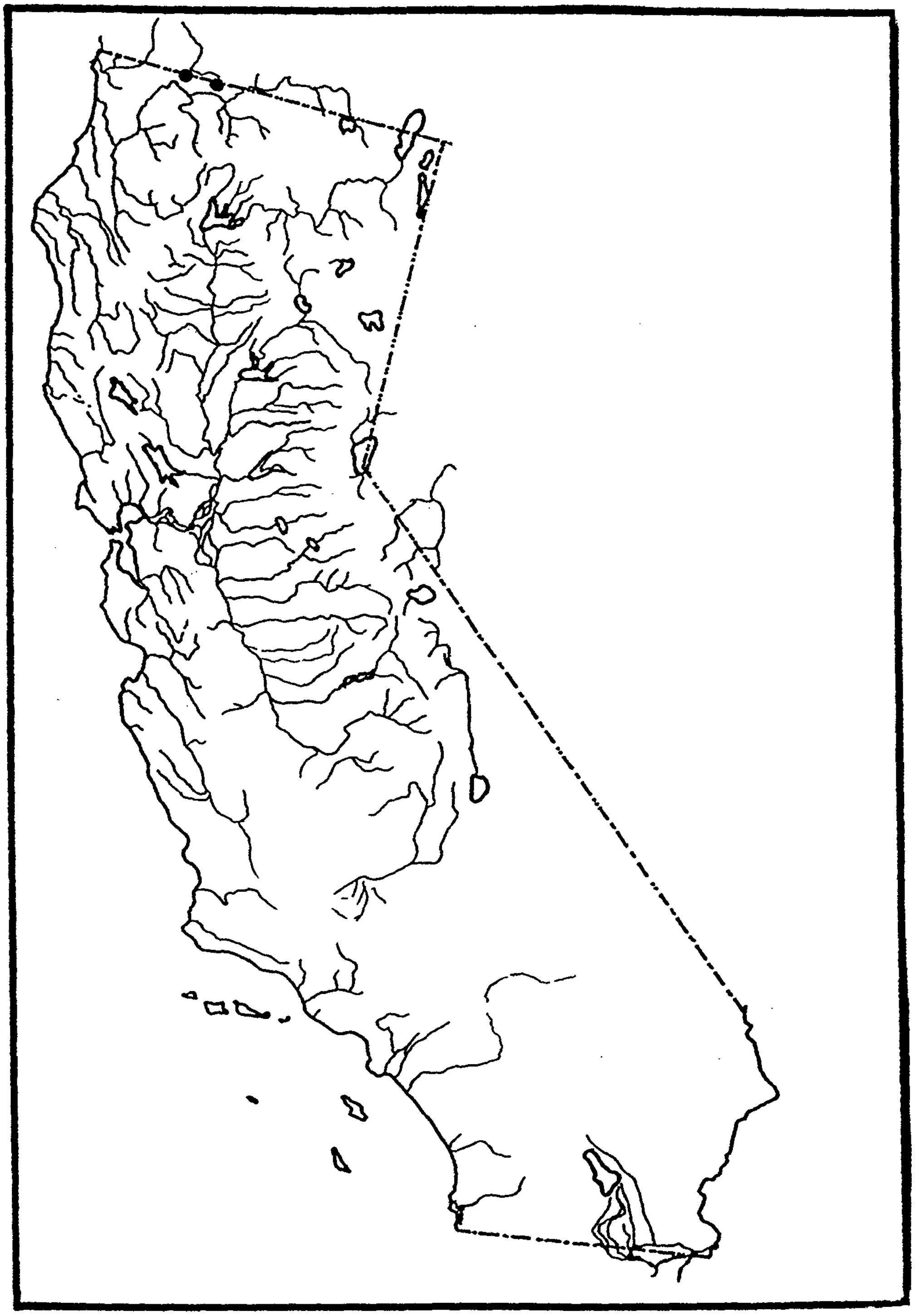
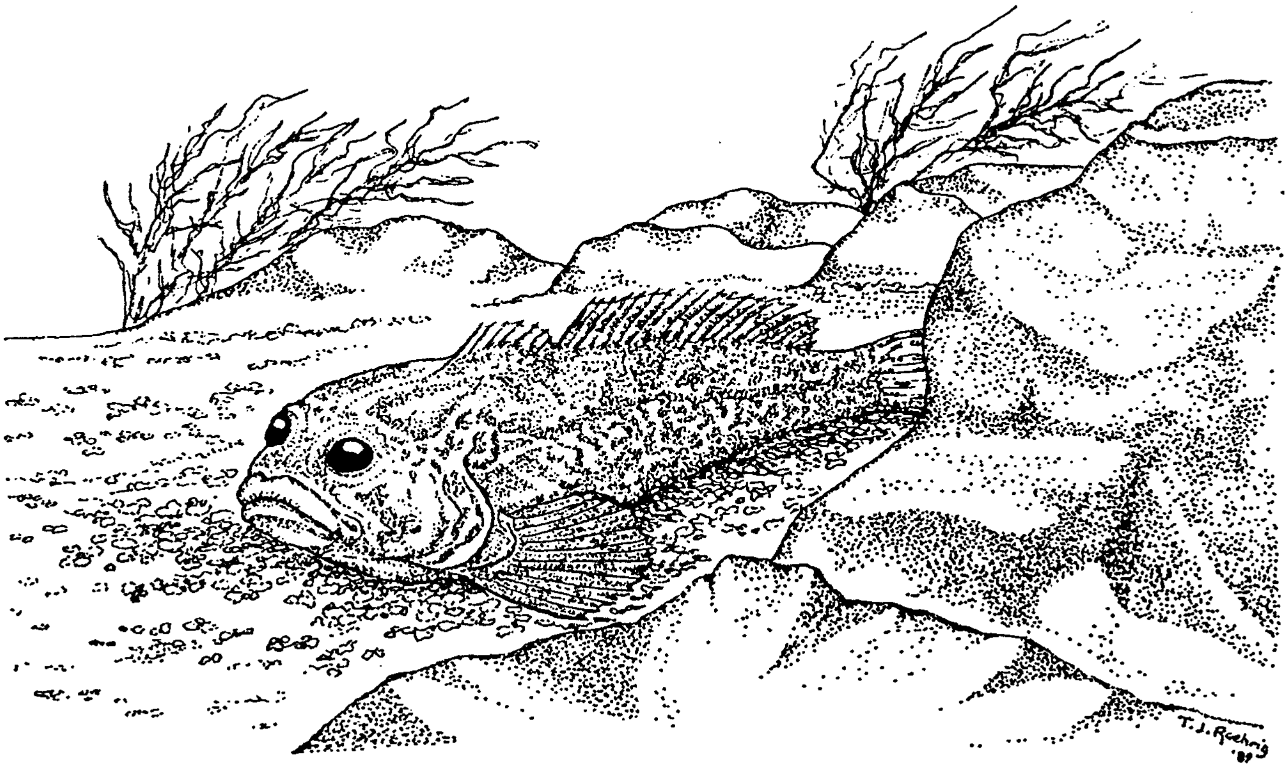


FIGURE 40. Distribution of the reticulate sculpin, *Cottus perplexus*, in California.



C-046127

BIGEYE MARBLED SCULPIN
Cottus klamathensis macrops (Rutter)

Description: Gross morphology of the marbled sculpin is typical of the genus *Cottus*. The head is large and dorsally flattened, pectoral fins are large and "fan-like," and the small pelvic fins are positioned ventrally between the pectorals. *Cottus klamathensis* is distinguished from other species of *Cottus* in that *klamathensis* usually has fewer than 7 dorsal fin spines, the dorsal fins are joined, the lateral line is incomplete, and the skin is relatively smooth (Daniels and Moyle 1984). All other species in California possess a split dorsal fin and more than 7 dorsal spines. The pectoral fins of *klamathensis* have four elements. The incomplete lateral line has 16-18 pores. The smooth skin has few prickles, which are usually below the lateral line. Fish have a green hue and possess a dark circular spot at the posterior end of the spinous dorsal fin. Marbled sculpins also lack palatine teeth and have only one pre-opercular spine (Moyle 1976). Other characteristics of *C. klamathensis* include a wide interorbital region, a wide head and blunt snout, a maxillary rarely extending beyond the anterior half of the eye, and unjoined pre-operculomandibular canals, but these characteristics are shared with one or more other species (Daniels and Moyle 1984).

The subspecies *C. klamathensis macrops* is distinguished from other subspecies by: few (if any) axillary prickles, a short pre-opercular spine (<1% SL), a large orbit diameter, and a long predorsal length (Daniels and Moyle 1984). It is also ecologically distinct (Daniels 1987).

Taxonomic Relationships: *Cottus klamathensis* was first described by Gilbert (1898) from the Klamath River system. Rutter (1908) then described *Cottus macrops* from the Fall River, a large tributary to the Pit River, and noted that it closely resembled *C. klamathensis*. Robins and Miller (1957) upon review of specimens and recent collections concluded that the two species were not sufficiently different to warrant separate species designations and considered *C. macrops* to be synomymous with *C. klamathensis*. Daniels and Moyle (1984), however, on the basis of meristic and mensural differences in fish from the Pit River and Klamath River systems concluded *C. klamathensis* could be divided into three subspecies:

1. *C. k. klamathensis*, the nominate subspecies found in the Upper Klamath River drainage.

2. *C. k. polyporus*, found in the lower Klamath River and some of its larger tributaries. Its range, however, is not well documented; it may also be found in the Trinity River system.

3. *C. k. macrops*, found in the Pit River system downstream from the confluence of the Fall River to the Pit 7 Reservoir and three tributaries, Hat Creek (downstream of the Rising River system), Burney Creek (downstream of Burney Falls), and the Fall River system (with the exception of Bear Creek).

Distribution: The bigeye marbled sculpin is distributed throughout the middle reach of the Pit River system (Fig. 41) (Moyle and Daniels 1982). In this region, it is found in the main river below Britton Reservoir, in Britton Reservoir, Tunnel Reservoir, lower Hat Creek, Sucker Springs Creek, and Clark Creek. It is the dominant sculpin in the sections of Lower Hat Creek and Burney Creek just above Britton Reservoir. The bigeye marbled sculpin also is found in the lower reaches of streams flowing into reservoirs of lower Pit River and in the lower Pit River itself.

They are present in the Fall River, but seem to be less abundant today than when Rutter (1908) first collected there.

Habitat Requirements: *Cottus k. macrops* is adapted for life in large, clear, cool, spring-fed streams but has also managed to adjust to the conditions in some reserviors. Brown (1988) found that the acute preferred temperature of fish acclimated at 10°, 15°, and 20°C was about 13°C. They are usually found in water with moderate flows (mean bottom velocity = 9.7 $\pm$ 3.0 SE, $cm.sec^{-1}$; mean water column velocity = 23.1 $\pm$ 4.5$cm.sec^{-1}$) and depths (mean 64.3 $\pm$ 7.3cm). Habitat use does not differ between adults and juveniles with respect to water velocity, but juveniles are found in shallower water. Typically these sculpins are associated with abundant aquatic vegetation and coarse substrates, especially cobble, boulder, and gravel (Daniels 1987). In artificial streams, when given a choice of cobble and sand, they always selected cobble (Brown 1988).

Life History: Bigeye sculpins live about 5 years, attaining 35% of their maximum length during their first year (Daniels 1987). The growing season begins in spring and lasts until early autumn. Fish attain sexual maturity after 2 years. Males and females begin to mature reproductively during the winter and spawning occurs from late February to March. Fecundity is low: females produce from 139 to 650 large ova per fish. Adhesive eggs are deposited in nests under flat rocks. More than one clutch of eggs may be present in a nest. Nests are generally guarded by males (Daniels 1987). The low fecundity, late reproductive maturation, and relatively long life span reflect this subspecies' adaption to an environment with relatively few fluctuations (Daniels 1987).

Status: Class 3.

This sculpin occurs at lowest population levels of the three sculpins endemic to the Pit River drainage, but still remains broadly distributed throughout most of its limited native range. It co-occurs with the rough sculpin, *Cottus asperrimus*, which is listed by the state as a threatened species.

Management: As long as rough sculpin are protected, bigeye sculpin presumably will be as well. However, its apparent decline in the Fall River may indicate that long-term, subtle changes in its native habitats may be occurring.

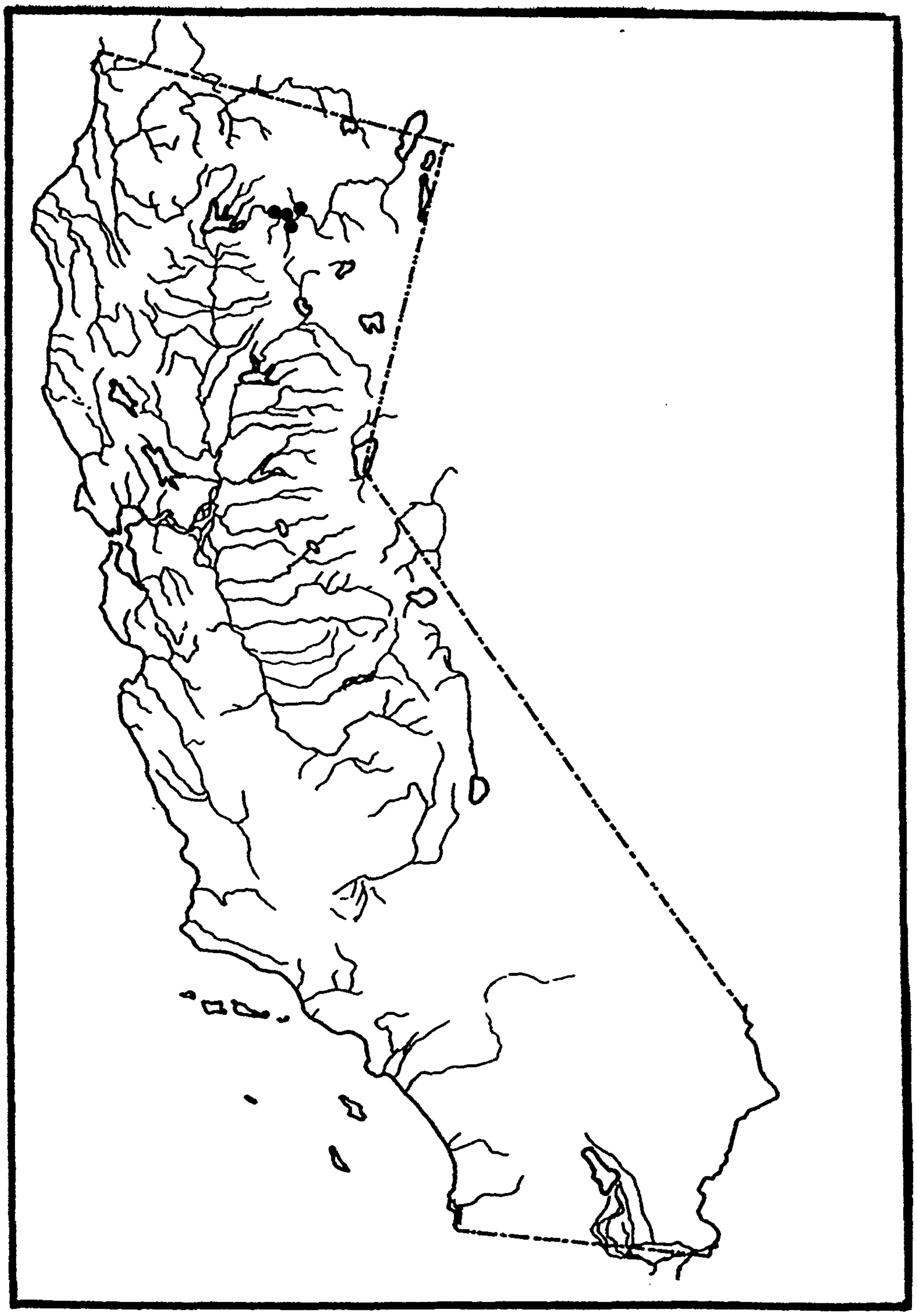


FIGURE 41. Distribution of the bigeye marbled sculpin, *Cottus klamathensis macrops*, in California.

C-046131

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