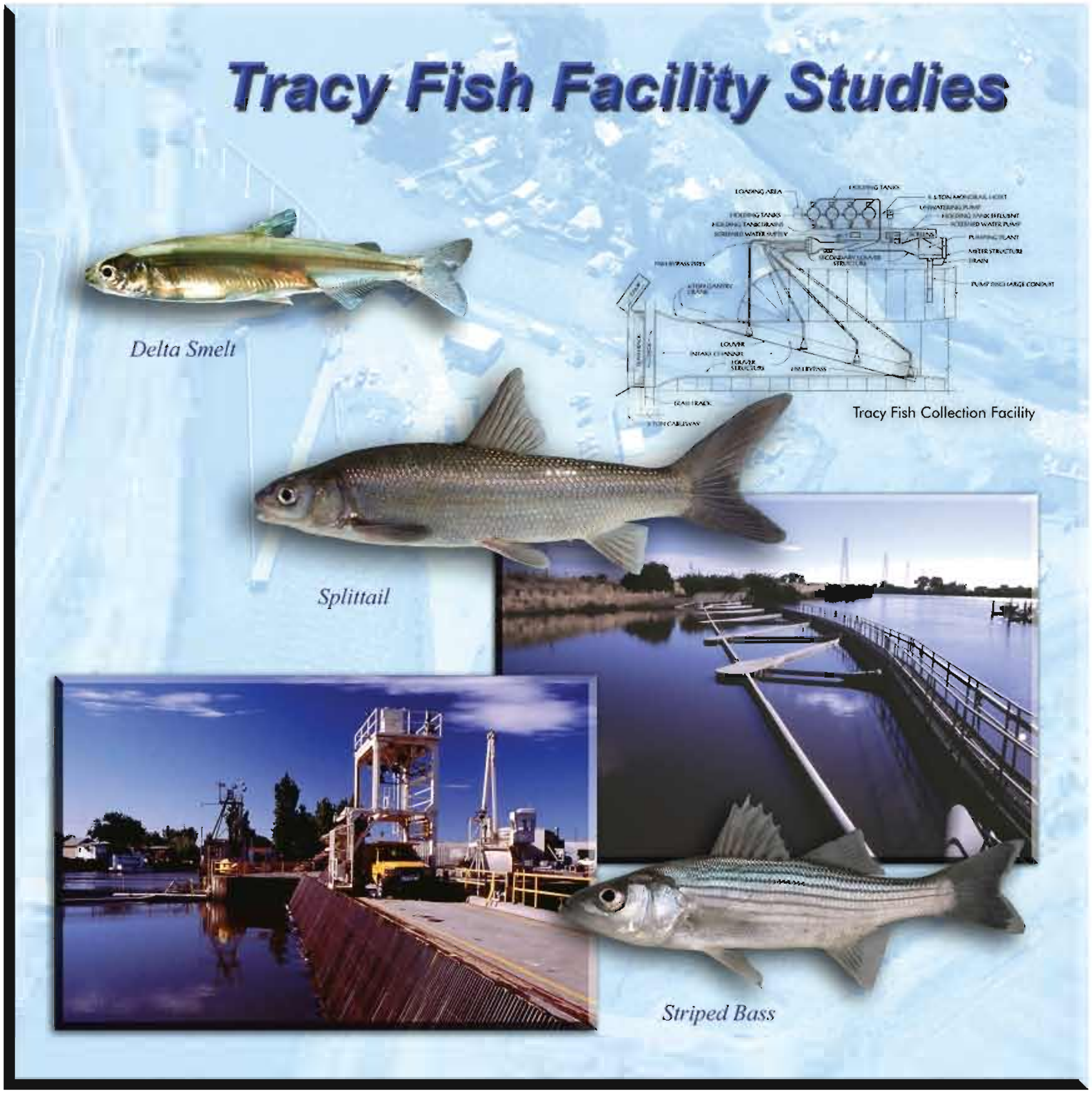
RECLAMATION
Managing Water in the West



Early Life Stages and Life Histories of Cyprinid Fish in the Sacramento-San Joaquin Delta, California: with Emphasis on Spawning by Splittail, *Pogonichthys macrolepidotus*

Volume 32

U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region
Technical Service Center

April 2007

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
April 2007

2. REPORT TYPE
Final

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Early Life Stages and Life Histories of Cyprinid Fish in the Sacramento-San Joaquin Delta, California: with Emphasis on Spawning by Splittail, *Pogonichthys macrolepidotus*

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Johnson C.S. Wang and René C. Reyes

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
National Environmental Sciences, Inc., Tracy Fish Collection Facility, 16650 Kelso Road, Byron CA 94514
Bureau of Reclamation, Tracy Fish Collection Facility (TO-412), 16650 Kelso Road, Byron CA 94514

8. PERFORMING ORGANIZATION REPORT NUMBER
Volume 32

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Bureau of Reclamation, Tracy Fish Collection Facility, TO-410, 16650 Kelso Road, Byron CA 94514-1909

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Available from the National Technical Information Service (NTIS)
Operations Division, 5285 Port Royal Road, Springfield VA 22161

13. SUPPLEMENTARY NOTE

14. ABSTRACT
Dichotomous keys were developed from examination of preserved and live specimens to identify the early life stages for 11 species of cyprinid fish (minnows) residing in Suisun Bay (the Bay) and the extended area associated with the Sacramento-San Joaquin River Delta (Delta). Three keys were developed for each of the 11 species based on 3 defined life stages: prolarvae-postlarvae, late postlarvae-prejuvenile, and early juvenile. Keys are presented for goldfish, *Carassius auratus*; red shiner, *Cyprinella lutrensis*; common carp, *Cyprinus carpio*; California roach, *Hesperoleucus symmetricus*; hitch, *Lavinia exilicauda*; hardhead, *Mylopharodon conocephalus*; golden shiner, *Notemigonus crysoleucas*; Sacramento blackfish, *Orthodon microlepidotus*; fathead minnow, *Pimephales promelas*; splittail, *Pogonichthys macrolepidotus*; and Sacramento pikeminnow, *Ptychocheilus grandis.* A description of spawning habits, developmental biology, and life histories for each species are also included. This report places special emphasis on the early life stages and spawning of splittail. Catch and salvage of adult splittail in spawning condition, observed behavior of newly hatched larvae, and the widespread collection of prolarvae suggest that the Bay and Delta are both used for spawning. Based on data presented in this report, we conclude that splittail are not all potamodromous: some reside and spawn each year in the suitable habitat of the Bay and Delta.

15. SUBJECT TERMS
Cyprinidae; cyprinid; minnows, guide to identification, dichotomous key, early life stages; eggs, larvae, larva; prolarvae, prolarva; postlarvae, postlarva; prejuvenile; juvenile; California; Delta; Central Valley; goldfish, *Carassius auratus*; red shiner, *Cyprinella lutrensis*; common carp, *Cyprinus carpio*; California roach, *Hesperoleucus symmetricus*; hitch, *Lavinia exilicauda*; hardhead, *Mylopharodon conocephalus*; golden shiner, *Notemigonus crysoleucas*; Sacramento blackfish, *Orthodon microlepidotus*; fathead minnow, *Pimephales promelas*; splittail, *Pogonichthys macrolepidotus*; Sacramento pikeminnow, *Ptychocheilus grandis*

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Doug Craft
a. REPORT	b. ABSTRACT	a. THIS PAGE		100	19b. TELEPHONE NUMBER *(Include area code)*
					303-445-2182

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

Tracy Fish Facility Studies
California

Early Life Stages and Life Histories of Cyprinid Fish in the Sacramento-San Joaquin Delta, California: with Emphasis on Spawning by Splittail, *Pogonichthys macrolepidotus*

Volume 32

by

Johnson C.S. Wang[1] and René C. Reyes[2]

April 2007

U.S. Department of the Interior
Bureau of Reclamation
Mid-Pacific Region

[1] National Environmental Sciences, Inc.,
Tracy Fish Collection Facility
16650 Kelso Road
Byron CA 94514

[2] Bureau of Reclamation
Tracy Fish Collection Facility TO-412
16650 Kelso Road
Byron CA 94514

MISSION STATEMENTS

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

SERIES EDITOR

Doug Craft
U.S. Department of the Interior – Bureau of Reclamation
Technical Service Center
Fisheries and Wildlife Resources Group, 86-68290
PO Box 25007
Denver CO 80225-0007

COVER

Fish photography by René Reyes, Tracy Fish Collection Facility, Tracy, California.
Design by Doug Craft.

DISCLAIMER

Mention of commercial products does not constitute endorsement.

TABLE OF CONTENTS

Table of Contents—continued

Figures

Figure *Page*

Table of Contents—continued

Figures

Figure *Page*

EXECUTIVE SUMMARY

Dichotomous keys – which identify a fish species by posing a series of paired questions regarding morphological features that become more specific as the user works through the key – were developed to identify the early life stages for 11 species of cyprinid fish (minnows) residing in Suisun Bay (Bay) and the extended area associated with the Sacramento-San Joaquin River Delta (Delta), and its adjoining river, reservoir, and aqueduct system (River). Three keys were developed from examination of preserved and live specimens for each of the 11 species based on 3 defined life stages: prolarvae-postlarvae, late postlarvae-prejuvenile, and early juvenile. Keys are presented for goldfish, *Carassius auratus*; red shiner, *Cyprinella lutrensis*; common carp, *Cyprinus carpio*; California roach, *Hesperoleucus symmetricus*; hitch, *Lavinia exilicauda*; hardhead, *Mylopharodon conocephalus*; golden shiner, *Notemigonus crysoleucas*; Sacramento blackfish, *Orthodon microlepidotus*; fathead minnow, *Pimephales promelas*; splittail, *Pogonichthys macrolepidotus*; and Sacramento pikeminnow, *Ptychocheilus grandis*. A detailed description of each species' spawning habits, eggs, larvae, and life history is also included.

Cyprinid spawning is distributed temporally and spatially in the Bay and Delta and River. Cyprinids spawn in a sequential manner with splittail starting earliest in the year (late winter/early spring), and hardhead finishing in late summer. Sacramento pikeminnow move up-river to spawn. Splittail spawn in floodplains and up-river tributaries; however, collections of splittail larvae and gravid males and females suggest that some remain and spawn in the Delta. California roach and hardhead do not travel as far and most spawning is restricted to foothill streams. Most other cyprinids are opportunistic spawners, spawning in creeks, rivers, ponds, sloughs, and lakes in both lotic and lentic environments.

The various cyprinid life stages found in the Bay, Delta, and River systems contribute to an already complex fish community (appendix tables A1, A2, and A3). All the cyprinids can produce more than one clutch of eggs and all have demersal eggs except hitch which have free-floating eggs. Unlike the other cyprinids, fathead minnow deposit their eggs on the undersides of rocks or other substrates and guard them. Other cyprinids build shallow nests or deposit eggs in other fish nests. Newly hatched larvae have a large yolk sac and stay on the bottom and near nesting sites for a few days or up to a week to avoid predation. Postlarvae have a short planktonic life for dispersal. Late postlarvae become epibenthic and blend into aquatic vegetation in shallow waters.

Large schools of juvenile splittail can be seen in the Bay and Delta from summer to early fall, particularly in high flow years. Hitch and Sacramento blackfish are present in the Bay, Delta, and River; however, hitch larvae were not collected in the California Department of Fish and Game (CDFG) fish Egg and Larvae (E&L) surveys, whereas

Sacramento blackfish larvae were found unevenly distributed in the Delta. Red shiner were introduced into the Delta as bait fish in the early 1990's and are now observed in most waters in the Bay, Delta, and River.

Investigators have noted that splittail larvae found in the Bay and Delta originated up-river. It is now known that splittail spawn in localized areas of the Bay and Delta. Splittail prolarvae are present in the E&L samples collected throughout the Bay and Delta. They have also been collected from the southern reaches of the Delta (South Delta), adjacent to the Tracy Fish Collection Facility (TFCF). Ripe males and gravid females are often collected at the TFCF. The presence of spawning splittail in the South Delta and the collections of prolarvae from different locations in the Bay and Delta suggest that these locations are likely spawning sites.

From 1988–1995, Bay and Delta E&L sampling stations accounted for 38 percent of the total catch of early life stages of splittail, whereas the Sacramento River stations contributed 62 percent (appendix tables A4, A5, A6). Although drifting larvae can be carried downstream great distances in just a few days, the predominance of splittail larvae measuring 11 mm TL (total length) or less (93 percent of larvae from the Bay and Delta and 95 percent from the Sacramento River) suggests that spawning grounds are near the sampling stations. Gravid splittail have often been salvaged at the TFCF during the spawning season, demonstrating that some splittail spawn in the South Delta. E&L surveys conducted in the Central and South Delta and the North Bay Aqueduct Project (1995–2004) have further demonstrated the adaptability of splittail to different environments.

INTRODUCTION

The Tracy Fish Collection Facility (TFCF), Tracy, California, is a fish salvage facility developed, built, and operated by the Bureau of Reclamation (Reclamation) as part of the Central Valley Project (CVP) system of irrigation canals, reservoirs, aqueducts, and water diversions. The TFCF, located on the Old River near Byron, California, salvages (removes) fish from the intake channel of the Tracy Pumping Plant, located at the head of the Delta Mendota Canal. Reclamation performs research and other investigations to examine fish salvage issues at the TFCF and improve survival and protection of the South Delta fishery. These efforts are funded by the Tracy Fish Facility Improvement Program (TFFIP), established and funded by appropriations from the Central Valley Project Improvement Act of 1992 (CVPIA) (Liston, *et al.*, 2000).

The TFCF salvages more than 60 species of fish, including endangered species such as the winter-run Chinook salmon, *Oncorynchus tshawytscha*, threatened species such as the delta smelt, *Hypomesus transpacificus*, and other species of concern such as the splittail, *Pogonichthys macrolepidotus*, a native minnow. Operators at the TFCF are expected to identify all fish species salvaged. Several species are very similar in appearance and therefore identification materials (*e.g.,* posters and keys) are an integral part of the identification process. However, keys for certain groups of fishes, especially for the early life stages of the minnows (family Cyprinidae, or the cyprinids), were unavailable. The TFFIP has funded the preparation of identification keys for all fish species potentially observed at the TFCF, including the keys in this report to identify the early life stages of cyprinids.

Cyprinidae is one of the largest family of fishes with around 2,100 species worldwide, and over 230 species found in North America. As a family, cyprinids are classified based on having 1 dorsal fin, abdominal pelvic fins, cycloid scales, and a lateral line (Page and Burr, 1991). The cyprinids include fish commonly known as carps, shiners, chubs, daces, and pikeminnows. There are 22 species of cyprinids known to California. Fifteen species are native and 7 are introduced (Moyle, 2002), and 13 species have been observed in the Delta (Wang, 1986). Some of the native species include the California roach, *Hesperoleucus symmetricus*, hitch, *Lavinia exilicauda*, hardhead, *Mylopharodon conocephalus*, Sacramento blackfish, *Orthodon microlepidotus*, splittail, *Pogonichthys macrolepidotus*, Sacramento pikeminnow, *Ptychocheilus grandis*, and speckled dace, *Rhinichthys osculus*. The introduced species include goldfish, *Carassius auratus*, red shiner, *Cyprinella lutrensis*, common carp, *Cyprinus carpio*, golden shiner, *Notemigonus crysoleucas*, fathead minnow, *Pimephales promelas*, and Lahontan redside, *Richardsonius egregious*.

Cyprinids in the Delta live and spawn in a variety of aquatic habitats. California roach and hardhead are mainly found in nontidal creeks and rivers. Hitch, Sacramento blackfish, splittail, and Sacramento pikeminnow are found in tidal and nontidal waters. California roach spawn in creeks. Hitch spawn in creeks, ponds, lakes, and reservoirs but their larvae have not been observed in the tidal freshwater. Sacramento pikeminnow spawn in creeks, rivers, and tributaries from lakes and reservoirs and their larvae are observed in the tidal freshwaters, but only in high flow years. Sacramento blackfish spawn in tidal and nontidal freshwater; however, most successful spawning occurs in ponds, lakes and reservoirs. Splittail spawn in tidal and nontidal freshwaters of the Delta but their larvae have not been observed in impounded environments. Lastly, hardhead congregate in deep pools before spawning. Their spawning preference, streams with good flow, is similar to Sacramento pikeminnow. Introduced cyprinids such as goldfish, red shiner, common carp, golden shiner, and fathead minnow spawn in tidal and nontidal waters.

Native cyprinids typically spawn in a chronological sequence while the introduced cyprinids tend to spawn throughout the spring and summer. Splittail start spawning as early as January in high flow years, but mainly spawn from March to May. Sacramento pikeminnow, California roach, hitch, and Sacramento blackfish spawn from April to June. Hardhead spawn from May to July, and even later at higher elevations.

Dichotomous keys – which identify a fish species by posing a series of paired questions regarding morphological features that become more specific as the user works through the key – were developed to identify the early life stages for 11 cyprinid species described in this report. Three keys were developed for each of the 11 species based on 3 defined life stages: prolarvae-postlarvae, late postlarvae-prejuvenile, and early juvenile (Wang & Kernehan, 1979; Wang, 1991). Specimens for developing the keys in this report came from three bodies of water: the Suisun Bay (Bay), the Sacramento-San Joaquin Delta (Delta), and its adjoining rivers, reservoirs, and aqueduct system (River). Keys are presented for goldfish, red shiner, common carp, California roach, hitch, hardhead, golden shiner, Sacramento blackfish, fathead minnow, splittail, and Sacramento pikeminnow. A detailed description of each species' spawning habits, eggs, larvae, and life history is also included. Speckled dace were reported in Coyote Creek (Scoppetone and Smith, 1978), a tributary of San Francisco Bay, but they were not observed in the Delta. However, this species was observed upstream of the Delta in the Sacramento River at Reclamation's Red Bluff Pumping Plant intake, Stony Creek, and in Clear Creek. Lahontan redside were not observed in this study. These two species are not discussed in this report because of insufficient specimens.

The purposes of this report are to: (1) provide keys to help identify the early life stages for 11 cyprinids; (2) revise the Interagency Ecological Program (IEP) Technical Report 9 (Wang, 1986) by updating life histories descriptions of the cyprinids; and 3) document previously unreported splittail spawning grounds in the Bay and Delta. Splittail have been a species of concern in California since the mid-1980's (Williams, *et al.*, 1989); however, they were removed in 1993 from the threatened species list of the U.S. Fish and Wildlife Service (USFWS). Accurate identification of cyprinid larvae will help researchers understand the ecological role of cyprinids in the Bay, Delta, and River fish communities.

METHODOLOGY

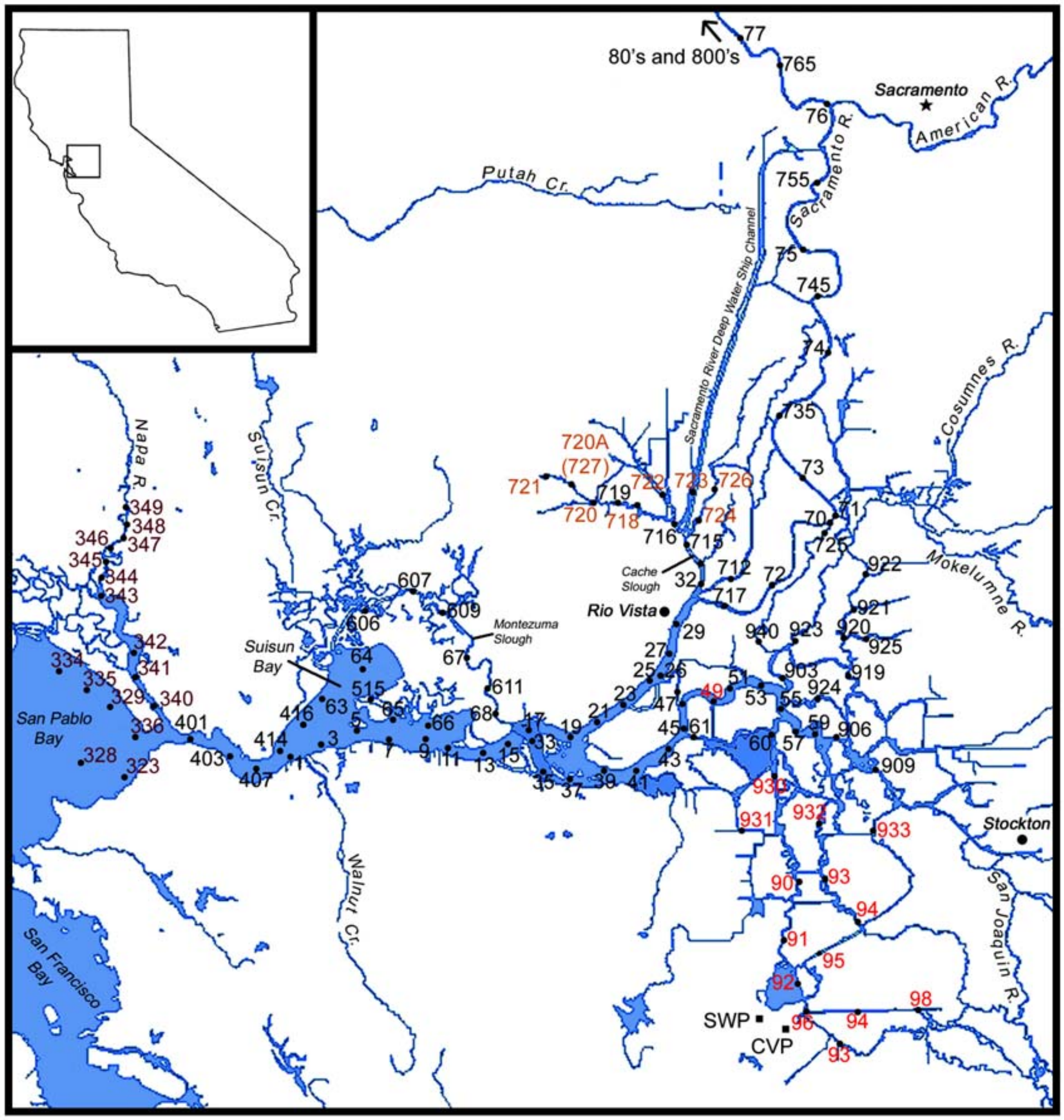
Specimens Examined

Specimens were collected through three large and several smaller sampling programs, preserved in formalin, and stained with Rose Bengal to facilitate identification in samples. Three major eggs and larvae (E&L) sampling programs were conducted, and a map of the study area (figure 1) identifies all the sampling stations from these three programs:

- In the the Delta, 1988–1995, by the California Department of Fish and Game (CDFG), including the Bay, eastward to the lower San Joaquin River, the lower Mokelumne River, and northward to the upper Sacramento River.
- In the North Bay Aqueduct (NBA), 1995–2004, by CDFG and the California Department of Water Resources (DWR), including Barker Slough, Lindsey Slough, Miner Slough, Cache Slough, and the Sacramento Deep Water Shipping Channel.
- In the Central and South Delta, 1991–1995, by DWR. This program was part of a study of fish entrainment losses the TFCF and the nearby California State Water Project's (SWP) fish salvage facility, the J.E. Skinner Delta Fish Protective Facility (SDFPF).

Smaller E&L sampling and identification and quality control (QC) programs that contributed specimens to this key were also conducted:

- At the TFCF intake canal by Reclamation in 1991, 1992, and 1994 (Hiebert, *et al.*, 1995, Siegfried, *et al.*, 2000).
- In Suisun Marsh by University of California at Davis (UCD, Scott Matern and Robert Schroeter), 1995–2002.
- In Putah Creek, by UCD (Michael Marchetti), 1997 and 1998.
- In Putah Creek, Cosumnes River Preserve, and Lodi Lake, by Andy Rockriver (California State University [CSU] Sacramento), 1997 and 1998.
- Identification and QC program for E&L specimens collected in Butte Creek, Big Chico Creek, and Mud Creek by CSU Chico (Michael Marchetti and Gabriel Kopp), 2002–2004.
- Identification and QC program for fish eggs, larvae, and juvenile specimens collected in Delta and River by Interagency Ecological Program (IEP) member agencies, 1995–2003.



LEGEND
CDFG Striped Bass Egg & Larvae Survey Stations
CDFG North Bay Aqueduct Fish Eggs & Larvae Sampling Stations
DWR Central and South Delta Fish Eggs & Larvae Sampling Stations
CDFG Napa River and San Pablo Sampling Stations (except 347, 348, 349)

FIGURE 1.—Map of the study area.

Additional specimens collected in Putah Creek by Marchetti and Moyle (2000) were loaned from Grimaldo *et al.* (2004) and used in development of the cyprinid keys. Reference specimens are listed in appendix table A7 (List of Reference Specimens for Species Accounts, pp. A38–A46). This section lists the origin of specimens examined (Study project/programs, location, year, and collector) and major references used to describe spawning and early life stages of each species.

We also used live specimens from the wild and laboratory cultures. The major sources were from the TFCF, from 1991 to 2004, and the Delta and River, collected by Reclamation employees from 2000 to 2004. Sampling equipment included the TFCF holding tank with a receiving bucket made of 4.0-mm metal mesh, 3.2-mm and 6.4-mm fine-mesh beach seines, 505-µm plankton nets, and light traps. Eggs collected from the wild were incubated at collection location temperature using a Haier® refrigerator (incubator) equipped with a digital temperature controller from Aqua Logic, Inc., San Diego, California. Live specimens were raised indoors in 10-gal glass aquaria and were fed rotifers and artemia. After examination, live specimens were preserved in 5-percent formalin to minimize specimen shrinkage. Measurements were taken from both preserved and live specimens. The Fish Conservation and Culture Laboratory (FCCL) at the state SDFPF also provided live specimens.

We examined splittail early life stages from field and lab specimens. Field E&L and fish specimens were collected mainly by the CDFG and DWR programs in the Delta, the NBA, and Central and South Delta sampling (1988–2004, appendix tables A4, A5, A6). Lab specimens were obtained in 2002–2004 from the FCCL. Reclamation biologists and Bradd Bridges of the FCCL spawned a captive brood stock (1998 year class) of splittail in 2003–2004. Females were injected with Ovaprim™ (Syndrel Laboratories, Ltd., Vancouver, Canada) to stimulate ovulation and to synchronize spawning.

Laboratory Equipment

We observed and recorded the morphological development of each species and their life stages using Leica™ models MZ8 and MZ7 dissecting microscopes with a Polaroid™ digital camera and Image Pro© image analysis software. Additional images were obtained using a Hitachi™ Color Video Printer. Both drawings and images were of wild specimens when possible.

Adequate magnification is necessary to identify early life stage cyprinids. Because the body structures of the prolarval to postlarval stages are transparent, translucent, and exhibit low contrast, transmitted light (bright field) is best for counting myomeres and for observing internal structures and pigmentation. For prejuveniles and juveniles, reflected light from above with little or no light from below the specimen (dark field lighting) is necessary for observing structures since specimens are more opaque except for the fins. For all but the larger postlarvae and juveniles, a magnification range of 10-12.5X was suitable for measuring fish length and structures; however, detailed observations required magnification of 30-50X.

Species Accounts

The species accounts provide a summary of spawning information, taxonomic characteristics for each life stage, life histories, and two illustrations (drawings and digital photographs) showing the development of the species. Common and scientific names of fishes follow Nelson, *et al.* (2004). Account format and content are as follows:

Common Name, *scientific name*.

SPAWNING

Location:	Specific geographic locations and general habitat types.
Season:	Months.
Temperature:	Upper and Lower preferred.
Salinity:	Preference for freshwater and (or) brackish water (oligohaline, mesohaline).
Substrates:	Observed substrates, including rock, gravel, sand, mud, vegetation, and man-made structures.
Fecundity:	Estimate based on subsamples or counts of mature eggs in ovaries.

EGGS

Shape:	Fertilized egg spherical, oval, or elongated.
Diameter:	Fertilized eggs measured across the maximum outer chorion diameter or long and short axes for distinctly oval eggs.
Yolk:	Color, texture and shape.
Oil globule:	Size, number, and color.
Chorion:	Smoothness, thickness, transparency, and elasticity.
Perivitelline space:	Width of vitreous space between the chorion and the yolk measured in early developmental stages.
Egg mass:	Fish eggs deposited individually or in clusters.
Adhesiveness:	Most demersal eggs have some degree of adhesiveness; pelagic eggs are not adhesive.
Buoyancy:	Pelagic eggs are floating or neutrally buoyant, demersal eggs are negatively bouyant.

LARVAE

Length of hatching:	Total length (TL in mm), tip of snout to tip of tail.
Snout to anus length:	Percentage of the total length (the location of anus may change with developmental stage) measured to center of anus.
Yolk sac:	Size, shape, location from recently hatched larvae.
Oil globule(s):	Size, color, number, and location.
Gut:	Length, shape (straight, curled, or coiled), and thickness depending on development stage of larvae.
Air Bladder:	Location, shape (narrow, shallow, inflated in spherical or oval), size, and pigmentation on top of air bladder.
Teeth:	Type, size, and number of rows of teeth on upper jaw and lower jaw (pharyngeal teeth formations are not included).
Size at absorption of yolk sac:	TL when the yolk appears completely absorbed.
Total myomeres:	The number of myomeres between the most anterior myoseptum and the most posterior (true) myoseptum (preanal plus postanal myomeres).
Preanal myomeres:	Number counted from a line perpendicular to the long axis of fish's body at the anus to the most anterior myoseptum.
Postanal myomeres:	Counted from the first completed myomere behind the perpendicular line at the anus to the most posterior myoseptum.
Last fin(s) to complete development:	Name of the fin(s) that develops last indicating onset of juvenile stage.
Pigmentation:	Melanophores and chromatophores in all shapes and sizes on head, body, and finfolds.
Distribution:	Both general geographic distribution and specific range are described.
Key Taxonomic Characteristics:	Distinctive features useful in identifying life stage specimen.

JUVENILES

Dorsal fin rays:	The number of spiny rays or hardened rays in Roman numerals; soft rays in Arabic numerals (Example III-10).
Anal fin rays:	As for dorsal fin.
Pectoral fin rays:	A similar description as dorsal and anal fins.

Mouth:	Mouth location (inferior, superior, terminal) and size (large, small, slanted).
Vertebrae:	Total number of vertebrae including weberian ossicles.
Distribution:	Both general geographic distribution and specific information on habitats are included.
Key Taxonomic Characteristics:	Distinctive features useful in identifying life stage specimen.

LIFE HISTORY

Geographic distribution:	Range, origin, and local records of distribution.
Spawning biology:	Includes spawning runs or movements, habitats and substrates, period and frequency of spawn, sexual dimorphism, and other pertinent characteristics.
Characteristics of eggs:	Includes incubation time period, development, and temperature requirements.
Characteristics of newly hatched yolk-sac larvae and postlarvae:	Includes habitat, behavior, movement, and biology.
Characteristics of juvenile fish:	Includes habitat, stratum, behavior, movement, feeding, and biology.
Sexual maturity, size, and economic or other value:	Includes comments on the ecological status.

The life history section of splittail includes additional information on the spawning of splittail in the Bay and Delta. This section adds adult spawning characteristics, laboratory observations of spawning and early life history behavior, field observations from fish E&L sampling on early life history behavior, and a discussion.

Although we have tried to be comprehensive in developing this guide, some limitations should be noted. The eggs and yolk-sac larvae of hardhead were not collected. Specimens for myomere and vertebrae counts for the California roach were limited to those collected in the River and the Delta's adjacent coastal streams. Because of the complexity of the California roach species, measurements may not be representative of the full geographic range of this species. Finally, laboratory reared fish eggs and larvae may not represent the normal characteristics found in the wild stock such as melanophore density and overall color. When measurements from laboratory specimens are used, they are noted.

RESULTS

The 3 life stages described in this report are prolarvae-early postlarvae, late postlarvae-prejuveniles, and early juveniles (Wang and Kernehan, 1979; Wang, 1991). Prolarvae-early postlarvae are larvae with yolk sac (prolarvae) up to larvae with completely absorbed yolk sac (early postlarvae). Late postlarvae-prejuveniles are larvae with developed flexion and finbuds (late postlarvae) to larvae with almost fully developed fins and fin rays (prejuvenile). Early juveniles are larvae with all the fin rays developed. Refer to figures 2a and 2b for egg and larval anatomy and for illustrations of meristics and morphometrics used in the keys.

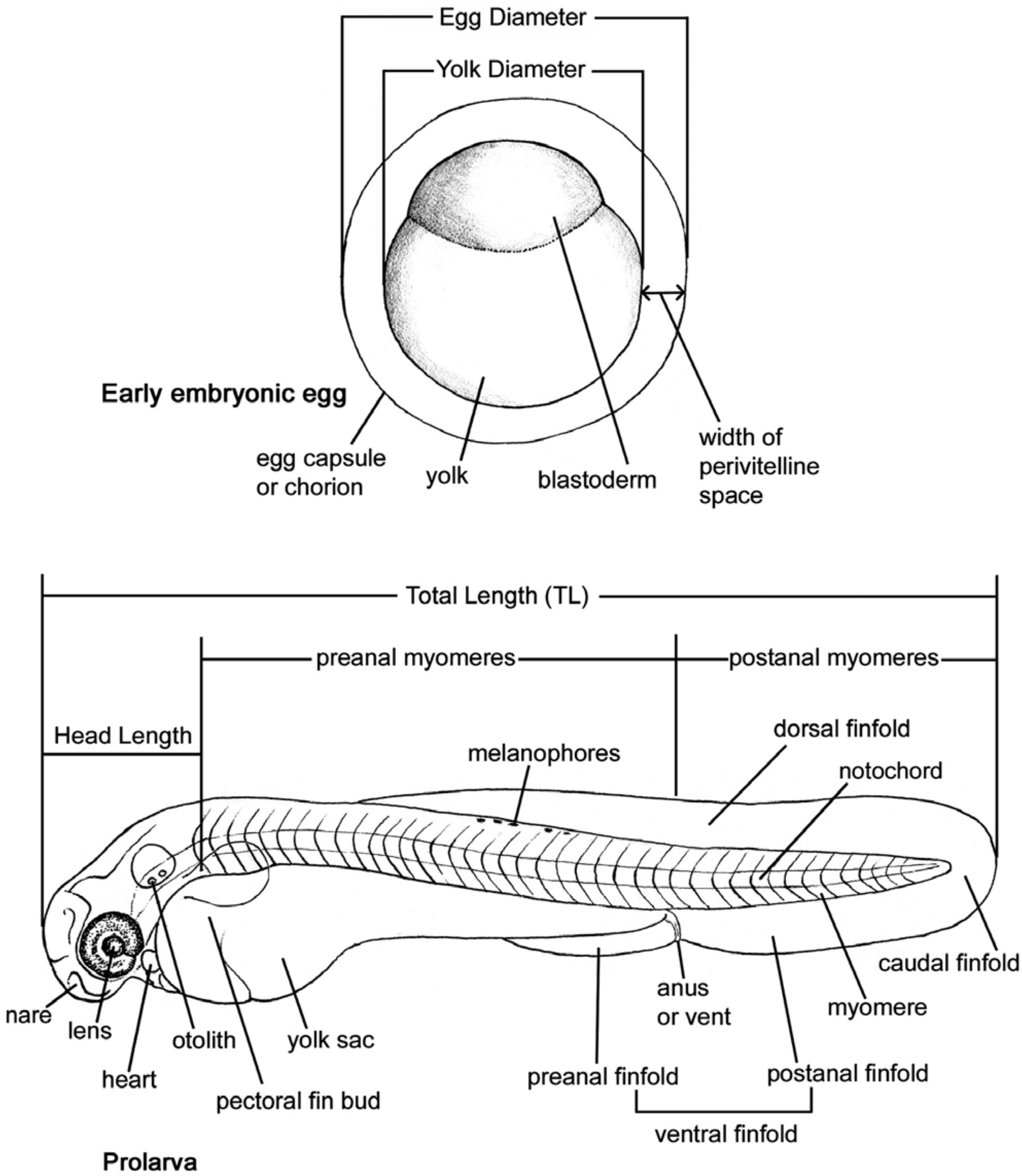
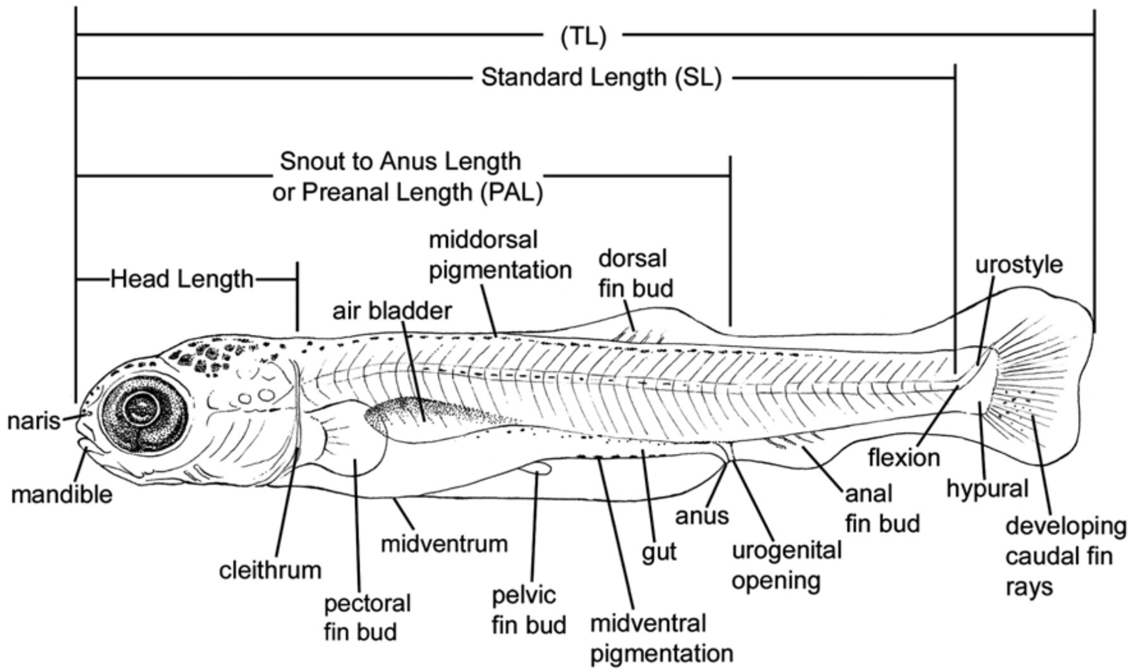
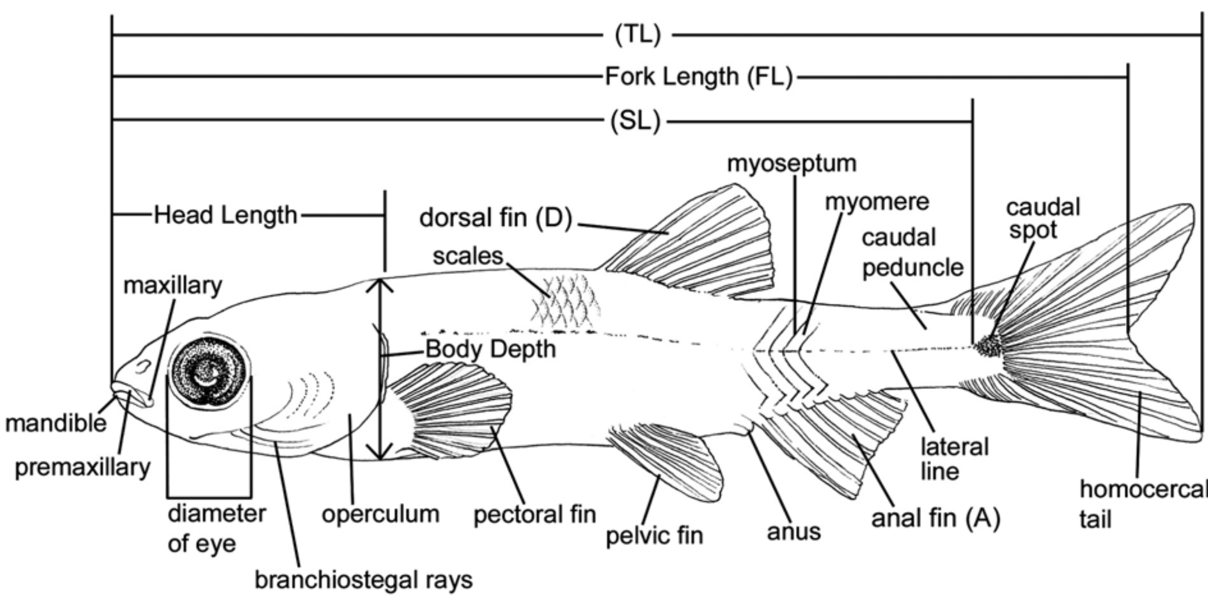


FIGURE 2a.—Anatomical features for fish eggs (top) and prolarva (bottom) life stage fish used in this key.



Postlarva-Prejuvenile



Juvenile

FIGURE 2b.—Anatomical features for postlarva-prejuvenile (top) and juvenile (bottom) life stage fish used in this key.

Species Identification Key for Prolarval to Early Postlarval Cyprinids in the Delta

(Refer to figures 3a and 3b for this key.)

Life stages: The key covers larvae that have a yolk sac, finfolds, and a straight notochord to larvae that have absorbed the yolk sac and a completed or nearly completed notochord flexion.

Size range: Larvae generally ≤ 8.0 mm TL, with the exception of Sacramento pikeminnow which may extend to 12.0 mm TL.

1a. Fish have little or no pigmentation on mid-dorsum, preanal length (PAL) short or ≤ 60 percent of TL 2
1b. Fish have pigmentation on middorsum, PAL longer or > 60 percent of TL 3

2a. Fish have no middorsal pigmentation, except on top of head .... Red shiner
2b. Fish have light and sparse middorsal pigmentation .... Fathead minnow

3a. Fish have a heavy and full-length line of midventral pigmentation (figures 3a- and 3b-1) .... Golden shiner
3b. Fish have scattered or no pigmentation on midventral 4

4a. Fish have a matching pair of melanophores on middorsum (figures 3a- and 3b-2) .... Splittail
4b. Fish have mismatched or random pigmentation on middorsum (figures 3a- and 3b-2) 5

5a. Fish have a “U”-shaped pigmentation in front of pectoral fin (figures 3a- and 3b-3) 6
5b. Fish have no “U”-shaped pigmentation in front of pectoral fin 7

6a. Postanal myomeres 11-14, gut pigmentation heavy, “U”-shaped pigmentation is well defined .... Common Carp
6b. Postanal myomeres 8-10, gut pigmentation light, “U”-shaped pigmentation not well-defined .... Goldfish

7a. Total myomeres 42 or less 8
7b. Total myomeres 44 or more 10

8a. Fish have “hatchet”-shaped pigmentation at caudal fin (figures 3a- and 3b-4) .... Hitch
8b. Fish have no “hatchet”-shaped pigmentation at caudal fin 9

9a. Caudal pigmentation usually separated into two groups, ventral caudal peduncle may have no pigmentation-free zone, thoracic and midventral has pigmentations arranged as "cathedral" pattern (figures 3a- and 3b-5)........... Sacramento blackfish

9b. Caudal pigmentation usually in one group, ventral caudal peduncle has a pigmentation-free zone, thoracic and midventral has no pigmentation arranged as "cathedral" pattern .... California roach

10a. Dense patch of pigmentation radiated at lower part of caudal fin, caudal peduncle can have a stubby look, and midventral usually has no pigmentation (figures 3a- and 3b-6) .... Sacramento pikeminnow

10b. Caudal pigmentation scattered, and has two dark spots (one above the flexion, and other at the ventral base of caudal peduncle), caudal peduncle is not stubby, and a short midventral pigmentation may occur .... Hardhead

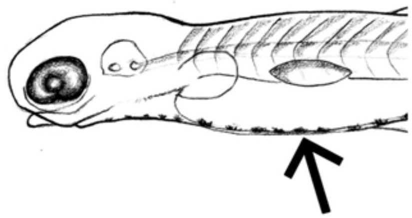


Figure 3a-1 - Ventral view of golden shiner late prolarva showing heavy midventral pigmentation

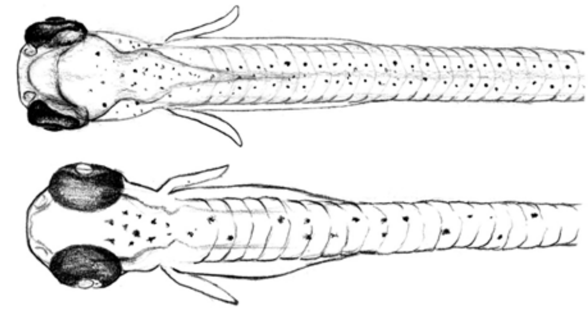


Figure 3a-2 - Dorsal views of large paired melanophores on splittail (top) and random pigmentation on a non-splittail (bottom).

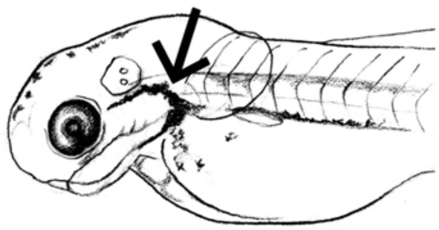


Figure 3a-3 - U-shaped pigmentation in front of pectoral fin.

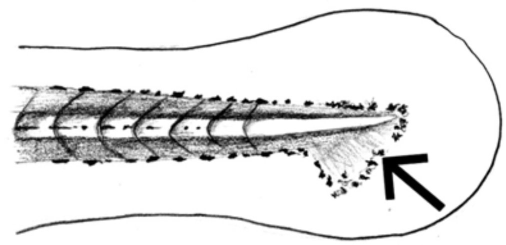


Figure 3a-4 - Hatchet-shaped pigmentation at the caudal fin.

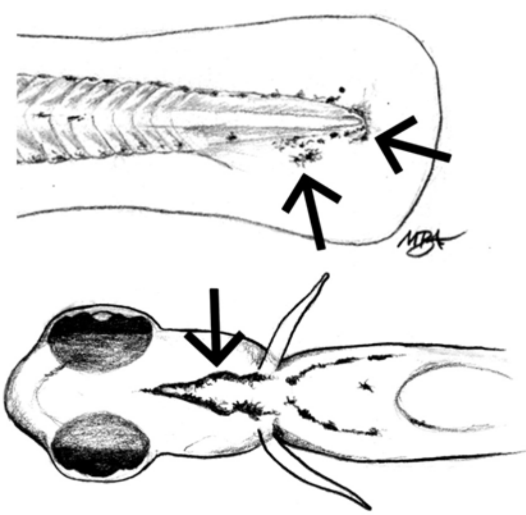


Figure 3a-5 - Lateral view (top) of Sacramento blackfish caudal region showing 2 pigmentation groups, and ventral view (bottom) of thoracic region with "cathedral" pattern.

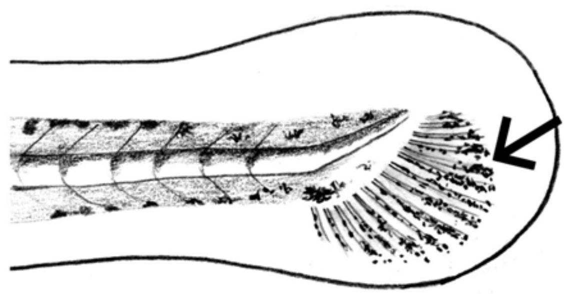


Figure 3a-6 - Caudal fin with dense pigmentation patch radiating from the base.

FIGURE 3a.—Line drawings showing features common to to prolarvae to early postlarvae life stage fishes.

Figure 3b-1 - Ventral view of the golden shiner late prolarva showing heavy midventral pigmentation.

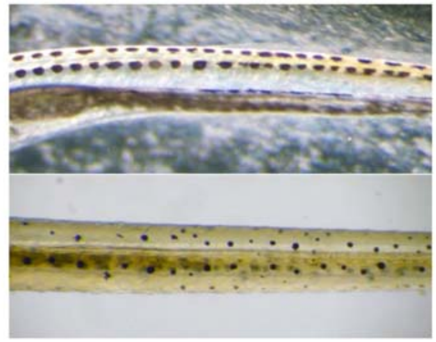


Figure 3b-2 - Dorsal view of large paired melanophores of splittail (top) and random pigmentations of a non-splittail (bottom).

Figure 3b-3 - U-shaped pigmentation in front of pectoral fin.

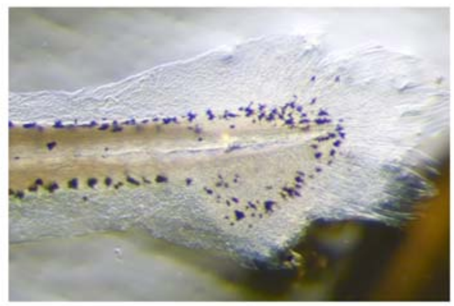


Figure 3b-4 - Hatchet-shaped pigmentation pattern at the caudal.

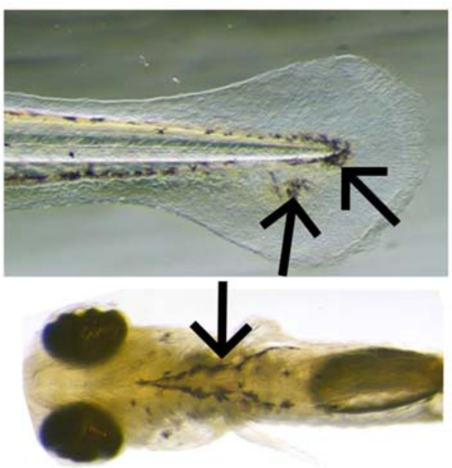


Figure 3b-5 - Lateral view (top) of Sacramento blackfish showing 2 pigmentation groups, and ventral view (bottom) of thoracic region with "cathedral" pattern.

Figure 3b-6 - Sacramento pikeminnow prolarva with dense pigmentation patch radiating from the base of the caudal fin.

FIGURE 3b.—Photographs showing features common to prolarvae to early postlarvae life stage fishes.

Species Identification Key for Late Postlarval to Prejuvenile Cyprinids in the Delta

(Refer to figures 4a and 4b for this key.)

Life stages: The key covers the life stages where the flexion and finbuds are almost fully developed to when most fins and fin rays are fully developed.

Size range: ~ 8.0-15.0 mm TL (except for the red shiner prejuvenile, which starts at ~ 12.0 mm TL).

1a. Dorsal finbud has an elongated base (figures 4a- and 4b-1)....................................2
1b. Dorsal finbud has short base (figures 4a-and 4b-2)..3

2a. Postanal myomeres 8-10...Goldfish
2b. Postanal myomeres 11-14...Common carp

3a. Midventral pigmentation extends from anus forward (figures 4a- and 4b-3)..........4
3b. Midventral pigmentation does not extend from anus forward.................................6

4a. Dense midventral pigmentation extends from anus to thoracic..........Golden shiner
4b. Loose midventral pigmentation distributed from anus forward to abdominal 5

5a. Total myomeres ≥ 34, web like pigmentation surrounds the vertebrae, upper half of the body well-pigmented when viewed laterally (figures 4a- and 4b-4) ....Fathead minnow
5b. Total myomeres ≤ 33, no web like pigmentation surrounds vertebrae, upper half of the body lightly pigmented when viewed laterally............................. Red shiner

6a. Large melanophores paired in two rows along dorsum, upper body unpigmented (figures 4a- and 4b-5) ....Splittail
6b. Different sizes of melanophores concentrated along dorsum, upper body partially pigmented...7

7a. Myomeres count ≥ 44 8
7b. Myomeres count ≤ 43 9

8a. Myomeres count 46-50, isthmus pigmented, middorsal melanophores have two different sizes, midventral surface with scattered melanophores .... Hardhead
8b. Myomeres count 44-48, isthmus unpigmented, middorsal melanophores are even size, midventral surface usually unpigmented (some may have 1-2 melanophores) ....Sacramento pikeminnow

9a. "Cathedral" shaped pigmentation arranged in thoracic region, 2 pigmentation-free zones behind caudal peduncle (figures 4a- and 4b-6)............. Sacramento blackfish
9b. No "cathedral" shaped pigmentation arranged in thoracic region, 2 pigmentation-free zones behind caudal peduncle is less defined...10

10a. Ventral caudal peduncle has pigmentation-free "gap", light pigmentation along gut and air bladder (figures 4a- and 4b-7) .... California roach
10b. Ventral caudal peduncle has no such "gap", dense pigmentation along gut and air bladder ....Hitch

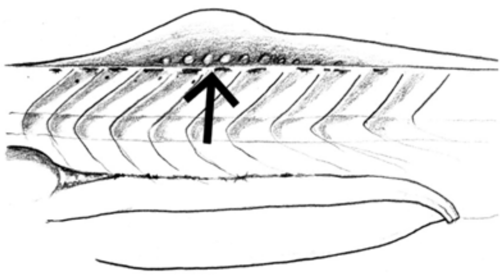


Figure 4a-1 - Dorsal finbud with elongated base.

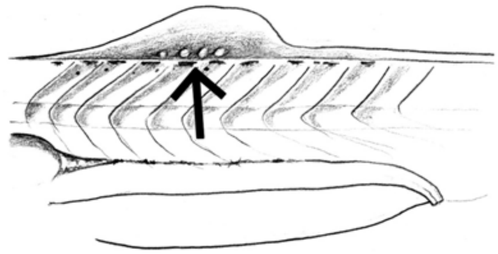


Figure 4a-2 - Dorsal finbud with a short base

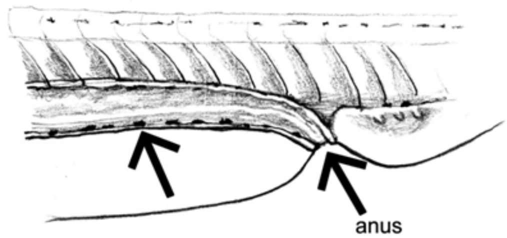


Figure 4a-3 - Midventral pigmentation extending forward from anus.

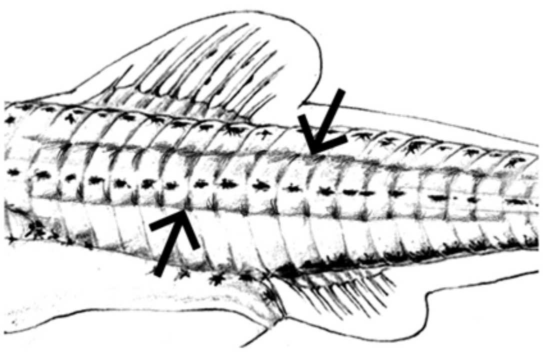


Figure 4a-4 - Lateral view of fathead minnow prejuvenile showing pigmentations around the vertebrae.

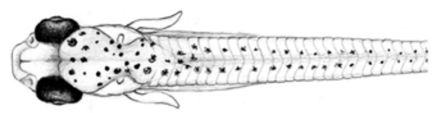


Figure 4a-5 - Dorsal view of splittail late prolarva showing paired pigmentation.

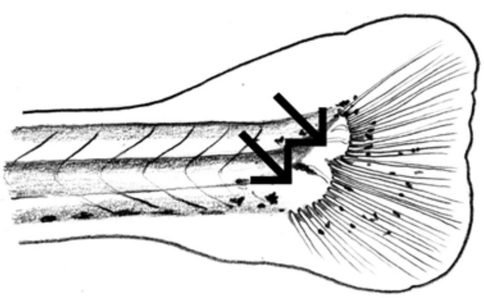


Figure 4a-6 - Sacramento blackfish prejuvenile with two pigmentation-free zones behind the caudal.

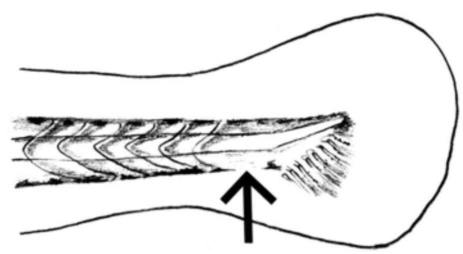


Figure 4a-7 - California roach late prolarva with pigmentation-free gap on the ventral caudal peduncle.

FIGURE 4a.—Line drawings showing features common to late postlarvae to prejuvenile life stage fishes.

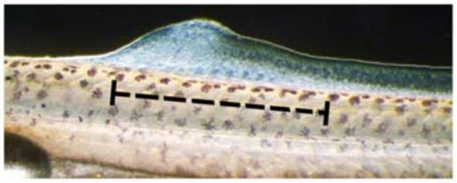


Figure 4b-1 - Dorsal finbud with elongated base.

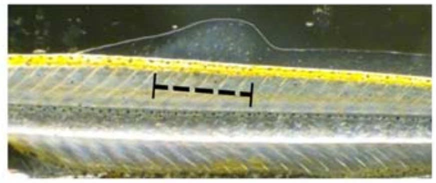


Figure 4b-2 - Dorsal finbud with a short base.

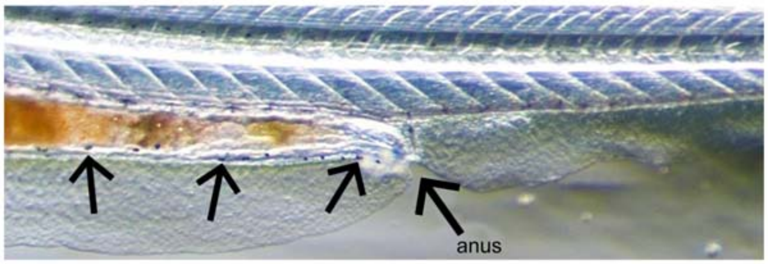


Figure 4b-3 - Midventral pigmentation extending forward from anus.

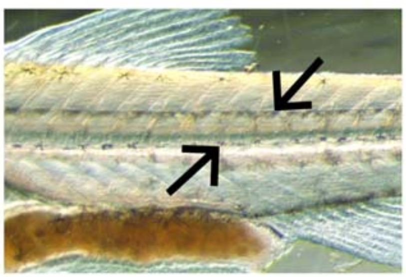


Figure 4b-4 - Lateral view of fathead minnow prejuvenile showing pigmentations around the vertebrae.

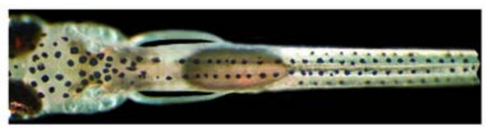


Figure 4b-5 - Dorsal view of splittail late prolarva showing paired pigmentation.

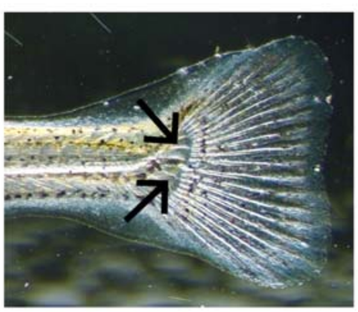


Figure 4b-6 - Sacramento blackfish prejuvenile with two pigmentation-free zones behind the caudal.

Figure 4b-7 - California roach late prolarva with pigmentation-free gap on the ventral caudal peduncle.

FIGURE 4b.—Photographs showing features associated with late postlarvae to prejuvenile life stage fishes.

Species Key for Early Juvenile Cyprinids in the Delta

(Refer to Figures 5a and 5b for this key.)

Life stage: The key covers the life stage when all fin rays developed; scales may or may not be completely developed.

Size range: ~ 15.0-25.0 mm TL. Red shiner range ~ 12.0-25.0 mm TL. Sacramento pikeminnow reach juvenile stage at a larger size (between 21-25 mm TL).

1a. Base of the dorsal fin is long with ≥ 14 fin rays (figures 5a- and 5b-1) 2
1b. Base of the dorsal fin is short with 8-13 fin rays... 3

2a. Mouth barbels present, body narrow and elongate ....Common carp
2b. Mouth has no barbels, body deeper and short ....Goldfish

3a. Caudal fin may be asymmetrical with enlarged upper lobe, mouth slightly subterminal and may have barbels. ....Splittail
3b. Caudal fin symmetrical, mouth terminal, no barbels… 4

4a. Anal fin rays 11 and greater...5
4b. Anal fin rays 10 and lesser...6

5a. Anal fin ray count 13-15 (typically 14); anal fin has a "hook" profile (figures 5a- and 5b-2) ....Golden shiner
5b. Anal fin ray count 11-14 (typically 12); anal fin has falçate appearance (figures 5a- and 5b-2) ....Hitch

6a. ≥ 45 myomeres...7
6b. ≤ 43 myomeres...8

7a. Mouth large (maxilla reaches to front edge of eye); nostril flap not enlarged (figures 5a- and 5b-3) ....Sacramento pikeminnow
7b. Mouth small (maxilla does not reach front edge of eye), myomeres count as high as 46-50, nostril flap enlarged (figures 5a- and 5b-3)...............................Hardhead

8a. Lateral line scales count high (up to 105)..............................Sacramento blackfish
8b. Lateral line scales count low (≤ 65)...9

9a. Pigments on outer edge of scales forming crescent-shape (figures 5a- and 5b-4).. Red shiner
9b. No crescent-shaped formation on scales..10

10a. Snout blunt, caudal peduncle thick, no caudal spot........................Fathead minnow
10b. Snout pointed, caudal peduncle thin, caudal spot visible .... California roach

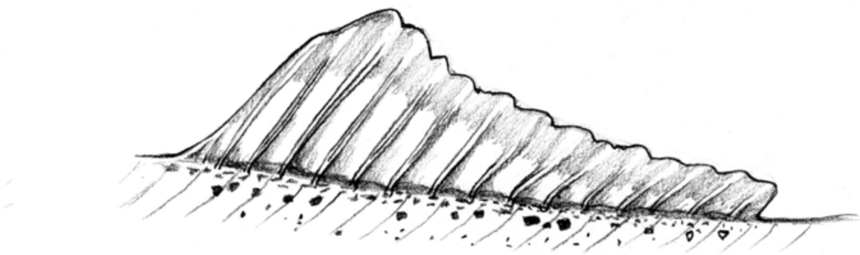


Figure 5a-1 - base of dorsal fin with 14 or more fin rays.

Figure 5a-2 - Golden shiner anal fin showing “hook” profile (left), and hitch fin showing flacate appearance (right).

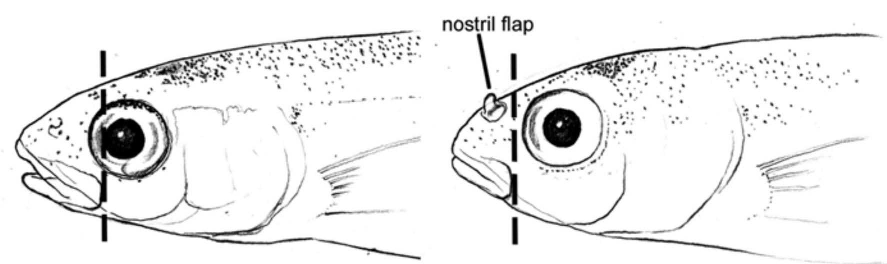


Figure 5a-3 - Sacramento pikeminnow with large mouth (maxilla reaches to front edge of eye) and small nostril flap (left). Hardhead with small mouth (maxilla does not reach edge of eye) and enlarged nostril flap (right).

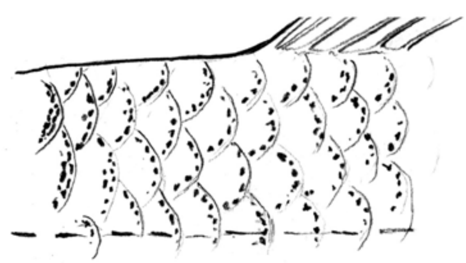


Figure 5a-4 - Crescent-shaped pigmentations on outer edges of scales.

FIGURE 5a.—Line drawings of features associated with early juvenile fish.

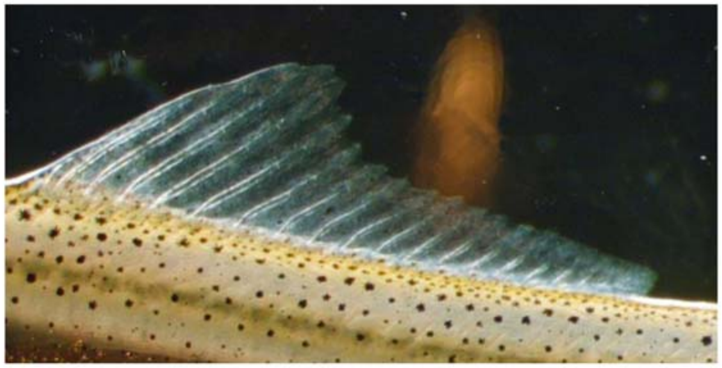


Figure 5b-1 - base of dorsal fin with 14 or more fin rays.

Figure 5b-2 - Golden shiner anal fin showing "hook" profile (left), and hitch fin showing flacate appearance (right).

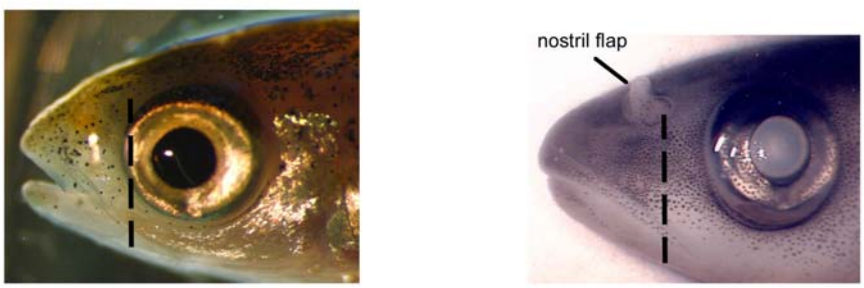


Figure 5b-3 - Sacramento pikeminnow with large mouth (maxilla reaches to front edge of eye) and small nostril flap (left). Hardhead with small mouth (maxilla does not reach edge of eye) and enlarged nostril flap (right).

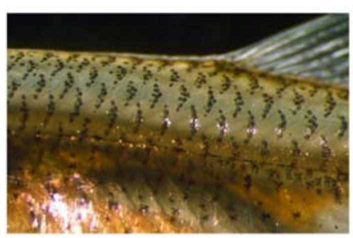


Figure 5b-4 - Crescent-shaped pigmentations on outer edges of scales.

FIGURE 5b.—Photographs of features associated with early juvenile fish.

Species Accounts

Goldfish, *Carassius auratus* (Linnaeus)

SPAWNING

Location:	Delta, River, in shallow water among aquatic vegetation in creeks, ditches, ponds and reservoirs such as Cache, Lindsey, and Wilson sloughs, Coyote Creek, Lodi Lake, Putah Creek, flood control ditch in the Hillcrest Community Park (in the Walnut Creek system, City of Concord, CA), Diablo Creek golf course pond (City of Concord, CA), Lake Berryessa, Millerton Lake at the San Joaquin River, and the TFCF intake canal and abandoned intake canal.
Season:	Spawning adults were observed in late March; first spawns in April or May (Moyle, 1976); spawning occurs from April to July based on larval presence.
Temperature:	15-23 °C (Moyle, 1976); 16-23 °C (Jones, *et al.*, 1978); 18.5-29.5 °C (Battle, 1940); 16-23 °C (Lippson and Moran, 1974); 16-26 °C (Wang, 1986).
Salinity:	Freshwater.
Substrates:	Aquatic vegetation, submerged tree branches, roots, and leaves.
Fecundity:	Size dependent; average 14,000 (Moyle, 1976); up to 400,000 (Slastenenko, 1958); absolute fecundity 160,000-380,000 (Becker, 1983).

EGGS

Shape:	Spherical.
Diameter:	1.0-1.7 mm (Okada, 1959–1960); 1.2-1.5 mm (Wang and Kernehan,1979); 1.4-1.7 mm (Wang, 1986).
Yolk:	Pale yellow, granular (Battle, 1940; Jones, *et al.*, 1978); yellowish, granular.
Oil globule:	Many small globules (Battle, 1940).
Chorion:	Transparent, smooth (Smith, 1909); transparent, smooth except for the adhering area.
Perivitelline space:	Narrow.
Egg mass:	Individually, can be very dense in certain areas from repeated deposition.
Adhesiveness:	Adhesive (Battle, 1940).
Buoyancy:	Demersal.

LARVAE

Length of hatching:	3.0 mm TL (Watson, 1939); 5.0 mm TL (Okada, 1959–1960); 4.0-4.5 mm TL (Wang and Kernehan, 1979); up to 5.2 mm from field collections.
Snout to anus length:	~ 62-68 percent of TL for both prolarval and postlarval stages.
Yolk sac:	Elongated, enlarged and oval in thoracic region; tapered and cylindrical in abdominal region; develops into a cylindrical shape (Jones, *et al.*, 1978); two sections turn into one elongated yolk sac.
Oil globule(s):	Minute oil globules, scattered in the yolk sac (Battle, 1940).
Gut:	Straight.
Air Bladder:	Elongated, small near thoracic region and develops into two chambers in postlarval stages.
Teeth:	None.
Size at absorption of yolk sac:	~ 5.5-6.0 mm TL (Battle, 1940; Okada, 1959–1960; Nakamura, 1969; Wang, 1986).
Total myomeres:	32-34 (Mansueti and Hardy, 1967); 29-32 (Wang, 1986); 28-32.
Preanal myomeres:	21-22 (Mansueti and Hardy, 1967; Wang, 1986).
Postanal myomeres:	11-12 (Mansueti and Hardy, 1967); 8-12 (Wang, 1986).
Last fin(s) to complete development:	Pelvic.
Pigmentation:	Melanophores found in dorsal region of gut, midventral, and postanal regions; large stellate melanophores on snout, cephalic and middorsal region. Pigmentation is lighter than that of common carp larvae of similar life stage. A "U"-shaped pigmentation pattern (rotated 90° to left), the lines of which are sometimes not well connected, in front of cleithrum.
Distribution:	Newly hatched larvae remain at bottom (Smith, 1909); near surface after yolk sac is absorbed (Fearnow, 1925); the late postlarval stages stay at the bottom of shallow water with dense vegetation, such as the Putah Creek, upper Cache slough, and Lindsey slough.

Key Taxonomic Characteristics:

1. Elongated dorsal finbud.
2. Fewer postanal myomeres count (~ 8-10) than common carp (~ 11-14).
3. "U"-shaped pigmentation in front of cleithrum, may have incomplete "U".

JUVENILES

Dorsal fin rays: I-II, 14-20 (Scott and Crossman, 1973; Nichols, 1943); III-V, 14-19 (Lippson and Moran, 1974); II, 17-19 (Moyle, 2002).

Anal fin rays: I-II, 5-6 (Scott and Crossman, 1973; Nichols, 1943); II-III, 5-7 (Lippson and Moran, 1974); II, 5-6 (Moyle, 2002).

Pectoral fin rays: 12-17 (Sterba, 1959; Jones, *et al.*, 1978); 15-17 (Scott and Crossman, 1973).

Mouth: Small, terminal, oblique (Scott and Crossman, 1973).

Vertebrae: 28-32 (Slastenenko, 1958; Berg, 1964); 28-29 (Scott and Crossman, 1973); 30 (Jones, *et al.*, 1978).

Distribution: Commonly found in freshwater drainages of the Delta and River, including most land-locked warm water ponds and reservoirs.

Key Taxonomic Characteristics:

1. Front fin rays in dorsal and anal fins have fused segments.
2. Mouth has no barbels.
3. Body short, wide, and deep.
4. Lateral line scales count: 28-31.
5. Myomere count between the insertion of dorsal fin (D) and origin of anal fin (A): 3-4. Insertion of D is posterior to origin of A.

LIFE HISTORY

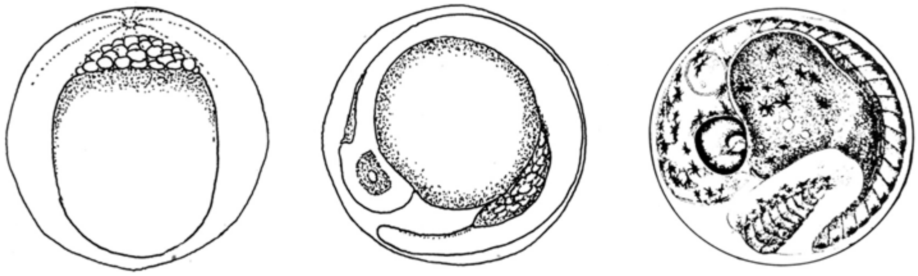
Goldfish originally ranged from China through Eastern Europe, where they were bred domestically as pets in a wide variety of colors, shapes, and sizes. The goldfish were introduced into North America probably during the late 19th century (Scott and Crossman, 1973). Dill and Cordone (1997) estimated that goldfish might have been established in California as early as the 1880's. This species is now widely distributed throughout the warm waters of California (Moyle, 2002). We observed both wild and domestic goldfish in the freshwater portions of the Delta and River.

Spawning occurs in shallow, weedy coves during spring and summer. The goldfish residing in Cache Slough and Putah Creek spawn much later than that of common carp. Goldfish larvae were observed from April to July, and seemed to be more abundant in late June and July. Goldfish can reproduce in small ponds, such as those located at the Diablo Creek golf course. During spawning, each female may be pursued by several males, either at her side or from behind (Scott and Crossman, 1973). The highly adhesive eggs are deposited on submerged substrates and remain there throughout the incubation period. The eggs hatch in about five days at 20 °C (Okada, 1959–1960) or in three to four days at 20-27.5 °C (this study). Observations of different sizes and development of ova in individual ovaries indicate that female goldfish are iteroparous.

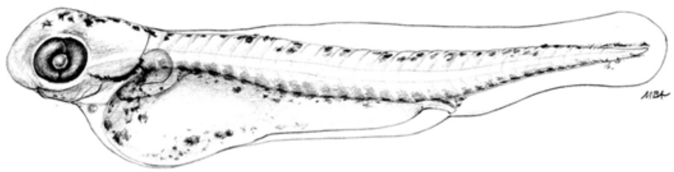
Newly hatched larvae remain near the spawning area. Specimens were collected primarily with a light trap near shore at Putah Creek and Lodi Lake (Rockriver, 1998). The rest were collected in open-water plankton townets from the CDFG fish E&L sampling programs in the Delta and the NBA. Remaining in shallow water with vegetation is a good strategy for minimizing predation.

Large juveniles (35-50 mm TL) were occasionally captured with a beach seine in dense vegetation at Sweeney Creek, Coyote Creek, backwater sloughs of the Delta, including the intake canal of the TFCF. Juvenile goldfish were observed in several shallow coves in Millerton Lake in summer and fall. Juveniles feed primarily on zooplankton, insect larvae and algae and are considered omnivorous (Moyle, 2002).

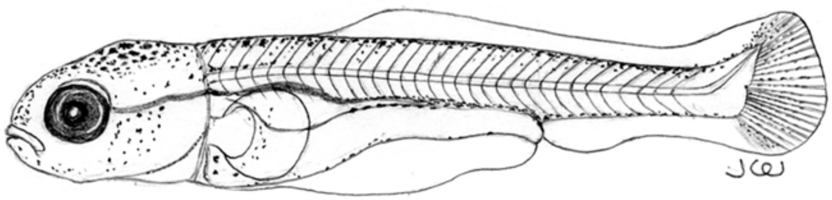
Female goldfish reach maturity in 3 to 4 years; male fish usually mature in 2 to 3 years (Moyle, 2002). Breder and Rosen (1966) reported that goldfish may mature in less than one year or as many as 3-4 years. Goldfish may live as long as 25-30 years in aquaria (Trautman, 1957; Carlander, 1969; Moyle, 1976). Large wild goldfish are sold on the Asian fish market. They are called "Gee-Yu", and are cooked for a fish broth. The domestic strains have been used as fish food for other carnivorous fish and as domestic pets.



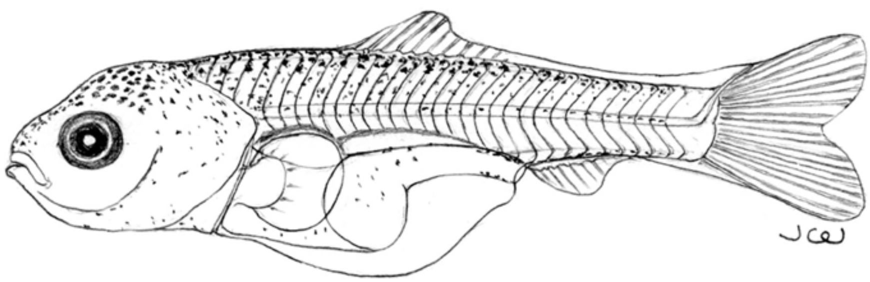
Egg, 1.4-1.7 mm (Wang & Kernehan, 1979)



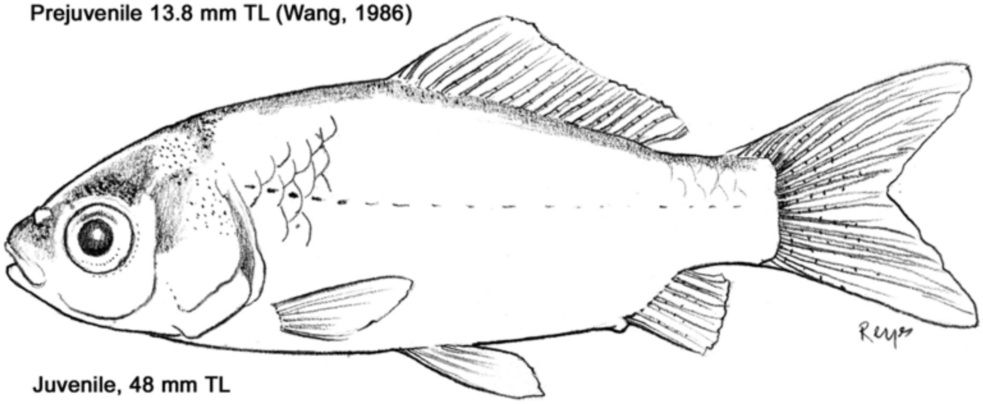
Prolarva, 4.8 mm TL (Wang, 1986)



Postlarva, 9.5 mm TL (Wang, 1986)



Prejuvenile 13.8 mm TL (Wang, 1986)



Juvenile, 48 mm TL

FIGURE 6a.—Line drawings showing goldfish early life stage specimens.

FIGURE 6b.—Photographs showing goldfish early life stage specimens.

Red Shiner, *Cyprinella lutrensis* (Baird and Girard)

SPAWNING

Location:	Delta, River, Putah Creek, Cache Slough, Sacramento River, vicinity of the SDFPF and the TFCF at the South Delta, Lower San Joaquin River, and near McKenzie Point of Millerton Lake.
Season:	May through October, usually in June and July in Kansas (Cross, 1967); March through June in Arizona (Minckley, 1972); June and July in Colorado (Beckman, 1970); April through August in the Delta and River.
Temperature:	15-30 °C (Moyle, 1976); 15-30 °C in the field, 20-30 °C in laboratory environment.
Salinity:	Freshwater (tidal and nontidal).
Substrates:	Aquatic plant, gravel, sand and mud (Cross, 1967); man-made plastic substrates (Spawntex™ spawning mat, Aquatic Eco-Systems, Inc., Apopka, FL).
Fecundity:	485 (Becker, 1983); ~ 1,200 mature ova, with numerous immature ova in female of 65 mm TL (Wang, 1986).

EGGS

Shape:	Spherical.
Diameter:	1.3-1.7 mm for mature unfertilized eggs (Wang, 1986); often 1.2-1.4 mm for fertilized eggs collected in the laboratory in 2003–2004.
Yolk:	Whitish to pale yellow.
Oil globule:	None.
Chorion:	Transparent and smooth except at the adhering spot.
Perivitelline space:	0.2-0.3 mm.
Egg mass:	Individually and scattered; some in small clusters.
Adhesiveness:	Adhesive (Cross, 1967; this study).
Buoyancy:	Demersal.

LARVAE

Length of hatching:	4.2-5.1 mm TL in the laboratory; the smallest field specimen in prolarval stage was 4.5 mm TL.
Snout to anus length:	For newly hatched larvae, 57-60 percent (often 57-59 percent); for postlarvae, 56-59 percent (often 56-57 percent).
Yolk sac:	Elongated and formed two sections; slightly larger in thoracic section.
Oil globule(s):	None.
Gut:	Thin and straight in prolarvae, and slightly bent below the air bladder.
Air Bladder:	Small, oval front position (near pectoral); posterior chamber becomes visible at 4.5-5.0 mm TL, and anterior chamber at ~ 7.0 mm TL.
Teeth:	None.
Size at absorption of yolk sac:	5 mm TL, usually < 5 mm TL (Snyder, *et al.*, 2005); ~ 4.4-5.0 mm TL.
Total myomeres:	30-35 (Taber, 1969); 34-37 (Snyder, 1981; Snyder, *et al.*, 2005); 31-33 (Wang, 1986); 30-34 (often 32-33).
Preanal myomeres:	20-23 (Taber, 1969); 19-24 (Snyder, 1981; Snyder, *et al.*, 2005); 17-19, usually 18 (Wang, 1986); 17-21 (often 18-19).
Postanal myomeres:	10-13 (Taber, 1969); 12-15, usually 13-14 (Snyder, 1981; Snyder, *et al.*, 2005); 13-15, and often 14-15 (Wang, 1986, this study).
Last fin(s) to complete development:	Pelvic.
Pigmentation:	Few melanophores observed on the top of the head and body; sparse pigmentation along midventral regions for newly hatched larvae; pigmentation along postanal region and extending to midventral region in postlarvae.
Distribution:	Most often found in shallow water of sloughs, ponds and lakes in patchy pattern; abundant in Putah Creek; widespread in the Delta, especially in polluted sloughs and intermittent streams.

Key Taxonomic Characteristics:
1. Head has ~ 3 large melanophores, and body has a few pigments.
2. Short gut (~ 57-60 percent PAL/TL).
3. Total myomere count in the low 30's (30-34, often 32-33).

JUVENILES

Dorsal fin rays: 8 (Cross, 1967; Moyle, 1976; Wang, 1986).

Anal fin rays: 8-10 (Cross, 1967); 9 (Wang, 1986).

Pectoral fin rays: Usually 14 (Cross, 1967); 13-14 (Wang, 1986).

Mouth: Terminal, oblique (Cross, 1967; Minckley, 1972, 1973).

Vertebrae: 34-36 (Cross, 1967); 35-36 (Snyder, 1981; Snyder, *et al.*, 2005); 33 (Wang, 1986).

Distribution: Patchy pattern in the Delta freshwater systems.

Key Taxonomic Characteristics:
1. Gut length: short.
2. Scale pigmentation: lining the edges.
3. Scale: ~ 30 along the lateral line.
4. Myomere count between the insertion of D and origin of A: 0-2 before the origin of A.

LIFE HISTORY

The red shiner is a freshwater fish native to the northern United States (Wyoming to Minnesota) and extends southward to Mexico. Its range covers most of the drainages of the Mississippi and Rio Grande Rivers (Eddy, 1957; Hubbs and Lagler, 1958; Pflieger, 1975). They were introduced into the Colorado River (Hubbs, 1954) and the Delta in California (Hubbs and Lagler, 1958). Kimsey and Fisk (1964) did not observe this species in Northern California. However, it spread quickly from Southern California northward, when they became a popular bait fish (Swift, *et al.*, 1993; Jennings and Saiki, 1990). Wang (1986) reported a reproductive population of red shiner in the Millerton Lake. From the fish E&L specimens collected by the CDFG and UCD in the Delta and adjacent waters, larval red shiner first appeared in 1997. Moyle (2002) expects red shiner to be everywhere in California freshwater. They have not been reported in Oregon or Washington (Wydoski and Whitney, 2003).

Red shiners spawn over a variety of substrates. Cross (1967) described red shiner as spawning usually in calm water with substrates ranging from aquatic vegetation to gravel, sand, and mud, from May through October in Kansas. At Millerton Lake, spawning adults were collected at McKenzie Point and Madera boat ramp over fragmented granite and gravel bottoms in June and July. The male has breeding tubercles on its snout and head and has a brilliant orange-red coloration on its fins (except the dorsal fin), head, side of the body (Cross, 1967), and blue sides (Moyle, 2002). We observed similar orange-red coloration on all fins, snout, thoracic, and ventral portion of body. In the laboratory, the adhesive eggs were deposited singly in the deeper crevices of the synthetic Spawntex™ mat. Like the golden shiner, red shiners sometimes deposit eggs in the nests of centrarchids (Cross, 1967; Pflieger, 1975). Since red shiners do not guard their eggs (Cross, 1967), we believe that this strategy, along with depositing eggs in crevices, decreases the chance of eggs being eaten.

Red shiners spawn typically during summer. Different sizes of ova were found in multiple development stages from a single ovary indicating that red shiner may spawn more than once during the breeding season. This was observed for fish collected from the wild as well as in the laboratory. There seems to be a limitation of total ova produced per female per season since no more eggs were observed in the laboratory by the end of September. The males may retain the spawning color throughout the year when the water temperature is ≥ 20 °C. Yolk sac larvae were observed in Putah Creek from May through August (Rockriver, 1998) and in Cache Slough in June and July. Eggs were observed in the TFCF fish laboratory from April through August. Dominant males exhibit strong territorial behavior and chase other males out of the nesting site.

Red shiner larvae and juveniles are well-suited to their environment. Newly hatched larvae have a pair of over-sized pectoral fin buds, perhaps used in balancing. Just like most cyprinid larvae, they remain in the shallow inshore water and have been successfully captured using light traps. Larvae have little body pigmentation and look almost transparent which may help them blend into their surroundings. The larval development was described by Saksena (1962) and Taber (1969). Juvenile red shiners swim in schools in the shallow inshore waters and sheltered coves. They feed on small crustaceans, aquatic insects, larvae, and algae (Hardwood, 1972). Plant leaves and detritus were also observed in their stomachs.

Red shiners reach maturity at one year with a maximum life span of three years (Carlander, 1969). The largest specimens collected at Millerton Lake were 70 mm TL and had two annuli on their scales. The red shiner may pose a threat to native fish in California (Moyle, 2002) because it is better adapted to unstable environmental conditions than any native fish species known to the study area. Red shiners are used as a bait fish and are commonly found throughout the Delta.

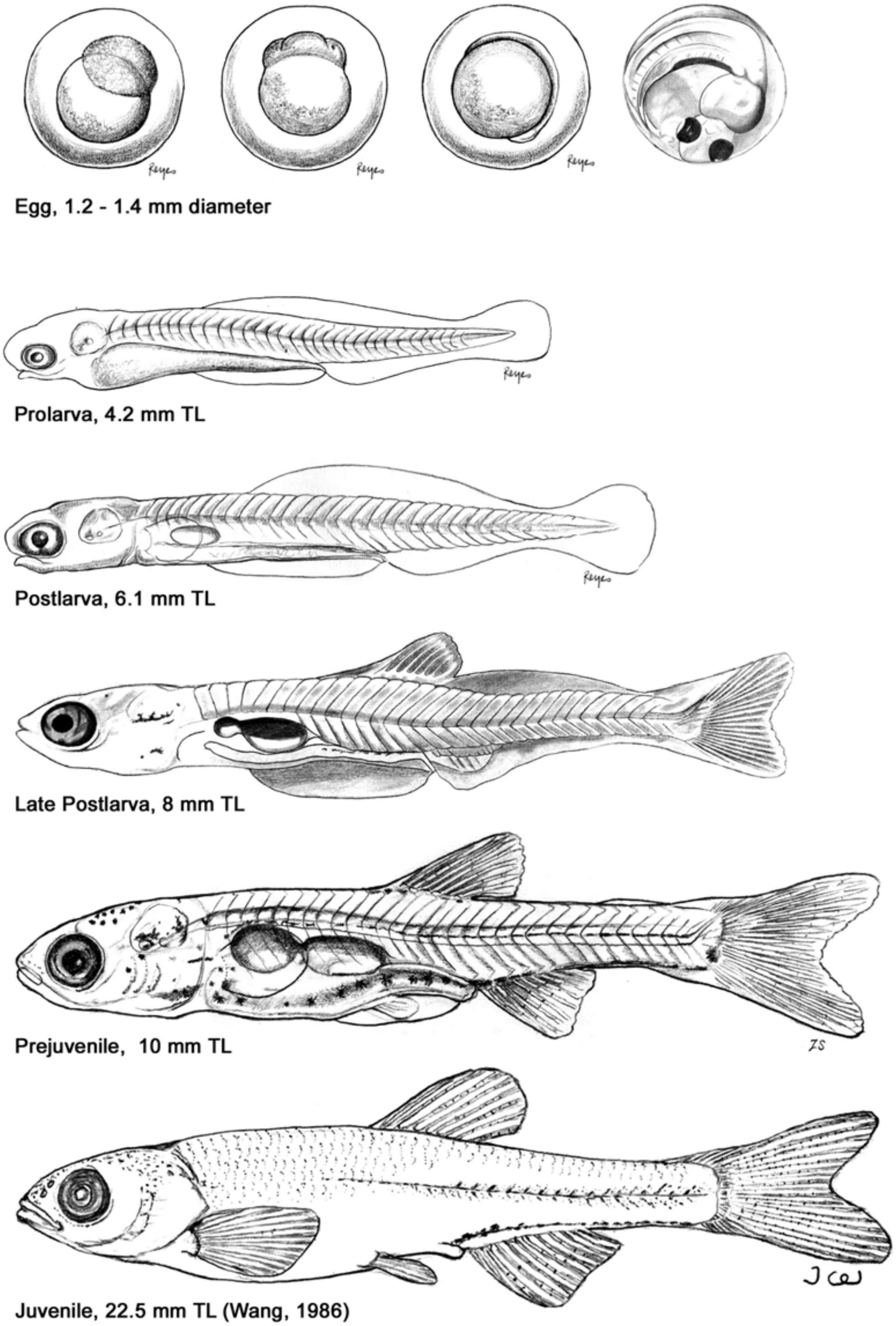


FIGURE 7a.—Line drawings showing red shiner early life stage specimens.

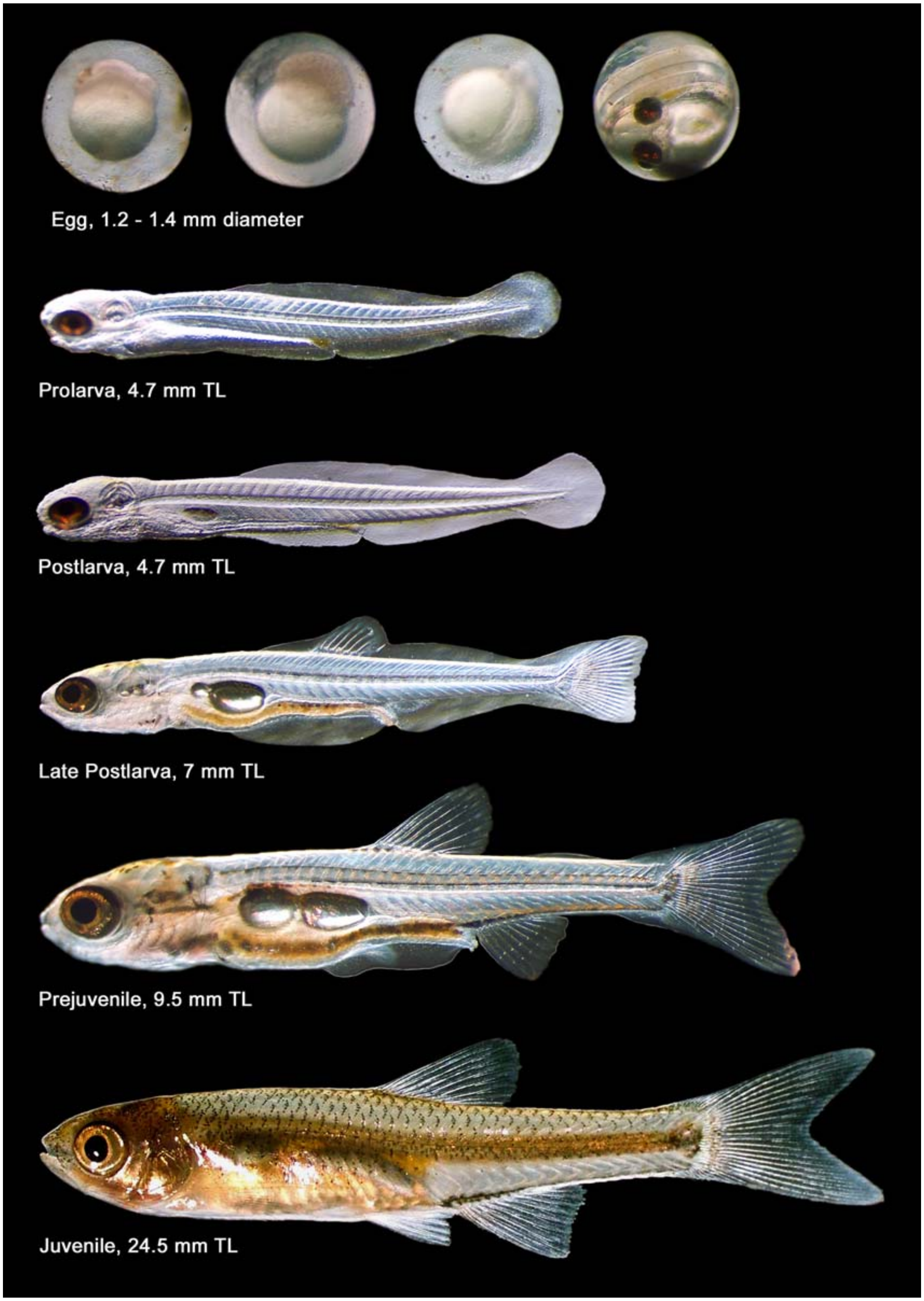


FIGURE 7b.—Photographs showing red shiner early life stage specimens.

Common Carp, *Cyprinus carpio* (Linnaeus)

SPAWNING

Location:	Delta, River, near the water surface in shallow weedy area of tidal and nontidal freshwater. Spawning has been observed in Montezuma Slough, New York Slough, Lindsey Slough, Cache Slough, French Camp Slough, Three mile Slough, Millerton Lake, Lake Berryessa, Folsom Lake, and the TFCF intake canal and abandoned intake canal.
Season:	Spring to early summer (Moyle, 2002); March to July; a ripe male (but no females) was observed in November (Wang, 1986).
Temperature:	Starting at 15 °C (Moyle 2002); optimum 18-22 °C (Berg, 1964; Mansueti and Hardy, 1967); peaking at 22-26 °C (Wang, 1986).
Salinity:	Freshwater to oligohaline (such as in Montezuma Slough); up to 10 ppt mesohaline water in Russia (Berg, 1964).
Substrates:	Submerged plants, tree roots, grass roots of undercut banks, dead leaves, and floating plants, logs and filamentous algae.
Fecundity:	36,000-2,208,000 (Swee and McCrimmon, 1966); 50,000-2,000,000 per season (McCrimmon, 1968; Becker, 1983); minimum 3,950 (Balon, 1974).

EGGS

Shape:	Spherical (Sigler, 1955); some slightly irregular.
Diameter:	As small as 1.0 mm (Slastenenki, 1958); 1.5-2.1 mm.
Yolk:	Colorless (Okada, 1959–1960); pale yellowish, granular.
Oil globule:	None (Hoda and Tsukahara, 1971); many minute oil globules (Brinley, 1938); no oil globules observed.
Chorion:	Transparent or translucent.
Perivitelline space:	~ 1/5 egg radius (Okada, 1959–1960); fairly wide, ~ 19-20 percent of egg diameter at morula stage (Wang, 1986).
Egg mass:	In clusters (Migdalski, 1962); individually (can be very dense in certain areas because of repeated deposition; some eggs become exposed to the air due to repeated disturbing of substrates).
Adhesiveness:	Highly adhesive throughout incubation period.
Buoyancy:	Demersal.

LARVAE

Length of hatching:	Minimum 3.0 mm TL (Sigler, 1955); 3.0-6.69 mm TL (Jones, *et al.*, 1978) ; most average 4.38-5.70 (Swee and McCrimmon, 1966); 4-5 mm TL (Snyder, 1981; Snyder, *et al.*, 2005); ~ 4.0-5.0 mm TL from field collection; ~ 5.0-6.5 mm TL (fertilized eggs collected in the backwater of the TFCF and hatched at the TFCF fish laboratory).
Snout to anus length:	For newly hatched larvae, 66-73 percent (often 68-69 percent); for postlarvae, 63-68 percent (often 64-66 percent).
Yolk sac:	Very elongate, oval in thoracic, becomes cylindrical in abdominal region.
Oil globule(s):	None.
Gut:	Straight, and can be slightly curved (pressed by the air bladder) in thoracic region.
Air Bladder:	Oval, shallow, behind the pectoral, the posterior chamber appears as early as 6.3 mm TL, and the anterior chamber developed in postlarval stages ~ 10-11mm TL.
Teeth:	None on jaws.
Size at absorption of yolk sac:	~ 6.5 mm TL (Okada, 1959–1960); 7.0-9.5 mm TL (Jones, *et al.*, 1978); 6.0-8.0 mm TL (Snyder, 1981; Snyder, *et al.*, 2005); ~ 6.0-7.0mm TL of field specimens and ~ 7.0-8.0 mm TL of laboratory specimens.
Total myomeres:	36-39 (Snyder, 1981; Snyder, *et al.*, 2005); 32-37 (typically 36).
Preanal myomeres:	24 (Hikita, 1956; Okada, 1959–1960); 25-28 (Snyder, 1981; Snyder, *et al.*, 2005); 24-26 (Wang, 1986); 21-26 (often 23-24).
Postanal myomeres:	10-13 (Snyder, 1981; Snyder, *et al.*, 2005); 10-12 (Wang, 1986); 11-14 (often 11-13).
Last fin(s) to complete development:	Pelvic.
Pigmentation:	Large stellate melanophores on cephalic and middorsal regions, one ventral side of yolk sac and postanal regions, and particularly heavy on dorsal side of gut; pigmentation is similar to that of goldfish but heavier.

Distribution: On bottom or on aquatic vegetation immediately after hatching, then gradually moving into bottom of shallow waters along vegetation, occasionally in water column during prolarval and early postlarval stages. Common in Montezuma Slough, New York Slough, Lindsey Slough, Lake Berryessa, Millerton Lake, Putah Creek, Lodi Lake, the backwater of intake canal at the TFCF, and throughout the warm waters of the Delta.

Key Taxonomic Characteristics:

1. Very dense gut pigmentation.
2. A "U"-shaped pigmentation pattern (rotated 90° to left) in front of pectoral fin (or cleithrum).
3. Elongate dorsal fin bud.
4. Carp have more postanal myomeres (~ 11-14) than goldfish (~ 8-10).

JUVENILES

Dorsal fin rays: III-V, 15-23 (Smith, 1909); I, 18-20 (Scott and Crossman, 1973); III, 17-21 (Moyle, 2002); typically I, 20-2l (Wang, 1986).

Anal fin rays: III, 4-6 (Smith, 1909); I, 5 (Scott and Crossman, 1973); III, 5-6 (Moyle, 2002); typically I, 5 (Wang, 1986).

Pectoral fin rays: 14-17 (Scott and Crossman, 1973); 17-18.

Mouth: Terminal or subterminal.

Vertebrae: 32-39 (Berg, 1964); 35-36 (Scott and Crossman, 1973).

Distribution: Inhabits the bottom, shallow weedy waters of both freshwater and oligohaline areas of the Delta; they are abundant in most warm water reservoirs and ponds.

Key Taxonomic Characteristics:

1. Dorsal fin elongated; with hardened dorsal and anal fin rays.
2. Body elongated (compared to the goldfish).
3. Mouth has 1-2 pairs of barbels.
4. The myomere count between the insertion of D. and origin of A.: 6-7 before the origin of A.

LIFE HISTORY

Common carp originated in China. They were introduced to Europe as a major freshwater food fish (Balon, 1995). They were then introduced from Europe into California in 1872 (Dill and Cordone, 1997). This species is now well established throughout California (Moyle, 2002). The spawning activity and larval fish were distributed in the freshwater and oligohaline reaches of the rivers and estuary. Also, they were particularly abundant in warm-water reservoirs, such as Millerton Lake, Folsom Lake, and Lake Berryessa.

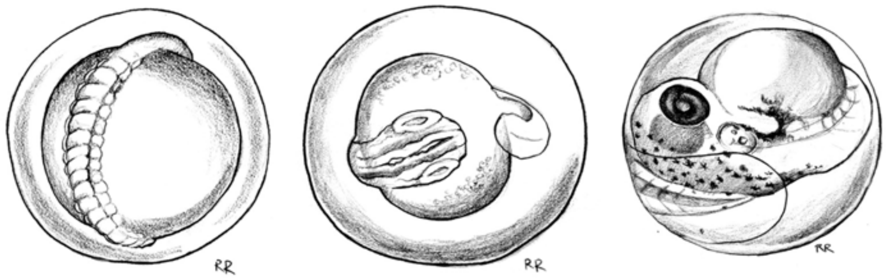
Based on the abundance of larvae collected, the peak spawning period for common carp is from late April through July. Some spawning activity has been observed as early as March near New York Slough, probably due to the elevated water temperatures caused by the thermal discharge from an adjacent power plant. Ripe males have been collected in these same areas as late as November, but no ripe females were observed. Major spawning occurs in the freshwater and minor spawning in the oligohaline (Wang and Kernehan, 1979). Berg (1964) reported that common carp spawn in water up to 10 parts per thousand (ppt) salinity in Russia.

During mating, small groups of common carp congregate in shallow weedy waters. Their dorsal fins are frequently exposed above the water surface, and there is much splashing and pursuing from one area to another. The adhesive eggs are deposited on submerged vegetation and hatched in 3-5 days at 20 °C (Okada, 1959–1960). In the TFCF fish laboratory, common carp eggs hatched in 4-5 days at 20-21 °C. Like goldfish, different sizes of ova are present in the ovary at the same time indicating that common carp are able to spawn more than once during the breeding season. In the TFCF intake canal, several pulses of spawning were observed from April to July and as late as early September. From laboratory observations, newly hatched common carp larvae lay on their side at the bottom of the aquarium for several days, and then swim in the water column for a very short period. After their first week, most carp larvae have taken cover in submerged vegetation (Moyle, 1976; this study). Both prolarvae and postlarvae were often collected in the fish E&L study (CDFG specimens collected in the Delta and NBA).

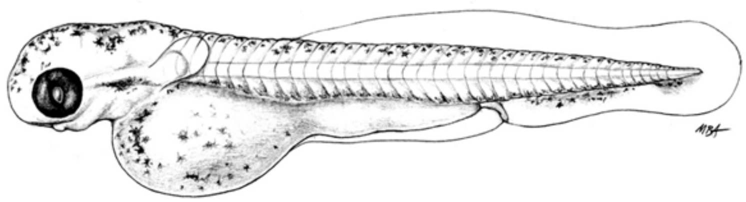
Juveniles are found in areas of dense vegetation that offer protection from predation. They are not collected by the plankton tow nets, but can be collected with a fine mesh beach seine. Juvenile carps are an epibenthic fish. As growth proceeds (~ 10 cm TL and greater), the common carp moves into deeper water and form small schools. Juveniles primarily feed near the bottom on small invertebrates, aquatic plants, and algae (Moyle, 1976).

Scott and Crossman (1973) reported that the spawning population of carp in Lake St. Lawrence, Ontario was composed of fish between the age of 2 and 16 years. The life span of this species in North America is approximately 20 years or less (McCrimmon, 1968).

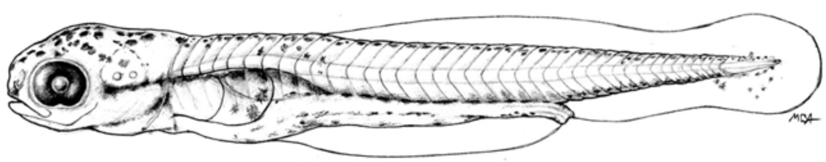
The common carp has been a human food fish for centuries and is an important source of protein for Asians and Europeans. Common carp are easily raised in small farm ponds. In Japan, ornamental carp (koi) have been bred for color, shape, and size variations for use in garden ponds. Although this species was originally introduced into the United States for food and sport purposes, it has not become widely popular. Common carp has been responsible for destruction of game fish habitat by up-rooting aquatic vegetation and increasing turbidity. Common carp are generally considered pests in this country.



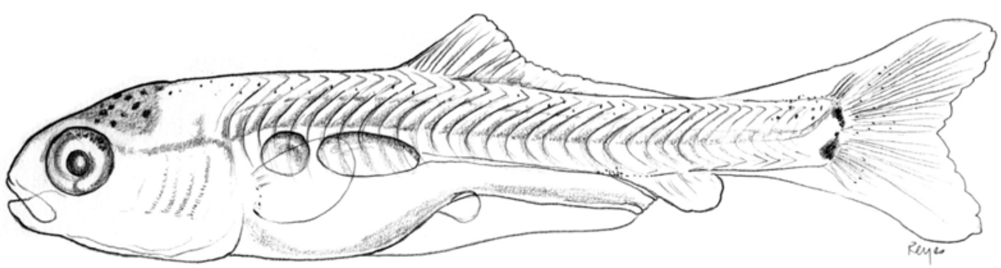
Egg, 1.5 - 2.1 mm



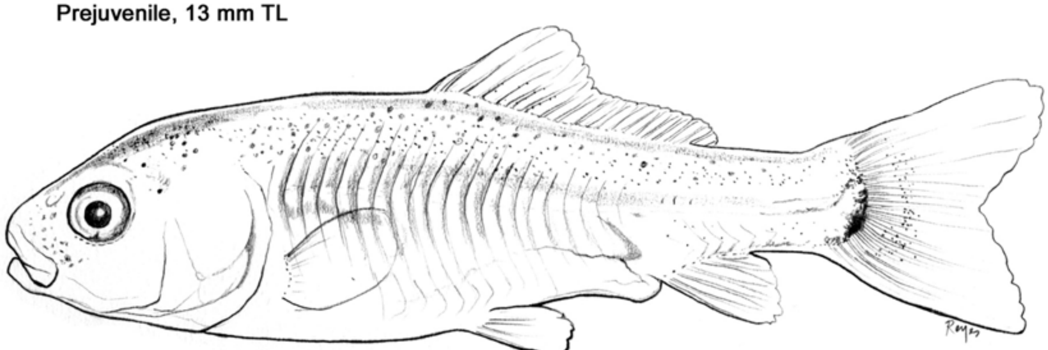
Prolarva, 5.4 mm TL (Wang, 1986)



Postlarva, 6.6 mm TL (Wang, 1986)



Prejuvenile, 13 mm TL



Juvenile, 22 mm TL

FIGURE 8a.—Line drawings showing common carp early life stage specimens.

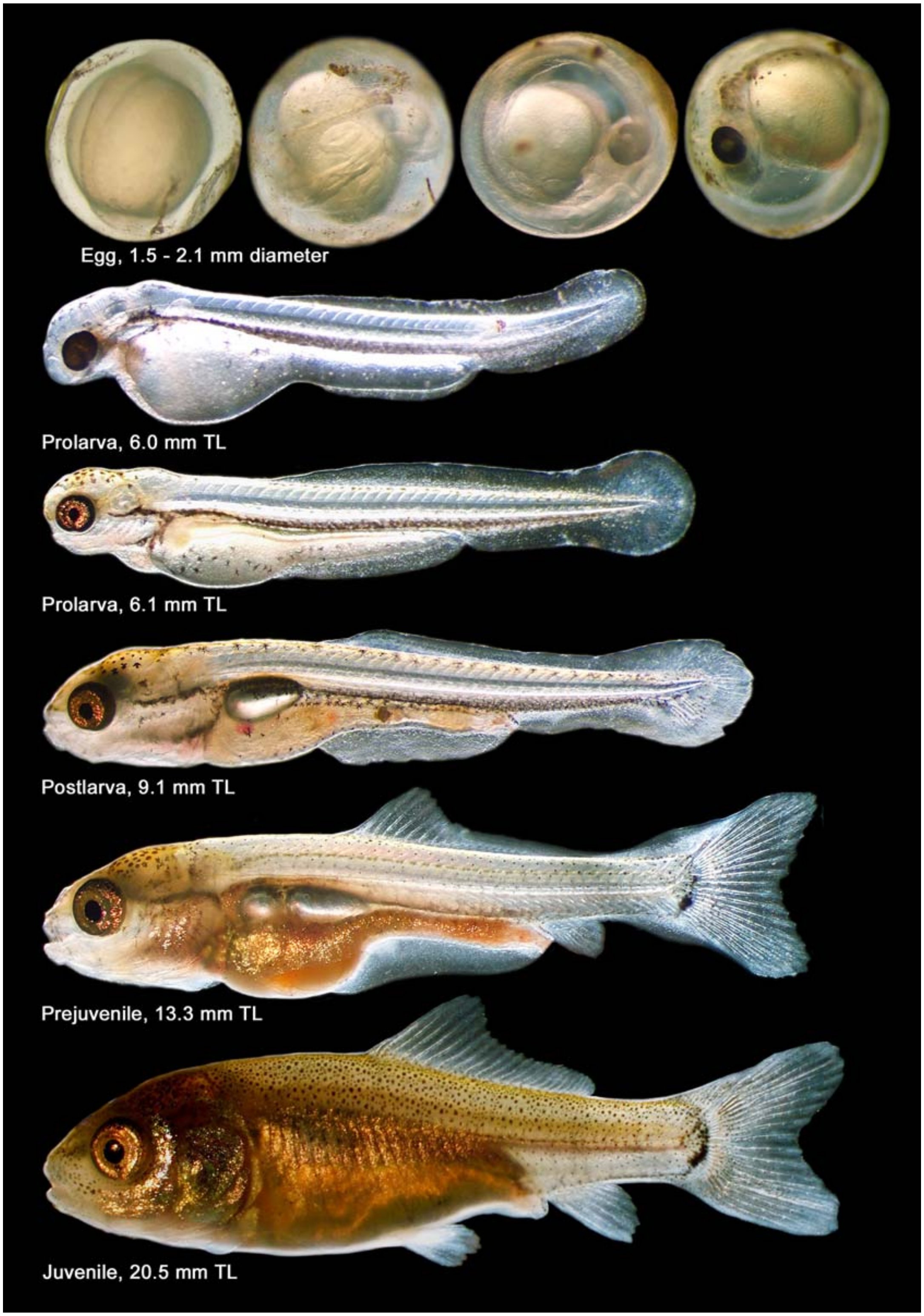


FIGURE 8b.—Photographs showing common carp early life stage specimens.

California Roach, *Hesperoleucus symmetricus* (Baird and Girard)

SPAWNING

Location:	In nontidal tributaries of the Delta such as San Ramon Creek, Napa River, San Anselmo Creek, Lagunitas Creek, Olema Creek, Sonoma Creek, Huichia Creek, Navato Creek, Suisun Creek, Green Valley Creek, Alameda Creek, and Mt. Diablo Creek, Stony Creek, Mud Creek, Little Chico Creek, Big Chico Creek, and Clear Creek.
Season:	March through June (Fry, 1936; Moyle, 1976); April through June (Wang, 1986, this study).
Temperature:	12-17.5 °C (Wang, 1986); exceeding 16 °C (Moyle, 2002).
Salinity:	Freshwater.
Substrates:	Gravel (Fry, 1936); gravel, sand and lamprey nesting area (Wang, 1986).
Fecundity:	150-900 (Fry, 1936); 250-2000 (Roscoe, 1993; Barnes, 1957).

EGGS

Shape:	Spherical.
Diameter:	~ 1.5 mm (Barnes, 1957); 1.9-2.25 mm (Wang, 1986); 1.8-2.25 mm.
Yolk:	Yellowish, granular.
Oil globule:	None.
Chorion:	Transparent, smooth, except the adhering area.
Perivitelline space:	~ 0.1-0.3 mm in width (Wang, 1986); ~ 0.3 mm in width at the morula stage.
Egg mass:	Individually or in smaller clusters (Fry, 1936); individually (Wang, 1986, this study).
Adhesiveness:	Exceedingly adhesive (Fry, 1936); adhesive.
Buoyancy:	Demersal.

LARVAE

Length of hatching:	~ 5.0 mm TL (Fry, 1936); 5.6-6.0 mm TL eggs collected in Sonoma Creek (Wang, 1986); 4.7-6.8 mm TL eggs collected from Clear Creek to Mount Diablo Creek.
Snout to anus length:	~ 65-68 percent of TL of newly hatched larvae, decreasing to ~ 60-63 percent of TL of late yolk-sac and postlarvae.
Yolk sac:	Elongate, enlarged, spherical to oval in thoracic region and tapered and cylindrical in abdominal region.
Oil globule(s):	None.
Gut:	Straight in prolarvae, and slightly depressed in thoracic region in postlarvae.
Air Bladder:	Elongate, near pectorals, posterior chamber evident ~ 7.5 mm TL and anterior chamber evident ~ 9.7 mm TL.
Teeth:	None.
Size at absorption of yolk sac:	~ 7.0-7.8 mm TL (Wang, 1986).
Total myomeres:	37-42 (Wang, 1986), 36-39.
Preanal myomeres:	24-29 (Wang, 1986), 20-24.
Postanal myomeres:	12-14 (Wang, 1986), 13-16.
Last fin(s) to complete development:	Pelvic.
Pigmentation:	Eyes of newly hatched larvae have light pigments; sparse pigment may or may not appear on cephalic and dorsum. Within 1-2 days, eyes are completely pigmented, large stellate melanophores appear on snout, cephalic, and middorsal regions. Melanophores are also found along dorsal surface of gut, jugular, thoracic, and postanal regions. A series of dash-shaped melanophores appear on the lateral region. There is a pigment-free zone or a gap near the distal end of postanal region.
Distribution:	Prolarvae remain in the crevices of gravel or on sandy bottom close to the spawning site. After yolk sac is absorbed, postlarvae move into shallow pools or near extremely shallow inshore with vegetations.
Key Taxonomic Characteristics:	1. Myomere counts up to 42; larvae look chunky. 2. Pigmentation-free zone at ventral side of the caudal peduncle. 3. Dense pigmentation on head and along dorsum.

JUVENILES

Dorsal fin rays:	7-9 (Moyle, 2002); 9 (Wang, 1986); 7-9 (often 8-9).
Anal fin rays:	6-8 (Moyle, 2002); 8-9 (Wang, 1986); 6-9 (often 7-8).
Pectoral fin rays:	13-16 (Wang, 1986).
Mouth:	Terminal or slightly subterminal.
Vertebrae:	39-42 (Wang, 1986).
Distribution:	Roach are often found in the River such as low elevation foothill creeks, valley floor waters such as Napa River, Walnut Creek, Alameda Creek, Suisun Creek, and Mt. Diablo Creek. No specimens were observed in Delta sloughs and tidal freshwater and the Bay.
Key Taxonomic Characteristics:	1. Pigmentation-free zone still exists at the ventral peduncle. 2. Mottled pigmentation in the upper half of the body; pigmentation-free or almost free on the lower half of the body. 3. Chunky body, tapering off at postanal region. 4. The myomere count between the insertion of D. and origin of A.: 2-4 (often 2) before the origin of A.

LIFE HISTORY

The California roach, a native freshwater cyprinid, is found throughout the Delta and its tributaries (Moyle, 1976); however, we observed California roach only in the Delta's nontidal tributaries. Because of its long history of geographical isolation by mountains and watersheds, several California roach subpopulations developed, some of which may deserve a subspecies or species status because of the genetic differences between populations (Snyder, 1913; Murphy, 1943; Loggins, 1997; Moyle, 2002). Conservation efforts are needed to preserve this unique native cyprinid. Because of the complexity of the California roach, description of this fish is limited only to areas where specimens were collected.

California roach spawn from March through June. Prior to spawning, the California roach congregate in small pools in groups of 15 to 50 fish. Both sexes exhibit spawning colors, becoming darker with rusty orange coloration on sides of body and at the base of the pectoral fins. Males also develop small white breeding tubercles on their snout, head, mouth, and operculum (Fry, 1936; Barnes, 1957). Eggs are deposited singly or in small clusters in rock crevices or in the gravel (Fry, 1936; Wang, 1986). If gravel substrate is unavailable, roach may deposit their eggs on cattails or tules (Barnes, 1957) and even in abandoned lamprey nests. California roach spawn predominantly in smaller streams and creeks. Most nesting sites are located at the lower end of shallow pools with moderate flow, such as Mt. Diablo Creek in Clayton, California. The females deposit a few eggs at a time, and as spawning proceeds the group moves from site to site. Roach do not build nests and no parental care has been observed in the wild or laboratory culture. The eggs hatch in five days at 13.5-17 °C. Larvae were also observed in the entrainment samples collected from the Sacramento River at Reclamation Red Bluff Research Pumping Plant in 1998. They could be flushed from the creeks during wet water-years or storm flows.

Newly hatched larvae are large in size (~ 5.6-6.8 mm TL) for a small fish (adults range from ~ 50-70 mm TL), lie on their sides, and tend to remain in the rock crevices or sandy bottom where the eggs are deposited until the eyes become pigmented and yolk sac is absorbed. Small larval California roach were observed darting from one hiding place to another even before their yolk sacs were completely absorbed. Postlarval roach move into shallow pools and swim in small schools or stay in the shallow inshore weedy areas.

After the California roach become juveniles they move into the deeper pools and the main body of a creek. They often share this habitat with similar age Sacramento suckers *Catostomus occidentalis*, Sacramento pikeminnows, and threespine sticklebacks *Gasterosteus aculeatus*. The major food items of juvenile California roach include diatoms, filamentous algae, small aquatic insects, and crustaceans (Fite, 1973).

The California roach matures after 1-3 years (Fry, 1936; Barnes, 1957). Roach generally live three years, although a few may live a year or two longer (Moyle, 1976). The male fish is larger than the female. Roach are important forage fish and are often used as bait by fishermen (Barnes, 1957).

The California roach is still abundant in the upper reaches of streams studied, but in the lower portions of creeks, such as Walnut Creek and Napa River, they have been gradually replaced by green sunfish *Lepomis cyanellus*, bluegill *Lepomis macrochirus*, golden shiner, and yellowfin goby *Acanthogobius flavimanus*. We noticed that some California roach died in the dried-up pools of intermittent creeks. However, it appears that most descend to the larger pools before the small shallow pools dry up. California roach will retreat to the confluence between the creek mouth and the river during severe drought water-years (Loggins, 1997).

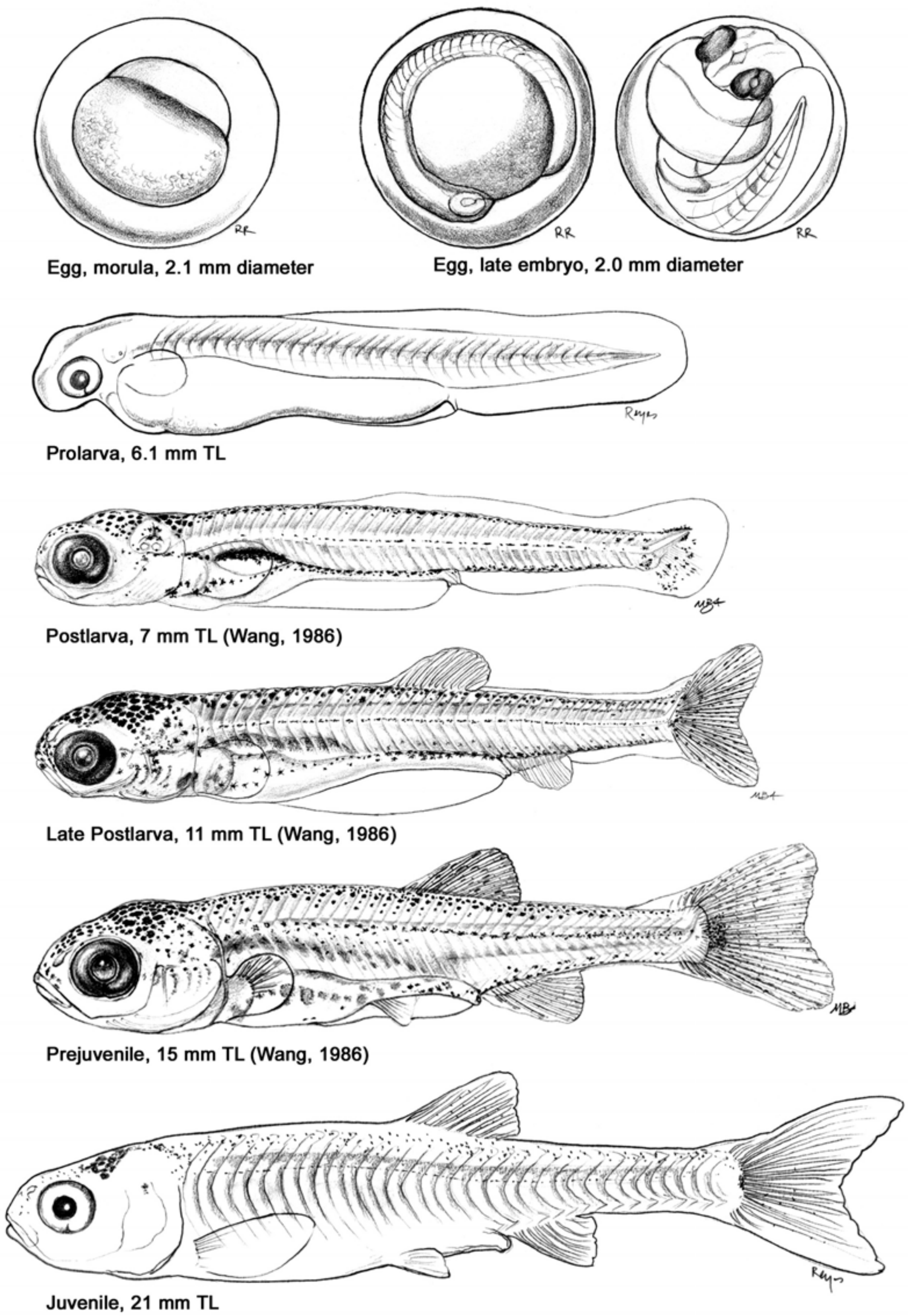


FIGURE 9a.—Line drawings showing California roach early life stage specimens.

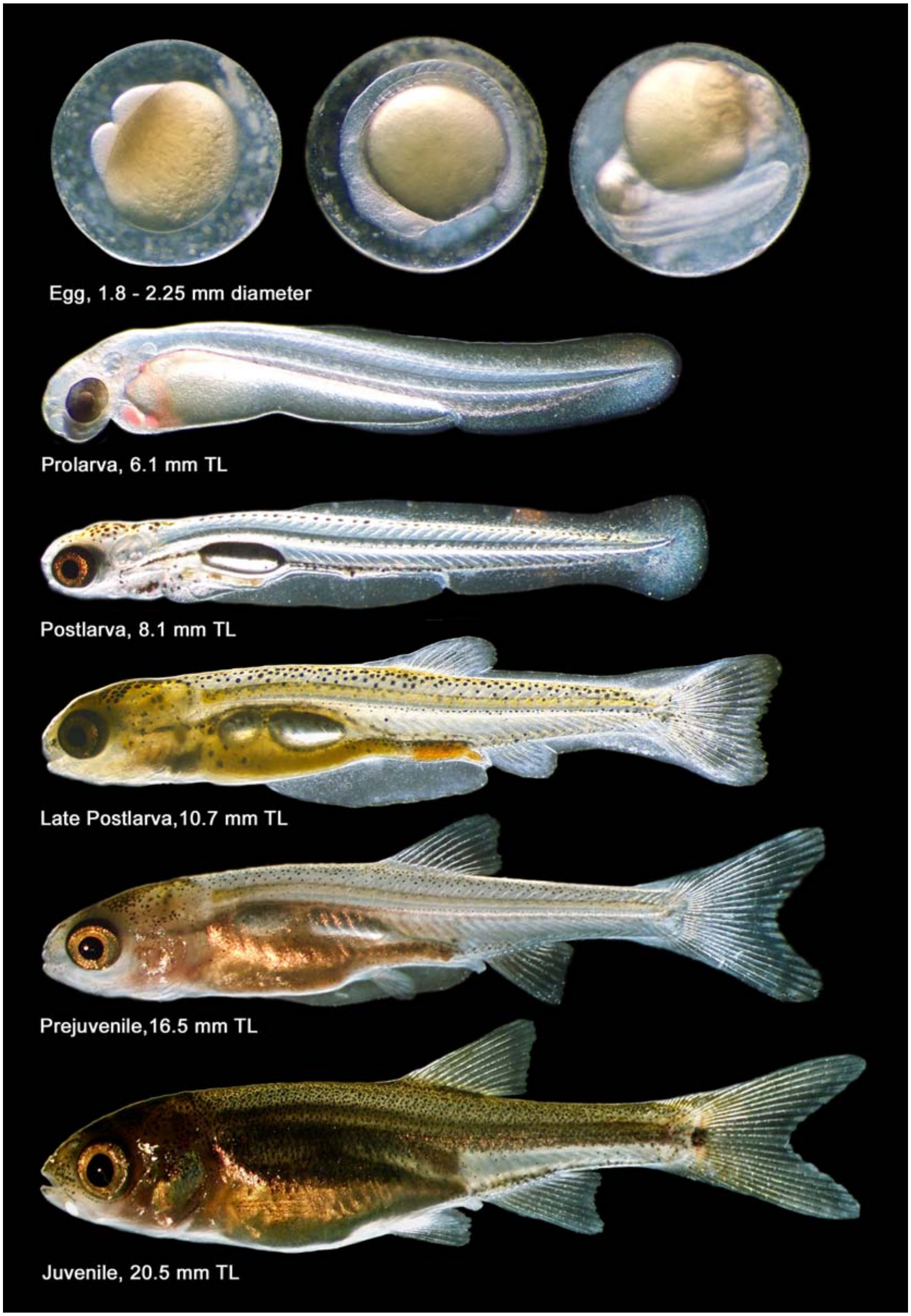


FIGURE 9b.—Photographs showing California roach early life stage specimens.

Hitch, *Lavinia exilicauda* (Baird and Girard)

SPAWNING

Location:	In nontidal creek, channelized ditches, irrigation canals, some ponds and reservoirs such as Tassajara Creek, Arroyo Mocho, Sweeney Creek, upper Cache Slough, Pine Creek at the Hillcrest Community Park (Concord, CA), Walnut Creek, Putah Creek, Lodi Lake, Alameda Creek, Fine Gold Creek near Millerton Lake, Sage Creek, Lake Hennessey, New Melones Reservoir, and Consumnes River Preserve. In tidal water: spawning may occur in the sloughs of the Delta, since the adult fish were observed in Broad Slough, Prospect Slough, Sherman Island and Sherman Lake, Sacramento Deep Water Ship Channel, Fishermans Cut, Steamboat Slough, Lindsey Slough, South Fork of Mokelumne River, Sacramento River by Steamboat Slough and False River (CDFG specimens, 1997–2002), and the TFCF intake canal (2003). Spawning adults were occasionally observed at the TFCF, usually in March.
Season:	March (Murphy, 1948); April (Swift, 1965); March through July (Moyle, 1976); March through June (Wang, 1986).
Temperature:	14-18 (Murphy, 1948; Kimsey, 1960); 18-26 °C (Smith, 1982); 15-22 °C (Wang, 1986).
Salinity:	Freshwater, and may occur in tidal freshwater.
Substrates:	Fine to medium gravel (Murphy, 1948); varies from hard clay bottom to gravel and to emergent vegetation.
Fecundity:	~ 110,000 (Murphy, 1948); 3,000-26,000, with a mean of 9,000 (Nicola, 1974); 9,000-63,000 (Geary and Moyle, 1980).

EGGS

Shape:	Spherical.
Diameter:	2.0-2.2 (Swift, 1965); 1.6-2.4 mm (Wang, 1986).
Yolk:	Pale yellow (Swift, 1965), pale yellow, granular (Wang, 1986).
Oil globule:	None.
Chorion:	Transparent, smooth.
Perivitelline space:	Very wide, ~ 0.3-0.5 mm at morula stage.
Egg mass:	Individually.
Adhesiveness:	None (Murphy, 1948; Swift, 1965); not adhesive (Wang, 1986).
Buoyancy:	Demersal, heavier than water (Murphy, 1948; Swift, 1965); demersal, slightly heavier than water, bounces when disturbed (Wang, 1986).

LARVAE

Length of hatching:	6.0 mm TL (Swift, 1965); 4.2-5.5 mm TL (Wang, 1986).
Snout to anus length:	61-65 percent of TL of specimens at 4.4-4.7 mm TL; 56-63 percent at 10.3-12.0 mm TL.
Yolk sac:	Large, elongate.
Oil globule(s):	None.
Gut:	Straight, slightly depressed when air bladder developed.
Air Bladder:	Shallow and elongate, near and behind pectorals, developing into a smaller oval anterior chamber and a larger tear-shaped posterior chamber in prejuvenile life stage, ~ 10.0 mm TL.
Teeth:	None.
Size at absorption of yolk sac:	~ 6.5-7.0 mm TL.
Total myomeres:	36-39 (Wang, 1986); 35-41.
Preanal myomeres:	24-28 (Wang, 1986); 21-28 (often 25-26).
Postanal myomeres:	11-13 (Wang, 1986); 14-18 (often 15-16).
Last fin(s) to complete development:	Pelvic.
Pigmentation:	Newly hatched larvae have no pigment. Within 1-2 days, very large stellate melanophores appear scattered on head and middorsum; very large melanophores along gut and on postanal region; dashed melanophores along the lateral line region. A group of melanophores frame the end of the notochord and developing hypural.
Distribution:	Shallow weedy area of nontidal creeks, channelized ditches, pond, and reservoirs, some may occur in tidal freshwater sloughs of the Delta.

Key Taxonomic Characteristics:

1. A "hatchet"-shaped pigmentation pattern on the peripheral region of the end of notochord and developing hypural (prolarval stage only).
2. Caudal has a large spot. Caudal spot appears at the prejuvenile stage around 10 mm TL.
3. Anal finbud large, evident in prejuvenile (developing into 10 or more fin rays).

JUVENILES

Dorsal fin rays: 10-13 (Moyle, 2002); 10-11.

Anal fin rays: 11-14 (Moyle, 2002); 11-14 (looking at hitch from Cosumnes River Preserve and New Melones Reservoir collection).

Pectoral fin rays: 15-16 (Wang, 1986).

Mouth: Terminal, small, oblique.

Vertebrae: 39-41.

Distribution: Shallow weedy areas of nontidal creek, channelized ditches, ponds, and reservoirs, some in tidal freshwater sloughs of the Delta in patchy pattern.

Key Taxonomic Characteristics:

1. Anal fin has 10-12 finrays, there is a slight falcate but not deeply forked like golden shiner.
2. A very large triangular black spot at the middle of caudal peduncle (compare to the Sacramento blackfish which has a bar-like spot).
3. Myomere count between the insertion of D and origin of A: 0-3 before the origin of A. However, some juveniles may have the insertion of D posterior to the origin of A by one myomere.

LIFE HISTORY

The hitch is a freshwater fish native to California inland waters throughout the Delta and its watershed, in the tributaries of San Francisco and Monterey Bays, Clear Lake, and the Russian River (Moyle, 1976, 2002). Hitch were introduced into some reservoirs, and were carried by aqueduct to Southern California (Moyle, 2002). However, all hitch reside within California freshwaters.

Moyle (1976, 2002) noted that the hitch population has declined in the Delta, River, and in other California habitats. Hitch are distributed irregularly in the warm waters of the Delta and River and often their habitats are threatened by pollution. For example, hitch were once abundant in Pine Creek, a tributary of the Walnut Creek in the 1980s (Wang, 1986), but the population has since declined because of a nuisance species of brown algae which restricted water flow. However, hitch are still abundant in the main stem of lower Walnut Creek where the hybridized hitch/roach, pumpkinseed (*Lepomis gibbosus)*, and green sunfish co-exist in the same habitat. Hitch are also known to hybridize with the Sacramento blackfish in the San Luis Reservoir (Moyle and Massingill, 1981) but the hybrids are sterile.

Hitch spawning takes place in streams, intermittent streams, ponds, reservoirs, in the Delta from March to June, but mainly in May and June. During spawning, four or five males will often attend each female (Murphy, 1948). Male hitch exhibit an orange-red to rusty color on their paired fins and ventral thoracic-abdominal region during spawning. The large spherical eggs (~ 1.6-2.4 mm in diameter, eggs keep expanding in size after fertilization) are nonadhesive —unusual for cyprinids—and are also semi-bouyant and will float with any slight disturbance. Hitch eggs are generally deposited on hard clay bottoms and are also found on gravel and among submerged vegetation. The incubation period was reported to be 7 days at 16-17 °C (Swift, 1965), and spawning can occur at temperature as high as 18-26 °C (Smith, 1982). Freshly laid eggs at the morula stage collected from Pine Creek near Hillcrest Community Park hatched in 3-5 days in the laboratory at 15-22 °C (Wang, 1986).

Newly hatched larvae have large yolk sac, with no or little pigmentations on the eye and body and remain on the bottom for several days before becoming free-swimming (Murphy, 1948; Swift, 1965). Postlarvae form small schools in the open water near the surface surrounded by vegetation or in shaded pools and use these habitats for their nursery and for shelter, quickly diving into nearby submerged vegetation when threatened.

Juvenile hitch usually remain in the same habitat as the larvae, particularly among populations located in confined environments such as channelized ditches. Murphy (1948) described juvenile hitch in the tributaries of Clear Lake that were able to swim to the lake before streams dried up in summer. Juvenile hitch have been observed near the shoreline of the Bay, probably coming from nearby tributary inflows. This strategy also applies to hitch that live in the intermittent creeks adjacent to the Delta. However, not all hitch escape before the loss of their early life stage habitat; many dead juveniles have been observed in dried-up creek beds of intermittent streams such as Marsh Creek and Tassajara Creek (Contra Costa and Alameda Counties). Hitch were also observed in various areas from the Sacramento Deep Water Ship Channel to False River of the Lower San Joaquin River of the Delta (CDFG specimens, 1997–2002). Male hitch in spawning colors were observed at the TFCF intake canal as early as March, the same time period as golden shiner and splittail. However, detailed information on hitch spawning in the tidal freshwater is very limited. Hitch larvae have not been collected in the Delta (CDFG specimens, 1988–1995; NBA specimens, 1995–2004). The major food items for juveniles are plankton, algae, crustaceans, gnats, and other insects (Lindquist*, et al.*, 1943; Murphy, 1948; Moyle, 1976; this study).

Male fishes reach sexual maturity at 1-3 years; females at 2-3 years (Kimsey, 1960; Nicola, 1974; Moyle, 1976). Hitch have been used as bait, and have been sold, along with Sacramento blackfish, in California's Asian fish markets for human consumption. Hitch have wide adaptabilities in terms of spawning, habitat, and feeding items. They are a potential fish farming species.

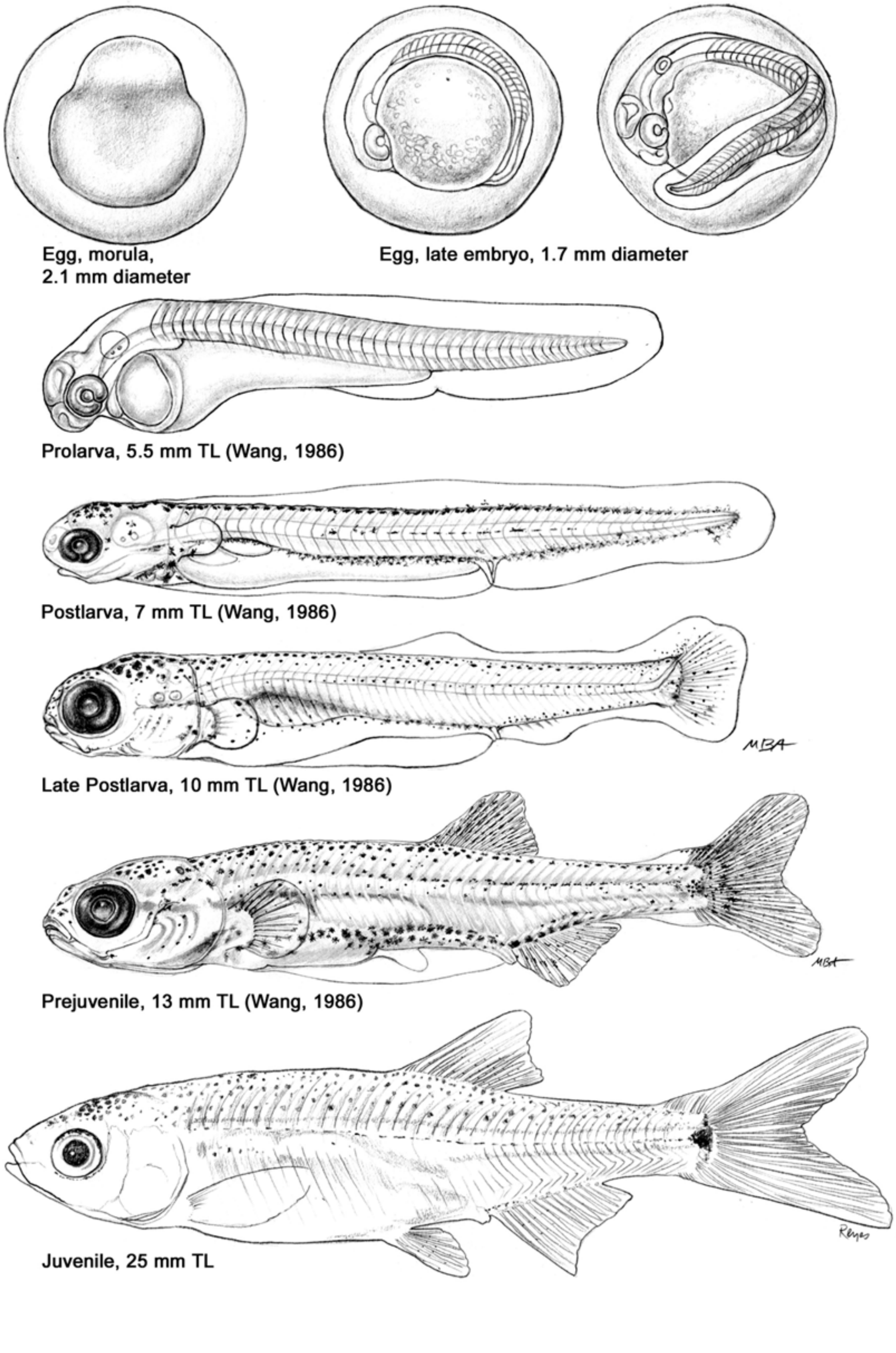


FIGURE 10a.—Line drawings showing hitch early life stage specimens.

FIGURE 10b.—Photographs showing hitch early life stage specimens.

Hardhead, *Mylopharodon conocephalus* (Baird and Girard)

SPAWNING

Location:	Pools and side pools of rivers and creeks: *e.g.*, Napa River near Yountville, Clear Creek, Stony Creek and Mud Creek of the Sacramento River, Feather River, and Upper San Joaquin River both above and below Kerckhoff Dam.
Season:	April and May (Reeves, 1964; Moyle, 1976); May through August in Upper San Joaquin River; May and July in the tributaries of the Sacramento River.
Temperature:	~ 15-18 °C in Upper San Joaquin River.
Salinity:	Freshwater.
Substrates:	Gravel (Moyle, 1976); sand, gravel, weathered granite, and rocky area as recorded in the Upper San Joaquin River (Wang, 1986).
Fecundity:	21,800 (Burns, 1966); 7,000-24,000 (Grant and Maslin, 1997).

EGGS

Shape:	Unfertilized eggs, spherical (Upper San Joaquin River specimens, Wang, 1986).

LARVAE

Length of hatching:	No available information.
Snout to anus length:	~ 60-67.5 percent of TL of postlarvae at 8.7-16.5 mm TL (Wang, 1986).
Yolk sac:	No available information.
Oil globule(s):	No available information.
Gut:	Straight in early postlarvae and slightly bent below the air bladder in postlarvae.
Air Bladder:	No available information.
Teeth:	None.
Size at absorption of yolk sac:	No available information.
Total myomeres:	46-50 (Wang, 1986); 46-49.
Preanal myomeres:	29-34 (Wang, 1986); 29-31.
Postanal myomeres:	14-18 (Wang, 1986); 16-20.
Last fin(s) to complete development:	Pelvic.
Pigmentation:	In postlarvae, large and heavy stellate melanophores on snout and cephalic regions; two rows of melanophores on middorsum, surrounded by small melanophores on side; large melanophores are also found on dorsal surface of gut and postanal regions. Dashed melanophores on lateral region; a few melanophores line up in the midventral below isthmus; two groups of melanophores concentrate at tip of urostyle and hypural regions in postlarvae only; melanophores scattered on caudal fin, similar to Sacramento pikeminnow but sparse.
Distribution:	Near surface of pools, and side pools of creeks and rivers; near inshore weedy areas of reservoirs and lakes.
Key Taxonomic Characteristics:	1. Larvae with an elongated body, total myomeres count is 46 or greater. 2. Very narrow caudal peduncle. 3. Caudal pigmentation scattered on two lobes, and with two dark spots. 4. May have a line of pigmentation at isthmus and midventral near thoracic.

JUVENILES

Dorsal fin rays:	8 (Moyle, 1976; Wang, 1986).
Anal fin rays:	8-9 (Moyle, 1976); 8 (Wang, 1986).
Pectoral fin rays:	15-16 (Wang, 1986).
Mouth:	Terminal, large, with a frenum on upper jaw (Moyle, 1976); frenum may not be apparent in early juvenile.
Vertebrae:	45-48 (Wang, 1986); up to 50.
Distribution:	Pools of rivers and creeks, shallow to deeper water of lakes and reservoirs.

Key Taxonomic Characteristics:

1. Frenum present at premaxilla.
2. High myomere count, ≥ 46.
3. Midventral whitish, may have scattered melanophores.
4. Prominent nostril flap.
5. Myomere count between the insertion of D and origin of A: 3-5 before the origin of A.

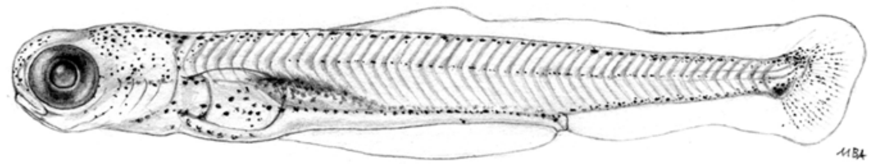
LIFE HISTORY

The hardhead is a freshwater fish native to California, with a distribution limited to the Delta and River (Moyle, 1976) and the Russian River (Moyle, 1976; Leidy, 1984). We observed a small number of hardhead in the Napa River below Yountville. This species is still common in the lower foothill tributaries of the Sacramento River between Redding and Chico. Most reports of early stages of the hardhead were from the San Joaquin River above and below the Kerckhoff Dam. A few larvae were observed in the tributaries of the Sacramento River. A single specimen (of unknown age) was recorded by CDFG at Beaver Slough, a side branch of the Mokelumne River, on June 25, 2001.

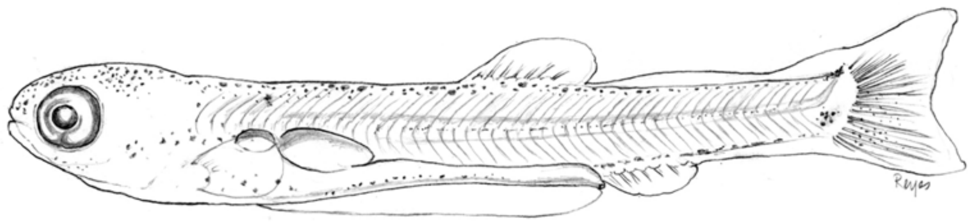
Moyle (2002) suggested that hardhead spawning behavior is similar to that of Sacramento pikeminnow and hitch. Although we did not observe spawning, large adult hardhead were observed in the pools below Kerckhoff Dam. This series of pools located in the gorge below the dam, with flows between 10 to 25 cubic feet per second (cfs) is regulated by CDFG to preserve the hardhead below the dam. Larvae collected just below the Kerckhoff No. 2 Hydroelectric Power House suggest that larvae originate both from below and above the dam. Larvae from the Millerton Lake, as small as 8.7 mm TL, were collected by plankton net from May to July. Spawning may extend to August in higher elevation foothill streams since small larvae were observed in July. Larvae were collected in Clear Creek, Stony Creek, and Mud Creek in May and July, 2002–2004. The hardhead larvae were observed in the side channel of the Feather River in 2003 (Seesholtz, *et al.*, 2004), indicating that hardhead will spawn in the moderate flow area of a larger river. The hardhead larvae share the pool habitat with the larvae of Sacramento sucker, Sacramento pikeminnow, and California roach.

Juvenile hardhead inhabit both littoral and pelagic areas of lakes and reservoirs. Juvenile hardhead may also be found in several temperature regimes such as seen at stratified Millerton Lake in summer. Discharge from the Friant Dam may also be responsible for the distribution of the hardhead further southward via Friant-Kern Canal. Juvenile hardhead feed on plankton and crustaceans (Wales, 1946) and on insects and small snails (Reeves, 1964). Juvenile hardhead may feed on filamentous algae in the intermittent pools of the Upper San Joaquin River, particularly in the fall months (Wang, 1986).

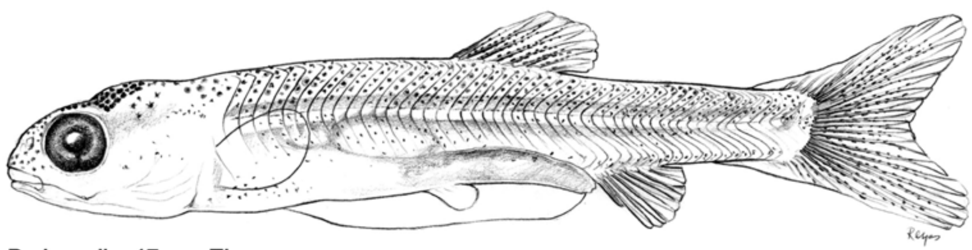
The hardhead is a large-sized native fish (~ 60 cm SL) and reaches maturity at age three (Moyle, 2002). In terms of the ecological status of this indigenous cyprinid, Moyle and Nichols (1973) reported that the population has been declining from their original range due to the introduction of exotic species. The Central Valley floor population is gradually being pushed up to the foothill rivers and streams. Hardhead adults were abundant in the Kerckhoff Reservoir and below Kerckhoff Dam of the San Joaquin River and the lower foothill tributaries of the Sacramento Rivers from Chico and Redding. Juvenile hardhead were collected by beach seine in the shallow inshore of Millerton Lake and Kerckhoff Reservoir. Hardhead are also collected occasionally at Reclamation's Red Bluff Research Pumping Plant.



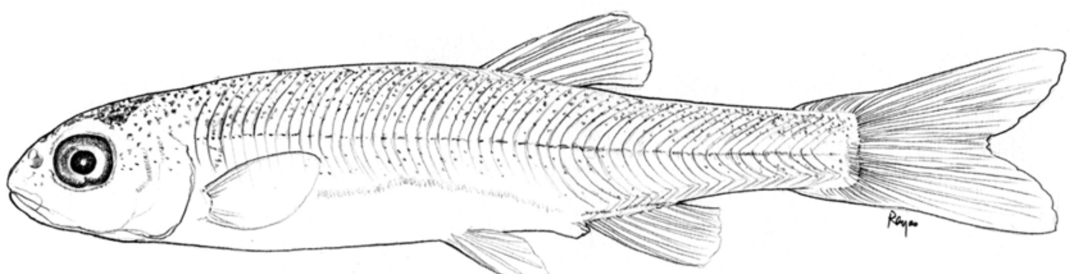
Postlarva, 11 mm TL (Wang, 1986)



Late postlarva, 12.5 mm TL



Prejuvenile, 17 mm TL



Juvenile, 21 mm TL

FIGURE 11a.—Line drawings showing hardhead early life stage specimens.

FIGURE 11b.—Photographs showing hardhead early life stage specimens.

Golden Shiner, *Notemigonus crysoleucas* (Mitchill)

SPAWNING

Location:	Low elevation areas such as lower reaches of the Petaluma River, Napa River, Lake Herman, Lake Anza, upper Rodeo Lagoon, Heather Farm Pond of Walnut Creek, Folsom Lake, some back sloughs in the Delta, Cache Slough, Putah Creek, Lodi Lake, San Luis Reservoir, and Cosumnes River Preserve; in the mid-elevations, such as Ice House Reservoir, Union Valley Reservoir, and Loon Lake.
Season:	March through October (Swingle, 1946); April through July (Wang and Kernehan, 1979); March through September (Moyle, 2002); March through July in the Delta and valley floor; and May through August in mid-elevation of the Sierra Nevada (Wang, 1986).
Temperature:	20-27 °C (Dobie, *et al.*, 1956); 18 °C and greater (Wang and Kernehan, 1979); 20 °C (Moyle, 2002); 17-21 °C (Wang, 1986).
Salinity:	Freshwater.
Substrates:	Among aquatic vegetation (Wright and Allen, 1913); attached to filamentous algae (Cooper, 1935); submerged vegetation and bottom debris (Becker, 1983); in the nest of largemouth bass (Carlander, 1969; Wang and Kernehan, 1979).
Fecundity:	2,700-4,700 (Becker, 1983).

EGGS

Shape:	Spherical.
Diameter:	1.0-1.4 mm (Cooper, 1935); 1.2-1.4 mm (Snyder, *et al.*, 1977); up to 1.2-1.4 mm.
Yolk:	Yellowish (Wang and Kernehan, 1979), pale yellow.
Oil globule:	None (Forbes and Richardson, 1920; Slastenenki, 1958; Wang, 1986).
Chorion:	Smooth.
Perivitelline space:	~ 0.2 mm at morula stage.
Egg mass:	Individually or in small clusters.
Adhesiveness:	Adhesive (Hubbs and Cooper, 1936; Schwartz, 1963; Lippson and Moran, 1974; Wang and Kernehan, 1979). Adhesive, with debris attached to the chorion.
Buoyancy:	Demersal (Lippson and Moran, 1974; Wang and Kernehan, 1979).

LARVAE

Length of hatching:	~ 4.5 mm TL or less (Lippson and Moran, 1974); 3.0 mm TL, as small as 2.7 mm (Snyder, *et al.*, 1977); 3.8-4.0 mm TL (Wang and Kernehan, 1979); 3.4-4.0 mm TL (Wang, 1986); up to 4.5 mm TL.
Snout to anus length:	~ 57-62 percent of TL for protolarvae and mesolarvae (Snyder, *et al.*, 1977); ~ 60-66 percent for late prolarvae and postlarvae (Wang, 1986); 57-64 percent (often 60-61 percent).
Yolk sac:	Elongated, large and oval in thoracic region, becoming cylindrical in abdominal region.
Oil globule(s):	None.
Gut:	Straight, slightly bent below air bladder.
Air Bladder:	Very elongate, behind the tip of pectoral; developing two chambers in postlarvae ~ 10 mm TL.
Teeth:	None.
Size at absorption of yolk sac:	~ 4.5-5.2 mm TL (Wang and Kernehan, 1979); ~ 5.0 mm TL (Wang, 1986).
Total myomeres:	35-39 (Snyder, *et al.*, 1977); 36-38 (Jones, *et al.*, 1978); 35-40 (often 36-37) (Wang, 1986, this study).
Preanal myomeres:	23-24 (Wang, 1986); 20-24 (often 20-22).
Postanal myomeres:	11-17 (Snyder, *et al.*, 1977); 11-15 (Wang, 1986); 14-17 (often 14-16).
Last fin(s) to complete development:	Pelvic.
Pigmentation:	Newly hatched larvae are unpigmented; as larvae grow, the large stellate melanophores develop on head, brachiostegal, mid-dorsum, side and dorsal surface of gut, midventrum and postanal regions up to beginning of caudal peduncle, dashed and dotted melanophores along lateral line, a group of melanophores concentrated at the tip of urostyle. Caudal peduncle is free from pigmentation.
Distribution:	Near the surface of shallow weedy creeks, ponds, sloughs, lakes, and reservoirs. Occasionally in open water, and may school with largemouth bass larvae.

Key Taxonomic Characteristics:

1. Large and paired melanophores observed on dorsum.
2. Pigmentation-free 'gap' found on the caudal peduncle.
3. A single line of pigmentation along entire length of midventral.
4. Dark pigmentation on the upper side of the urostyle.

JUVENILES

Dorsal fin rays: 7-9 (Fry, 1936; Scott and Crossman, 1973; Moyle, 2002); 8 (Wang, 1986).

Anal fin rays: 8-19 (Schultz, 1927); 11-14 (Moyle, 2002); 13-15 (typically 14) (Wang, 1986).

Pectoral fin rays: 15 (Moyle, 1976); 16-18 (Jones, *et al.*, 1978); 15-16 (Wang, 1986).

Mouth: Upward pointed mouth (Moyle, 1976); slightly superior, oblique (Wang, 1986).

Vertebrae: 37-39 (Scott and Crossman, 1973).

Distribution: In both shallow and open waters of pools, creeks, ponds, ditches, lakes, reservoirs, and the Delta. Scattered populations exist in many waters throughout California (Moyle, 2002).

Key Taxonomic Characteristics:

1. High anal finray count: 11-15, and often 14-15 for California population.
2. A wide and dark band observed along midlateral of the body.
3. Lateral line dips at abdominal region.
4. Myomere count between the insertion of D. and origin of A.: 0-3 before the origin of A.

LIFE HISTORY

The golden shiner is a freshwater fish native to the East Coast, inland to the Mississippi drainage (Scott and Crossman, 1973). This species was introduced into California in 1891 (Moyle, 2002). The golden shiner has been stocked as a forage fish for salmonids (*e.g.*, Ice House and Union Valley Reservoirs). It also has been sold as bait fish. This cyprinid has spread to most of the suitable warm water habitat in California, including the Delta (Dill and Cordone, 1997). Golden shiners were observed in the oligohaline portion of the Delta, coastal creeks, Rodeo Lagoon in Marin County, and foothill reservoirs such as Millerton Lake, and at higher elevation lakes such as Loon Lake (Wang, 1986).

Prior to spawning, the adult golden shiner becomes more active. Pre-spawning adults are observed in the TFCF fish salvage in January to March. Presumably they are seeking potential spawning habitat and mates. Spawning takes place from March to September (Moyle, 2002). At lower elevation, golden shiners spawn from March through July in the sluggish or still waters of the Delta and its tributaries. At the foothills and higher elevations, they spawn from May through August in lakes and reservoirs. During the breeding season, the male exhibits a brilliant golden glow on the body and fins. Eggs are deposited over and adhere to aquatic vegetation (Wright and Allen, 1913; Webster, 1942) and are also wrapped in sand particles or debris. As with most cyprinids, the golden shiner exhibits no parental care for its eggs. They do sometimes deposit eggs in the nest of the largemouth bass or other centrarchids, with the male centrarchid guarding the nest (Kramer and Smith, 1960; this study). This odd behavior assures a greater hatching success for the golden shiner eggs. Eggs hatch in 4-5 days at temperatures 24-27 °C (Becker, 1983); 2-3 days at 21-24 °C (Snyder, *et al.*, 1977); 3-4 days at 17-21 °C (this study).

Newly hatched larvae, with no pigmentation on the eyes or body, remain on the bottom near the nesting area until the oversized yolk sac is absorbed. Once the larvae are able to swim, the body becomes covered with large dark pigmentation, and larvae are found near the surface or the periphery of the littoral zone near vegetation. Golden shiner larvae can be found schooling with centrarchid larvae. The dark horizontal band on the body is similar to that found on largemouth bass larvae of the same age. The camouflage pigmentation may confuse other predator fish.

Juveniles form large schools and cruise offshore in the warm water lakes and reservoirs. In small ponds and pools, golden shiner juveniles are associated with centrarchids and other cyprinids. Major food items of juvenile golden shiners include small insects, cladocerans, and zooplankton (Moyle, 1976) such as rotifers, diatoms, and crustaceans as they grow into large juvenile (Chivers and Smith, 1995).

The golden shiner matures at 2-3 years of age (Scott and Crossman, 1973). The maximum life span of this species has been recorded as nine years (Carlander, 1969). It is an important forage fish, especially for such predators as bass and trout. However, golden shiner in some lakes and reservoirs can compete with trout for zooplankton, an important food for both (Moyle, 2002).

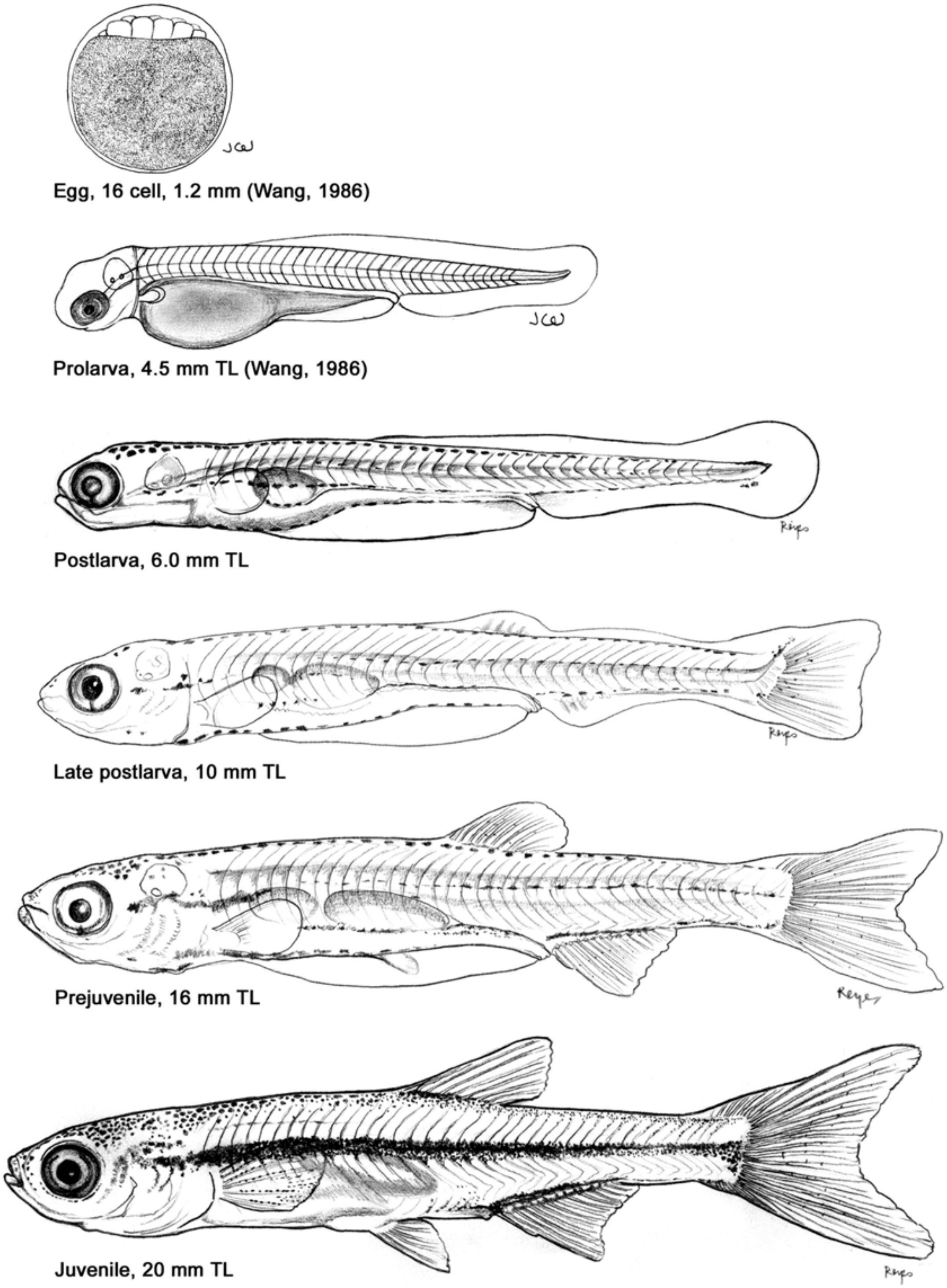


FIGURE 12a.—Line drawings showing golden shiner early life stage specimens.

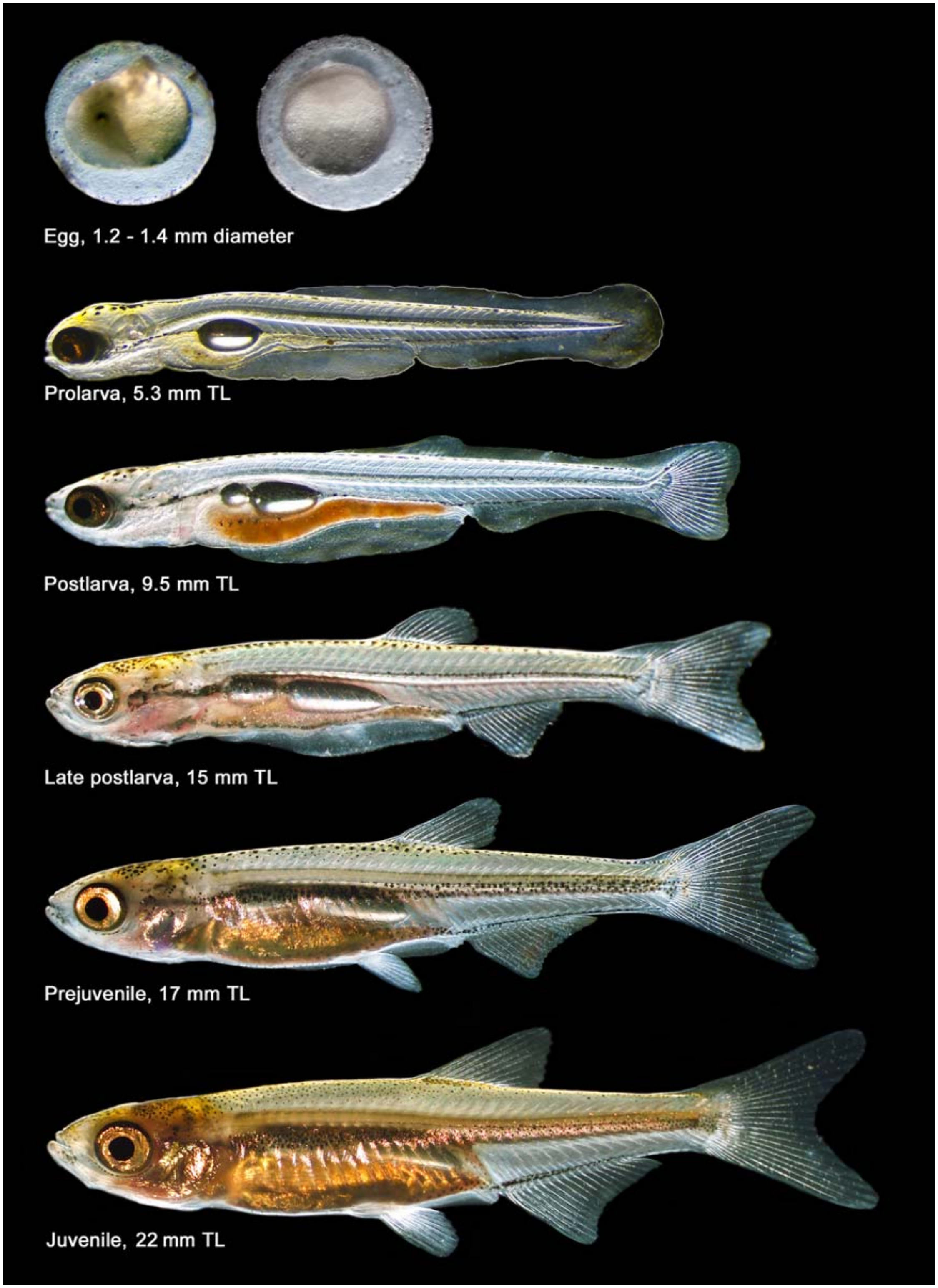


FIGURE 12b.—Photographs showing golden shiner early life stage specimens.

Sacramento Blackfish, *Orthodon microlepidotus* (Ayers)

SPAWNING

Location:	Delta and River. In small lentic environments such as ponds located in Diablo Creek golf course (City of Concord), Heather Farm (City of Walnut Creek), and Sonoma Mountain Zen Center (City of Santa Rosa); large lentic environments such as Lake Hennessey, San Luis Reservoir, Clear Lake, and Morone Reservoir. In lotic environments such as Lindsey Slough, Sonoma Creek, Putah Creek, Walnut Creek, Alameda Creek, Coyote Creek (Leidy, 1983), Salinas River, and Pajaro River (Moyle, 1976); TFCF intake canal and abandoned intake canal, Clifton Court Forebay, Lagoon Valley Regional Park (City of Vacaville, CA), Lodi Lake, Cosumnes River Preserve, and some Sierra Lakes.
Season:	April through June (Murphy, 1950); April through July in Clear Lake (Moyle, 1976); mainly March through July in the South Delta.
Temperature:	12-24 °C (Murphy, 1950; Moyle, 2002); prolarvae were collected at 14-23.2 °C (Wang, 1986); 17-18 °C.
Salinity:	Freshwater.
Substrates:	Over beds of aquatic vegetation (Murphy, 1950); over rocks (Cook, *et al.*, 1966); algae, rock, and other rooted aquatic vegetation (Wang, 1986); aquatic vegetation such as Brazilian elodea *Egaria densa,* algae, and rocks.
Fecundity:	350,000 (Murphy, 1950); 171 mm FL female produced 14,700 eggs , a 466 mm FL female produced 346,500 eggs (Monaco, *et al.*, 1981).

EGGS

Shape:	Spherical.
Diameter:	~ 1.0-1.2 mm for mature unfertilized eggs (Wang, 1986); 1.5-1.8 mm for fertilized eggs.
Yolk:	Pale yellow, granular.
Oil globule:	None.
Chorion:	Transparent.
Perivitelline space:	0.2-0.3 mm in width in early embryo stage.
Egg mass:	Individually, some eggs adhere to each other, but no clusters were observed.
Adhesiveness:	Very adhesive.
Buoyancy:	Demersal.

LARVAE

Length of hatching:	4.8-6.7 mm, often between 5.3-5.5 mm (the smallest prolarvae specimens collected at the TFCF intake canal and SDFPF were 6.5-6.7 mm TL).
Snout to anus length:	For newly hatched larvae, 64-71 percent (often 65-68 percent); for the postlarvae, 60-65 percent (often 60-63 percent).
Yolk sac:	Large, elongate, bulbous anteriorly.
Oil globule(s):	None.
Gut:	Straight, and slightly bent below the air bladder.
Air Bladder:	Small, two chambers, the posterior chamber visible at 6.0-7.0 mm TL and anterior chamber visible at 9.0-10.0 mm TL.
Teeth:	None.
Size at absorption of yolk sac:	~7.0-8.0 mm TL.
Total myomeres:	36-42 (Wang, 1986); 39-42 (often 40-42 for South Delta specimens).
Preanal myomeres:	25-29 (Wang, 1986); 24-27 (often 25-27).
Postanal myomeres:	11-16 (Wang, 1986); 13-17 (often 14-15).
Last fin(s) to complete development:	Pelvic.
Pigmentation:	Heavy pigmentation on head, scattered along middorsal (not paired) thoracic, dorsal of gut, and postanal regions; dashed and dotted melanophores on lateral line region. Two distinguishable groups of melanophores on tail, one wrapping the urostyle and other at the hypural observed in the prolarval to late postlarval stages.

Distribution: Often found in shallow waters, ponds, lakes and reservoir, scattered in the sloughs of the Delta. Larvae have been transported to the south via the aqueduct systems. Some larvae were observed in the oligohaline waters of the Bay.

Key Taxonomic Characteristics:

1. Caudal pigmentation in two groups.
2. Two rows of unpaired melanophores on dorsum, and mixed with small melanophores.
3. Narrow caudal peduncle.
4. Midventral has short dashed melanophores near the thoracic region.

JUVENILES

Dorsal fin rays: 9-11 (Moyle, 1976); 9-10 (Wang, 1986); 9-11 (usually 10).

Anal fin rays: 8-9 (Moyle, 1976); 8 (Wang, 1986); 8-9 (usually 8).

Pectoral fin rays: 16-18; typically 16 (Wang, 1986).

Mouth: Slightly upturn (Moyle, 1976); terminal, small, oblique.

Vertebrae: 39-42 (Wang, 1986).

Distribution: Found often in shallow water with or without vegetation, landlocked pond, lakes, reservoirs, and sloughs of the Bay (such as Harris and Montezuma Slough) and the Delta.

Key Taxonomic Characteristics:

1. High lateral line scales count, ~ 100.
2. Black peritoneum and narrow caudal peduncle.
3. A dark stripe may be present at the posterior edge of operculum.
4. Caudal spot shaped as an elongated bar; may be visible as early as 18 mm TL.
5. Myomere count between the insertion of D and origin of A: 3-5 before the origin of A.

LIFE HISTORY

The Sacramento blackfish is a California native freshwater species. Sacramento blackfish are well-distributed in the River and Delta, Clear Lake, Pajaro River, and Salinas River (Murphy, 1950; Moyle, 1976); however, the detailed distribution of this species is poorly understood (Moyle, 2002). Sacramento blackfish are abundant in small and large impoundments scattered throughout the freshwaters of the California. Specimens were also collected by gill net and otter trawl in Honker Bay, Grizzly Bay, and near Martinez (Ganssle, 1966); and by midwater trawl in Carquinez Strait (Messersmith, 1966). They have been introduced in some lakes and reservoirs in Nevada.

Sacramento blackfish spawn from March to July. Small groups of Sacramento blackfish congregate over emergent vegetation or rocks in water less than one meter deep (Murphy, 1950; Cook, *et al.*, 1966). We observed spawning in small bodies of water such as Diablo Creek golf course pond and a tomato tank located at the FCCL, and in large bodies of water such as Clifton Court Forebay, the TFCF intake canal and abandoned intake canal, Lake Hennessey, New Melones Reservoir, and San Luis Reservoir. We observed spawning in the field from March through June, which was extended in the laboratory until July.

The male fish bears tiny breeding tubercles (Moyle, 2002), and the male is apparently darker than the female (Murphy, 1950). Fish collected from the TFCF have breeding tubercles (≥1 mm in diameter at base and height) all over the head and body with exception of the ventral part. Tubercles are at the outer edge of individual scales and are dense on the top of the head and on the entire dorsum of the body, with fewer tubercles found on the sides of the body. The active spawning male fish is much darker in upper body and may have rusty color on the lateral and ventral sides. The gravid female is lighter on upper body and whitish on the abdomen.

Sacramento blackfish, like other cyprinids, broadcast adhesive eggs on aquatic vegetation near or at the bottom of shallow coves. Ripe fish were observed at the TFCF trash rack, the backwater of the intake canal, and the abandoned intake canal, in March and April. Most larvae were collected in shallow water associated with vegetation. Sacramento blackfish larvae were observed in various locations in the Delta, adjacent ponds, and lakes since the identification of the Sacramento blackfish was confirmed in the mid-1980's (Wang, 1986). They can be locally abundant, particularly when there are limited numbers of other fish species in the same area, such as in the TFCF intake canal and abandoned intake canal, and Lagoon Valley Regional Park pond. We observed Sacramento blackfish eggs in a largemouth bass nest at the TFCF abandoned intake canal in late March and April, 2004. The Sacramento blackfish eggs were found mainly on the peripheral rim of the largemouth bass nest. This is a very interesting interaction between a native cyprinid and an introduced centrarchid, and it could either be incidental or intentional. Shao (1997) noted that golden shiner dropped eggs on the periphery of pumpkinseed nest and suggested that golden shiner eggs in such locations have a better chance of hatching.

Newly hatched Sacramento blackfish larvae have black eyes and light body pigmentation. Yolk sac is absorbed within a few days; the body gains more pigmentation, and becomes more active. Larvae were found near the bottom as well as in open water at sampling stations in the Bay and Delta (CDFG Fish E&L sampling program in the Delta, 1992–1995; CDFG Fish E&L sampling program in NBA, 1995–2003; laboratory observations, 2003–2004). More Sacramento blackfish larvae were observed in the CDFG samples in wet water-years (such as 1993, 1995, and 1998) than the dry water-years, a similar situation found with splittail. Sacramento blackfish larvae are planktonic in their early life stages, a similar dispersal strategy as other cyprinids.

Juvenile Sacramento blackfish school in large numbers in shallow water during summer months. Juveniles are seldom observed in these same areas when water temperature decreases, apparently moving to deeper water. They feed primarily on phytoplankton (*e.g.*, green algae, diatoms), zooplankton (*e.g.*, rotifers, copepods, cladocerans), invertebrates (*e.g.,* midges, insect larvae), and bottom-suspended detritus (Murphy, 1950; Cook, *et al.*, 1966; Sanderson and Cech, 1992). As their food shifts to organic matter and algae, Sacramento blackfish develop elongated and coiled intestines capable of digesting these materials (Moyle, 2002).

Sacramento blackfish reach sexual maturity in one to four years (Moyle, 2002). Growth can be stunted in confined areas (*e.g.* the ponds at Diablo Creek golf course and the Sonoma Mountain Zen Center). The Sacramento blackfish population can be reduced by introducing exotic species, such as the fathead minnow, which has replaced Sacramento blackfish and Sacramento perch, *Archoplites interruptus*, as the most abundant fish species at the Lagoon Valley Regional Park pond (2002–2003). Overall Sacramento blackfish are still abundant and spreading in the Delta, lakes, reservoirs and ponds. The TFCF intake canal population provides juvenile fish for San Luis Reservoir via the Delta Mendota Canal and are transported further southward via aqueduct to Southern California. Sacramento blackfish have an established fishery in the San Luis Reservoir. Some lakes may have been stocked deliberately with the Sacramento blackfish in the foothill regions, harvesting them later for commercial purposes. Fish farming of the Sacramento blackfish has not been economical in California (Ken Beer, 1987). However, in Nevada, the Murray Fish Company (Silver Springs, Nevada) harvested blackfish from the Lahontan Reservoir an average of 353,000 lb/yr (160,000 kg/yr) in the 1980's (Craft and Yoder, 2005). Moyle (2002) stated that Sacramento blackfish are probably less abundant in their native lowland habitats than in the recent past, but may have expanded their range through human introduction.

Feeding on organic matter and phytoplankton, their flesh is reputed to be tender and tasty, making it a prized fish in the Asian fish markets of major cities along the West Coast. The demand for the Sacramento blackfish has increased substantially in recent years and over fishing may exist. The harvest of the Sacramento blackfish has been extended from the State of California to the neighboring State of Nevada. However, fish collected from the old mining lakes and reservoirs may require the safety testing of chemical and heavy metal contents before marketing. Currently, Sacramento blackfish collected from Lahontan Reservoir have levels of mercury in their tissues above Environmental Protection Agency advisory levels (> 0.6 mg/kg) and Food and Drug Administration levels (1.0 mg/kg) (Craft and Yoder, 2005).

This page left intentionally blank.

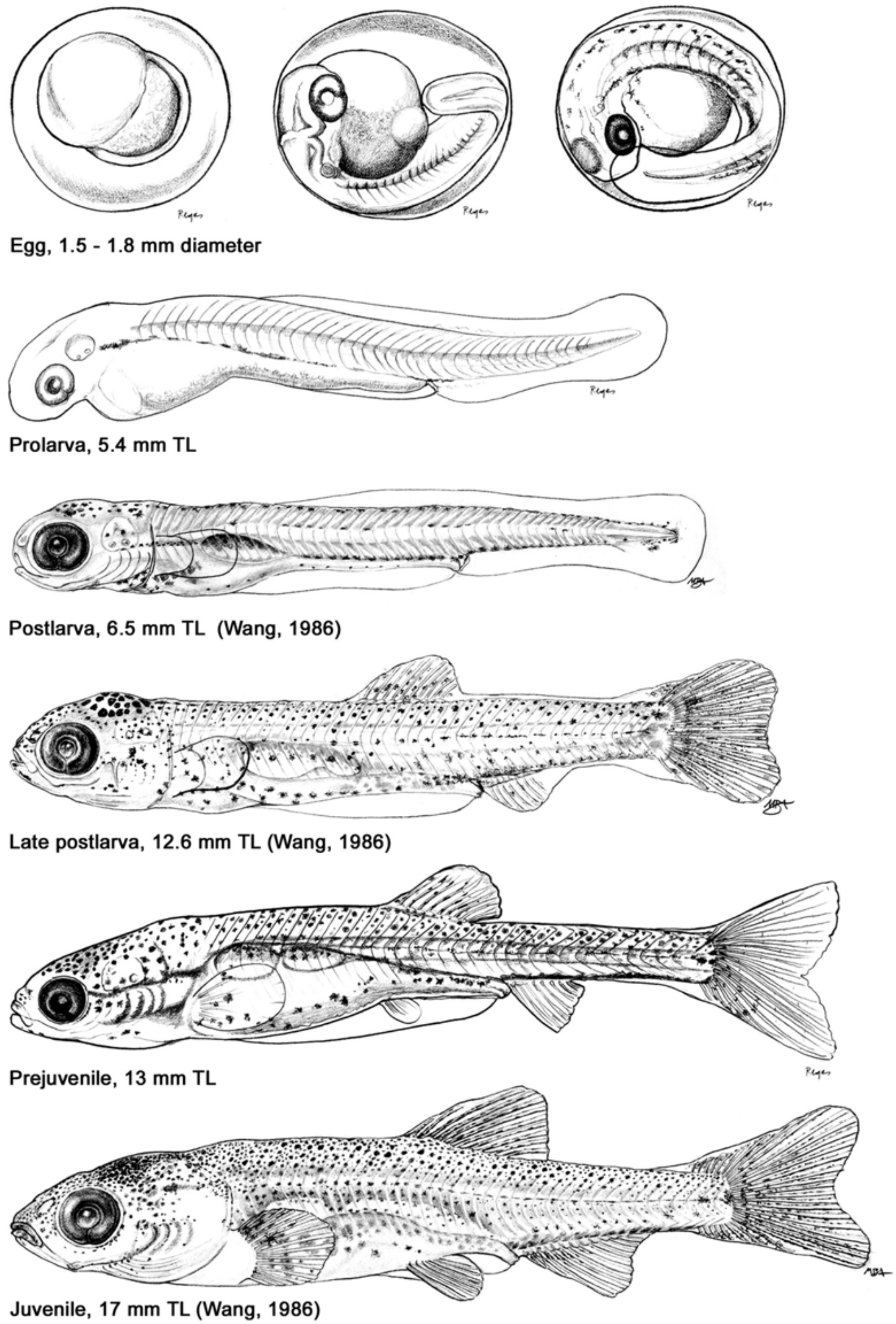


FIGURE 13a.—Line drawings showing Sacramento blackfish early life stages.

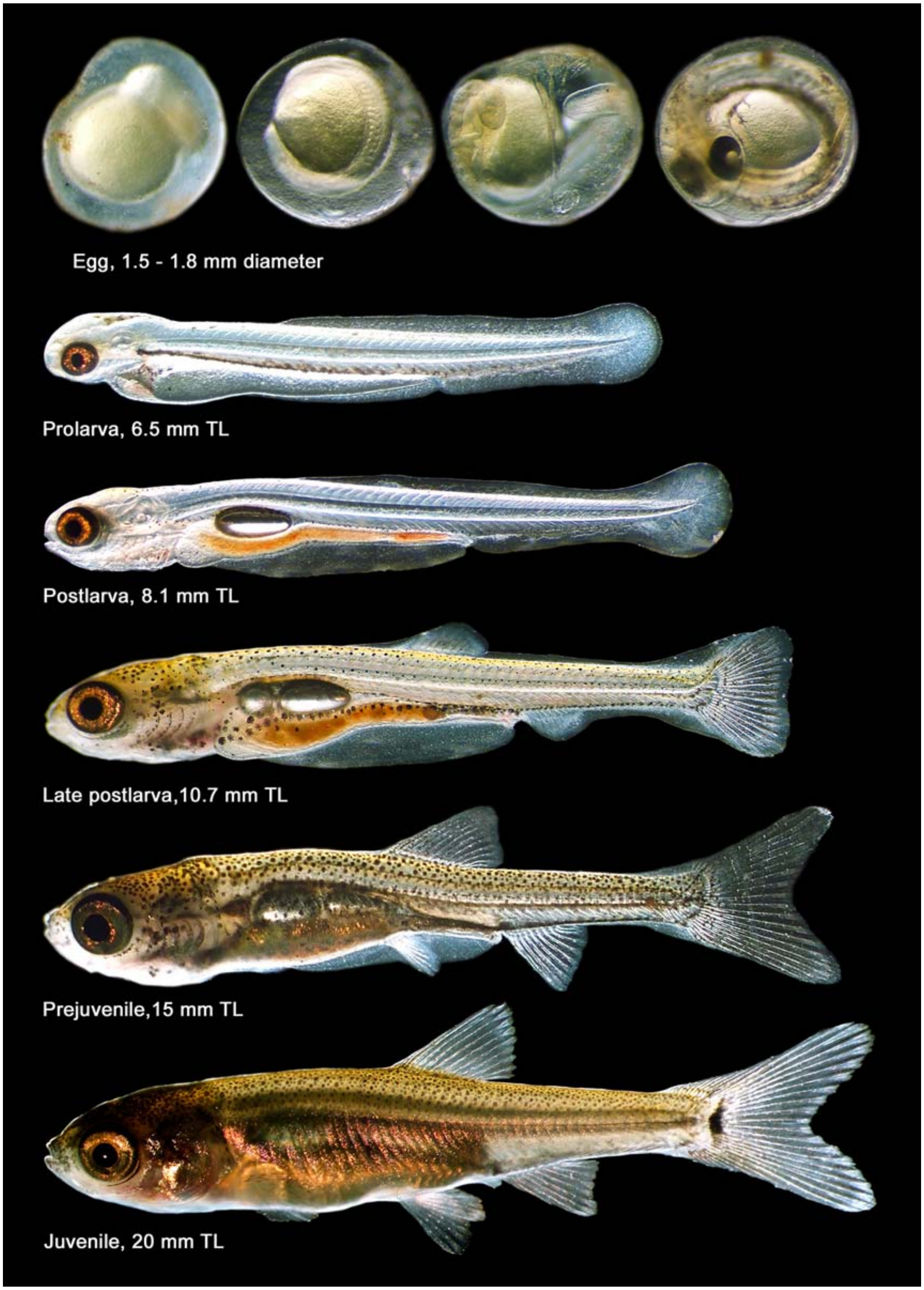


FIGURE 13b.—Photographs showing Sacramento blackfish early life stages.

Fathead Minnow, *Pimephales promelas (*Rafinesque)

SPAWNING

Location:	Delta and River. Shallow water with vegetation, channelized ditches, dead-end sloughs, and ponds. Wilson Slough, Coyote Creek, Sweeney Creek, Lindsey Slough, Cache Slough, TFCF intake canal, and Lagoon Valley Regional Park pond (City of Vacaville, CA).
Season:	Throughout the summer (Moyle, 1976); June through August (Scott and Crossman, 1973); March through July (Wang, 1986); usually from April through June.
Temperature:	Temperature exceeding 17.8 °C (Dobie, *et al.*, 1956); minimum 15.6 °C (Scott and Crossman, 1973); males show spawning color at 12 °C, and actual spawning starts at 15 °C.
Salinity:	Freshwater.
Substrates:	Stone, boards, branches (Moyle, 1976), logs, rocks, boards, lily pads (Wynne-Edwards, 1932); vertical stalks of plants (Cross, 1967); cattail, plastic tubing, stone, ceramic products, PVC tubes inner-lined with nylon mesh, and other man-made plastic substrates (Wang, 1986; this study).
Fecundity:	4,144 eggs spawned by a single female twelve times in eleven weeks (Dobie, *et al.*, 1956).

EGGS

Shape:	Spherical.
Diameter:	1.3 mm (Wynne-Edwards, 1932); 1.15 (Markus, 1934); 1.4-1.6 mm (Snyder, *et al.*, 1977); 1.3-1.45 (Wang, 1986); 1.1-1.4 mm, often 1.3 mm.
Yolk:	Often whitish or very pale yellow, granular.
Oil globule:	None.
Chorion:	Transparent, smooth.
Perivitelline space:	~ 0.2 mm in the morula stage, and very narrow in late embryo stage, ~ 0.05 mm (Wang, 1986); 0.15-0.23 mm.
Egg mass:	Individually and in small, one-layered clusters.
Adhesiveness:	Adhesive (Wynne-Edwards, 1932; Scott and Crossman, 1973); adhesive throughout incubation (Wang, 1986; this study).
Buoyancy:	Demersal.

LARVAE

Length of hatching:	~ 5.0 mm TL (Scott and Crossman, 1973); as small as 4.3 mm TL (Snyder, *et al.*, 1977); ~ 4.6-5.2 mm TL (Wang, 1986); 4.6-4.8 mm TL.
Snout to anus length:	58-62 percent of TL of protolarvae and mesolarvae (Snyder, *et al.*, 1977); ~ 55-60 percent of TL for prolarvae and postlarvae (Wang, 1986); 57-60 percent of TL for postlarvae (often 58-59 percent).
Yolk sac:	Elongate and almost spherical in thoracic and tapering off in abdominal region.
Oil globule(s):	None.
Gut:	Straight, slightly depressed below air bladder.
Air Bladder:	Elongate, near pectorals, posterior chamber visible at 5 mm TL; anterior chamber visible ~ 7.5 mm TL.
Teeth:	None.
Size at absorption of yolk sac:	5.5-6.0 mm TL (Wang, 1986); 5.0-5.2 mm TL.
Total myomeres:	34-37 (Snyder, *et al.*, 1977); 33-36 (Wang, 1986); 34-38 (Snyder, *et al.*, 2005); 34-38, (often 35-37).
Preanal myomeres:	20-22 (Wang, 1986); 21-25 (Snyder, *et al.*, 2005); 19-23 (often 20-21).
Postanal myomeres:	12-14 (Snyder, *et al.*, 1977); 12-15 (Wang, 1986); 12-15 or as few as 11 in metalarvae (Snyder, *et al.*, 2005); 14-16 (often 15-16).
Last fin(s) to complete development:	Pelvic.
Pigmentation:	Newly hatched larvae have little pigment on body. In postlarvae, stellate melanophores on snout, head, and sparsely distributed on middorsum; dense melanophores on dorsal surface and side of gut, and postanal regions; dashed and dotted melanophores along the lateral line region; scattered melanophores along the midventral. Dense melanophores observed at hypural and wrapping the urostyle.

Distribution: Newly hatched larvae, with dark eyes, remain on bottom near nesting area until yolk is nearly absorbed, and then disperse into shallow and also in open water (CDFG sampling in the NBA).

Key Taxonomic Characteristics:

1. Light and sparse pigmentation observed on dorsum in prolarval and early postlarval stages.
2. Pigmentation wraps around vertebrae as a series of chain in large larvae.
3. Midventral pigmentation may run the full length or in intermittent pattern.

JUVENILES

Dorsal fin rays: 8 (Scott and Crossman, 1973; Moyle, 1976; Wang, 1986).

Anal fin rays: 7 (Scott and Crossman, 1973; Moyle, 1976; Wang, 1986).

Pectoral fin rays: 14-18 (Scott and Crossman, 1973); 15-16 (Wang, 1986).

Mouth: Small, near terminal (Scott and Crossman, 1973); small, terminal, and oblique (Wang, 1986).

Vertebrae: 35-38 (Scott and Crossman, 1973; Snyder, *et al.*, 2005); 34-36.

Distribution: Shallow creeks, ditches, sloughs, and rivers, in patchy patterns.

Key Taxonomic Characteristics:

1. Blunt snout, round head and thick caudal peduncle.
2. Dark horizontal band on body.
3. Fish looks chunky and robust.
4. The myomere count between the insertion of D. and origin of A.: 1-3 before the origin of A.

LIFE HISTORY

The fathead minnow is a freshwater fish native to the central and eastern portions of North America (Scott and Crossman, 1973; Moyle, 2002). They were introduced into California in the early 1950’s (Shapovalov, *et al.*, 1959; Dill and Cordone, 1997). Fathead minnows are now found in most streams in the Delta and River (Moyle, 1976, 2002) and Southern California (Dill and Cordone, 1997). Fathead minnows were collected in the Delta and its associated tributaries, sloughs, and ponds such as Lindsey Slough, the TFCF intake canal, Putah Creek, Cosumnes River, and Lagoon Valley Regional Park pond. Their distribution is patchy but they are locally abundant. Moyle (2002) stated that anglers who discard unused bait into the water have enhanced the dispersal of this species. Currently, fathead minnow, like the red shiner, are abundant in areas close to good fishing spots.

In the Delta, fathead minnow spawn as early as March. Males become rusty brown, with several dark vertical bands on their sides. Whitish breeding tubercles are prominent on the snout and top of a darker head. In laboratory observations, only the most dominant male mates and less dominant males show little breeding color in a small aquarium. If the dominant male is removed from the aquarium, the second dominant male immediately develops breeding colors. The male establishes a territory, and cleans the nesting area, which is usually the underside of a flat rock or vertical stalks of plants (Wynne-Edwards, 1932; Cross, 1967). After engaging in courtship (using of breeding tubercles to rub the abdominal region of the female), the female deposits eggs in the nest. After fertilization, the male remains and guards the eggs. Male fish from our laboratory used a wrinkled pad modified from the front dorsal fin rays as a cleaning device to sweep the eggs back and forth. This behavior was also observed by Wynne-Edwards (1932). Since the female deposits multiple batches of eggs in the breeding season, one female can generate over 40,000 eggs per season (Dobie, *et al.*, 1956). The various developmental stages found in the same nest suggest that the male apparently accepts the eggs deposited by several different females. The incubation period was reported to be five days at 25 °C (Dobie, *et al.*, 1956). Fathead minnow eggs hatched in 5 days at 19-21 °C at the TFCF fish laboratory.

Newly hatched larvae have dark eyes and remain in the nesting area for several more days until much of the yolk material is absorbed. From laboratory observations, the prolarvae lie on their sides on the bottom, then move to a dorsal-ventral position as late prolarvae. After much of the yolk sac is absorbed, the postlarvae swim freely in the water column. Field observations suggest that postlarvae are most commonly found in shallow water; however, some venture into open water (CDFG, NBA specimens, 1995–2002).

Juveniles inhabit shallow weedy areas where they may be locally abundant. Young fathead minnows feed on filamentous algae, diatoms, detritus, small invertebrates, and bottom organic matters (Keast, 1966; Moyle, 1976).

The fathead minnow has a short life span, seldom living more than two years (Scott and Crossman, 1973). It matures within 1-2 years (Carlander, 1969; Becker, 1983). Fathead minnow is commonly used as bait fish in California, and is stocked as a forage species for larger predators (Shapovalov, *et al.*, 1959). In confined environments with few predators, fathead minnows can over populate and dominate the ecology. An example is the introduction of fathead minnow at the Lagoon Valley Regional Park. Sacramento blackfish and Sacramento perch were originally stocked at this park pond by the CDFG, in order to save these two native fish species. Sacramento blackfish are used as forage for the Sacramento perch. It was an ideal plan. However, anglers began using live bait (such as the fathead minnow and golden shiner) to catch the Sacramento perch. The unused bait fish established and reproduced in the pond (larval fathead minnow were collected in the pond from 1997 to 2003). Sacramento perch, Sacramento blackfish, and golden shiner do not guard their nesting areas and leave the eggs on the substrates. In contrast, the male fathead minnow guards the nest and the female fathead minnow can deposit multi-clutches of eggs during a spawning season. Fathead minnows are bottom browsers (Moyle, 2002), thus feeding on the eggs of Sacramento blackfish, Sacramento perch, and golden shiner. Eventually, the population of the Sacramento perch and the Sacramento blackfish were quickly replaced by the fathead minnow. No larvae and juveniles of the Sacramento perch and golden shiner were observed in recent monitoring and only a few Sacramento blackfish larvae were collected.

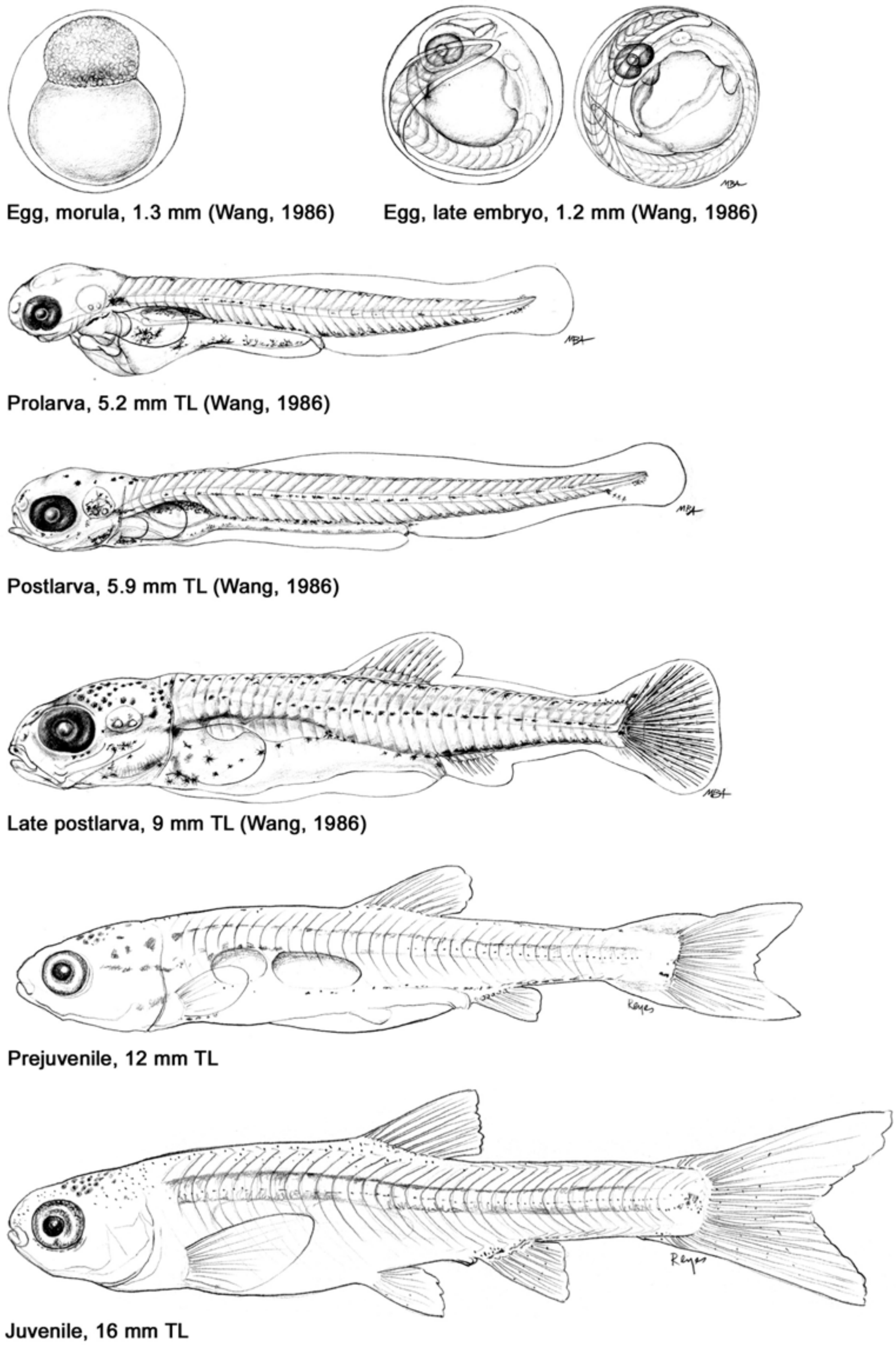


FIGURE 14a.—Line drawings showing fathead minnow early life stage specimens.

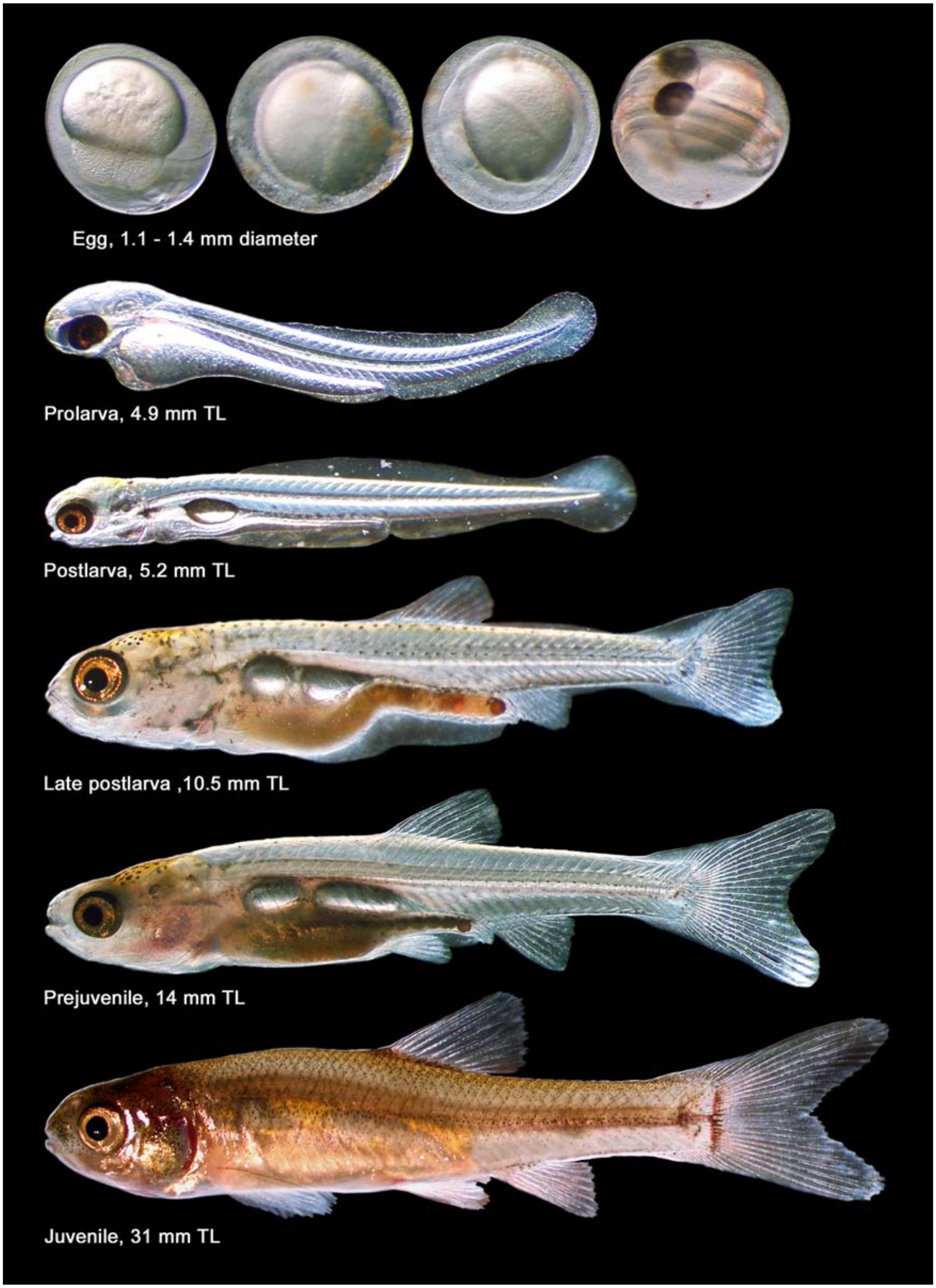


FIGURE 14b.—Photographs showing fathead minnow early life stage specimens.

Splittail, *Pogonichthys macrolepidotus* (Ayers)

SPAWNING

Location:	Bay and Delta. Sloughs, floodplains, flooded river and stream channels of the Delta (Caywood, 1974). Upper Sacramento River in dry-water years; Lower Sacramento River and its adjacent floodplains, Montezuma Slough, Napa River, and the Bay during normal and wet-water years.
Season:	March through June (Caywood, 1974); usually in March and April (Moyle, 2002); January through July (Wang, 1986); March through May at the FCCL in the South Delta (Bridges, 2003–2004).
Temperature:	9-20 °C (Caywood, 1974); preferring temperatures 14-19 °C (Moyle, 2002); ~ 20 °C during the end of the spawning season (Wang, 1986); 14-18 °C at the FCCL in the South Delta (Bridges, 2003–2004).
Salinity:	Freshwater (Caywood, 1974); oligohaline (Wang, 1986).
Substrates:	Aquatic vegetation, stream or river beds, and banks (Caywood, 1974); marsh and slough vegetations (Wang, 1986), hard surface of various artificial substrates such as plastic.
Fecundity:	5,000-100,800 (Caywood, 1974); 100,000 (Daniels and Moyle, 1983); 28,416-168,196 (Feyrer and Baxter, 1998).

EGGS

Shape:	Spherical.
Diameter:	Mature eggs, 1.3-1.6 mm (Wang, 1986); 1.0-1.5 mm (Feyrer and Baxter, 1998); fertilized eggs, 1.6-2.1 mm, slightly dilated prior to hatching.
Yolk:	Yellowish, granular.
Oil globule:	None.
Chorion:	Transparent, thick, smooth except at adhering point.
Perivitelline space:	Very wide, 0.4-0.5 mm in width in morula stage.
Egg mass:	Individually and in small clusters.
Adhesiveness:	Adhesive (Caywood, 1974). Very adhesive to substrate and to each other.
Buoyancy:	Demersal, suspended on substrates (Caywood, 1974); demersal.

LARVAE

Length of hatching:	Less than 6.5 mm (Wang, 1986); 5.0-6.8 mm TL from cultured stock.
Snout to anus length:	~ 62-70 percent of TL for prolarvae and postlarvae (Wang, 1986); for newly hatched l arvae, 70-75 percent of TL (often 74-75 percent); for postlarvae, 65-70 percent of TL (often 65-70 percent).
Yolk sac:	Elongate, enlarged in thoracic region and slender in abdominal region.
Oil globule(s):	None.
Gut:	Straight and slightly depressed in the thoracic area when air bladder inflates.
Air Bladder:	Two chambers at 11.4 mm (Deng, *et al.*, 2004); narrow behind pectorals, first chamber inflates around 7 mm TL, develops into two chambers in late postlarval stage around 11 mm TL, with a much larger posterior chamber.
Teeth:	None.
Size at absorption of yolk sac:	7.0-8.0 mm TL.
Total myomeres:	39-43 (Wang, 1986); 40-44 (often 41-43).
Preanal myomeres:	25-31 (Wang, 1986); 26-31 (often 29-31).
Postanal myomeres:	10-15 (Wang, 1986); 11-15 (often 12-15).
Last fin(s) to complete development:	Pelvic.
Pigmentation:	Large melanophores on head. Scattered melanophores on middorsal region, gradually forming two paired rows; very heavy melanophores on jugular, on dorsal surface of gut and postanal regions; dotted to dashed melanophores on lateral line region; scattered melanophores in thoracic region.
Distribution:	Most are planktonic, found in freshwater to oligohaline portions of the estuary; Upper and Lower Sacramento River; scattered in the Delta and its tributaries, the Bay, Montezuma Slough and its tributaries.

Key Taxonomic Characteristics:

1. Large paired stellate melanophores on dorsum.
2. Dashed type melanophores run through the lateral region of the body.
3. Scattered melanophores in midventral region distributed randomly.
4. Thick caudal peduncle.

JUVENILES

Dorsal fin rays: 9-10 (Moyle, 1976); 10 (Wang, 1986); 8-9 (typically 9).

Anal fin rays: 7-9 (Moyle, 1976); 9 (Wang, 1986); 7-8 (typically 8).

Pectoral fin rays: 16-19 (Moyle, 1976); 16 (Wang, 1986).

Mouth: Subterminal (Moyle, 1976); terminal then changes to subterminal (Wang, 1986).

Vertebrae: 39-43 (typically 40) (Wang, 1986).

Distribution: In the Bay, Montezuma Slough, Napa River, and eastern San Pablo Bay, in the shallow and open water of the Delta, Sutter and Yolo Bypasses, and the Sacramento River. Juveniles occasionally found in the San Luis Reservoir (Caywood, 1974), O'Neill Forebay (Hess, *et al.*, 1995), and in the Petaluma River (Meng and Moyle, 1995).

Key Taxonomic Characteristics:

1. C. deeply forked, upper lobe is longer than lower lobe.
2. Caudal peduncle thick (~ 50 percent of the maximum body depth).
3. Mouth transforms from terminal to slightly inferior, corner may have tiny barbels at the corners.
4. The myomeres between insertion of D. and origin of A.: 5-10 before the origin of A.

LIFE HISTORY

Splittail is a native freshwater fish of California, once abundant in lakes and rivers of the Central Valley. Currently splittail spawning takes place in many areas such as the Sacramento River below the Red Bluff Dam and the tributaries of the Sacramento River, including Butte Slough, Sutter Bypass, Feather River, American River, and Yolo Bypass (Caywood, 1974; Meng and Moyle, 1995; Baxter, *et al.*, 1996; Baxter, 1999; Sommer, *et al.*, 1997; Meng and Matern, 2001; Moyle, 2002; Feyrer, *et al.*, 2004). In addition, spawning has also been documented in the San Joaquin River, the Tuolumne River to the Cosumnes River Preserve, and south to Modesto (Rockriver, 1998; Moyle, 2002; Crain, *et al.*, 2004). Splittail larvae were found in Putah Creek in 1997–1998 (Marchetti, 1998; Rockriver, 1998); however, it is believed that these splittail larvae originated from the Yolo Bypass and not Putah Creek. Newly hatched larvae have been collected at many sampling stations located in the Bay and Delta, outside of the traditional floodplains and up-river spawning areas. Feyrer *et al.* (2004) suggested that a self-sustaining splittail population may exist in down-bay tributaries, such as in the Napa and Petaluma Rivers. Baerwald, *et al.* (2006) revealed that there are two genetically distinct splittail populations of splittail; one largely composed of splittail from the Petaluma and Napa Rivers and the second composed of splittail from the tributaries of the Sacramento and San Joaquin Rivers. Spawning location for this distinct group, however, is unclear. Additional larval fish sampling would help substantiate the life history of this distinct population or group.

Splittail are versatile spawners. Male splittail can be sexually mature at one year, female mainly at age 3, and both sexes can live up to 6–7 years (Daniels and Moyle, 1983) or longer (Bridges, 2004). Splittail may spawn intensively over a short period when the conditions are most favorable (Wang, 1995) but they are fractional spawners, with individuals spawning over a period of several months, when the environment is less favorable.

Splittail larvae have a very short planktonic phase, usually starting at 7 to 8 mm TL when their air bladder develops. Juveniles are strong swimmers and are abundant in secondary channels, backwater areas upriver (Sommer, *et al.*, 2002; Feyrer, *et al.*, 2004), and in shallow waters of the Bay, Montezuma Slough, and most sloughs in the Delta (Wang, 1986; Meng and Moyle, 1995). The large numbers of juvenile splittail collected at the TFCF from May to July (~0.5 million in May, 4.1 million in June, and ~1 million in July, TFCF salvage data, 1995–2005) suggest there is a downstream movement of juvenile splittail from upriver to the Delta. These juveniles start the downstream movement to the estuary from May through July and into fall. More juvenile splittail are observed downstream in the Bay, Montezuma Slough, and San Pablo Bay in winter through spring. Juvenile (age-0) splittail seem to be most commonly found in brackish water (Meng and Moyle, 1995). Some juveniles may remain in the river for their first year (Feyrer, *et al.*, 2004). The mouth of early juvenile splittail moves gradually from terminal into a subterminal position. This subterminal position enhances the juvenile splittail's ability to feed on algae, invertebrates, crustaceans, and detritus near or on the bottom (Caywood, 1974; Moyle, 2002). Some investigators consider the areas down river as the primary nursery grounds for juvenile splittail.

SPLITTAIL EXPANDED LIFE HISTORY

Splittail Adult Spawning Characteristics.—Spawning movement of adult splittail (≥ 170 mm FL) starts in late winter and early spring (figure 15), with the fish seeking spawning grounds. Both sexes exhibit brilliant orange-red color on their fins. Older males have a hump (figure 16) between the head and dorsal fin; males bear tiny whitish tubercles (< 1.0 mm) (figure 17) on top of their head and slightly larger and thicker tubercles cover the entire length of the dorsum. Males also have an elevated area of thick tissue or padding (with scales having sandpaper-like ridges) at the ventral side of the pectoral girdle (figure 18). Observed in the laboratory during courtship, the male uses a combination of fins, dorsal breeding tubercles, and pectoral padding to rub the female body. Lacerated tissues have been observed on male fins and scales presumably from the spawning activity. Ripe splittail of both sexes have been observed at the TFCF; therefore, it can be postulated that these fish spawn in the South Delta near the state and federal fish facilities.

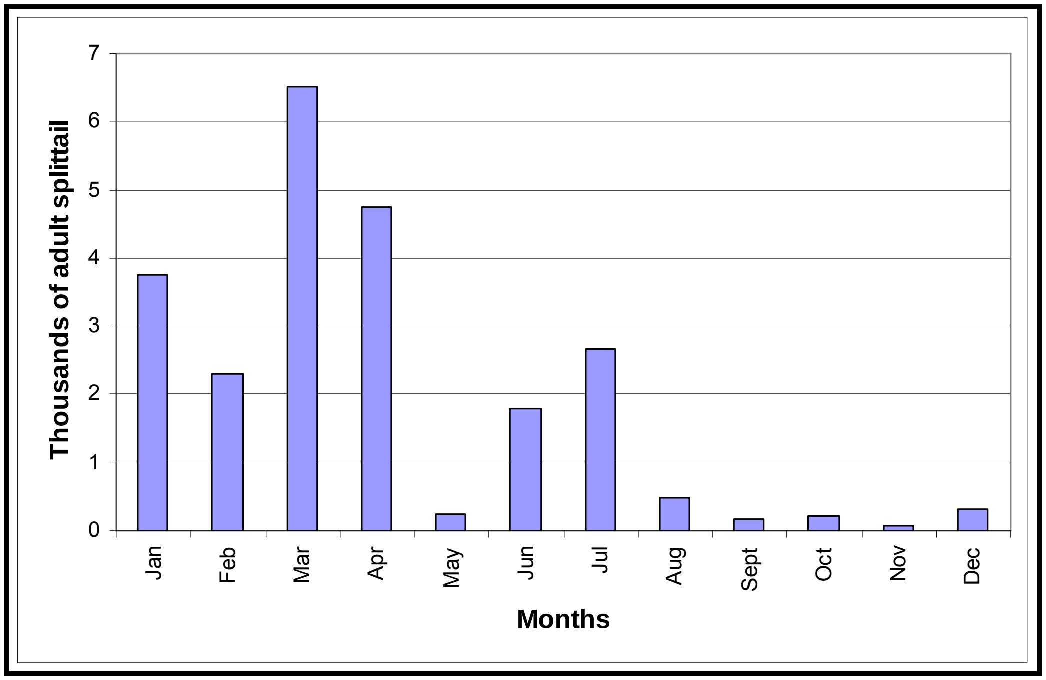


FIGURE 15.—Monthly adult splittail salvaged at the TFCF (1995–2005).

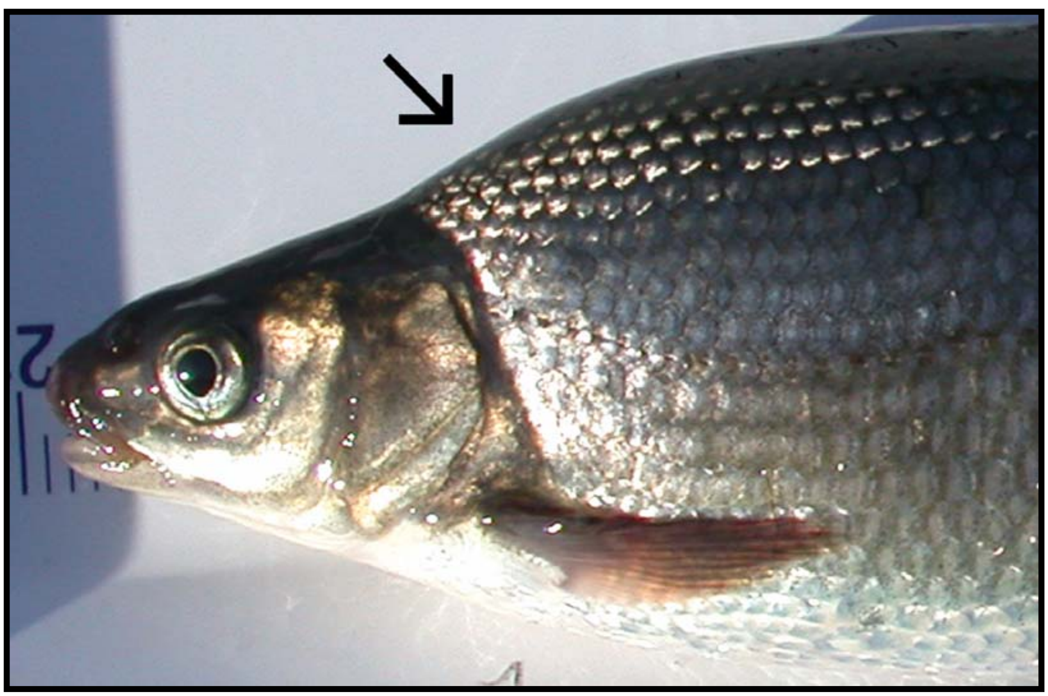


FIGURE 16.—Hump between the head and dorsal fin of adult splittail.

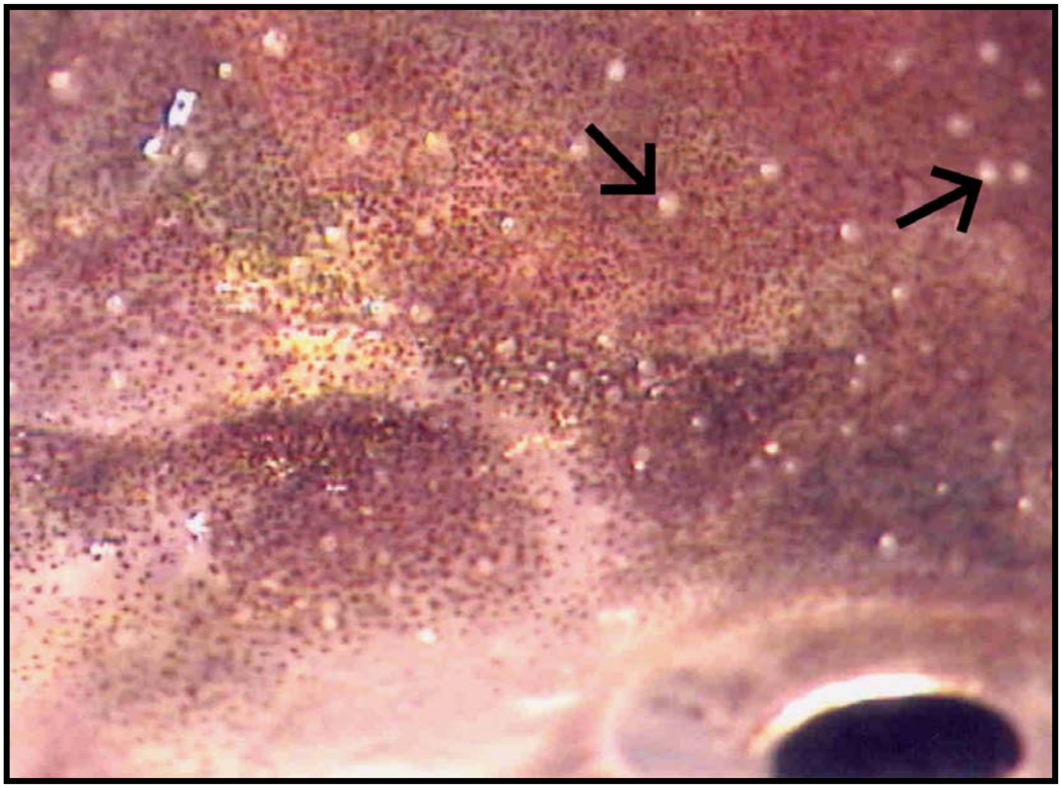


FIGURE 17.—Tiny whitish tubercles (< 1.0 mm) on top of the head of adult splittail.

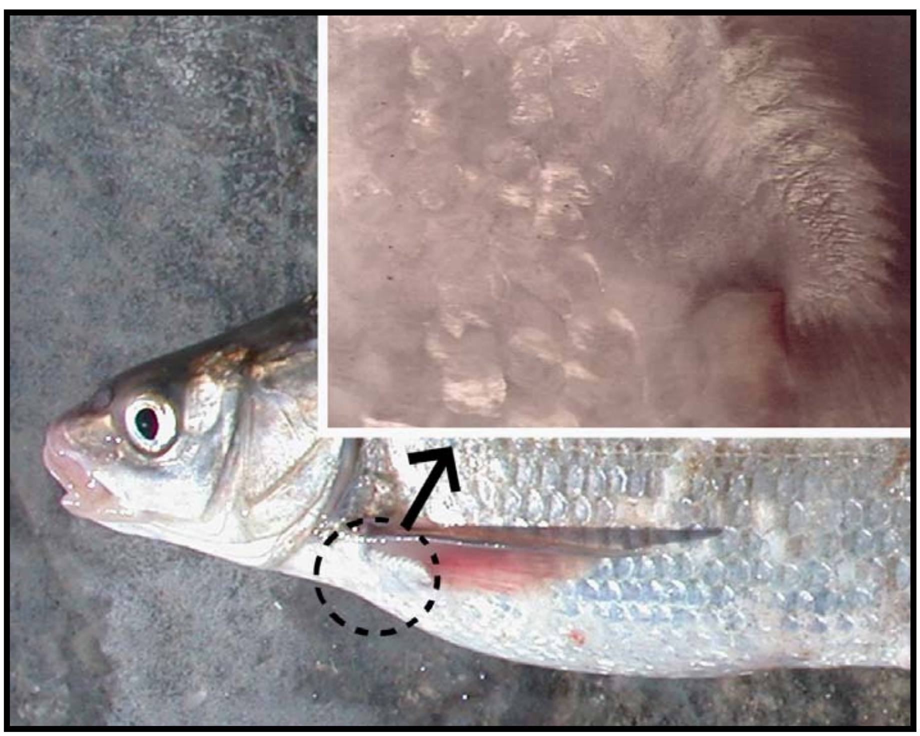


FIGURE 18.—Thick tissue or padding at the ventral side of the pectoral girdle.

SPLITTAIL EXPANDED LIFE HISTORY – continued

Reclamation tracked prespawning splittail that were captured at the TFCF intake canal and from the TFCF holding tanks. Healthy fish were implanted with a 45-day sonic transmitter and released into the intake channel or in front of the facility. Nineteen fish were tagged in 1994 and seven in 1995. Most of the fish remained in a one mile radius of the release site in March and April including the Old River, Grant Line Canal, and the upper section of the Delta Mendota Canal. It is very likely that these splittail are spawning in the South Delta (Karp, 2003).

Laboratory Observations Of Splittail Spawning and Early Life History Behavior.—All observations of egg development and hatching are from eggs fertilized in vitro. Splittail eggs range in size from 1.6 to 2.1 mm in diameter. They were extremely adhesive and remained attached to the substrates and each other during the incubation period. After the eggs were fertilized, the blastoderm developed within 3 hours at water temperature of 17-19 °C. Eggs hatched within 7 days at 14-17 °C or 5 days at 20 °C. Eggs commonly died at 3 developmental stages:

1. During the incubating process, mortalities were quickly observed in those eggs that were not fertilized, or were under or over ripe (these eggs turn white within 5-6 hours).

2. At the morula stage, the blastomeres developed unevenly in size and stopped the cleavage by the end of the stage.

3. At hatching, death occurred when the embryo failed to break through the chorion.

The following observations of morphological development and swimming behavior were made once in 2003 and twice in 2004 in an aquarium at water temperatures of 18-22 °C (refer to figure 19b).

0-1 day post hatch (dph): Prolarvae lie on their side at the bottom of the aquarium, eye has pale pigmentation, larval body has little pigmentation, and larvae seldom move. Newly hatched larvae range in size from 5.0 to 6.5 mm TL.

2 dph: Prolarvae lie on their side at the bottom of the aquarium as in Day 1, eyes and bodies gain more pigmentation.

3 dph: Prolarvae with less yolk material in abdominal region still lie on their sides at the bottom of the aquarium, and occasionally move if disturbed.

4 dph: Prolarvae have more pigmentation on the dorsum and dorsal gut. Prolarvae lie on their sides at the bottom of the aquarium, some move in circle in the water column and then return to the bottom. Most prolarvae do not move. Air bladder visible.

5 dph: Prolarvae have absorbed most of the yolk material in the yolk sac, body gains more pigmentation. Some prolarvae lie on their sides, some swim in normal dorsal-ventral position, and some are attached to the side of the glass wall. Prolarvae become more alert and respond quickly when disturbed.

6 dph: Air bladder chamber inflated, most of prolarvae are off bottom and swim in water column (planktonic larvae), and some sit on the bottom in dorsal-ventral position, and only a few remain on their sides. They become postlarvae at 7-8 mm TL, and yolk material is absorbed or almost absorbed.

7-9 dph: Postlarvae are feeding and are 8-9 mm TL. Postlarvae vigorously swim in the upper water column near the surface.

As apparent from the first 5 days, the prolarvae remain very close to their spawning site and likely avoid collection by scientific studies and predation by being motionless at the bottom and blending into the surrounding environment. Once splittail reach 9 mm TL, the air bladder is fully inflated enabling fish to swim off the bottom and move to the surface and to disperse. The presence of splittail less than 9 mm TL suggests that spawning grounds for the larvae were in the immediate proximity.

Field Observations from Fish E&L Sampling on Splittail Early Life History Behavior.—Fish E&L specimens from three areas in the Bay and Delta were examined (see figure 1). The CDFG collections from the Delta included 1,466 early life stage splittail. Splittail were observed in all four areas (Sacramento River, South Suisun Bay/Lower San Joaquin River, North Suisun Bay/Montezuma Slough and Lower San Joaquin River/Lower Mokelumne River). Of the 1,466 splittail collected, 44 percent were from wet water years, 11 percent from dry water years, and 45 percent from critical water years. The peak of splittail catch was from March to May. Eighty four percent of the splittail collected were less than 9 mm. The small larvae are thought to be caught very close to their spawning locations. Among the four areas, approximately 62 percent of larval splittail were observed in the Sacramento River stations; 24 percent in South Suisun Bay/Lower San Joaquin River; 9 percent in Lower San Joaquin River/Lower Mokelumne River; and 5 percent in North Suisun Bay/Montezuma Slough (appendix table A4 and summary table). Splittail eggs were not observed in the CDFG fish E&L surveys and this is what one would expect since the eggs are adhesive, sticking to the bottom and vegetation.

In the NBA survey a total of 555 early life stage splittail were examined. All 8 sampling stations are in close proximity. Splittail appeared in the samples from February to July and with a peak of catch in March to June. Over 78 percent of the splittail were in prolarval to postlarval stages and juveniles constituted 22 percent. It appears that splittail use the NBA area as spawning and nursery grounds (appendix table A5 and summary table).

Only 73 early life stage splittail were examined from Central/South Delta sampling stations. Most of the active sampling stations were near the Tracy Pumping Plant and Banks Pumping Plant. Splittail appeared in the samples from March to June. Over 94 percent of splittail were in prolarval and postlarval life stages (Appendix Table 6 and summary table).

Splittail Discussion.—Splittail are typically unable to complete their life cycle in a freshwater-only environment such as the O'Neill Forebay and San Luis Reservoir (Hess, *et al.*, 1995). However, if cultured splittail receive a balanced diet with sufficient amino acids and marine nutrients (such as Silver Cup, Nelson and Sons, Inc., Murray, Utah), the splittail can spawn and complete their life cycle in a freshwater environment (Baskerville-Bridges, 2003–2004). Currently, we are holding at the FCCL splittail brood stock that came from wild fish collected in 1998 (7-year old fish). This captive splittail brood stock spawned successfully in 2003 and 2004.

Splittail basically are a potamodromous fish, meaning they migrate within lentic and lotic environments of the same salinity; although some do move between oligohaline and freshwaters. Our observations indicate that not all splittail move upstream to spawn and that some spawn in the Bay and Delta. Small splittail larvae (< 9 mm) that are incapable of moving any appreciable distance from their spawning sites have been collected in the Bay and Delta (*e.g.*, San Joaquin River, Central Delta, South Delta, and the TFCF abandoned intake canal). We believe splittail have two different spawning habitats, one in the Bay and Delta, and the other upstream in floodplains. Additional study is needed to determine if genetic differences explain the selection of different spawning locations or whether spawning ground differences are an expression of phenotypic variations within the population.

Years with higher river flows produce better splittail spawning conditions, especially in the floodplains and upper river tributaries (Sommer, *et al.*, 1997; Baxter, 1999). We also note apparently better splittail spawning conditions with high flows in the Bay and Delta (Wang, 1996). The better Delta conditions are associated with a shift in the entrapment zone (or X2) from the lower rivers to below the confluence, in the Bay. In the good splittail reproduction year of 1993, the X2 zone was located in the Bay. In 1995, a high flow or a flood year, the X2 zone moved further downstream into San Pablo Bay, where the number of splittail early life stages was reduced, probably due to the greater volume of water in the Bay and Delta. During the wet years of 1982–1986, Wang (1986) observed splittail spawning in the Bay, in the vicinity of Pittsburg, and in New York slough. During the wet years of 1997–1999, splittail larvae were observed at the TFCF salvage and Mossdale (CDFG sampling). Other freshwater fish species, such as white sturgeon, *Acipenser transmontanns*, wakasagi, *Hypomesus hipponensis*, striped bass, *Morone saxatilis*, American shad, *Alosa sapidiissima*, and Sacramento blackfish had similar downstream egg and larval distributions during these high freshwater flow years (Wang, 1986; CDFG sampling 1988–1995). Although splittail is a resilient fish (Sommer, *et al.*, 1997) and an opportunistic spawner, splittail spawning behavior is unpredictable. For example, in contrast with the other studies, splittail larvae catches from the NBA were low during certain wet years. This is especially true with the wet years of 1997 and 1999 (appendix table A5).

Splittail was listed as threatened in 1999 by the USWFS, but were subsequently delisted in 2003 (Sommer, *et al.*, 2004). Moyle (2002) stated that the existing splittail population is still facing various environmental problems, such as reduced habitats, loss of spawning habitat, change of estuarine hydraulics, climate changes, toxic materials, introduced species, and increased angler fishing. Lehman (2000, 2004) suggested that fishery declines were caused by several fundamental problems in the Delta, from water quality to the lower food web production. The population of splittail has fluctuated greatly in recent years.

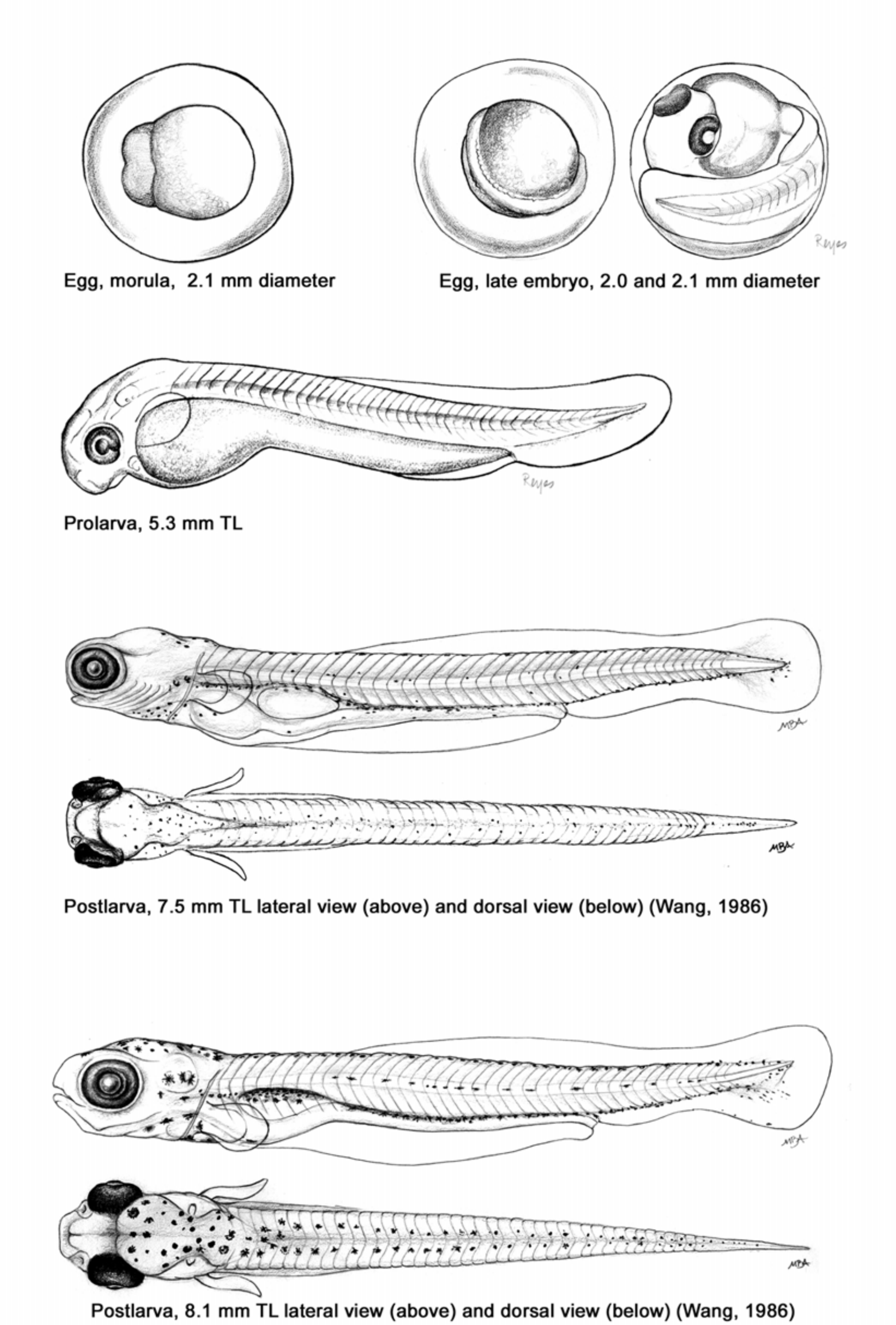
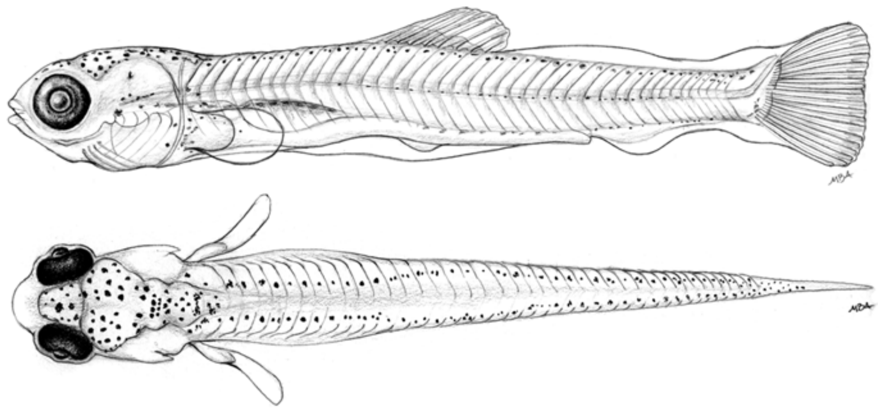
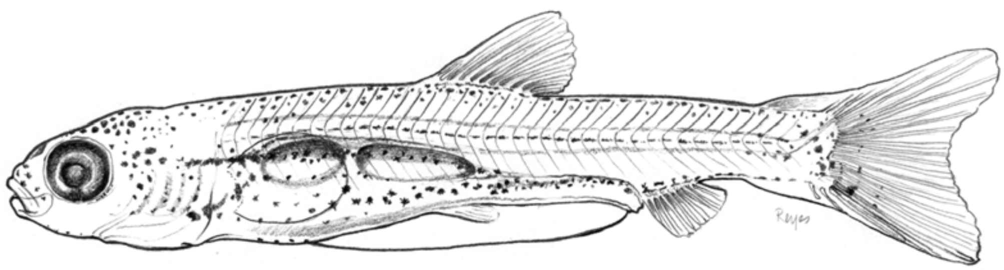


FIGURE 19a.—Line drawings showing splittail early life stage specimens.



Late postlarva, 10.4 mm TL lateral (above) and dorsal views (below) (Wang, 1986)



Prejuvenile, 14 mm FL

Juvenile, 24.2 mm TL (Wang, 1986)

FIGURE 19a.—Line drawings showing splittail early life stage specimens – continued.

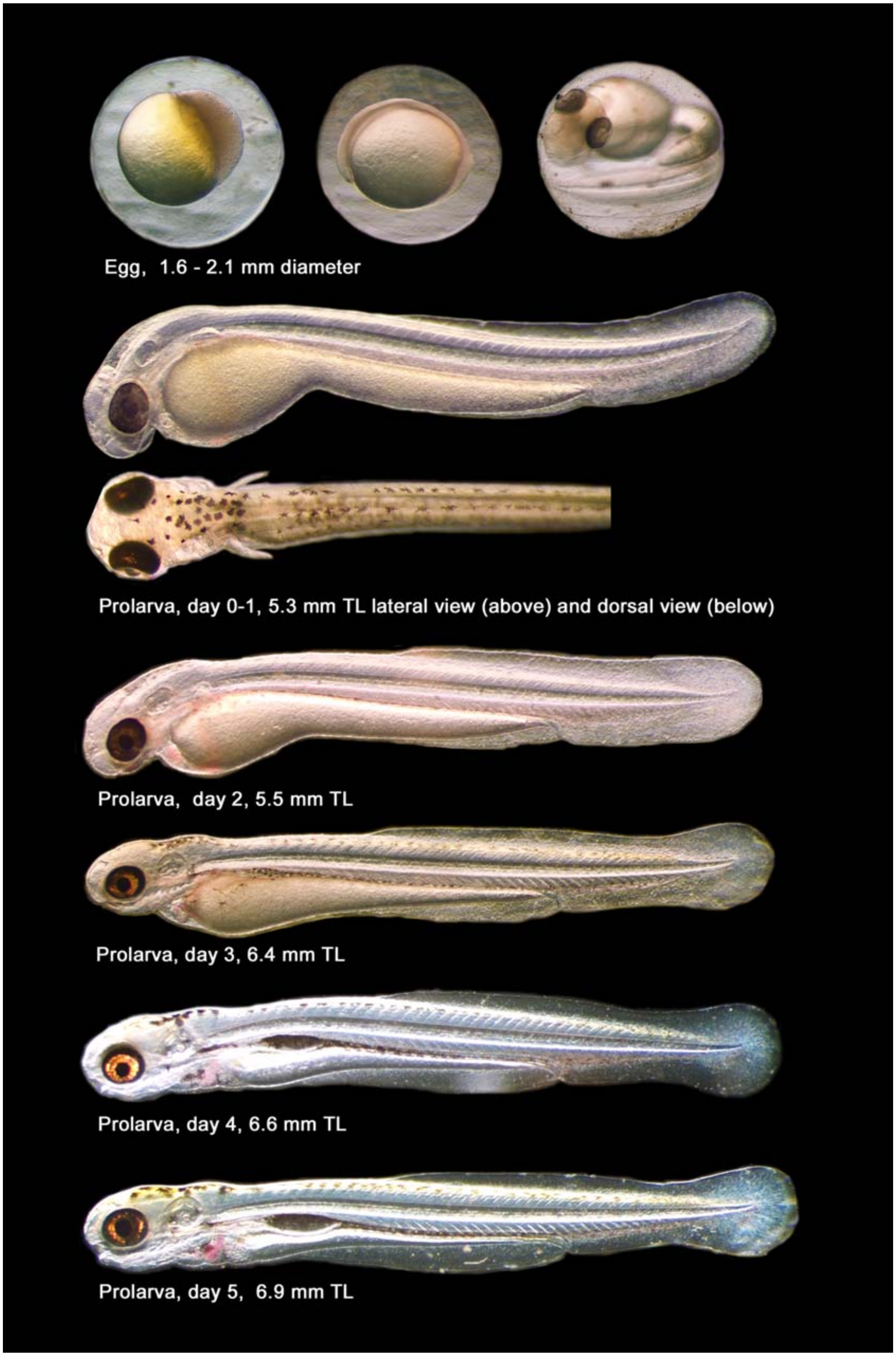


FIGURE 19b.—Photographs showing splittail early life stage specimens.

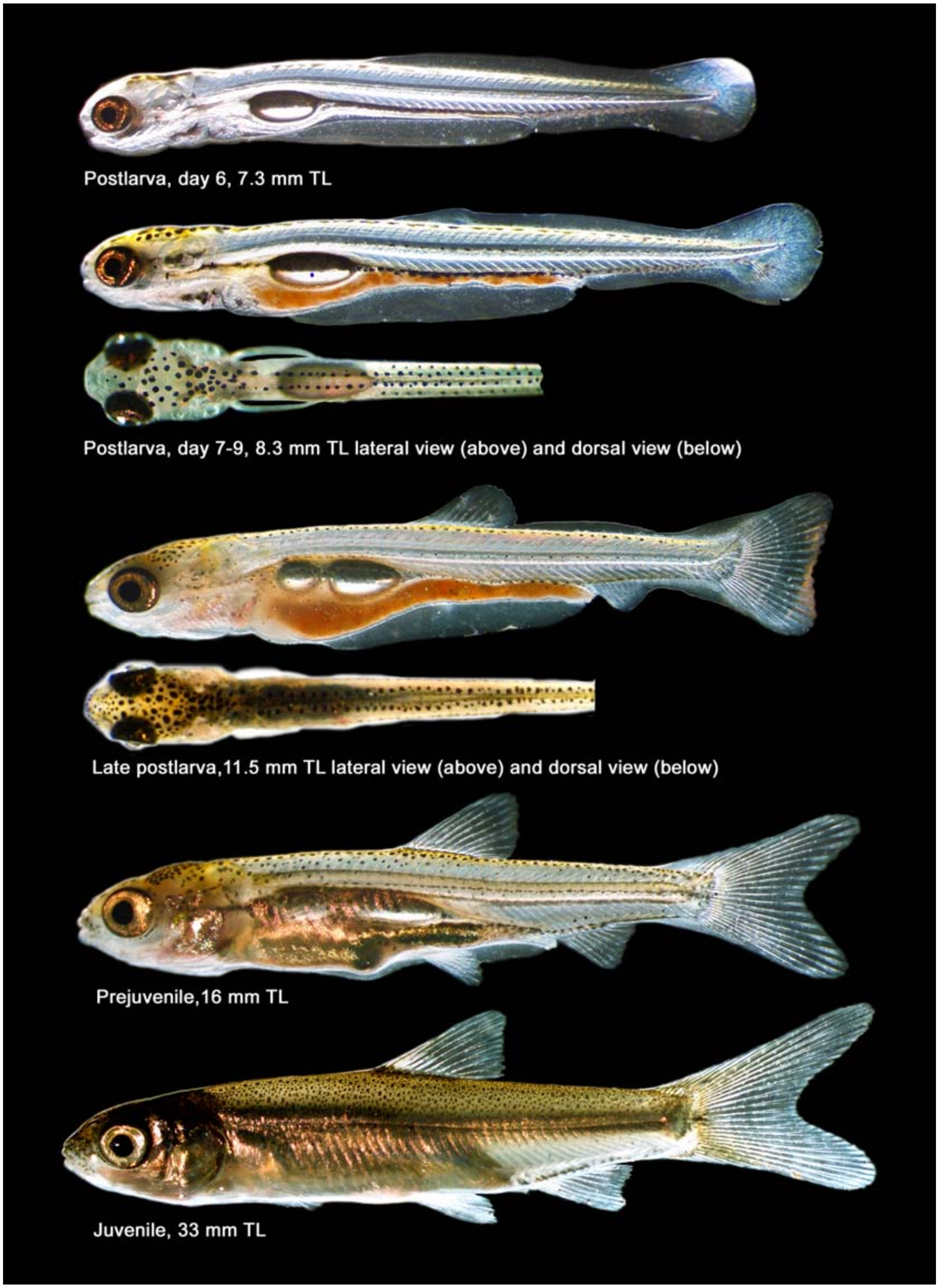


FIGURE 19b.—Photographs showing splittail early life stage specimens – continued.

Sacramento Pikeminnow, *Ptychocheilus grandis* (Ayers)

SPAWNING

Location: Delta. In gravel riffle streams (Taft and Murphy, 1950); gravel riffle and shallow flowing area at the base of pool (Moyle, 2002); often seen in the shallow running water foothill streams, Delta tributaries such as the Sonoma Creek, Napa River, Suisun Creek, Dry Creek (upper portion of Putah Creek), Alameda Creek, Walnut Creek, Stony Creek, Mud Creek, Little Chico Creek, Big Chico Creek, Cosumnes River, Capell Creek of Lake Berryessa, Sacramento River (above Red Bluff), American River, Feather River, and Clear Creek. Spawning may occur downstream, such as the lower Sacramento River, during wet years (*e.g*., 1993, 1995).

Season: April through May (Taft and Murphy, 1950); April through July (Wang, 1986).

Temperature: 15-18 °C (Moyle, 2002); larvae were collected from 16-19 °C (Wang, 1986); 15-16 °C.

Salinity: Freshwater.

Substrates: Rocks and gravel (Moyle, 1976; this study).

Fecundity: 17,700 from a single female of 50 cm TL (Burns, 1966); 15,000-40,000 (Taft and Murphy, 1950; Grant, 1992).

EGGS

Shape: Mature eggs spherical; fertilized eggs spherical to oval.

Diameter: Mature eggs, ~ 2.2-2.4 mm; soaked in the water and without fertilization, water-harden up to 3.0+ mm (Wang, 1986); fertilized spherical eggs range from 2.5 to 3.2 mm (oval egg size, 2.7 for short axis and 3.0 for long axis).

Yolk: Pale yellow, granular.

Oil globule: Many small oil globules or globulets dispersed in the yolk.

Chorion: Transparent, smooth.

Perivitelline space: 0.2-0.5 mm, often 0.3-0.4 mm in morula and early embryo stages.

Egg mass: Individually.

Adhesiveness: Adhesive (Taft and Murphy, 1950); not very adhesive, loosely attach to the substrates and easily dislodged from gravel.

Buoyancy: Demersal (Taft and Murphy, 1950); demersal, detached eggs may bounce along bottom and move downstream during development.

LARVAE

Length of hatching: 7.8-10.1 mm TL.

Snout to anus length: ~ 64-68 percent of TL of larvae at 8.0-12.5 mm TL (Wang, 1986); for newly hatched larvae, 67-72 percent (often 69-71 percent); for postlarvae, 64-66 percent (often 64-65 percent).

Yolk sac: Large and elongate (~ 5.0 mm), oval in thoracic region, and cylindrical in abdominal region; roughly divided into two sections (Wang, 1986).

Oil globule(s): None.

Gut: Straight, slightly bent below the first chamber of the air bladder in postlarvae.

Air Bladder: Round to oval in thoracic and cylindrical in abdominal region. Posterior air bladder visible around 10 mm TL; anterior air bladder visible around 12 mm TL.

Teeth: None.

Size at absorption of yolk sac: 8.5-9.0 mm TL (Wang, 1986); 10-12 mm TL.

Total myomeres: 45-49 (Wang, 1986); 45-49 (often 46-49).

Preanal myomeres: 32-34 (Wang, 1986); 32-34 (often 32-33).

Postanal myomeres: 13-16 (Wang, 1986); 13-17 (often 15-16).

Last fin(s) to complete development: Pelvic.

Pigmentation: Newly hatched larvae have light pigmentation on dorsum and gut; in postlarvae, large stellate melanophores on top of head, middorsal, jugular, side and dorsal surface of gut and postanal regions. Dashed or dotted melanophores on lateral region. Pigment is concentrated above the urostyle and in radiating pattern in the hypural region. A dark spot is located at the ventral base of the caudal peduncle. Eventually, a dark spot at the center base of the caudal peduncle in juveniles forms. Midventral is free from pigmentation or with sparse melanophores.

Distribution: Shallow water, small pool and side pools of streams and rivers; a few found in the tidal freshwater portion of the estuary during wet water-years.

Key Taxonomic Characteristics:	1. Large size larvae, ~ 8.0 mm and greater; yolk sac large and divided into two subsections. 2. Pigmentation in radiating pattern observed on lower lobe of caudal fin. 3. High myomeres count, ≥ 45.

JUVENILES

Dorsal fin rays:	8 (Moyle, 1976; Wang, 1986); 7-9 (usually 8).
Anal fin rays:	8 (Moyle, 1976; Wang, 1986); 7-9 (usually 8).
Pectoral fin rays:	15-18 (Moyle, 2002); 16-18 (Wang, 1986).
Mouth:	Large (Moyle, 1976); mouth large and maxillary extends the entire length of the snout and stops at front margin of the eye.
Vertebrae:	47-50 (Wang, 1986).
Distribution:	Often found in the tributaries of the Delta. Juveniles, and occasionally adults, venture into tidal freshwater as far as the Bay during the winter months of wet water-years.
Key Taxonomic Characteristics:	1. High myomere count, ~ 45 and greater. 2. Long snout and flat head. 3. Mouth large and extends to the front of eye. 4. The myomere count between the insertion of D. and origin of A.: 5-7 before the origin of A.

LIFE HISTORY

The Sacramento pikeminnow (previously known as the Sacramento squawfish) is one of the largest freshwater cyprinids native to California. The largest recorded specimen was 115 cm long (TL) and weighed 14.5 kg from Avocado Lake, Fresno County (Moyle, 1976). This species is distributed throughout the Delta, Pajaro Creek, Salinas River, Russian River, and upper Pit River (Taft and Murphy, 1950; Moyle, 1976). Sacramento pikeminnow are occasionally observed in salvage operations at the SDFPF and the TFCF and are transported involuntarily southward via the California Aqueduct and Delta Mendota Canal (Swift, *et al.*, 1993). They occur in the tidal Carquinez Strait and the Bay (Messersmith, 1996; Ganssle, 1966). Sacramento pikeminnow are common at the Reclamation Red Bluff Research Pumping Plant, in the Sacramento River below the Red Bluff Dam, the Feather River below Oroville Dam, and the American River below Nimbus Dam. Larvae and juveniles are common in tributaries, such as Clear Creek, Stony Creek, Mud Creek, Dry Creek (a tributary of Putah Creek), Sonoma Creek, Napa River, and Capell Creek (a tributary of Lake Berryessa).

Sacramento pikeminnow spawn in clear, lotic environments from spring to summer. Taft and Murphy (1950) observed the spawning migration of the Sacramento pikeminnow from the Russian River to a tributary stream, Sulphur Creek, in March and April. Mature Sacramento pikeminnow were observed at the fish ladder at the Red Bluff Dam during their upstream (potamodromous) migration in May and June. Sacramento pikeminnow eggs were collected in May from deeper water (>1 m depth) next to the fast flowing water below Fair Oaks in the American River and also in June from shallower water (<150 mm depth) in the riffle sections of Clear Creek, a tributary of the Sacramento River. Larvae collected from the upper Sonoma Creek and Capell Creek suggest that spawning also occurs in smaller creeks with year round clean running water and pools. While some Sacramento pikeminnow construct poorly defined nests at the downstream end of pools with gravel substrates, some may construct no nests at all, such as those observed in the American River. Eggs are demersal and adhesive, but they are easily detached from substrates. Many remain in the crevices between gravel. Often, Sacramento pikeminnow eggs are found with Sacramento sucker eggs. Breeding males show bright orange-red color on fins with breeding tubercles on head (Taft and Murphy, 1950). Apparently, the adult fish return to the deeper water after spawning and are seldom seen in small streams during other seasons. Large adults were observed at the TFCF intake canal occasionally during winter months. The Sacramento pikeminnow may not spawn in turbid Delta sloughs (CDFG Fish E&L surveys failed to collect Sacramento pikeminnow larvae at the sampling stations located in the Delta, 1988–1995), or in small, intermittently flowing creeks lacking suitable pools and escape routes, such as Mt. Diablo Creek and Marsh Creek.

Newly hatched larvae have large yolk sacs (similar to the Sacramento sucker, but with two sub-sections instead of three) and lie on their sides in the crevices or the nesting area for one or two days after hatching before they become active swimmers. Postlarvae were observed in CDFG Sacramento River E&L sampling stations above the Feather River confluence and E&L sampling at the Reclamation Red Bluff Project. Some larvae were carried out into the lower Sacramento River sampling stations, particularly during wet years (CDFG Fish E&L sampling program 1988–1995).

Juvenile Sacramento pikeminnow school in shallow waters of large stream pools or reservoirs (Nobriga, *et al.*, 2004). Juveniles share the same habitat with other native fish such as the hitch, hardhead, California roach, Sacramento sucker, rainbow trout, *Oncorhynchus mykiss* and riffle sculpin, *Cottus gulosus* in foothill creeks, and with native and exotic species in valley floor creeks. Juvenile Sacramento pikeminnow remain in the stream pools until October or November, and then move into deeper portions of the large water bodies, such as moving from Capell Creek to Lake Berryessa. The larger juveniles move from the upper shallow stream pools into the lower deeper water of rivers.

The diet of the juvenile Sacramento pikeminnow in the tributaries includes insect larvae, small insects, small cyprinids, and salmonid juveniles (Taft and Murphy, 1950). In the estuarine habitats, small striped bass, splittail and other small fish, and crustaceans are the common food items. Below the Red Bluff Dam and near the Nimbus Fish Hatchery, larger Sacramento pikeminnow often preyed on juvenile salmonids and suckers. However, under natural conditions, Sacramento pikeminnow feed mainly on non-salmonid fishes such as sculpins (Moyle, 2002, Buchanan, *et al.*, 1981, Tucker, *et al.*, 1998).

Sacramento pikeminnow mature at end of their third or fourth year with males maturing usually one year earlier than females (Moyle, 2002). The Sacramento pikeminnow can live up to nine years (Taft and Murphy, 1950). Older fish (detected by the opercular bone) were found to live in the Russian River (Scoppetone, 1988). The Sacramento pikeminnow have not been used as food fish by most sport anglers but it is a prized fish in the Asian fish market. Historically, Indian midden mounds contain the bones of the Sacramento pikeminnow (Moyle, 1976; 2002).

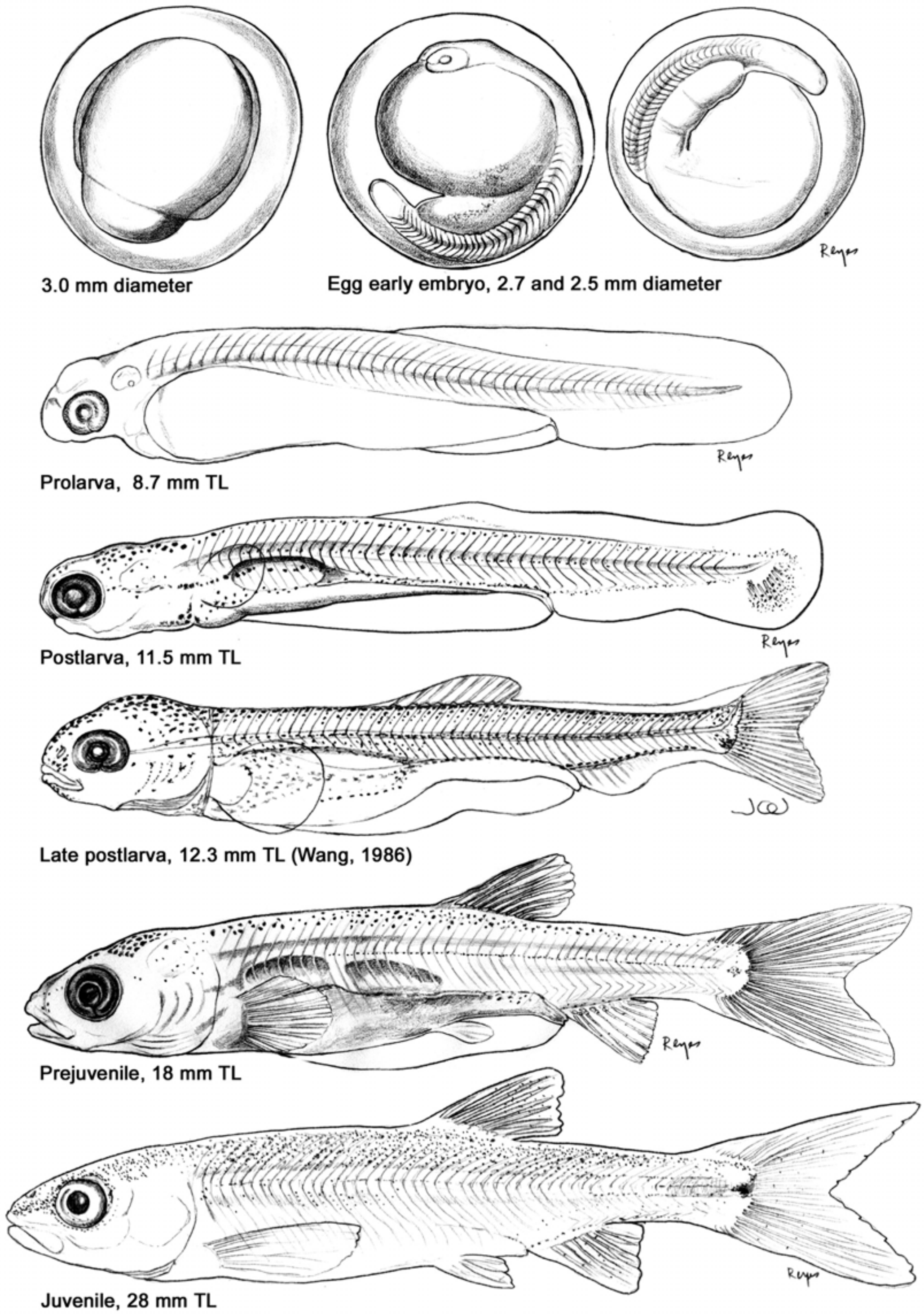


FIGURE 20a.—Line drawings showing Sacramento pikeminnow early life stage specimens.

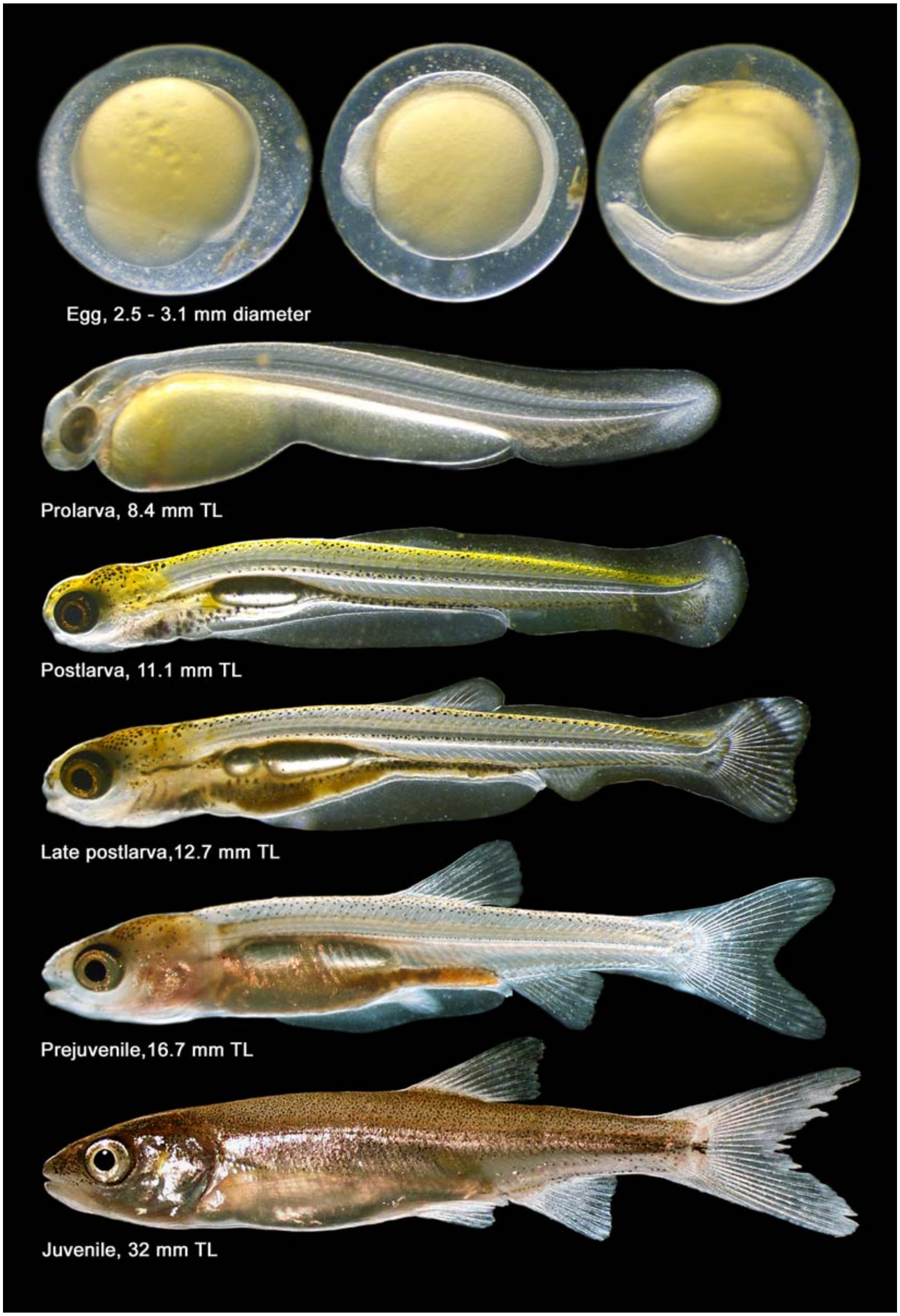


FIGURE 20b.—Photographs showing Sacramento pikeminnow early life stage specimens.

ACKNOWLEDGEMENTS

We would like to thank the following: The Reclamation Mid-Pacific Regional Office, Sacramento, California, and Ron Silva, TFFIP program manager, Tracy, California, for financial support; Dr. Randy Brown, Lloyd Hess, Steve Hiebert, Brent Bridges, Bradd Baskerville-Bridges, and Doug Craft (Reclamation), and Dr. Darrel E. Snyder, Colorado State University, Ft. Collins, Colorado, for their technical and editorial review and comments; Janice Wang-Polagruto for proof-reading and Jean Temple, for word processing. The organizations and individuals that provided field specimens, including the CDFG and DWR; UCD; Andy Rockriver, California State University (CSU) Sacramento; CSU Chico; and salvage personnel at the TFCF. The biologists who contributed time and expertise to this effort: Dorothy Platz, Lisa Lynch, Michael Dege, and Russ Gartz (CDFG); Stephani Spaar, Tracy Woods, and Lenny Grimaldo (DWR); Scott Matern, Michael Marchetti, and Robert Schroeter (UCD); Gabriel Kopp and Alicia Seesholtz (CSU Chico); Keith Whitener (Cosumnes River Preserve); Richard Corwin, Scott Siegfried, Zak Sutphin, Brandon Wu (Reclamation); John Pedretti, and Mike Marshall (USFWS). Mark Adams and Zak Sutphin for drawings and illustrations.

GLOSSARY AND ABBREVIATIONS

A	Anal fin.
Abdominal	On or pertaining to the belly or abdomen.
Absolute fecundity	Total number of eggs in a female.
Air bladder	Membranous gas-filled sac present in the dorsal portion of the body cavity.
Anus	The posterior opening of the digestive tract.
Barbel	A fleshy, elongated sensory structure located at the corner of the jaw or adjacent to the mouth.
Bay	Suisun Bay.
Blastoderm	The single layered germinal cells that lie on top of the yolk in the early developmental stage of an egg and later form embryo.
Blastula	An early embryonic stage of active cleavage characterized by the presence of a blastoderm and blastocoele.
Bottom	A habitat description; it is similar to that of the epibenthic.

Branchiostegal rays	A series of elongated flexible bones connected by membranes between the interopercle and the isthmus in the gills.
Breeding tubercles	A secondary sexual characteristic often attributed to males during spawning season; they grow on the top of the head and may extend to other parts of the body.
Caudal finfold	The integument that wraps around the tip of the notochord or the urostyle, and connects to the dorsal finfold and ventral finfold.
Caudal peduncle	The slender portion of the body that is between the anal and caudal fins.
Caudal spot	A grouping of pigments usually located at the hypural region at the base of the caudal fin or caudal peduncle.
CDFG	California Department of Fish and Game.
Cephalic	Pertaining to the head.
Chorion	The outermost semipermeable layer of an egg, also known as egg capsule.
Chromatophore	A pigment cell that has coloration.
Cleithrum	A dermal bone in the pectoral girdle.
Compressed	Laterally constricted.
Cyprinid	Any member of the carp and minnow family, Cyprinidae.
D	Abbreviation for the dorsal fin.
Delta	A tidally influenced body of water composed of the lower reaches of the Sacramento and the San Joaquin Rivers and their tributaries.
Demersal	Living on or close to the bottom substrate; usually relates to fish species.
Depressed	Dorsoventrally flattened.
Depth	Usually indicates the vertical measurement of head, nape, body, or the caudal peduncle areas, excluding finfolds.
Dorsal	Pertaining to the back or the upper part of the body – opposite of ventral.
Dorsal finfold	The median fold of integument that extends along the middorsum from the cephalic to the caudal regions from which the dorsal fin develops.

Dorsum	The backside of a structure (the back).
Down bay	San Pablo Bay and San Francisco Bay, below the Carquinez Straight.
Dry water-year	A year when unimpaired runoff (measured in million acre-feet) is low (DWR's standard and measurement). Unimpaired runoff represents the natural water production of a river basin, unaltered by diversions, storage, or water exports (source: DWR).
DWR	California Department of Water Resources.
Early embryo	The embryonic stage in which the embryonic axis and somites are evident.
Early postlarva	Stage of larval development when yolk sac is absorbed and notochord flexion is developed.
Epibenthic	Living on the surface of bottom substrate; usually relates to invertebrates species or fish larval stages.
Euryhaline	Capable of tolerating a wide range of salinities.
FCCL	Fish Conservation and Culture Laboratory located at the Skinner Delta Fish Protective Facility in Byron, California.
Fin bud or finbud	An undifferentiated fin.
Finfold	Median fold of integument that extends along the middorsum, midventrum, and caudal which the dorsal, anal, and caudal fins develop.
Fin ray	The supporting bony elements of fins, including spines and soft rays; can be segmented, unsegmented, or spinous.
Fish E&L sampling	Fish eggs and larvae sampling.
Flexion	The posterior end of the notochord or later developed vertebral column that bends upwards signaling the initial development of the caudal fin and fin ray.
Frenum	A ridge of skin between the upper jaw (premaxillary bone) and the nasal bone at the tip of the snout.
Fresh water or freshwater	Salinities less than 0.3 ppt.
Gastrula	An embryonic stage which begins when the caudal edge of the embryonic shield begins to turn inward under the blastoderm and ends when the embryonic axis is evident; the yolk is partially or completely enveloped by the germinal ring during this stage.

Gravid	Having ripe eggs or pregnant.
Gut	Digestive tract from the mouth to anus.
Heterocercal	A condition where the caudal vertebrae are bent upward and the dorsal lobe of the caudal fin is much larger than the ventral lobe.
Homocercal	Tail morphology where both the caudal and ventral lobes of the caudal fin are of similar size.
Hypural	A serial bony structure below the urostyle which supports the caudal fin.
Interagency Ecological Program (IEP)	The program is composed of several state and federal resource management agencies that share information, monitoring results, and research on factors that affect ecological resources in the Delta.
Incubation period	The elapsed time between fertilization and hatching of the egg.
Inferior mouth	A mouth located on the ventral side of the snout; upper jaw extends over lower jaw.
Insertion of fin	Posterior-most point of attachment of a fin.
Interopercle	One of the bones comprising the operculum; bordered antero-dorsally by the preopercle and postero-dorsally by the opercle and subopercle.
Isthmus	The narrow area between the sets of branchiostegal rays across the jugular.
Iteroparous	Producing offspring in successive annual or seasonal batches.
Jugular	Related to the throat or throat area.
Juvenile	Stage of larval development when all finfold has been absorbed, fin development has completed (all fin rays and spines similar to adult form are present), and scales may or may not be completely developed.
Late embryo	The final phase of embryonic development, characterized by a free tail and a resemblance to yolk-sac larvae.
Late postlarva	Stage of larval development when flexion and finbuds are almost fully developed.

Lateral line	Part of the sensory system extending in two major branches from the cranial nerves to the lateral side of the body; several branches extend to the head region.
Lentic	A description of standing or slow moving water such as a pond or a lake.
Littoral	Near-shore waters where light penetrates. Also, the intertidal zone of the marine environment, delimited by the tide marks of low and high water.
Lotic	A description of running water such as a river or a stream.
Major axis of egg or long axis of egg	The longest axis of a nonspherical egg.
Mandible	Lower jaw.
Maxillary	Lateral part of upper jaw or a dermal bone of the upper jaw which lies posterior to the premaxillary. Used interchangeably with maxilla or upper jaw.
Melanophore	A black pigment cell.
Meristic	Having or composed of segments.
Mesohaline	Water with salinity range of 5.0 to 18.0 ppt.
Middorsal	Pertaining to the middle of the dorsum or back.
Middorsum	The area running along the middle of the dorsum or back.
Midlateral	Pertaining to the middle section of the larvae from the base of the caudal to the jugular when viewed laterally.
Midventral	Pertaining to the middle of the ventral side of the larvae from anus (vent) to jugular.
Minor axis of egg or short axis of egg	The shortest axis of a nonspherical egg.
Morphometry	The measurement of the external form or shape of a structure.
Morula	Embryonic stage which has raspberry-like clusters of blastomeres on top of yolk.
Myomere	A single lateral muscular segment of the body, separated from each other by a connective tissue called myoseptum.
Myoseptum (pl. myosepta)	Partition made of connective tissue separating adjacent myomeres.

Nape	The area along the middorsum just behind the cephalic region.
NBA	North Bay Aqueduct Project.
Notochord	The longitudinal cartilaginous rod that is eventually replaced by the vertebral column in the body of teleostean fishes.
Oblique	Slanted position.
Oil globule	A clear lipid droplet in the yolk of an egg or yolk-sac larval stage; it is an additional food source and maintains body buoyancy of the egg.
Oil globulet	Tiny droplets of residual oil in the yolk before consolidation into oil globule.
Oligohaline	Water with salinity range of 0.3 to 5.0 ppt.
Operculum or opercle	A bony flap covering the gills.
Opportunistic spawner	A spawning fish that spawns at any time there is a suitable spot.
Optical vesicles	Embryonic structures that give rise to the eyes.
Origin of the fin	The anterior-most point of attachment of a median fin.
Pelagic	In the water column (not necessarily near the surface).
Peritoneum	The line of the body cavity.
Perivitelline space	Vitreous space between the chorion and yolk.
Postanal myomeres	The myomeres between the middle of the anus and the most posterior true myoseptum (at the last vertebra).
Posterior	Located behind.
Postlarva (larva)	The stage of development between the absorption of the yolk sac and developing of finbud.
Potamodromous	Migrating within lentic and lotic environment of the same salinity.
Preanal length (PAL)	The distance from the tip of snout to the anus.
Preanal myomeres	The myomeres between the most anterior myoseptum and the mid-margin of the anus.
Prejuvenile	The early life stage of development when most fins and fin rays are fully developed.
Premaxillary	The more anterior bone forming the upper jaw.

Prolarva (Yolk-sac larva)	The stage of larval development when yolk sac is not yet absorbed, finfolds are present, and notochord is straight.
Ripe fish	Fishes with free-flowing milt or eggs evident upon gentle abdominal squeezing.
River	The adjoining river, reservoir, and aqueduct system of the Delta.
SDFPF	Skinner Delta Fish Protective Facility, salvage facility operated by the State Water Project.
Snout	The tip of the front nostril.
Snout to anus length	The ratio of the distance from the tip of the snout to the anus to the total length of the fish.
Spawning	Release or deposition of spermatozoa or ova. Also, a fish reproduction process characterized by females and males depositing eggs and sperm into the water simultaneously or in succession in order to fertilize the eggs.
Standard length (SL)	The distance from the tip of the snout to the base of the urostyle.
Stellate	Pertaining to the star-shape of a melanophore.
Subterminal mouth	Position of the mouth where the mouth, located ventrally, is near but not at the end of the snout.
Superior mouth	Position of the mouth where the mouth is located on the dorsal side of the snout; lower jaw extends beyond upper jaw.
SWP	State Water Project.
SWS	Shallow Water Survey.
Terminal mouth	Jaws meet at the tip of the snout.
TFCF	Tracy Fish Collection Facility, Tracy, California, Central Valley Project.
TFFIP	Tracy Fish Facility Improvement Program.
Thoracic	Posterior to the throat area.
Total length (TL)	The distance from the tip of the snout to the tip of the caudal fin.
Trunk	The body between the nape (behind the head) and anus.

Tubercles	Temporary epidermal projections on head, body, or fins of males (and some females) which facilitates contact with females (or each other) during spawning or which is used for defense of territories.
Up-river	The upper reaches of the Sacramento River starting upstream from the city of Sacramento and northward.
Urostyle	Rod like bone consisting of a number of fused vertebrae at the posterior tip of the notochord, usually bending upward.
USFWS	U.S. Fish and Wildlife Service.
Ventral	Pertaining to the underside or lower part of the fish. Opposite of dorsal.
Ventral finfold	The median finfold on the ventral side of the body; divided by the anus into the preanal finfold and postanal finfold.
Wet water-year	A year when unimpaired runoff (measured in million acre-feet) is high. In the Sacramento River, $\geq$ 9.2; in the San Joaquin River, $\geq$ 3.8. Unimpaired runoff represents the natural water production of a river basin, unaltered by diversions, storage, or water exports (source: DWR).
Water hardening	A process after fertilization of an egg in which the chorion expands because of absorption of water into the perivitelline space.
Water-year	A hydrologic classification of a year based on unimpaired runoffs and used as an index A water-year begins on October 1 and ends on September 30 of the following year (source: DWR).
Weberian ossicles	Modified anterior vertebrae joining the ear with the air bladder.
Width of the perivitelline space	The distance between the yolk and the chorion.
X2	The distance of the entrapment zone spanning from the Golden Gate Bridge to the tidally average, near-bed, 2 psu isohaline; a “contour line” in the Estuary’s waters where the salinity is 2 psu (source: IEP).
Yolk	Nutritive material of an ovum stored for the nutrition of an embryo; it is the source of basic nutrients for the egg and larva prior to the ability to ingest food.

REFERENCES

Baerwald, M, V. Bien, F. Feyrer, and B. May, 2006. *Genetic Analysis Reveals Two Distinct Sacramento Splittail (Pogonichthys macrolepidotus) Population,* Conserv. Genet, 9 pp.

Balon, E.K., 1974. *Domestication of Carp (Cyprinus carpio, L.)*, R. Ont. Mus. Life Sci., Misc. Pub. VIII, 37 pp.

Balon, E.K., 1995. *The Common Carp, Cyprinus carpio: Its Wild Origin, Domestication and Selection as Colored nishikigoi*, Guelph Ichthyol, 3, pp. 1–56.

Barnes, R.N., 1957. *A Study of the Life History of the Western Roach, Hesperoleucus symmetricus,* M.A. Thesis, University of California at Davis, California, 25 pp.

Baskerville-Bridges, B., 2004. Personal communication.

Battle, H.I., 1940. *The Embryology and Larval Development of the Goldfish, Carassius auratus L. from Lake Erie,* Ohio J. Sci. 40(2), pp. 82–93.

Baxter, R.D., 1999. *Status of Splittail in California*, California Fish and Game 85(1), pp. 28–30.

Baxter, R.D., W. Harrell, and L. Grimaldo, 1996. *1995 Splittail Spawning Investigations,* IEP Newsletter 9(4), pp. 27–31.

Becker, G.C., 1983. *Fishes of Wisconsin,* Madison: University of Wisconsin Press.

Beckman, W.C., 1970. *Guide to the Fishes of Colorado,* University of Colorado Press, Boulder, Colorado, 110 pp.

Beer, K., 1987. Personal communication.

Berg, L.S., 1964. *Freshwater Fishes of the U.S.S.R. and Adjacent Waters,* Vol. 2, 4th ed., Guide to the Fauna of the U.S.S.R., (transl. from Russian), Israel Program Sci. Transl., Jerusalem, 496 pp.

Borthwick, S.M., and E.D. Weber, 2001. *Larval Fish Entrainment by Archimedes Lifts and an Internal Helical Pump at Red Bluff Research Pumping Plant, Upper Sacramento River, California,* Red Bluff Research Pumping Plant Report Series, Vol. 12, 14 pp.

Breder, C.M., Jr., and D.E. Rosen, 1966. *Modes of Reproduction in Fishes,* Distributed by T.F.H. Publications, Neptune City, New York, 941 pp.

Bridges, B., 2004. Personal communication.

Brinley, F.J., 1938. *Eggs of Fishes,* Tabulae Biol. 16(1), pp. 51–59.

Buchanan, D.V., R.M. Hooton, and J.R. Morin, 1981. *Northern Squawfish Ptychocheilus oregonensis,* Predation on juvenile salmonids in sections of the Willamette River Basin, Oregon, Can. J. Fish. Aquat. Sci. 38, pp. 360–364.

Burns, J.W., 1966. *Various Species Accounts,* A. Calhoun, ed., "Inland Fisheries Management" California Department of Fish and Game, Sacramento, California, pp. 510–529.

Carlander, K.D., 1969. *Handbook of Freshwater Biology*, Vol. 1, Life history data on freshwater fishes of the United States and Canada, exclusive of the Perciformes, Iowa State University Press, Ames., 752 pp.

Caywood, M.L., 1974. *Contributions to the Life History of the Splittail, Pogonichthys macrolepidotus (Ayres)*, M.S. Thesis California State University, Sacramento, 77 pp.

Chivers, D.P., and R.J.F. Smith, 1995. C*hemical Recognition of Risky Habitats Is Culturally Transmitted Among Fathead Minnow, Pimephales promelas (Osteichthyes, Cyprinidae)*, Ethology 99, pp. 286–296.

Cook, S.F., Jr., R.L. Moore, and J.D. Connors, 1966. *The Status of the Native Fishes of Clear Lake, Lake County, California,* Wassmann J. Biol. 24, pp. 141–160.

Cooper, G.P., 1935. *Some Results of Forage Fish Investigation in Michigan,* Trans. Am. Fish Soc. 65, pp. 132–142.

Cross, F.B., 1967. *Handbook of Fishes of Kansas,* University of Kansas Mus. Nat. Hist. Mis. Pub. 45, 357 pp.

Craft, D., J. Fields, and N. Yoder, 2005. *Mercury in the Carson River Basin, California and Nevada*, Technical Memorandum TSC-2005-8290-001, U.S. Bureau of Reclamation, Denver, Colorado, p. 27.

Crain, P.K., K. Whitener, and P.B. Moyle, 2004. *Use of a Restored Central Floodplain by Larvae of Native and Alien Fishes.* In: Early life history of fishes in San Francisco estuary and watershed (F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi ed.) Am. Fish. Soc. Symposium 39, pp. 125–140.

Daniels, R.A., and P.B. Moyle, 1983. *Life History of Splittail (Cyprinidae: Pogonichthys macrolepidotus) in the Sacramento-San Joaquin Estuary,* NOAA Fishery Bull. 84, pp. 105–117.

Deng. X., S.J. Teh, S.L. Doroshov, and S.O. Hung, 2004. *Embryonic and Larval Development of Sacramento Splittail*, CALFED poster, Sacramento, California.

Dill, W.A., and A.J. Cordone, 1997. *History and Status of Introduced Fishes of California, 1871–1996.* California Department of Fish and Game Fish Bull. 178, 414 pp.

Dobie, J.O., L. Meechan, S.F. Snieszko, and G.N. Washburn, 1956. *Raising Bait Fishes,* U.S. Fish Wildlife, Circ. 35; 124 pp.

Eddy, S., 1957. *How to Know Freshwater Fishes,* Wm. D. Brown Co., Dubuque, Iowa, 259 pp.

Fearnow, E. C., 1925. *Goldfish: Their Care In Small Aquaria and Ponds,* U.S. Comm. Fish. Rep. 1924 (Append. 7), pp. 445–458.

Feyrer, F., and R.D. Baxter, 1998. *Splittail Fecundity and Egg Size,* California Fish and Game 84, pp. 119–126.

Feyrer, F., T.R. Sommer, and R.D. Baxter, 2004. "*Spatial and Temporal Distribution of Age-0 Splittail,*" In: Lower San Francisco Estuary Watershed, Manuscript, 35 pp.

Fite, K.R., 1973. *Feeding Overlap Between Roach and Juvenile Steelhead in the Eel River*, M.S. Thesis, Humboldt State University, Arcata, California, 38 pp.

Forbes, S.A., and R.E. Richardson, 1920. *The Fishes of Illinois,* Illinois Nat. Hist. Serv., 2nd ed., 493 pp.

Fry, D.H., 1936. *Life History of Hesperoleucus venustus,* (Snyder), California Fish and Game 22(2), pp. 65–98.

Ganssle, D., 1966. "*Fishes and Decapods of San Pablo and Suisun Bays,*" In: Ecological Studies of the Sacramento-San Joaquin Estuary, Part I (D. W. Kelley, comp.), California Dept. of Fish Game Bull. 133, pp. 64–94.

Geary, R.E., and P.B. Moyle, 1980. *Aspects of the Ecology of the Hitch, Lavinia Exilicauda (Cyprinidae), A Persistent Native Cyprinid in Clear Lake, California,* SW Nat. 25, pp. 385–390.

Grant, G.C., 1992. *Selected life history aspects of Sacramento squawfish and hardhead in Pine Creek, Tehama County, California.* M.S. Thesis, California State University, Chico, 86 pp.

Grant, G.C., and P.E. Maslin, 1997. *Movements and Reproduction of Hardhead and Sacramento Squawfish in a Small California Stream,* SW Nat. 44, pp. 296–310.

Grimaldo, L.F., R.E. Miller, C.M. Peregin, and Z.P. Hymanson, 2004. *Spatial and temporal distribution of native and alien ichthyoplankton in three habitat types of the Sacramento-San Joaquin Delta.* In: Early Life History Of Fishes In The San Francisco Estuary and Watershed (F. Feyrer, L.R. Brown, R.L. Brown, and J.J. Orsi, ed., Am. Fish. Soc. Symposium 39, pp. 81–96).

Hardwood, R.H., 1972. *Diurnal Feeding Rhythm of Notropis lutrensis,* (Baird and Girard), Texas J. Sci. 24(1), pp. 97–99.

Hess, L., C. Karp, and J. Wang, 1995. S*acramento Perch, Wakasagi, Splittail, Sacramento Blackfish, and Shimofuri Goby in the San Luis Reservoir, and O'neil Forebay,* IEP Newsletter, Autumn 1995, pp. 18–20.

Hiebert, S., C. Liston, P. Johnson, C. Karp, and L. Hess, 1995. *Continuous Monitoring of Fish Eggs and Larvae During 1991 and 1992 Tracy Fish Collection Facilities*, Vol. 2, U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Services Center, 55 pp.

Hikita, T., 1956. *On the Anatomy and Development of the Carp in Hokkaido,* Sci. Rep. Hokkaido Fish Hatchery 11, pp. 65–95.

Hoda, S.M.S., and H. Tsukahari, 1971. *Studies on the Development and Relative Growth in the Carp, Cyprinus carpio (Linnaeus),* J. Fac. Agric. Kyushu University 16(4), pp. 387–509.

Hubbs, C.L., 1954. *Establishment of a Forage Fish, the Red Shiner (Notropis lutrensis), in Lower Colorado River System,* California Fish and Game 40(3), pp. 279–294.

Hubbs, C.L., and G.P. Cooper, 1936. *Minnows of Michigan,* Cranbrook Inst. Sci. Bull. 8, 95 pp. and plates.

Hubbs, C.L., and K.F. Lagler, 1958. *Fishes of the Great Lake Region,* Revised ed., Cranbrook Inst. Sci. Bull 26, 186 pp. and plates.

Jennings, M.R., and M.K. Saiki, 1990. *Establishment of Red Shiner, Notropis lutrensis, the San Joaquin Valley, California,* California Fish and Game 67, pp. 46–57.

Jones, P.W., F.D. Martin, and J.D. Hardy, Jr, 1978. *Development of Fishes of the Mid-Atlantic Bright: An Atlas of Egg, Larval and Juvenile Stages,* Vol. 1, Acipenseridae through Ictaluridae, FWS/OBS-78/12, U.S. Fish and Wildlife Service, Office of Biological Services, 366 pp.

Karp, C., 2003. Personal communication.

Keast, A., 1966. *Trophic Interrelationships in Fish Fauna of a Small Stream,* University of Michigan, Great Lake res. Div. Pub., 15, pp. 51–79.

Kimsey, J.B., 1960. *Observations on the Spawning Of Sacramento Hitch in a Lacustrine Environment,* California Fish and Game 46(2), pp. 211–215.

Kimsey, J.B., and L.O. Fisk, 1964. *Freshwater Nongame Fishes of California,* California Department of Fish and Game, 54 pp.

Kramer, R.H., and L.L. Smith, Jr., 1960. *Utilization of Nests of Largemouth Bass, Micropterus Salmoides, By Golden Shiners, Notemigonus crysoleucas,* Copeia 1960(1), pp. 73–74.

Lehman, P.W., 2000. *The Influence of Climate on Phytoplankton Community Carbon in San Francisco Bay Estuary,* Limnology and Oceanography 45, pp. 580–590.

Lehman, P.W., 2004. *The Influence of Climate on Mechanistic Pathways that Affect Lower Food Web Production In Northern San Francisco Bay Estuary,* Estuaries 27, pp. 311–324.

Leidy, R.A., 1983. *Distribution of Fishes in Streams of the Walnut Creek Basin, California,* California Fish and Game, 69, pp. 23–32.

Leidy, R.A., 1984. *Distribution and Ecology of Stream Fishes in San Francisco Bay Drainage*, Hilgardia 52, pp. 1–175.

Lindquist, A.W., C.D. Deonier, and J.E. Hanley, 1943. *The Relationship to Fish of the Clear Lake Gnat. Clear Lake, California,* California Fish and Game, 29(4), pp. 196–202.

Lippson, A.J., and R.L. Moran, 1974. *Manual for Identification of Early Development Stages of Fishes of the Potomac River Estuary,* Prepared for Maryland Department of Natural Resources, Power Sitting Program, PPSP-MP-13, 282 pp.

Liston, C., R. Christensen, B. Mefford, and A. Glickman, 2000. Feasibility Report No. 2: *A Proposed Technology Development Facility to Support Improvement or Replacement of Fish Screening and Salvage Facilities in the Sacramento-San Joaquin Delta, California,* U.S. Bureau of Reclamation, Mid-Pacific Region and Denver Technical Service Center, 61 pp.

Loggins, R.E., 1997. *Comparison of Four Populations of California Roach, Lavinia symmetricus, Using RAPD Markers,* M.S. Thesis. California State University, Chico, 58 pp.

Mansueti, R.J., and J.D. Hardy, Jr., 1967. *Development of Fishes of the Chesapeake Bay Region: An Atlas of Egg, Larval, and Juvenile Stages, Part I,* University of Maryland, Natural Resources Institute, 202 pp.

Marchetti, M.P., 1998. Personal communication.

Marchetti, M.P., and P.B. Moyle, 2000. *Spatial and temporal ecology of native and introduced fish larvae in lower Putah Creek, California*, Env. Biol. Fish. 58, pp. 75-87.

Markus, H.C., 1934. *Life History of the Blackhead Cyprinid (Pimephales promelas),* Copeia 1934(3), pp. 116–122.

McCrimmon, H.R, 1968. *Carp in Canada,* Fish. Res. Board Can. Bull. 165, 93 pp.

Meng, L., and S.A. Matern, 2001. *Native and Introduced Larval Fishes of Suisun Marsh, California: the Effects of Freshwater Flow,* Trans. Am. Fish. Soc. 130, pp. 750–765.

Meng, L., and P.B. Moyle, 1995. *Status of Splittail in the Sacramento-San Joaquin Estuary,* Trans. Am. Fish Soc. 124, pp. 538–549.

Messersmith, J.D., 1966. *Fishes Collected in Carquinez Strait in 1961–1962, In Ecological Studies of the Sacramento-San Joaquin estuary, Part I* (D.W. Kelley, comp), California Fish and Game Fish Bull. 133, pp. 57–63.

Migdalski, E.C., 1962. *Angler's Guide to the Fresh Water Sport – Fishes,* Ronald Press, N.Y. 431 pp.

Minckley, W.L., 1972. *Note on Spawning Behavior of Red Shiner, Introduced into Burro Creek, Arizona,* SW Nat., 17, pp. 101–103.

Minckley, W.L., 1973. *Fishes of Arizona,* Arizona Department of Fish and Game, 229 pp.

Monaco, G.A., R.L. Brown, and G.A.E. Gall, 1981. *Exploring the Aquaculture Potential of Sub-Surface Agriculture Drainage Water,* Unpubl. Rpt., University California Davis Agriculture Program 141.

Moyle, P.B., 1976. *Inland Fishes of California,* University of California Press, Berkeley, 405 pp.

Moyle, P.B., 2002. *Inland Fishes of California (revised and expanded),* University of California Press, Berkeley and Los Angles, 502 pp.

Moyle, P.B., and M. Massingill, 1981. *Hybridization Between Hitch, Lavinia exilicauda, and Sacramento Blackfish, Orthodon microlepidotus, in San Luis Reservoir, California,* California Fish and Game, 67, pp. 196–198.

Moyle, P.B., and R. Nichols, 1973. *Ecology of Some Native and Introduced Fishes of the Sierra and Nevada Foothills in Central California,* Copeia 1973(3), pp. 478–490.

Murphy, G.I., 1943. *Sexual Dimorphism in the Cyprinids Hesperoleucus and Rhinichthys,* Copeia, pp. 187–188.

Murphy, G.I., 1948. *Note on Biology of the Sacramento Hitch, Lavinia e. exilicauda, of Clear Lake, Lake County, California,* California Fish and Game 34(3), pp. 101–110.

Murphy, G.I., 1950. *The Life History of the Greaser Blackfish (Orthodon microlepidotus) of Clear Lake, Lake County, California,* California Fish and Game 36(2), pp. 119–133.

Nakamura, M., 1969. *Cyprinid Fishes of Japan – Studies on the Life History of Cyprinid Fishes of Japan,* Res. Inst. Nat. Res. Spec. Pub. 4, 455 pp.

Nelson, J.S., E.J. Crossman, H. Espinosa-Perez, L.T. Findley, C.R. Gilbert, R.N. Lea, and J.D. Williams, 2004. *Common and Scientific Names of Fishes from the United States, Canada, and Mexico,* Sixth edition, Am. Fish. Soc. Spec. Publ. 29, 386 pp.

Nichols, J.T., 1943. *The Fresh-Water Fishes of China.* Nat. Hist. Central Asia, Vol. 9, 322 pp.

Nicola, S.J., 1974. *The Life History of the Hitch, Lavinia Exilicauda Baird and Girard, in Beardsley Reservoir, California,* CDFG Inland Fish. Admin. Rpt. 74-6, 16 pp.

Nobriga, M.L., F. Feyrer, and R.D. Baxter, 2004. *Ecology and Status of Sacramento Pikeminnow in the Sacramento – San Joaquin Delta,* Manuscript, 26 pp.

Okada, Y., 1959–1960. *Studies on the Freshwater Fishes of Japan,* Prefect, University Mietsu. Mie Prefecture, Japan, 860 pp. plus plates.

Page, L.M., and B.M. Burr, 1991. *A Field Guide to Freshwater Fishes – North America North of Mexico,* Peterson Field Guide, Houghton Mifflin Company, Boston, 432 pp.

Pflieger, W.L., 1975. *The Fishes of Missouri,* Missouri Department of Conservation, 343 pp.

Reeves, J.E., 1964. *Age and Growth of Hardhead Cyprinid, Mylopharodon conocephalus* (Baird and Girard), in the American River Basin of California, with notes of its ecology, M.S. Thesis, University California Berkeley, California, 90 pp.

Rockriver, A.K.C., 1998a. *Spatial and Temporal Distribution of Larval Fish in Littoral Habitats of the Central Valley, California,* M.S. Thesis California State University, Sacramento, California, 83 pp.

Rockriver, A., 1998b. Personal communication.

Roscoe, T.J., 1993. *Life History Aspects of California Roach. Hesperoleucus symmetricus, Affected by Changes of Flow Regime in the North Fork of Stanislaus River, Calaveras Co. California,* M.S. Thesis, California State University, Sacramento, California, 57 pp.

Saksena, K., 1962. *The Post-Hatching Stages of the Red Shiner, Notropis lutrensis,* Copeia 1962(3), pp. 539–544.

Sanderson, S.L., and J.J. Cech, Jr., 1992. *Energetic Cost of Suspension Versus Particulate Feeding by Juvenile Sacramento Blackfish,* Trans. Am. Fish Soc. 121, pp. 149–157.

Schultz, L.P., 1927. *Temperature-Controlled Variation in the Golden Shiner, Notemigonus crysoleucas,* Pa. Mich. Acad. Sci. Arts Lett. 7, pp. 417–432.

Schwartz, F.J., 1963. *The Fresh-Water Cyprinids of Maryland,* Md. Conserv. 40(3), pp. 155–180.

Scoppetone, G.G., 1988. *Growth and Longevity of the Cui-Ui and Other Catostomids and Cyprinids in Western North America,* Trans. Am. Fish. Soc. 117, pp. 301–307.

Scoppetone, GG., and J.J. Smith, 1978. *Additional Records on the Distribution and Status of Native Fishes by Alameda and Coyote Creek, California,* California Department of Fish and Game 64(1), pp. 62–65.

Scott, W.B., and E.J. Crossman, 1973. *Freshwater Fishes of Canada,* Fish. Res. Board. Can. Bull., 148, 966 pp.

Seesholtz, A., B.J. Cavallo, J. Kindopp, and R. Kurth, 2004. *Juvenile Fishes of the Lower Feather River: Distribution, Emigration Patterns, and Associations with Environmental Variables.* In: Early life history of fishes in the San Francisco estuary and watershed (F. Feyrer, L. R. Brown, R. L. Brown, and J. J. Orsi ed., Am. Fish. Soc. Symposium 39, pp. 141–168).

Seesholtz, A., 2004. Personal communication.

Shao, B., 1997. *Nest Association of Pumpkinseed, Lepomis gibbosus, and Golden Shiner, Notemigonus crysoleucas,* Env. Biol. Fish. 50, pp. 41–48.

Shapovalov, L., A.J. Cordone, and W.A. Dill, 1959. *A Revised Check List of the Freshwater and Anadromous Fishes of California,* California Fish and Game 45(3), pp. 155–180.

Siegfried, S.D., D. Craft, S. Hiebert, and M. Bowen, 2000. *Continuous Monitoring of Fish Eggs and Larvae at the Tracy Fish Collection Facility, Tracy, California, February Through June 1994*, Tracy Fish Collection Facility Studies, California. U.S. Bureau of Reclamation, Mid-Pacific Region, South Central California Area Office and Denver Technical Services Center, Vol. 6, 30 pp., plus appendix.

Sigler, W.F., 1955. *An Ecological Approach to Understanding Utah's Carp Populations*, Proc. Utah Acad. Sci. 32, pp. 95–104.

Slastenenki, E.P., 1958. *The Freshwater Fishes of Canada*, Kiev Printers, Toronto. 388 pp.

Smith, H.M., 1909. *Japanese Goldfish, Their Varieties and Cultivation, a Practical Guide to the Japanese Method of Goldfish Culture for Amateurs and Professionals,* W.F. Roberts Co., Washington D.C., 112 pp.

Smith, J.J., 1982. *Fishes of the Pajaro River System*, University California Publ. Zool, 115, pp. 83–170.

Snyder, D.E., 1981. *Contributions to a Guide to the Cyrpiniform Fish Larvae of the Upper Colorado River System in Colorado,* U.S. Department of the Interior, Bureau of Land Management Biological Sciences Service, Denver, Colorado.

Snyder, D.E., K.R. Bestgeir, and S.C. Seal, 2005. *Native Cypriniform Fish Larvae of the Gila River Basin—Morphological Descriptions, Comparisons, and Computer-Interactive Keys,* Final Report by Colorado State University Larval Fish Laboratory to U.S. Department of the Interior, Bureau of Reclamation, Phoenix, Arizona.

Snyder, D.E., M.B.M. Snyder, and S.C. Douglas, 1977. *Identification of Golden Shiner, Notemigonus crysoleucas, Spotfin Shiner, Notropis spilopterus, and Fathead Minnow, Pimephales promelas, Larvae,* J. Fish. Board Can. 34(9), pp. 1397–1409.

Snyder, J.O., 1913. *The Fishes of the Streams Tributary to Monterey Bay, California.* Bull, U.S. Bur. Fish. 32, pp. 49–72.

Sommer, T.R., R. Baxter, and B. Herbold, 1997. *Resilience of Splittail in the Sacramento-San Joaquin Estuary,* Trans. Am. Fish. Soc. 126, pp. 961–976.

Sommer, T., L. Conrad, G.O'Leary, F. Feyrer, and W.C. Harrell, 2002. *Spawning and Rearing of Splittail in Model Floodplain Wetland,* Trans. Am. Fish. Soc. 126, pp. 961–976.

Sommer, T., R. Baxter, and F. Feyrer, 2004. *Splittail "Delisting" the Role of Recent Population Trends and Restoration Activities,* Status of Western native fishes. Am. Fish. Soc. Symposium (manuscript).

Sterba, G., 1959. *Freshwater Fishes of the World,* Vista Books, London, 878 pp.

Swee, U.B., and H.R. McCrimmon, 1966. *Reproductive Biology of the Carp, Cyprinus carpio L., in Lake St. Lawrence, Ontario,* Trans. Am. Fish, Soc. 96(4), pp. 372–380.

Swift, C., 1965. *Early Development of the Hitch, Lavinia exilicauda, of Clear Lake, California*, California Fish and Game 51(2), pp. 74–80.

Swift, C.C., T.R. Haglund, M. Ruiz, and R.N. Fisher, 1993. *The Status and Distribution of the Freshwater Fishes of Southern California,* Bull. S. California Acad. Sci. 92, pp. 101–167.

Swingle, H.S., 1946. *Experiments with Combinations of Largemouth Black Bass, Bluegills, and Cyprinids in Ponds,* Trans. Am. Fish, Soc. 76, pp. 46–62.

Taber, C., 1969. *The Distribution and Identification of Larval Fishes in Buncombe Creek arm of Lake Taxoma with Observations on Spawning Habitats and Relative Abundance,* Ph. D. Diss., University Oklahoma, 120 pp.

Taft, A.C., and G.I. Murphy, 1950. *Life History of the Sacramento Squawfish (Ptychocheilus grandis)*, California Fish and Game 36(2), pp. 147–164.

Trautman, M.B., 1957. *The Fishes of Ohio with Illustrated Keys*, Ohio State University Press., 701 pp. plus plates.

Tucker, M.E., C.M. Williams, and R.R. Johnson, 1998. *Abundance Food Habits, and Life History Aspects of Sacramento Squawfish and Striped Bass at Red Bluff Diversion Complex, California 1994–1996*, Red Bluff, California: USFWS Red Bluff Research Pumping Plant Rpt. 4, 54 pp.

Wales, J.H., 1946. *The Hardhead Problem in the Sacramento River Above Shasta Lake*, CDFG Inland Fish Admin, Report. 46-1, 4 pp.

Wang, J.C.S., 1986. *Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories,* IEP Tech Rpt. 9, 612 pp.

Wang, J.C.S., 1991. *Early Life Stages and Early Life History of the Delta Smelt, Hypomesus transpacificus, in the Sacramento-San Joaquin Estuary, with Comparison of Early Life Stages of the Longfin Smelt, Spirinchus thaleichthys.*

Wang, J.C.S., 1995. *Observations of Early Life Stages of Splittail (Pogonichthys macrolepidotus) in the Sacramento-San Joaquin Estuary, 1988 to 1994*, IEP Tech Rpt 43, 22 pp. plus appendix (unpubl. rpt.).

Wang, J.C.S., 1996. Observation of larval smelt and splittail in a dry year and in a wet year, IEP Newsletter 9(3), pp. 31–35.

Wang, J.C.S., and R. Kernehan, 1979. *Fishes of the Delaware estuaries: A guide to the early life histories,* Ecological Analysts, Tow netson, Maryland, 410 pp.

Watson, J.M., 1939. *The Development of Weberian Ossicles and Anterior Vertebrae in the Goldfish,* Proc. R. Soc. Lond., Ser. B. 123(849), pp. 452–472.

Webster, D.A., 1942. *The Life History of Some Connecticut Fishes.* In: A fishery survey of important Connecticut lakes, Conn. Board Fish, Game, Lake Pond Surv. Unit, Bull, 63, pp. 122–127.

Williams, J.E., J.E. Johnson, D.A. Handerson, S. Contreras-Balderas, J.A. Williams, M. Navarro-Mendoza, D.E. Allister, and J.E. Deacon, 1989. *Fishes of North America Endangered, Threatened, or of Special Concern: 1989*, Am. Fish. Soc. Fisheries, Vol. 14, No. 6, 80 pp.

Wright, A.H., and A.A. Allen, 1913. *Field Notebook of Fishes, Amphibians, Reptiles, and Mammals,* Ithaca, New York, 88 pp.

Wydoski, R.S., and R.R. Whitney, 2003. *Inland Fishes of Washington (second edition, revised and expanded),* Am. Fish Soc., and University of Washington Press, 322 pp.

Wynne-Edwards, V.C., 1932. *The Breeding Habitats of the Black-Headed Cyprinid, Pimephales promelas Raf*, Trans. Am. Fish, Soc. 62, pp. 382–383.

Appendix

Detailed Summaries of Fish Egg and Larva and Early Life Stage Sampling Programs and Reference Specimen Sources

Appendix Table A1.—Species Composition of Fish Eggs and Larvae Sampling in the Sacramento-San Joaquin Delta (Collected by CDFG, 1988–1995)

	1988	1989	1990	1991	1992	1993	1994	1995
Family Petromyzontidae, lampreys								
Lampetra tridentata, Pacific lamprey	–	+	+	+	–	+	–	–
Family Acipenseridae, sturgeons								
Acipenser transmontanus, white sturgeon	+	–	–	–	+	+	–	+
Family Engraulidae, anchovies								
Engraulis mordax, northern anchovy	+	+	+	+	+	+	+	–
Family Clupeidae, herrings								
Alosa sapidissima, American shad	+	+	+	+	+	+	+	+
Clupea pallasii, Pacific herring	+	+	+	+	+	+	+	–
Dorosoma petenense, threadfin shad	+	+	+	+	+	+	+	+
Family Cyprinidae, carps and minnows								
Carassius auratus, goldfish	–	+	–	+	+	+	–	–
Cyprinus carpio, common carp	+	+	+	+	+	+	+	+
Notemigonus crysoleucas, golden shiner	+	+	+	+	+	+	+	+
Orthodon microlepidotus, Sacramento blackfish	–	–	–	–	+	+	–	+
Pimephales promelas, fathead minnow	–	–	–	–	+	+	+	+
Pogonichthys macrolepidotus, splittail	+	+	+	+	+	+	+	+
Ptychocheilus grandis, Sacramento pikeminnow	–	–	–	–	+	+	+	+

Appendix Table A1.—Species Composition of Fish Eggs and Larvae Sampling in the Sacramento-San Joaquin Delta (Collected by CDFG, 1988–1995) – continued

	1988	1989	1990	1991	1992	1993	1994	1995
Family Catostomidae, suckers								
Catostomus occidentalis, Sacramento sucker	+	+	+	+	+	+	+	+
Family Ictaluridae, North American catfishes								
Ameiurus catus, white catfish	+	–	–	+	+	+	+	+
Ameiurus nebulosus, brown bullhead	+	+	–	+	+	+	+	+
Ictalurus punctatus, channel catfish	–	–	+	+	+	+	–	–
Family Osmeridae, smelts								
Hypomesus nipponensis, wakasagi	–	+	–	+	+	+	+	+
Hypomesus transpacificus, delta smelt	+	+	+	+	+	+	+	+
Spirinchus thaleichthys, longfin smelt	+	+	+	+	+	+	+	+
Family Salmonidae, trouts and salmons								
Oncorhynchus tshawytscha, Chinook salmon	–	–	–	+	+	+	+	+
Family Batrachoididae, toadfishes								
Porichthys notatus, plainfin midshipman	–	–	+	–	–	–	+	–
Family Antherinopsidae, silversides								
Atherinops affinis, topsmelt	–	+	+	–	–	–	–	–
Atherinopsis californiensis, jacksmelt	+	+	+	+	+	+	+	–
Menidia beryllina, inland silverside	+	+	+	+	+	+	+	+

Appendix Table A1.—Species Composition of Fish Eggs and Larvae Sampling in the Sacramento-San Joaquin Delta (Collected by CDFG, 1988–1995) – continued

	1988	1989	1990	1991	1992	1993	1994	1995
Family Fundulidae, topminnows								
Lucania parva, rainwater killifish	–	–	–	–	+	–	+	+
Family Gasterosteidae, sticklebacks								
Gasterosteus aculeatus, threespine stickleback	+	+	+	+	+	+	+	+
Family Syngnathidae, pipefishes								
Syngnathus leptorhynchus, bay pipefish	+	–	–	–	–	–	–	–
Family Cottidae, sculpins								
Cottus asper, prickly sculpin	+	+	+	+	+	+	+	+
Leptocottus armatus, Pacific staghorn sculpin	–	–	–	–	+	–	+	+
Family Moronidae, temperate basses								
Morone saxatilis, striped bass	+	+	+	+	+	+	+	+
Family Centrarchidae, sunfishes								
Lepomis machrochirus, bluegill	–	+	–	–	–	–	–	–
Micropterus salmoides, largemouth bass	+	+	+	+	+	+	+	+
Lepomis spp.	+	+	+	+	+	+	+	+
Pomoxis spp.	+	+	+	+	+	+	+	+

Appendix Table A1.—Species Composition of Fish Eggs and Larvae Sampling in the Sacramento-San Joaquin Delta (Collected by CDFG, 1988–1995) – continued

	1988	1989	1990	1991	1992	1993	1994	1995
Family Percidae, perches								
Percina macrolepida, bigscale logperch	+	+	+	+	+	+	+	+
Family Sciaenidae, drums								
Genyonemus lineatus, white croaker	–	–	–	–	+	–	+	–
Family Embiotocidae, surfperches								
Hysterocarpus traskii, tule perch	–	+	+	–	+	–	–	–
Family Gobiidae, gobies								
Acanthogobius flavimanus, yellowfin goby	+	+	+	+	+	+	+	+
Gillichthys mirabilis, longjaw mudsucker	+	+	+	+	+	+	+	+
Ilypnus gilberti, cheekspot goby	+	+	+	+	+	+	+	–
Lepidogobius lepidus, bay goby	+	+	+	+	–	–	–	–
Tridentiger bifasciatus, shimofuri goby	+	+	+	+	+	+	+	+
Family Pleuronectidae, righteye flounders								
Platichthys stellatus, starry flounder	+	+	+	+	–	–	+	+

Appendix Table A2.—Species Composition of Fish Eggs and Larvae Sampling in the North Bay Aqueduct Project (Collected by CDFG for DWR), 1995–2004

	1995	1996	1997	1998	1999	2000	2001	2002	2003*	2004*
Family Petromyzontidae, lampreys										
Lampetra tridentata, Pacific lamprey	–	+	–	–	–	–	–	–	–	–
Family Acipenseridae, sturgeons										
Acipenser transmontanus, white sturgeon	+	–	+	+	–	+	–	–	+	+
Family Clupeidae, herrings										
Alosa sapidissima, American shad	+	+	+	+	+	+	+	+	+	+
Dorosoma petenense, threadfin shad	+	+	+	+	+	+	+	+	+	+
Family Cyprinidae, carps and minnows										
Carassius auratus, goldfish	–	+	+	+	+	–	–	+	–	–
Cyprinella lutrensis, red shiner	–	–	+	–	+	+	+	+	+	+
Cyprinus carpio, common carp	+	+	+	+	+	+	+	+	+	+
Notemigonus crysoleucas, golden shiner	+	–	+	–	+	+	–	–	–	–
Orthodon microlepidotus, Sacramento blackfish	+	–	+	+	+	–	+	+	+	–
Pimephales promelas, fathead minnow	+	+	+	+	+	+	+	+	+	+
Pogonichthys macrolepidotus, splittail	+	+	+	+	–	+	+	+	+	+
Ptychocheilus grandis, Sacramento pikeminnow	+	–	–	–	–	–	–	–	–	–
Family Catostomidae, suckers										
Catostomus occidentalis, Sacramento sucker	+	+	+	+	+	+	+	–	+	+
Family Ictaluridae, North American catfishes										
Ameiurus catus, white catfish	+	+	+	–	+	+	+	+	+	+
Ameiurus nebulosus, brown bullhead	–	–	–	–	–	+	+	–	–	–
Ictalurus punctatus, channel catfish	–	+	+	–	+	+	+	+	+	+

Appendix Table A2.—Species Composition of Fish Eggs and Larvae Sampling in the North Bay Aqueduct Project (Collected by CDFG for DWR), 1995–2004 – continued

	1995	1996	1997	1998	1999	2000	2001	2002	2003*	2004*
Family Osmeridae, smelts										
Hypomesus nipponensis, wakasagi	+	+	+	+	+	+	+	+	+	+
Hypomesus transpacificus, delta smelt	+	+	+	+	+	+	+	+	+	+
Spirinchus thaleichthys, longfin smelt	+	+	+	–	+	+	+	+	+	+
Family Salmonidae, trouts and salmons										
Oncorhynchus tshawytscha, Chinook salmon	+	–	+	–	+	+	+	–	–	+
Family Antherinopsidae, silversides										
Menidia beryllina, inland silverside	+	+	+	+	+	+	+	+	+	+
Family Poeciliidae, livebearers										
Gambusia affinis, western mosquitofish	–	–	+	+	–	+	+	+	+	+
Family Gasterosteidae, sticklebacks										
Gasterosteus aculeatus, threespine stickleback	–	+	+	–	+	+	+	+	+	+
Family Cottidae, sculpins										
Cottus asper, prickly sculpin	+	+	+	+	+	+	+	+	+	+
Family Moronidae, temperate basses										
Morone saxatilis, striped bass	+	+	+	+	+	+	+	+	+	+
Family Centrarchidae, sunfishes										
Lepomis macrochirus, bluegill	–	–	+	–	+	–	–	+	–	?
Lepomis microlophus, redear sunfish	–	–	–	–	–	+	+	+	?	?
Micropterus salmoides, largemouth bass	+	+	–	–	–	+	+	+	?	?

Appendix Table A2.—Species Composition of Fish Eggs and Larvae Sampling in the North Bay Aqueduct Project (Collected by CDFG for DWR), 1995–2004 – continued

	1995	1996	1997	1998	1999	2000	2001	2002	2003*	2004*
Pomoxis annularis, white crappie	–	+	–	–	–	–	–	–	?	?
Pomoxis nigromaculatus, black crappie	–	–	+	–	–	–	–	–	?	?
Lepomis spp.	+	+	+	+	+	+	+	+	+	+
Pomoxis spp.	+	+	+	+	+	+	+	+	+	+
Family Percidae, perches										
Percina macrolepida, bigscale logperch	+	+	+	+	+	+	+	+	+	+
Family Embiotocidae, surfperches										
Hysterocarpus traskii, tule perch	+	–	–	–	+	–	+	–	–	–
Family Gobiidae, gobies										
Acanthogobius flavimanus, yellowfin goby	–	–	+	–	+	+	+	+	+	+
Tridentiger bifasciatus, shimofuri goby**	+	+	+	+	+	+	+	+	+	+
Family Pleuronectidae, righteye flounders										
Platichthys stellatus, starry flounder	–	+	+	–	+	+	–	–	–	+

*: Part of samples was re-examined.

**: May include larvae of *Tridentiger barbatus*, Shokihaze goby (catch after 1997).

Appendix Table A3.—Species Composition of Fish Eggs and Larvae Sampling in the Central and South Delta (Collected by DWR), 1991–1995

	1991	1992	1993	1994	1995
Family Clupeidae, herrings					
Dorosoma petenense, threadfin shad	+	+	+	+	+
Family Cyprinidae, carps and minnows					
Cyprinus carpio, common carp	+	+	+	+	+
Notemigonus crysoleucas, golden shiner	+	+	+	+	+
Orthodon microlepidotus, Sacramento blackfish	–	–	–	–	+
Pimephales promelas, fathead minnow	–	–	–	+	+
Pogonichthys macrolepidotus, splittail	+	+	+	+	+
Family Catostomidae, suckers					
Catostomus occidentalis, Sacramento sucker	+	+	+	+	+
Family Ictaluridae, North American catfishes					
Ameiurus catus, white catfish	+	–	–	+	+
Ameiurus nebulosus, brown bullhead	+	+	–	+	–
Ictalurus punctatus, channel catfish	+	+	+	–	+
Family Osmeridae, smelts					
Hypomesus nipponensis, wakasagi	–	–	–	+	+
Hypomesus transpacificus, delta smelt	+	+	+	+	+
Spirinchus thaleichthys, longfin smelt	+	+	+	+	–
Family Antherinopsidae, silversides					
Menidia beryllina, inland silverside	+	+	+	+	+
Family Poeciliidae, livebearers					
Gambusia affinis, western mosquitofish	+	+	+	+	+
Family Cottidae, sculpins					
Cottus asper, prickly sculpin	+	+	+	+	+
Family Moronidae, temperate basses					
Morone saxatilis, striped bass	+	+	+	+	+

Appendix Table A3.—Species Composition of Fish Eggs and Larvae Sampling in the Central and South Delta (Collected by DWR), 1991–1995 – continued

	1991	1992	1993	1994	1995
Family Centrarchidae, sunfishes					
Lepomis macrochirus, bluegill	–	+	–	+	–
Micropterus salmoides, largemouth bass	+	+	+	+	+
Pomoxis nigromaculatus, black crappie	–	+	–	–	–
Lepomis spp.	+	+	+	+	+
Pomoxis spp.	+	+	+	+	+
Family Percidae, perches					
Percina macrolepida, bigscale logperch	+	+	+	+	+
Family Gobiidae, gobies					
Acanthogobius flavimanus, yellowfin goby	–	+	–	+	–
Tridentiger bifasciatus, shimofuri goby	+	+	+	+	+

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta
(Samples collected by CDFG), 1988–1995

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1988	04/16/88	32	1	7.0	1989 (cont)	04/20/89	72	1	12.5
		57	1	7.5			73	1	17.7
		909	1	7.3			745	1	13.1
	05/02/88	47	1	8.2		04/24/89	21	1	7.7
		49	1	8.0			23	1	14.5
		51	1	8.8			906	1	7.0
		53	1	7.4			73	1	12.0
	05/06/88	27	1	8.0			74	1	12.5
	05/14/88	57	1	7.8		04/28/89	70	2	7.6
		59	1	7.5					7.9
	05/26/88	37	1	7.5			71	1	7.1
	05/30/88	15	1	7.0			73	3	7.3
		33	1	7.0					7.5
		39	1	7.7					7.7
		43	1	6.8			74	4	7.0
		906	1	6.9					7.2
		909	1	7.2					7.6
	06/03/88	47	1	4.7					7.7
		57	1	7.3			745	6	7.0
		61	1	7.1					7.2
	06/11/88	53	1	6.5					7.3
	06/23/88	41	1	7.5					7.3
1989	04/12/89	17	1	9.6					7.7
		27	2	9.5					7.7
				10.0			75	3	7.3
		29	8	10.0					7.5
				10.2					7.5
				10.4			29	1	8.0
				10.4			32	1	7.4
				10.4			51	1	7.7
				11.0			59	1	7.0
				11.7			71	1	7.3
				11.8			73	1	8.0
		32	3	9.2			735	2	13.4
				9.2					14.0
				17.5			75	1	7.0
		33	2	7.8		05/06/89	745	1	14.5
				9.5		05/10/89	41	1	6.7
						05/14/89	73	1	14.6
		45	1	5.5		05/18/89	29	1	7.5
	04/16/89	19	1	11.2			71	1	7.5
		32	5	5.5			725	1	7.0
				5.8			75	1	14.8
				6.5		05/26/89	43	1	7.1
				11.8			49	1	6.5
				12.0		06/03/89	51	1	6.7

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta
(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1989 (cont)	06/19/89	21	1	6.9
	06/23/89	21	1	6.9
1990	04/14/90	61	1	7.5
	04/16/90	29	1	7.7
		55	1	7.2
	04/20/90	39	1	6.5
		775	1	7.0
		785	2	7.0
				7.5
		80	1	7.0
		81	2	7.5
				7.8
		82	2	7.3
				8.2
	04/22/90	41	2	5.9
				9.0
		53	1	6.6
		55	1	7.0
		906	1	6.7
		815	1	7.2
	04/24/90	41	1	7.0
		57	2	6.2
				6.5
		61	1	6.4
		78	1	7.0
		785	2	7.5
				7.7
		79	4	6.7
				7.0
				7.3
				8.0
		795	1	7.6
		805	1	7.5
	04/26/90	37	1	6.7
		57	1	6.0
		59	1	6.5
		78	1	7.8
		82	1	9.0
	04/28/90	45	1	7.2
	05/02/90	21	1	6.7
		41	1	6.8
		60	1	7.2
		785	1	6.5
		79	1	7.0

Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1990 (cont)	05/02/90 (cont)	795	1	9.2
	05/04/90	775	1	8.0
		79	1	7.2
		80	1	7.8
	05/06/90	82	1	7.0
	05/08/90	39	1	7.2
		906	1	7.3
		775	1	7.2
		805	1	7.4
		81	1	8.7
	05/10/90	57	1	7.1
		775	3	7.2
				7.8
				8.0
		785	2	7.7
				8.0
		79	5	7.0
				7.2
				7.8
				8.0
				8.0
		815	2	6.8
				6.9
		825	2	7.0
				7.3
	05/12/90	906	1	6.5
		775	2	6.8
				7.2
		785	1	7.7
	05/14/90	60	1	6.8
		61	1	6.8
		775	3	6.6
				7.3
				8.0
		78	1	7.0
		785	1	7.7
		79	1	7.3
	05/16/90	47	1	6.5
		61	1	7.0
		79	1	7.1
	05/20/90	78	2	7.2
				7.5
	05/24/90	37	1	6.8
	05/30/90	23	1	40.0
		785	1	10.5

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta
(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1990 (cont)	05/30/90 (cont)	79	1	10.0	1991 (cont)	04/30/91 (cont)	80	1	7.4
	06/15/90	795	1	8.3			815	3	6.3
	06/19/90	775	4	5.0					7.3
				6.5					7.6
				9.4			82	8	6.5
				10.4					7.2
		825	1	10.0					7.4
1991	04/04/91	32	3	7.5					7.5
				7.6					7.7
1991 (cont)	04/04/91 (cont)	32 (cont)		8.0					7.7
		55	1	7.6					7.7
	04/06/91	57	3	7.3					7.8
				7.7			825	2	6.4
				8.1					7.4
		906	1	7.6		05/02/91	745	1	7.2
	04/10/91	23	1	9.0			78	1	7.7
		29	2	7.9			785	3	7.2
				8.6					7.3
	04/12/91	29	2	8.6					7.3
				8.6			79	4	7.0
		59	1	7.4					7.2
	04/16/91	51	1	7.4					7.2
	04/24/91	78	1	7.0					7.3
		825	1	7.8			795	5	7.0
	04/26/91	74	1	7.4					7.2
		76	1	8.4					7.7
		82	1	7.8					7.8
	04/28/91	735	1	7.5					8.3
		75	1	8.0			80	3	7.5
		765	2	7.2					8.1
				8.4					8.3
		77	1	7.2			805	1	7.5
		785	1	7.2			81	2	6.8
		825	1	7.5					7.2
	04/30/91	77	4	4.5			815	2	7.2
				4.5					7.5
				7.5			82	6	7.1
				8.8					7.3
		775	1	7.6					7.3
		785	3	7.5					7.7
				7.6					7.8
				7.7					7.8
		79	1	7.5			825	4	7.1
		795	1	8.1					7.2

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta
(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1991 (cont)	05/02/91 (cont)			7.4
				7.5
	05/04/91	745	1	7.0
		77	1	7.2
		775	3	7.1
				7.5
				8.2
		78	2	6.8
				7.8
		785	3	7.5
				7.5
				7.7
		79	5	7.0
				7.1
				7.2
				7.3
				8.0
		795	1	7.7
		80	6	7.4
				7.5
				7.5
				7.7
				7.8
				8.0
		805	3	7.0
				7.4
				7.7
		81	5	6.9
				7.3
				7.5
				7.7
				7.8
		82	5	7.1
				7.2
				7.4
				7.7
				7.8
		825	3	7.2
				7.5
				7.7
	05/06/91	75	1	7.3
		76	1	7.7
		775	1	7.8
		78	6	6.9
				7.0
1991 (cont)	05/06/91 (cont)	78 (cont)		7.2
				7.5
				7.9
				8.1
		80	1	7.9
		81	1	7.7
		815	1	7.7
		82	1	7.8
		825	2	7.2
				8.2
	05/08/91	735	1	8.8
		745	1	7.2
		75	4	7.7
				7.7
				8.0
				8.0
		77	1	7.7
		775	1	7.8
		79	2	7.2
				7.8
		80	7	7.2
				7.3
				7.5
				7.5
				7.7
				8.0
				8.0
		825	1	6.9
	05/10/91	725	1	8.5
		70	2	7.5
				7.8
		738	2	7.3
				8.0
		745	2	8.3
				8.6
		76	3	8.0
				8.4
				23.5
		765	2	7.3
				8.2
		77	1	7.5
		79	2	7.9
				8.0
	05/12/91	57	1	7.1
		72	2	8.2

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta
(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1991 (cont)	5/12/91 (cont)			8.1	1991 (cont)	05/22/91	775	1	28.5
		74	1	9.0		05/23/91	923	1	6.5
		745	7	7.3		05/24/91	805	1	9.8
				7.5		05/26/91	80	1	7.8
				7.5		05/28/91	76	1	8.7
				8.3		06/03/91	5	1	38.0
				8.6			21	1	38.0
				8.8			43	1	7.0
				9.0			71	1	7.1
		75	6	7.0			74	1	8.8
				7.2			77	1	8.0
				7.2		06/05/91	735	1	7.0
				7.7			75	2	8.0
				7.8					8.2
				8.4		06/06/91	785	1	8.1
		76	2	7.3			80	1	10.2
				7.6			805	2	8.0
		765	1	7.8					8.4
		775	1	7.8		06/07/91	78	1	8.4
		78	1	7.6			785	2	7.8
		795	1	7.7					7.8
		82	1	7.8			79	1	7.9
	05/14/91	73	1	7.2			815	1	7.0
		74	1	7.1		06/09/91	76	2	8.0
		755	1	7.3					9.4
		765	1	7.5			77	1	6.7
		77	2	7.0		06/11/91	72	1	9.3
				7.5		06/15/91	57	1	7.3
		775	5	7.3		06/19/91	9	1	44.5
				7.6	1992	03/03/92	76	2	6.7
				7.8					7.6
				7.9			765	1	7.5
				8.0			77	1	6.5
	05/16/91	72	1	7.5			775	7	6.7
		725	1	8.2					6.9
		70	1	7.0					7.0
		805	1	8.0					7.3
	05/18/91	725	1	9.0					7.5
		74	1	8.5					7.5
		775	1	7.2					7.8
		79	1	7.6		03/07/92	712	2	7.2
		815	1	7.9					7.5
	05/20/91	755	1	7.2			715	2	7.2
		77	2	29.0					7.2
				32.5			725	1	7.1

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta

(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1992 (cont)	03/07/92 (cont)	73	1	8.0	1992 (cont)	3/11/92 (cont)	775 (cont)		8.0
		735	4	7.3					8.0
				7.7					8.5
				7.7					8.7
				7.9					8.8
		74	2	7.2					9.0
				7.8		03/12/92	70	2	7.4
		755	6	7.1					9.1
				7.2		03/13/92	73	2	7.0
				7.2					7.1
				7.3			735	5	7.2
		755 (cont)		7.5					7.5
				7.7					8.2
		76	3	7.4					9.0
				7.5					9.2
				7.5			74	13	7.2
		765	4	7.4					7.7
				7.4					7.7
				7.5					8.3
				7.5					8.8
		77	3	7.4					8.5
				8.0					8.7
				8.0					8.7
				8.0					8.7
		775	2	7.7					8.8
				8.0					9.1
	03/11/92	47	1	7.3					9.2
		53	1	8.5					9.3
		60	1	8.0		03/15/92	27	2	7.8
		906	1	7.9					8.5
		755	1	7.7			32	3	6.8
		765	3	7.7					6.8
				8.2					9.7
				8.5			72	1	8.3
		77	10	7.6		03/17/92	70	1	7.7
				7.8			713	1	14.2
				7.9			715	1	8.7
				7.9			716	2	8.2
				8.0					8.5
				8.1			72	1	8.3
				8.6			725	1	9.3
				8.7			735	2	7.0
				8.8					9.0
				9.2			745	1	8.6
		775	7	7.8			75	1	9.2

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta
(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1992 (cont)	03/17/92 (cont)	755	4	7.6	1992 (cont)	04/06/92 (cont)	717	1	7.7
				7.7			725	1	7.9
				7.7			73	1	7.8
				9.4			735	1	7.4
		76	1	10.0			74	1	7.8
		785	1	9.5		04/08/92	32	2	7.4
		79	1	9.9					7.4
	03/19/92	41	1	8.0			37	2	7.0
		43	1	8.7					7.3
		59	1	8.0			72	1	7.5
	03/20/92	26	3	7.8			735	4	7.2
				8.5					7.6
				8.7					7.7
		919	1	7.6					7.8
		921	3	8.2			75	1	8.0
				8.2			755	2	7.0
				8.6					7.1
		923	1	8.0			765	1	7.5
	03/23/92	712	1	10.1			77	1	7.6
		77	1	8.6		04/10/92	712	1	6.7
	03/27/92	77	1	10.3			725	1	7.7
		775	1	9.8			735	1	7.7
		785	1	8.1		04/14/92	37	1	7.2
		79	1	7.5			725	1	7.5
	03/31/92	29	1	11.9			74	1	7.8
		70	1	13.7		04/16/92	32	2	7.5
		712	1	11.0					7.5
		713	1	12.8			715	1	6.3
		716	1	10.3		04/17/92	745	4	7.1
		775	1	7.5					7.5
		78	1	7.7					7.7
	04/04/92	72	1	14.3					7.7
		73	1	7.7			75	10	7.0
		74	1	8.2					7.0
		745	2	7.2					7.0
				8.1					7.2
		75	1	7.8					7.3
		755	1	16.0					7.3
		76	1	7.3					7.4
		765	1	18.6					7.5
		775	2	7.1					7.5
				7.2					7.6
	04/06/92	70	1	7.6			755	5	7.5
		712	1	7.0					7.7
		713	1	6.6					7.8

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta

(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1992 (cont)	04/17/92 (cont)	755 (cont)		8.0	1992 (cont)	04/22/92 (cont)	717	1	7.6
				8.0			75	4	6.6
		76	2	7.0					7.0
				7.0					7.5
		765	1	7.4					8.3
		77	1	29.5			755	7	7.2
		775	4	7.4					7.2
				7.5					7.3
				7.5					7.4
				8.0					7.7
		78	1	7.7					7.7
		785	1	7.1					7.8
		79	6	6.7			76	1	7.0
				6.7			77	1	8.3
				6.8			775	1	29.5
				6.8			785	1	7.6
				6.9		04/24/92	33	1	7.0
				7.5			70	1	7.8
		795	1	6.9			716	1	6.2
	04/18/92	70	2	7.7		04/26/92	74	1	7.2
				8.1			77	2	7.8
		713	2	6.9					35.0
				7.1		04/28/92	27	3	5.7
		716	1	7.3					7.1
		735	2	7.5					7.5
				7.6			716	1	7.5
	04/20/92	32	2	8.2		04/30/92	713	1	7.8
				8.2			735	1	8.0
		59	1	7.1		05/02/92	15	4	6.1
		715	1	7.3					6.8
		716	1	7.3					7.1
		75	1	8.3					7.3
		755	2	6.8			32	1	6.8
				7.4			77	1	7.2
		765	1	7.8		05/06/92	716	1	7.0
		77	1	7.8		05/08/92	33	1	7.5
		78	2	7.1			713	1	6.5
				7.9			716	1	7.2
		785	1	7.6			75	1	8.1
		795	1	7.0			77	1	8.3
	04/21/92	903	1	24.5			775	1	6.9
	04/22/92	70	3	7.7		05/10/92	79	1	8.2
				7.7		05/12/92	33	1	7.1
				7.7			716	1	7.4
		713	1	29.3		05/13/92	76	1	8.9

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta
(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1992 (cont)	05/14/92	716	1	7.1
		765	1	8.3
	05/16/92	745	1	6.7
		775	1	6.8
	05/18/92	715	1	7.1
		716	1	7.3
		725	1	9.1
	05/20/92	716	1	6.8
	05/21/92	925	1	6.7
	05/22/92	43	1	6.8
	05/24/92	923	1	27.7
	06/23/92	716	1	7.4
1993	03/11/93	735	5	7.3
				7.4
				7.4
				7.4
				7.7
		755	1	7.3
		76	2	7.0
				8.0
	03/15/93	32	1	7.6
		70	1	8.0
		71	1	6.0
		716	1	7.8
		78	1	7.5
		785	1	7.3
	03/16/93	920	3	7.5
				7.7
				7.9
		921	11	6.8
				7.0
				7.2
				7.4
				7.4
				7.5
				7.6
				7.9
				8.3
				8.3
				8.3
		925	3	7.3
				8.0
				8.0
		926	4	7.5
				7.6
1993 (cont)	03/16/93 (cont)	925 (cont)		7.7
				8.3
	03/17/93	718	2	7.3
				7.7
	03/19/93	716	1	9.1
		718	2	7.6
				8.0
		735	1	7.9
	03/23/93	5	1	7.5
		21	1	10.5
		27	1	7.6
		49	1	9.0
		51	1	7.8
		76	1	11.0
		713	1	7.2
		716	2	8.0
				9.3
		718	2	7.8
				9.0
		720	1	9.0
	03/24/93	919	1	7.7
		920	3	6.8
				7.5
				7.7
		921	5	7.4
				7.4
				7.6
				7.9
				7.9
		923	2	7.0
				7.7
		924	1	8.0
	03/25/93	718	1	8.9
		719	1	8.5
	03/27/93	9	1	9.9
		13	1	9.5
		17	2	8.7
				9.5
		21	1	8.6
		47	1	8.0
		49	1	8.0
		51	1	7.8
		55	2	7.3
				8.0
		59	1	7.5

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta

(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1993 (cont)	03/27/93 (cont)	716	2	7.4
				8.9
		72	1	11.3
		78	1	12.7
	03/29/93	719	1	8.5
	03/31/93	1	1	10.5
		13	2	6.7
				7.7
		76	1	6.6
	04/01/93	515	1	7.8
		67	1	4.7
		716	1	6.7
	04/04/93	1	1	7.0
		23	2	8.1
				8.3
		27	1	7.7
		29	2	7.2
				7.7
		43	1	7.9
		55	2	6.2
				6.7
		71	1	7.4
		713	1	7.7
		717	2	6.3
				6.8
		73	2	7.7
				7.8
		735	2	7.7
				7.7
		74	2	6.7
				7.7
		75	3	7.5
				7.6
				7.7
		755	5	7.2
				7.3
				7.3
				7.8
				7.9
		76	4	6.5
				6.6
				7.1
				7.7
		765	2	7.7
1993 (cont)	04/04/93 (cont)	765 (cont)		8.1
		77	4	7.3
				7.5
				7.5
				7.7
		775	4	6.7
				7.2
				7.4
				7.5
	04/07/93	37	1	7.5
	04/08/93	9	1	7.4
		11	3	7.5
				7.8
				7.8
		15	6	7.2
				7.4
				7.5
				7.5
				7.7
				7.7
		17	9	6.6
				6.7
				7.1
				7.3
				7.5
				7.5
				7.6
				7.7
				7.7
		25	4	6.8
				7.7
				7.9
				8.1
		27	16	6.6
				6.6
				6.9
				7.2
				7.3
				7.5
				7.5
				7.6
				7.6
				7.6
				7.6

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta
(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1993 (cont)	04/08/93 (cont)	27 (cont)		7.7	1993 (cont)	04/08/93 (cont)	755 (cont)		7.3
				7.7					7.3
				7.7					7.4
				7.8					7.6
				7.8					7.8
		29	4	7.3					8.3
				7.5			76	4	6.6
				7.7					7.5
				8.1					7.6
		32	2	6.2					7.7
				6.4			765	3	7.2
		45	1	7.0					7.8
		71	2	7.1					10.3
				7.1			77	1	6.7
		712	2	7.2			26	2	7.7
				7.3					7.8
		713	1	7.4			46	2	7.2
		72	3	7.2					7.8
				7.3			903	3	7.7
				7.7					7.7
		725	1	6.9					8.1
		73	4	7.4			923	3	7.3
				7.4					7.5
				7.5					7.7
				7.5			940	2	7.3
		74	2	7.6					7.3
				7.8		04/12/93	5	1	7.8
		745	1	6.7			9	1	7.2
		75	13	6.9			13	2	7.4
				7.0					7.7
				7.0			15	1	8.3
				7.3			21	1	7.3
				7.3			23	1	7.4
				7.4			29	3	7.6
				7.5					7.8
				7.5					7.9
				7.6			32	2	7.8
				7.7					7.8
				7.7			35	1	7.3
				7.8			37	1	8.5
				7.9			41	2	7.8
		755	10	7.0					7.9
				7.1			47	1	7.0
				7.1			51	1	6.7
				7.2			53	2	7.3

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta
(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1993 (cont)	04/12/93 (cont)	53 (cont)		8.0
		59	1	7.4
		61	1	8.0
		70	2	7.7
				9.2
		712	1	7.9
		713	1	7.0
		725	1	8.6
		735	1	8.0
		74	1	8.1
		745	3	7.7
				7.7
				8.4
		75	10	6.2
				7.6
				7.7
				7.8
				8.0
				8.1
				8.3
				8.3
				8.5
				8.6
		755	5	7.3
				7.7
				7.7
				7.8
				8.2
		775	2	7.8
				8.5
		76	7	6.7
				6.8
				7.4
				7.5
				7.5
				7.7
				7.7
		765	4	7.6
				7.7
				7.8
				9.1
	04/14/93	716	3	7.3
				7.6
				8.0
	04/16/93	7	2	6.8
1993 (cont)	04/16/93 (cont)	7 (cont)		7.0
		17	1	8.5
		19	2	8.1
				9.7
		25	2	7.5
				8.9
		27	3	7.4
				8.0
				8.5
		29	3	8.3
				8.4
				8.7
		41	1	6.8
		61	1	8.0
		70	4	8.3
				8.5
				9.3
				9.4
		712	1	9.2
		713	3	8.1
				9.3
				27.3
		715	2	8.1
				8.8
		716	3	7.8
				7.9
				8.3
		72	1	8.0
		725	1	8.7
		73	4	8.7
				8.8
				9.0
				9.4
		735	1	8.8
		74	1	8.7
		745	8	7.2
				7.6
				8.2
				8.2
				8.4
				8.4
				8.4
				8.5
		75	2	8.3
				8.7

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta

(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1993 (cont)	04/16/93 (cont)	755	3	8.1	1993 (cont)	04/17/93 (cont)	940 (cont)		9.6
				8.3					9.7
				9.5		04/20/93	11	1	7.7
		76	7	8.3			17	1	8.5
				8.3			19	3	9.7
				8.6					9.7
				9.1					10.5
				9.3			21	1	10.3
				9.5			23	5	7.6
				9.8					9.1
		765	1	8.6					9.8
		77	9	7.8					10.7
				8.0					11.0
				8.4			25	3	9.3
				8.5					10.6
				8.8					27.7
				8.8			29	12	8.7
				9.6					8.7
				10.0					9.0
				10.5					9.1
		775	1	7.3					9.5
	04/17/93	46	1	7.7					9.5
		68	2	7.4					9.5
				7.7					9.7
		903	4	8.7					9.7
				9.0					10.2
				9.2					10.2
				9.5					10.5
		920	3	7.7			32	1	10.3
				7.8			37	2	6.0
				8.1					6.7
		921	2	7.7			51	1	8.6
				8.0			59	1	7.2
		940	14	7.7			61	1	8.0
				7.7			70	1	10.0
				7.8			71	5	9.7
				8.2					10.1
				8.2					10.1
				8.2					10.6
				8.4					10.8
				8.5			713	6	8.2
				8.5					8.7
				8.6					9.0
				9.0					10.2
				9.4					10.8

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta

(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1993 (cont)	04/20/93 (cont)	713 (cont)		11.3
		716	1	10.1
		717	3	8.8
				9.3
				10.6
		725	2	9.5
				9.6
		73	2	8.0
				9.3
		74	1	10.4
		745	1	7.0
		76	3	6.8
				8.5
				9.0
		77	3	9.0
				10.0
				10.2
		785	1	9.7
	04/24/93	32	2	9.7
				11.4
		47	1	8.8
		53	1	10.0
		713	1	9.3
		76	2	11.2
				11.7
		765	1	10.7
		77	2	10.3
				12.4
	04/25/93	903	1	7.0
	04/28/93	35	1	6.5
	05/02/93	32	1	13.7
		43	1	7.2
		713	1	20.3
	05/06/03	60	1	7.9
		725	1	32.0
	05/07/93	29	1	8.5
		32	1	6.6
	05/10/93	74	1	7.5
		765	1	25.8
	05/14/93	73	1	26.7
		77	1	7.0
	05/26/93	717	1	8.0
		775	1	7.3
	05/27/93	920	1	7.2
	06/03/93	725	1	7.1

Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1993 (cont)	06/03/93 (cont)	755	1	9.5
	06/07/93	15	2	7.2
				8.0
		33	1	7.0
		720	1	6.8
	06/08/93	55	1	7.6
	06/11/93	761	1	8.0
	06/12/93	940	1	7.6
		735	1	7.4
		75	1	7.7
		735	1	7.9
	07/01/93	13	1	8.2
		72	1	8.1
		725	2	7.7
				7.9
	07/09/93	67	1	50.0
1994	03/23/94	76	1	6.6
	03/27/94	745	1	6.6
	03/31/94	32	1	7.1
		712	1	6.4
	04/04/94	713	1	7.0
		71	1	7.4
		715	1	7.8
		725	1	6.8
		74	2	7.1
				7.2
		76	1	7.8
	04/08/94	71	1	7.7
		72	2	6.6
				6.3
		712	1	7.5
		735	3	6.3
				6.4
				7.3
		745	2	5.9
				7.2
	04/09/94	921	4	8.0
				7.3
				7.3
				7.5
	04/12/94	712	1	7.5
		725	1	6.8
		735	1	6.3
		75	1	6.8
		755	1	7.5

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta
(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1994 (cont)	04/12/94 (cont)	76	3	6.5	1994 (cont)	05/02/94(cont)	755	1	6.8
				7.0			761	1	7.5
				7.3		05/06/94	716	1	8.2
	04/16/94	53	1	7.0			73	1	7.9
		61	1	7.0			74	2	7.6
		71	1	7.9					8.0
		712	1	7.4			745	2	7.5
		725	2	7.2					7.6
				7.5			75	1	7.9
		76	3	7.3			755	3	7.1
				7.5					7.4
				8.0					7.7
	04/20/94	70	1	7.0		05/14/94	29	1	6.8
		71	1	8.2			715	1	8.0
		735	1	7.3		05/18/94	27	1	7.2
		74	1	6.7		05/22/94	76	1	6.4
		745	2	7.7		05/26/94	75	1	8.0
				8.0		05/31/94	716	2	6.5
	04/24/94	35	1	7.0					7.2
		71	2	7.2		06/03/94	33	1	7.6
				7.3		06/05/94	720	1	7.0
		717	1	7.2		06/12/94	919	1	6.8
		725	1	7.5		07/14/94	515	1	33.0
		74	5	7.0	1995	02/12/95	68	1	7.3
				7.1		02/20/95	920	1	7.4
				7.2		02/28/95	924	1	7.5
				7.2		03/08/95	68	1	7.7
				7.5		03/15/95	5	2	8.3
		745	2	6.2					8.3
				7.0			9	2	10.3
		75	3	6.8					11.3
				7.2			17	3	8.3
				7.5					9.7
		76	1	6.5					10.2
		906	1	6.7			21	1	10.0
	04/25/94	903	2	7.0			25	1	9.3
				7.2			39	1	7.7
	04/28/94	72	1	7.4			66	1	9.8
		725	1	7.6		03/16/95	63	2	9.2
		735	1	6.8					11.7
		74	1	7.8			64	2	9.4
		76	1	7.3					9.7
	05/02/94	29	1	6.5			67	1	10.7
		51	1	6.9			68	1	8.8
		55	1	7.7			606	1	9.3

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta
(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1995 (cont)	03/16/95 (cont)	607	1	10.1
		609	7	8.0
				8.3
				9.2
				10.3
				10.4
				10.7
				11.6
		610	2	10.2
				11.5
		611	1	10.2
		921	1	9.3
	03/21/95	921	1	9.3
	03/24/95	515	1	9.1
	03/29/95	17	1	7.2
		25	1	13.2
		39	1	7.8
	03/31/95	17	1	7.2
		25	1	13.0
		39	1	7.8
	04/01/95	919	2	7.5
				7.7
		920	3	7.7
				7.7
				7.5
		921	1	7.3
		922	6	7.4
				7.5
				7.7
				7.8
				7.8
				8.5
		923	1	8.0
	04/08/95	17	5	7.5
				7.7
				7.9
				8.0
				8.1
		39	2	7.5
				7.6
	04/09/95	67	4	7.6
				7.7
				8.2
				8.3
		68	2	8.2

Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1995 (cont)	04/09/95 (cont)	68 (cont)		8.5
		606	1	6.9
		609	1	7.5
	04/15/95	5	2	8.2
				8.5
		9	2	9.3
				9.7
		13	1	8.0
		17	1	7.8
		21	9	7.0
				7.4
				7.6
				7.6
				7.7
				7.8
				7.9
				8.8
				8.8
		35	1	8.4
		39	1	7.2
		66	1	7.6
	04/17/95	515	2	7.7
				7.8
		64	1	7.5
		607	1	7.7
		919	1	8.3
		923	3	7.4
				7.8
				8.0
	04/24/95	5	1	8.0
		17	1	8.9
		35	1	7.6
		66	1	7.5
		915	1	20.0
	04/25/95	515	1	8.0
		63	1	7.4
		64	1	8.0
		610	1	7.8
		611	1	7.7
	05/02/95	39	1	8.2
		43	1	7.4
	05/03/95	920	2	7.7
				8.4
		921	1	7.5
		922	1	9.8

Appendix Table A4.—Splittail early life stages observed in the Sacramento-San Joaquin Delta
(Samples collected by CDFG), 1988–1995 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1995 (cont)	05/03/95 (cont)	926	1	8.4					
	05/08/95	912	1	—					
	05/10/95	13	1	7.1					
	05/11/95	67	1	7.1					
		68	1	14.2					
		607	3	6.2					
				6.7					
				6.9					
		609	1	—					
	05/18/95	39	1	14.6					
	05/27/95	63	1	40.0					
		64	1	29.4					
	06/12/95	610	2	50.0					
				52.0					
	06/28/95	610	1	38.0					
	07/13/95	25	1	18.5					

Summary Table of Appendix Table A4

Year	Sampling Station by Area I	II	III	IV	Catch by Month Feb	Mar	Apr	May	Jun	Jul	Total Catch
1988+	18	1	—	3	—	—	3	14	5	0	22
1989	36	0	34	1	—	—	50	18	3	0	71
1990	21	6	64	3	—	—	37	51	6	0	94
1991	20	0	223	2	—	—	51	170	24	0	245
1992	36	1	251	8	—	134	133	28	1	0	296
1993	162	8	260	67	—	87	379	14	12	5	497
1994	9	1	77	3	—	4	61	22	3	0	90
1995	49	53	—	49	2	37	71	33	7	1	151
Total	351	70	909	136	2	262	785	350	61	6	1,466*

Notes: Area I. South Suisun Bay/Lower San Joaquin River; sampling station code: 1-500.
Area II. North Suisun Bay/Montezuma Slough; sampling station code: 60-600
Area III. Sacramento River; sampling code: 70-800.
Area IV. Lower San Joaquin River/Lower Mokelumne River; sampling Station code: 90-900.
—: Not sampled
0: No catch.
*: Database of 1988–1994 obtained from Wang (1995, an unpublished IEP Technical Report 43).
Database of 1995 obtained by examining CDFG fish E & L samples collected in 1995 (this study).
+: Critical water-year types: 1988, 1990, 1991, and 1992.
Dry water-year types: 1989, 1994.
Wet water-year types: 1993, 1995.
(Source of information: CDFG Summer Townet Survey, 1959–1995).

Appendix Table A5.—Splittail early life stages observed in the North Bay Aqueduct Project
(Samples collected by CDFG for DWR), 1995–2004

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	
1995	02/15/95	723	1	7.6	
	02/23/95	726	1	7.7	
	03/03/95	723	1	7.3	
		724	1	8.7	
	03/11/95	723	1	8.8	
	03/13/95	718	1	9.3	
	03/15/95	723	2	10.3	
				10.6	
	03/19/95	722	1	10.2	
	03/21/95	718	2	9.6	
				10.8	
	03/29/95	718	1	10.5	
	04/02/95	718	2	9.6	
				10.8	
	04/04/95	718	1	14.2	
		723	3	7.1	
				7.3	
				7.9	
		724	1	7.0	
		726	1	7.3	
	04/06/95	718	1	14.3	
	04/08/95	723	1	7.8	
		724	2	7.8	
				7.9	
		726	3	7.2	
				7.5	
				8.3	
	04/16/95	723	3	6.4	
				7.5	
				7.9	
	04/20/95	723	3	7.0	
				7.6	
				8.0	
		724	2	7.5	
				8.3	
		726	2	7.4	
				7.9	
	05/06/95	723	2	7.9	
				70.3	(juv)
	05/10/95	720A	1	6.6	
	05/18/95	726	1	7.7	
	05/26/95	723	1	8.4	
	06/03/95	720A	1	—	
	06/07/95	718	1	21.0	(juv)
1995 (cont)	06/07/95 (cont)	720	1	—	
		721	2	—	
				—	
	06/11/95	723	1	41.0	(juv)
	06/17/95	720	1	7.0	
		720A	1	—	
		721	1	6.3	
	06/19/95	723	1	8.0	
	06/27/95	718	2	—	
				—	
	06/29/95	718	1	—	
	07/01/95	718	1	—	
		721	1	6.0	
	07/05/95	720	2	6.8	
				7.0	
	07/09/95	720	1	7.0	
	07/11/95	720	1	6.5	
		721	1	—	
	07/13/95	726	1	8.0	
	07/15/95	718	1	—	
1996	02/26/96	723	8	6.9	
				7.0	
				7.0	
				7.0	
				7.1	
				7.3	
				7.3	
				7.6	
	03/01/96	723	1	8.1	
	03/01/96	726	1	7.5	
	03/05/96	724	1	7.3	
		726	5	7.2	
				7.2	
				7.2	
				7.4	
				7.5	
	03/09/96	726	1	7.5	
	03/17/96	726	1	8.2	
	03/21/96	723	1	—	
	03/25/96	723	10	—	
				—	
				—	
				—	
				—	
				—	

Appendix Table A5.—Splittail early life stages observed in the North Bay Aqueduct Project

(Samples collected by CDFG for DWR), 1995–2004 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	
1996 (cont)	03/25/96 (cont)	10 (cont)		—	
				—	
				—	
				—	
	04/02/96	724	1	7.8	
		726	1	—	
	05/04/96	718	1	—	
	05/06/96	718	1	29.6	(juv)
	05/10/96	718	1	6.7	
		721	1	5.9	
		723	2	8.0	
				—	
		727	1	7.0	
	05/12/96	720	1	6.0	
	05/14/96	727	1	7.0	
	05/16/96	720	1	7.6	
		727	1	7.0	
	05/28/96	723	1	6.4	
	06/01/96	723	1	7.7	
		724	1	7.7	
		726	5	7.5	
				7.5	
				7.7	
				7.9	
				8.0	
	06/09/96	718	1	6.7	
	06/13/96	720	1	7.4	
		721	1	7.1	
	06/17/96	718	1	78.8	(juv)
	06/23/96	718	2	—	
				—	
	06/25/96	718	1	20.5	(juv)
		722	1	6.4	
		726	1	7.1	
	07/11/96	721	1	7.2	
1997	05/30/97	722	1	27.0	(juv)
	06/03/97	724	1	8.7	
		726	2	—	
				—	
1998	03/27/98	723	33	7.1	
				7.1	
				7.2	
				7.2	
				7.3	
				7.3	
				7.4	
1998 (cont)	03/27/98 (cont)	723 (cont)		7.4	
				7.4	
				7.5	
				7.5	
				7.5	
				7.6	
				7.6	
				7.6	
				7.7	
				7.7	
				7.7	
				7.7	
				7.7	
				7.7	
				7.7	
				7.8	
				7.8	
				7.8	
				7.8	
				7.9	
				7.9	
				8.0	
				8.0	
				8.0	
				8.2	
				8.3	
		724	3	7.6	
				7.7	
				8.0	
		726	6	6.8	
				7.2	
				7.7	
				7.7	
				7.7	
				7.7	
	03/31/98	722	1	7.1	
	04/04/98	722	1	7.2	
	04/08/98	723	1	7.3	
	04/10/98	718	1	11.3	
	04/16/98	723	1	7.7	
	04/22/98	718	1	10.0	
	05/02/98	720	1	7.1	
	05/06/98	722	1	6.5	
	05/08/98	718	1	7.2	
	05/20/98	727	1	33.7	(juv)
	06/11/98	723	1	8.1	

Appendix Table A5.—Splittail early life stages observed in the North Bay Aqueduct Project
(Samples collected by CDFG for DWR), 1995–2004 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)		Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1998 (cont)	06/11/98 (cont)	724	6	6.8		2000 (cont)	03/14/00 (cont)	723	1	7.2
				7.2				724	2	7.6
				7.3						7.8
				7.5				726	5	7.5
				7.9						7.5
				8.5						7.5
		726	2	5.7						7.6
				6.5						7.7
	06/15/98	724	2	7.5			03/18/00	718	1	8.0
				9.4				722	5	7.6
		726	4	7.2						7.7
				8.2						8.0
				8.3						8.0
				9.0						8.0
	06/19/98	720	1	6.7				723	9	7.3
		722	1	10.9						7.5
		723	5	8.3						7.5
				8.3						7.6
				9.5						7.6
				10.0						7.7
				11.0						7.7
	06/21/98	721	1	42.5	(juv)					8.1
	06/29/98	718	2	6.0						8.3
				10.2				724	11	7.1
	07/01/98	721	1	37.5	(juv)					7.2
	07/09/98	727	1	28.5	(juv)					7.5
	07/11/98	718	2	29.2	(juv)					7.5
				32.1	(juv)					7.5
		721	1	30.0	(juv)					7.5
	07/17/98	721	2	29.6	(juv)					7.6
				33.0	(juv)					7.6
1999	—	—	0	—						7.6
2000	03/10/00	723	4	7.2						7.7
				7.4						8.0
				7.4				726	1	8.0
				7.5				727	2	6.8
	03/14/00	722	9	7.6						7.5
				7.7			03/22/00	718	3	6.5
				7.8						7.7
				7.8						7.7
				8.0				723	1	8.0
				8.0				724	2	7.1
				8.0						7.4
				8.0				726	1	7.8
				8.0			03/24/00	718	1	8.5

Appendix Table A5.—Splittail early life stages observed in the North Bay Aqueduct Project
(Samples collected by CDFG for DWR), 1995–2004 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)
2000 (cont)	03/26/00	720	1	8.2
		723	4	8.7
				9.5
				10.2
				10.8
	03/28/00	718	4	7.6
				8.6
				9.1
				9.7
		720	2	7.5
				7.9
		727	1	8.0
	04/01/00	721	1	8.0
	04/09/00	720	2	10.0
				10.5
		721	2	10.5
				10.7
		724	2	10.5
				10.7
	04/22/00	723	1	15.5 (juv)
	04/25/00	718	1	20.6 (juv)
	04/27/00	722	1	22.0 (juv)
	04/29/00	718	1	20.0 (juv)
	05/01/00	723	1	15.5 (juv)
	05/03/00	718	1	7.0
	05/05/00	726	1	8.8
	05/09/00	722	1	31.0 (juv)
		726	1	7.7
	05/19/00	718	2	9.6
				9.7
	05/27/00	721	1	53.0 (juv)
	05/30/00	722	1	7.0
	05/31/00	721	2	34.8 (juv)
				45.0 (juv)
	06/02/00	722	2	7.5
				7.5
	06/12/00	720	1	6.8
		721	1	52.5 (juv)
	07/05/00	727	1	68.0 (juv)
2001	04/13/01	723	1	7.4
	04/21/01	724	1	7.6
	05/04/01	724	1	29.7 (juv)
	05/07/01	718	1	7.0
		727	1	7.3
2001 (cont)	05/11/01	727	1	7.3
	05/15/01	720	6	6.5
				6.5
				6.7
				6.8
				6.9
				7.0
		721	1	7.0
		727	7	6.0
				6.1
				6.1
				6.4
				6.6
				6.8
				6.8
	05/17/01	720	6	5.5
				5.7
				5.7
				6.0
				6.2
				7.5
	05/17/01 (cont)	727	2	6.8
				7.0
	05/19/01	718	1	7.7
		721	1	7.3
	05/21/01	720	1	8.3
		721	1	7.3
	05/25/01	720	1	7.0
	05/31/01	721	2	7.4
				7.5
	06/02/01	720	1	6.5
		727	1	6.2
	06/18/01	721	1	31.7 (juv)
2002	04/02/02	724	1	7.5
		726	1	8.1
	04/24/02	726	1	7.3
	05/22/02	726	10	Ranged 7.3 to 8.3
	05/28/02	721	1	6.8
	05/30/02	721	1	11.2
	06/03/02	721	2	6.7
				7.2
2003	03/18/03	726	1	7.8
	04/03/03	726	1	7.5
	04/11/03	724	1	7.5

Appendix Table A5.—Splittail early life stages observed in the North Bay Aqueduct Project

(Samples collected by CDFG for DWR), 1995–2004 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	Year	Date	Sampling Station	Number Caught	Size (mm in TL)	
2003 (cont)	05/01/03	723	1	7.5	2003 (cont)	05/17/03 (cont)	726		9.2	
	05/01/03	726	3	7.5		05/21/03	722	1	6.6	
				7.5			723	8	7.7	
				7.6					8.3	
	05/09/03	724	5	7.3					8.8	
				7.5					9.0	
				7.5					9.3	
				7.5					9.4	
				7.6					10.0	
	05/13/03	726	6	7.4					10.0	
				7.5			726	6	7.2	
				7.6					8.2	
				7.7					8.8	
				8.3					9.2	
				8.3					9.5	
	05/15/03	718	1	7.7					11.0	
	05/17/03	723	9	7.5			727	1	6.5	
				7.9		05/23/03	720	1	6.5	
				8.0			721	2	6.5	
				8.0					6.7	
				8.0		05/25/03	718	1	5.0	
				8.1			720	1	11.3	
				8.2			723	3	9.5	
				8.3					10.3	
				8.4					11.2	
		724	11	7.2			726	3	11.5	
				7.4					11.7	
				7.4					13.8	
				7.8		05/29/03	720	1	40.0	(juv)
				7.8			723	1	11.8	
				8.0		05/31/03	718	1	6.7	
				8.0			720	1	41.5	(juv)
				8.1		06/02/03	723	4	15.0	(juv)
				8.2					15.0	(juv)
				8.5					17.0	(juv)
				8.6					17.3	(juv)
		726	10	7.9		06/08/03	718	2	16.0	(juv)
				8.0					21.0	(juv)
				8.2			720	3	7.0	
				8.3					19.0	(juv)
				8.3					23.5	(juv)
				8.5			721	11	16.5	(juv)
				8.5					18.0	(juv)
				8.7					18.0	(juv)
				8.8					18.3	(juv)

Appendix Table A5.—Splittail early life stages observed in the North Bay Aqueduct Project
(Samples collected by CDFG for DWR), 1995–2004 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)
2003 (cont)	06/08/03 (cont)	721 (cont)		18.5 (juv)
				20.0 (juv)
				20.5 (juv)
				21.0 (juv)
				21.5 (juv)
				22.0 (juv)
				22.5 (juv)
		727	4	6.0
				20.0 (juv)
				20.5 (juv)
				21.0 (juv)
	06/12/03	721	1	24.8 (juv)
		727	2	22.0 (juv)
				31.0 (juv)
	06/14/03	718	1	7.0
		727	1	6.7
	06/16/03	721	1	32.0 (juv)
	06/22/03	720	1	24.5 (juv)
	06/24/03	727	1	32.0 (juv)
	06/28/03	721	1	26.2 (juv)
	07/02/03	718	2	26.0 (juv)
				34.0 (juv)
	07/05/03	718	1	7.0
		721	1	40.0 (juv)
		720	1	7.0
2004	03/10/04	723	1	8.4
	03/14/04	723	5	6.8
				7.3
				7.4
				7.5
				7.5
		724	4	7.2
				7.6
				7.7
				7.7
		726	1	7.4
	03/18/04	723	5	7.6
				7.6
				7.9
				8.1
				8.1
		724	1	7.3
	03/20/04	718	1	9.0
	03/24/04	718	1	9.8
	03/26/04	723	1	9.7
2004 (cont)	03/25/04 (cont)	724	2	8.0
				9.3
		726	1	9.8
	03/30/04	722	1	7.5
	04/01/04	720	1	10.4
	04/03/04	718	2	8.0
				9.5
		727	2	11.0
				11.1
	04/05/04	727	1	13.1
	04/07/04	722	1	15.0 (juv)
	04/15/04	718	1	21.5 (juv)
		722	1	22.0 (juv)
		723	2	15.0 (juv)
				19.2 (juv)
	04/17/04	727	1	17.2 (juv)
	04/19/04	723	1	24.8 (juv)
	04/29/04	721	1	26.5 (juv)
	05/05/04	718	1	31.3 (juv)
		720	1	31.0 (juv)
		721	18	29.0 (juv)
				30.0 (juv)
				30.0 (juv)
				30.5 (juv)
				31.0 (juv)
				31.0 (juv)
				31.0 (juv)
				31.0 (juv)
				31.0 (juv)
				31.0 (juv)
				32.0 (juv)
				32.0 (juv)
				32.0 (juv)
				32.5 (juv)
				32.5 (juv)
				32.5 (juv)
				32.5 (juv)
				34.0 (juv)
		727	11	28.0 (juv)
				30.0 (juv)
				30.0 (juv)
				31.0 (juv)
				31.5 (juv)
				33.0 (juv)
				33.0 (juv)

Appendix Table A5.—Splittail early life stages observed in the North Bay Aqueduct Project
(Samples collected by CDFG for DWR), 1995–2004 – continued

Year	Date	Sampling Station	Number Caught	Size (mm in TL)		Year	Date	Sampling Station	Number Caught	Size (mm in TL)
2004 (cont)	05/05/04 (cont)	727 (cont)		33.0	(juv)					
				33.5	(juv)					
				33.5	(juv)					
				34.0	(juv)					
	05/09/04	723	1	7.6						
	05/11/04	721	1	32.5	(juv)					
	05/17/04	720	6	29.0	(juv)					
				29.5	(juv)					
				30.0	(juv)					
				31.0	(juv)					
				32.0	(juv)					
				32.5	(juv)					
		721	1	31.0	(juv)					
	05/19/04	720	1	32.5	(juv)					
	05/27/04	727	1	30.0	(juv)					

Summary Table of Appendix Table A5

Year	Catch by Month						Total Catch
	February	March	April	May	June	July	
1995	2	10	25	5	13	9	64
1996	8	21	2	12	16	1	60
1997	0	0	0	1	3	0	4
1998	0	43	5	4	25	7	84
1999	0	0	0	0	0	0	0
2000	0	70	11	11	4	1	97
2001	0	0	2	33	3	0	38
2002	0	0	3	13	2	0	18
2003	0	1	2	77	33	5	118
2004	0	24	14	42	0	0	80
Total	10	169	64	198	99	23	563*

Notes: * — Database obtained by examining fish E & L samples collected in the North Bay Aqueduct in 1995–2004 (CDFG collected for DWR, this study).

Appendix Table A6.—Splittail early life stages observed in the Central and South Delta
(Samples collected by DWR), 1991–1995

Year	Date	Sampling Station	Number Caught	Size (mm in TL)	Year	Date	Sampling Station	Number Caught	Size (mm in TL)
1991	05/28/91	92	1	7.4	1993 (cont)	04/10/93 (cont)	931	2	7.4
	05/29/91	92	1	6.8					7.7
	05/31/91	94	1	7.5			934	1	7.6
	06/03/91	98	2	7.7		06/03/93	98	1	6.3
				8.0		06/05/93	93	1	7.4
	06/05/91	94	1	7.3		06/15/93	92	2	6.8
		96	1	7.5					7.2
		98	1	8.0	1994	04/07/94	94	1	7.5
	06/10/91	92	1	6.9			98	1	7.5
		95	1	6.8		04/21/94	96	1	8.0
	06/12/91	96	1	7.5		04/22/94	930	1	7.3
		98	1	11.8		05/10/94	930	1	6.9
	06/17/91	94	1	6.7		05/22/94	930	1	6.8
1992	03/27/92	94	1	7.4	1995	04/24/95	49	1	Larva
	04/01/92	94	1	7.0			91	1	Larva
	04/04/92	93	1	6.8			92	1	Larva
	04/06/92	934	1	7.6			94	1	Larva
	04/08/92	94	2	7.0			98	1	Larva
				7.1		04/28/95	91	1	Larva
	04/16/92	96	1	7.0			98	2	Prolarvae
		930	2	6.8		05/03/95	930	1	Larva
				7.3		05/08/95	91	1	Larva
		934	1	7.6			92	2	Larvae
1993	03/23/93	934	1	8.0			94	2	Larvae
	03/27/93	934	2	7.4			96	1	Larva
				8.0		05/12/95	92	1	Larva
	04/04/93	98	2	6.4			94	1	Juvenile
				8.0		05/19/95	94	1	Larva
	04/06/93	93	1	7.1		05/26/95	91	1	Larva
		98	1	6.5			95	1	Larva
		930	2	7.5		06/01/95	98	1	Juvenile
				7.7			931	1	Larva
	04/08/93	930	1	7.6		06/19/95	91	1	Larva
		934	1	7.4			92	1	Prolarva
	04/10/93	98	1	6.6		06/27/95	98	1	Juvenile

Note: Database obtained from Spaar (1992; 1993), Spaar and Wadsworth (1994), and Wadsworth (1996)

Summary Table of Appendix Table A6

Year	Catch by Month					Total Catch
	March	April	May	June	July	
1991	0	3	0	10	0	13
1992	1	9	0	0	0	10
1993	3	12	0	4	0	19
1994	0	4	2	0	0	6
1995	0	8	12	5	0	25
Total	4	36	14	19	0	73*

Appendix Table A7.—List of Reference Specimens for Species Accounts

Goldfish:

1.. Lodi Lake and Putah Creek—collected by Andy Rockriver, 1997–1998.

2. Putah Creek—collected by UCD (Scott Matern, Michael Marchetti), 1997–1998.

3. Fish E & L sampling in Delta—collected by CDFG, 1989–1993.

4. Fish E & L sampling in the NBA—collected by CDFG, 1995–2004.

5. Suisun Marsh Fish E & L sampling—collected by UCD (Scott Matern), 1997.

6. Shallow Water Survey (SWS)—collected by CDFG, 1998.

7. Lake Berryessa—collected by Johnson Wang, 1982–1985.

8. Coyote Creek—collected by Johnson Wang, 1981.

9. Diablo Creek golf course pond—collected by Johnson Wang, 1980–1981.

10. TFCF intake canal and abandoned intake canal—collected by Reclamation, 1998–2004.

11. IEP Technical Report 9 (Wang, 1986).

Red shiner:

1. Putah Creek—collected by Scott Matern, Andy Rockriver and Michael Marchetti, 1987–1988.

2. Fish E & L sampling in NBA—collected by CDFG, 1995–2003.

3. Central and South Delta—collected by CDFG, DWR, and Reclamation 1991–2004.

4. Sacramento River (near Colusa and Knights Landing)—collected by USFWS, 2002–2004.

5. Sutter Bypass fish sampling—collected by CDFG, 1996 and 1998.

6. TFCF fish laboratory (Brood stock from Sacramento River)—collected by USFWS and Reclamation, 2003–2004.

7. South Delta fish E & L sampling—collected by DWR, 2000.

8. South Delta Barrier fish E & L sampling—collected by CDFG (Mike Healey), 1998 and 2001.

9. Fish E & L sampling at the TFCF intake canal—collected by Reclamation (Steve Hiebert) in 1991–1992 and (Scott Siegfried) in 1994.

10. Fish E & L sampling at Millerton Lake—collected by the National Environmental Services, Inc., 1983–1998.

11. IEP Technical Report 9 (Wang, 1986).

Appendix Table A7.—List of Reference Specimens for Species Accounts – continued

Common carp:

1. Backwater of the TFCF intake canal and abandoned intake canal—collected by Reclamation, 1998–2004.
2. Cosumnes River Preserve—collected by Reclamation, 2003–2004.
3. Lodi Lake, Cosumnes River Preserve, and Putah Creek—collected by Andy Rockriver, 1997–1998.
4. Putah Creek—collected by Michael Marchetti, 1997–1998.
5. Fish E & L sampling in NBA—collected by CDFG, 1995–2003.
6. Fish E & L sampling in Suisun Marsh—collected by the UCD, Scott Matern and Robert Schroeter, 1995–2002.
7. Fish E & L sampling in the Delta—collected by CDFG, 1988–1995.
8. 20 mm fish survey in Napa River—collected by CDFG (Michael Dege), 1995–2003.
9. Fish E & L sampling in the Central and South Delta—collected by DWR (Stephani Spaar and Katey Wadsworth), 1991–1995.
10. Reclamation/ Red Bluff Project fish E & L sampling—collected by Reclamation, 1998.
11. Fish E & L sampling at entrapment zone of the Sacramento-San Joaquin estuary—collected by Bill Bennett, 1998.
12. Shallow water/flooded island study—collected by DWR (Lenny Grimaldo), 1998–1999.
13. Yolo Bypass zooplankton sampling—collected by DWR (Lenny Grimaldo), 1999.
14. Sutter Bypass Fish E & L sampling and 20 mm fish survey—collected by CDFG, 1998.
15. SWS sampling—collected by CDFG, 1997–1998.
16. RTM (Real Time Monitoring) fish sampling—collected by CDFG, 1999.
17. 20 mm fish survey—collected by CDFG, 2001.
18. South Delta Barrier fish E and L sampling: collected by CDFG (Mike Healey) 2000–2001.
19. Mud Creek—collected by Michael Marchetti, 2002–2003.
20. Feather River—collected by Alicia Seesholtz, 2003.
21. IEP Technical Report 9 (Wang, 1986).

Appendix Table A7.—List of Reference Specimens for Species Accounts – continued

California roach:

1. Mt. Diablo Creek—collected by Reclamation, 2003.
2. Walnut Creek and San Ramon Creek—collected by Johnson Wang, 1979–1985.
3. Napa River—collected by Johnson Wang, 1979–1995.
4. Cottonwood Creek (a tributary of the Sacramento River)—collected by Reclamation (Scott Siegfried, Don Faris) and Johnson Wang, 1997.
5. Suisun Creek—collected by Johnson Wang, 1995–1999.
6. Stony Creek—collected by Reclamation, 2003.
7. Mud Creek—collected by Michael Marchetti, 2002–2003.
8. Clear Creek—collected by Reclamation, 2004.
9. Feather River—collected by Alicia Seesholtz, 2004.
10. Reclamation/ Sacramento River Red Bluff Project—collected by Reclamation, 1998.
11. Sonoma Creek, San Ramon Creek, and Napa River—collected by Johnson Wang 1979–1985.
12. Lagunitas Creek—collected by Johnson Wang, 1982–1985.
13. IEP Technical Report 9 (Wang, 1986).
14. Laboratory reared specimens—eggs and larvae by Reclamation, 2003.

Hitch:

1. Pine Creek (a tributary of the Walnut Creek)—collected by Johnson Wang, 1980–1985, 1995.
2. Arroyo Mocho Creek—collected by Reclamation (Scott Siegfried), 1995–1997.
3. Putah Creek—collected by Michael Marchetti, 1997–1998.
4. Fish E & L sampling in Lodi Lake, Cosumnes River Preserve, and Putah Creek—collected by Andy Rockriver, 1996–1998.
5. Mud Creek—collected by Michael Marchetti and Gabriel Kopp, 2002–2003.
6. Walnut Creek—collected by Reclamation, 2003–2004.
7. Fine Gold Creek (a tributary of the Millerton Lake)—collected by Johnson Wang, 1980–1991.
8. TFCF—collected by Reclamation diversion workers, 1998–2004.
9. Big Chico Creek, Little Chico Creek, and Mud Creek—collected by Gabriel Kopp, 2004.
10. SWS sampling—-collected by CDFG, 1998.
11. Fish E and L sampling in the Suisun Marsh—collected by UCD (Scott Matern), 1997.

Appendix Table A7.—List of Reference Specimens for Species Accounts – continued

12. New Melones Reservoir—collected by Reclamation, 2003.
13. Cosumnes River Preserve—collected by Patrick Crain, 1999–2001.
14. Cosumnes River Preserve—collected by Reclamation, 2003.
15. Lake Hennessey—collected by Johnson Wang, 1984.
16. IEP Technical Report 9 (Wang, 1986).

Hardhead:

1. Millerton Lake and San Joaquin River (below and above the Kerckhoff Dam)—collected by Ecological Analysts, Inc., 1979–1982; Johnson Wang, 1983–1999.
2. Napa River (below Yountville)—collected by Johnson Wang, 1980 and 1984.
3. Reclamation Red Bluff Project in the Sacramento River—collected by Reclamation biologists, 1995–2000.
4. Stony Creek (a tributary of the Sacramento River)—collected by Reclamation, 2003.
5. Mud Creek (a tributary of the Sacramento River)—collected by Michael Marchetti, 2002–2003.
6. Clear Creek—collected by Reclamation, 2004.
7. Feather River—collected by Alicia Seesholtz, 2003.
8. IEP Technical Report 9 (Wang, 1986).

Golden shiner:

1. TFCF intake canal and abandoned intake canal—collected by Reclamation, 2002–2004.
2. Lagoon Valley Regional Park pond—collected by Reclamation (Brent Bridges) and Johnson Wang 1998–2002.
3. Fish E & L sampling in Delta—collected by CDFG, 1988–1995.
4. Fish E & L sampling in NBA—collected by CDFG, 1995–2003.
5. Fish E & L sampling in Cosumnes River Preserve, Lodi Lake, and Putah Creek—collected by Andy Rockriver, 1997–1998.
6. Fish E & L sampling in Putah Creek—collected by Michael Marchetti, 1997–1998.
7. Fish specimens from Sutter Bypass—collected by CDFG, 1996, 1998–1999.
8. Delta shallow water/flooded island fisheries study—collected by DWR (Lenny Grimaldo), 1998–1999.
9. SWS sampling—collected by CDFG, 1997.
10. TFCF fish E & L sampling—collected by Reclamation (Steve Hiebert) in 1991–1992 and (Scott Siegfried) 1994.

Appendix Table A7.—List of Reference Specimens for Species Accounts – continued

11. Fish E & L sampling at South Delta barrier—collected by CDFG (Mike Healey), 1996–2001.
12. Quality control of larval fish identification on 20 mm cyprinids and centrarchids—collected by CDFG, 1999.
13. Fish E & L sampling in Central and South Delta—collected by DWR (Stephani Spaar and Katey Wadsworth), 1991–1995.
14. Cosumnes River Preserve light trap sampling—collected by Reclamation, 2003–2004.
15. Fish E & L sampling at the TFCF intake canal—collected by Reclamation (Steve Hiebert) ,1991–1992, and (Scott Siegfried), 1994.
16. Rodeo Lagoon and Rodeo Lake—collected by Johnson Wang and Thomas Keegan, 1982–1985.
17. IEP Technical Report 9 (Wang, 1986).

Sacramento blackfish:

1. Lagoon Valley Regional Park pond—collected by Johnson Wang, 1998–2003; by Reclamation, 2002–2003.
2. Cosumnes River Preserve light trap sampling—collected by Andy Rockriver, 1997–1998; by Reclamation, 2003–2004.
3. TFCF intake canal and abandoned intake canal light trap sampling—collected by Reclamation, 2003–2004.
4. Sonoma Mountain Zen Center's pond (fine mesh beach seine)—collected by Johnson Wang, 1981–1982.
5. Putah Creek fish E & L sampling—collected by Michael Marchetti, 1997–1998.
6. Sonoma Creek (near Glen Ellen)—collected by Johnson Wang, 1980–1985.
7. Fish E & L sampling at the TFCF intake canal—collected by Reclamation 2002–2004.
8. Fish E & L sampling in Delta—collected by CDFG, 1992–1995.
9. Fish E & L sampling in Central and South Delta—collected by DWR (Stephani Spaar and Katie Wadsworth), 1995.
10. Fish E & L sampling at South Delta Barrier—-collected by CDFG (Mike Healey), 1996–2001.
11. Fish E & L sampling in entrapment zone—collected by Bill Bennett, 1998.
12. Fish E & L sampling in Sutter Bypass, and quality control on identification of 20 mm fish survey—collected by the CDFG, 1998.
13. SWS sampling—collected by CDFG, 1997–1998.

14. Fish E & L sampling in Clifton Court Forebay—collected by DWR (Lenny Grimaldo), 1999.
15. Shallow water/ flooded island fisheries study—collected by DWR (Lenny Grimaldo), 1998–1999.
16. Fish E & L sampling in NBA—collected by CDFG, 1993–2003.
17. Yolo Bypass zooplankton study—collected by DWR (Lenny Grimaldo), 1999.
18. FCCL (from a tomato tank)—collected by Reclamation, 2003.
19. New Melones Reservoir fine mesh sampling—collected by Reclamation, 2003.
20. Suisun Marsh fish E & L sampling—collected by UCD (Scott Matern), 1997.
21. San Luis Reservoir fine mesh sampling—collected by Reclamation (Lloyd Hess, Catherine Karp) and Johnson Wang, 1995.
22. At Lake Hennessey (fine mesh beach seine)—collected by Johnson Wang, 1984.
23. IEP Technical Report 9 (Wang, 1986.)

Fathead minnow:

1. Lagoon Valley Regional Park pond—collected by Reclamation and Johnson Wang, 1998–2002.
2. Lagoon Valley Regional Park pond—collected by Reclamation, 2002–2003.
3. TFCF fish laboratory—Live fish collected from Lagoon Valley Regional Park pond, and reared in the TFCF fish laboratory by Reclamation, 2003.
4. Fish E & L sampling program in Delta—collected by the CDFG, 1988–1955.
5. Fish E & L sampling program in NBA—collected by CDFG, 1995–2003.
6. Fish E & L sampling at Putah Creek—collected by Michael Marchetti and Andy Rockriver, 1997–1998.
7. Quality control on identification of osmerid and cyprinid E & L specimens from Sacramento River—collected by CDFG (Randy Baxter; 36 sets of sample total), 1995.
8. Shallow water/flooded island fishery sampling—collected by DWR (Lenny Grimaldo), 1998–1999.
9. Fish E & L sampling in Central and South Delta—collected by DWR (Stephani Spaar and Katie Wadsworth), 1994–1995.
10. Fish E & L sampling in Central and South Delta—collected by DWR, 1998.

Appendix Table A7.—List of Reference Specimens for Species Accounts – continued

Splittail:

1. Specimens from the confluence of the American River and Sacramento River—collected by Johnson Wang, 1980–1985.

2. Fish E & L sampling in the vicinity of the Pittsburg and Contra Costa power plants—collected by the Ecological Analysts, Inc. 1978–1982.

3. Fish E & L sampling in Delta—collected by CDFG, 1988–1995.

4. Fish E & L sampling in NBA—collected by CDFG, 1995–2003.

5. Fish E & L specimens from Suisun Marsh—collected by UCD (Scott Matern and Robert Schroeter), 1995–2002.

6. Fish (20 mm fish survey) sampling in Napa River—collected by the CDFG (Michael Dege), 1995–2004.

7. Fish E & L from Central and South Delta—collected by DWR (Stephani Spaar and Katie Wadsworth), 1991–1995.

8. Fish E and L sampling at South Delta barrier—collected by CDFG (Mike Healey), 1998.

9. Fish E & L sampling in Putah Creek—collected by Michael Marchetti and Andy Rockriver, 1987–1988.

10. Fish E & L sampling in Cosumnes River Preserve—collected by Andy Rockriver, 1997–1998.

11. Fish identification and quality control of larval fish specimens collected at Sutter Bypass (total 52 sets of specimen)—collected by CDFG, 1996.

12. Larval fish specimens from Sutter Bypass—collected by CDFG, 1997–1998.

13. Larval fish specimens from Cosumnes River Preserve—collected by Andy Rockriver, 1997–1998; Reclamation, 2003–2004.

14. Larval fish specimens from the shallow water/flooded island study—collected by DWR (Lenny Grimaldo), 1998–1999.

15. Juvenile fish specimens from beach seining program—collected by DWR (Lenny Grimaldo), 1999.

16. Larval fish specimens from Sutter Bypass and Yolo Bypass zooplankton sampling program—collected by DWR (Lenny Grimaldo), 1999.

17. Juvenile fish specimens from 20 mm fish survey at the Delta, Liberty Island, Middle River and Mossdale—collected by CDFG, 1995.

18. SWS sampling—collected by CDFG, 1997–1998.

19. Fish E and L sampling in Central and South Delta—collected by DWR, 1998.

Appendix Table A7.—List of Reference Specimens for Species Accounts – continued

20. Identification and quality control on osmerid and cyprinid E and L specimens (total 36 sets of specimen from Sacramento River)—collected by CDFG (Randy Baxter), 1995.
21. TFCF fish E & L specimens—collected by Reclamation, 1991–2004.
22. Fish specimens from Agricultural Drains Project—collected by DWR (Tracy Woods), 1993–1995.
23. Fish E & L sampling in the vicinity of Clifton Court Forebay and South Delta—collected by DWR (Fred Feyrer), 1990–1995.
24. 20 mm fish sampling in Delta (including Napa River)—collected by CDFG, 2001.
25. Larval fish specimens from Feather River—collected by Alicia Seesholtz, 2003.
26. Light trap fish E & L specimens from the TFCF intake canal—collected by Reclamation, 2004.
27. Larval fish specimens from Cosumnes River Preserve—collected by Patrick Crain, 1999 and 2001.
28. Early life stages of fish from Sacramento River channel and Yolo Bypass—collected by DWR (Ted Sommer), 1999–2002.
29. Sampling of larval and juvenile fishes distribution in San Francisco Estuary—collected by CDFG (Michael Dege), 1995–2001.
30. Laboratory reared splittail eggs and larvae images—obtained from Swee Teh, 2002.
31. Laboratory reared splittail specimens—obtained from UCD, by Brent Bridges, 1999.
32. Laboratory specimens—eggs and larvae obtained from FCCL (Bradd Baskerville-Bridges) with help from Reclamation (Brent Bridges and Zak Sutphin), 2003–2004.
33. IEP Technical report 43 (Wang, 1995, unpublished).
34. IEP Technical Report 9 (Wang, 1986).

Sacramento pikeminnow :

1. Clear Creek (a tributary of the Sacramento River)—collected by Reclamation, 2004.
2. American River (near Fair Oaks)—collected by Reclamation, 2004.
3. Sacramento River (at the Red Bluff)—collected by Reclamation, 1998.
4. Upper Sacramento River channel (CDFG Fish E & L sampling stations 785-825)—collected by CDFG, 1992–1995.
5. Stony Creek (a tributary of the Sacramento River)—collected by Reclamation, 2003.
6. Cosumnes River Preserve—collected by Patrick Crain, 1999 and 2001.
7. Feather River—collected by Alicia Seesholtz, 2003.
8. Dry Creek (a tributary of the Putah Creek)—collected by Michael Marchetti, 1998.

Appendix Table A7.—List of Reference Specimens for Species Accounts – continued

9. Reclamation/Red Bluff fish E & L sampling—collected by Reclamation, 1998.
10. Capell Creek (a tributary of the Lake Berryessa)—collected by Johnson Wang, 1982–1986.
11. Alameda Creek—collected by Johnson Wang 1980–1981.
12. Upper San Joaquin River above Millerton Lake—collected by National Environmental Services, Inc, 1983–1995.
13. Larval fish from Mud Creek—collected by Michael Marchetti, 2002–2003.
14. Sonoma Creek (near Glen Ellen)—collected by Johnson Wang, 1980–1985.
15. San Ramon Creek (below the spillway)—collected by Johnson Wang, 1979–1982.
16. Napa River (at Yountville Cross)—collected by Johnson Wang 1981–1990.
17. Fish E & L sampling in NBA—collected by CDFG, 1995.
18. IEP Technical Report 9 (Wang, 1986).