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Early Life Stages and Life Histories of Centrarchids in the Sacramento-San Joaquin River Delta System, California

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14. ABSTRACT
The early life stages and life histories of eleven species of centrarchids (family Centrarchidae) currently found in the Sacramento-San Joaquin Delta and its adjacent waters are described. Species accounts provide information on reproductive biology and the development of eggs, larvae, and juvenile stages. Early life history information and ecological status conclude each account along with detailed line drawings and colored photographs portraying developmental traits of eggs and young. Finally, taxonomic characteristics are summarized to distinguish centrarchid prolarvae and postlarvae (genus level) and adult specimens. A dichotomous identification key is presented for the juvenile stages of the eleven species.

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Early Life Stages and Life Histories of Centrarchids in the Sacramento-San Joaquin River Delta System, California

Volume 42

by

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Cover

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EXECUTIVE SUMMARY

Twelve members of the Centrarchidae family, representing four genera, are present in California. The only native centrarchid west of the Rocky Mountains, the Sacramento perch (*Archoplites interruptus*), is also present in California but is extirpated from the Sacramento-San Joaquin River Delta (Delta). The other centrarchid species present in the Delta were introduced from populations in the Eastern United States. These include members of three genera: (1) *Lepomis* spp. (green sunfish [*Lepomis cyanellus*], pumpkinseed [*L. gibbosus*], warmouth [*L. gulosus*], bluegill [*L. macrochirus*], and redear sunfish [*L. microlophus*]); (2) *Micropterus* spp. (redeye bass [*M. coosae*], smallmouth bass [*M. dolomieu*], spotted bass [*M. punctulatus*], and largemouth bass [*M. salmoides*]); and (3) *Pomoxis* spp. (white crappie [*P. annularis*] and black crappie [*P. nigromaculatus*]).

Many centrarchids are valued as sport fishes and panfishes; however, their introduction to the Delta and its tributaries has impacted native fishes. For example, competition with the more aggressive bluegill may have caused the decline of the Sacramento perch. Native cyprinids, such as the California roach (*Hesperoleucus symmetricus*), have also been preyed upon, outcompeted especially in lowland habitats (Moyle, 2002), and some have retreated further up the watershed. Most centrarchids are nest builders with the male parent usually guarding the incubating eggs and larvae. Adult centrarchids are carnivorous, feeding on a diversity of organisms including macroinvertebrates and other fishes. Aggressive behavior, parental techniques, and alterations of the Delta's ecosystem favorable to their life histories, have enabled non-native centrarchids to thrive in the Delta.

INTRODUCTION

Located in the uppermost part of the San Francisco Estuary, the Sacramento-San Joaquin River Delta (Delta) is formed by the confluence of the Sacramento and San Joaquin Rivers. The highly modified Delta currently consists of interconnecting and meandering channels supported by levees and is now mainly maintained as a freshwater ecosystem (Moyle, 2002). At the southern region of the Delta (south Delta), water diversion projects operated by the U. S. Bureau of Reclamation's (Reclamation) Central Valley Project (CVP) and the State of California's State Water Project (SWP) divert the Delta's freshwater mainly for irrigation and urban use. Water pumped out of the Delta supplies most of the drinking water for over 22 million Californians inhabiting southern California and the San Francisco Bay Area (Brown and Moyle, 2005). The CVP's Tracy Fish Collection Facility (CVP/TFCF) and the SWP's Skinner Delta Fish Protective Facility (SWP/SDFPF) are fish salvage facilities located upstream of the pumps (Bill Jones Pumping Plant and Harvey O. Banks Pumping Plant, respectively) responsible for collecting fish (salvage) from the water and transporting them downstream away from the influence of the pumps. Currently, the CVP/TFCF is required to record all fish that are 20 mm or greater, however, with improvements in the facility, identifying fishes smaller than 20 mm can become unavoidable (Wang and Reyes, 2007).

Centrarchids inhabit several types of habitats in the Delta and adjacent waters. Most centrarchids are found in warm waters of streams, ponds, lakes (reservoirs), sloughs, and lower saline waters and in mainly lentic environment. Centrarchids are successful during low flow years when water temperatures are warmer and low velocities aid nesting (Marchetti and Moyle, 2001). They are found in perennial floodplains such as the Sacramento River's Sutter Bypass and Yolo Bypass where small deep ponds with good water transparency generally support visually oriented fishes such as centrarchids (Feyrer, *et al.*, 2004; Feyrer, *et al.*, 2006). In Suisun Marsh, when freshwater conditions prevail, centrarchids temporarily move into the marsh (Matern, *et al.*, 2002). Reservoirs provide a source of refuge for centrarchids for invading upstream reaches of rivers above the reservoirs (Brown and Moyle, 2005). In areas of the Sacramento River drainage where natural flow regimes exist, native fish populations remain healthy and centrarchids are less represented (May and Brown, 2002). However, in the San Joaquin River drainage, flow alterations due to agricultural practices create habitat conditions more favorable to non-native species (Brown and Moyle, 2005). In the south Delta, the most altered region of the system, where rock-reinforced (riprap) banks dominate riparian habitats and only remnants of natural wetland vegetation are present (Feyrer and Healey, 2003), centrarchids have benefited most. The aquatic littoral zone of the south Delta is dominated by Brazilian elodea (*Egaria densa)* (Feyrer and Healey, 2003; Brown and Michniuk, 2007). *E. densa* habitat is very productive but supports fish assemblages dominated by non-native species, including predators and competitors of native fishes (Brown, 2003; Nobriga, *et al.*, 2005; Brown and May 2006). In a comparison of two sampling periods conducted in the 1980s and 2000s, catch per unit effort (CPUE) for total fish and non-native fish was greater in the 2000s compared with the 1980s largely because of increased centrarchid CPUE (Brown and Michniuk, 2007). Submerged non-native aquatic vegetation (Feyrer and Healey, 2003) and degraded, eutrophic habitat in the lower San Joaquin River drainage (Saiki, 1984; Brown, 2000) have contributed to the proliferation of centrarchids in the Delta.

There are twelve species of centrarchids known to California freshwaters, however, the Sacramento perch (*Archoplites interruptus*) is the only native centrarchid found west of the Rocky Mountains (Moyle, 2002). The other eleven species were introduced from eastern states (Moyle, 1976, 2002; Shapovalov, *et al*., 1981; Dill and Cordone, 1997). Centrarchids introduced into California waters include:

Panfishes or sunfish

- Green sunfish (*Lepomis cyanellus*)
- Pumpkinseed (*L. gibbosus*)
- Warmouth (*L. gulosus*)
- Bluegill (*L. macrochirus*)
- Redear sunfish (*L. microlophus*)

Black bass

- Redeye bass (*Micropterus coosae*)
- Smallmouth bass (*M. dolomieu*)
- Spotted bass (*M. punctulatus*)
- Largemouth bas (*M. salmoides*)

Crappies

- White crappie (*Pomoxis annularis*)
- Black crappie (*P. nigromaculatus*)

Four (bluegill, redear sunfish, largemouth bass, and black crappie) of the 12 species are very abundant in the Delta. Redear sunfish, although larger, seem to compete for similar habitat with bluegill especially in the south Delta where they nest side by side at the abandoned intake channel of the CVP/TFCF. Black crappie, a lentic fish, can adapt to lotic environments: from the tidal Suisun Marsh (Matern, *et al.*, 2002) to the still waters of Discovery Bay (B. Wu, 2005, personal communication). Spawning much earlier (mainly April) than other centrarchids, the black crappie nesting behavior is poorly understood. These four centrarchids are numerous at the Old River when an agricultural barrier is installed annually by the Department of Water Resource (DWR) in spring, creating a warm pool ideal for centrarchid reproduction. In the restored Cosumnes floodplain, these species enter as foraging yearlings early in the season and occasionally spawn in the floodplain late in the season (Moyle, *et al.*, 2007). In their native habitats, they are opportunistic floodplain spawners during extended periods of flooding in early summer (Sparks, *et al.*, 1998).

Seven (redeye bass, spotted bass, pumpkinseed, warmouth, green sunfish, smallmouth bass, and white crappie) of the 12 species are less abundant. The redeye bass probably descended from New Melones Reservoir and Cosumnes River basin to the Delta in recent years (Moyle, 2002) and is now the most abundant fish in the long reaches of the Cosumnes River (Moyle, *et al.*, 2003). Redeye bass was not observed in this study and was not included in the species accounts that follow. Spotted bass was widely introduced in foothill streams and reservoirs of the lower Sacramento and San Joaquin Valleys (McKechnie, 1966), such as Millerton Lake (Ecological Analysts sampling). It was not reported in the Delta until the early 2000s when it was collected in the lower Sacramento River by the U.S. Fish and Wildlife Service (USFWS; J. Pedretti, 2007, personal communication). Their method of introduction into the Delta is uncertain. Pumpkinseed were collected from Walnut Creek (Contra Costa County) but were not observed in the Delta. They are present in small numbers at lower San Joaquin River and the south Delta (Moyle, 2002); however, pumpkinseed has not been collected from the CVP/TFCF since 1992. Warmouth, a reclusive sunfish, was introduced to California but the details of its introduction are not clear (Dill and Cordone, 1997; Moyle, 2002). A small number of juvenile and adult warmouth were collected at the CVP/TFCF. Little is known of their life history in the Delta. Green sunfish are seldom seen in the tidal portion of the Delta, rather they are common in the non-tidal creeks, ditches and reservoirs, such as Putah Creek, Walnut Creek, and Napa River. Smallmouth bass prefer cool, lentic environments and are common in the upper Sacramento River (collected from Reclamation’s Red Bluff Research Pumping Plant), upper Putah Creek, Capell Creek, and descending to the Delta occasionally in winter months. White crappie are rare in the Delta tidal waters but are common in the non-tidal, clear water regions of the Sacramento River and some adjacent reservoirs (Moyle, 2002; USFWS unpublished beach seine data, 2000–2006).

The once abundant Sacramento perch has been extirpated from its former habitat throughout the Sacramento-San Joaquin watershed (Moyle, 2002). A few Sacramento perch were observed in the vicinity of Pittsburg and Contra Costa power plants by Ecological Analysts between 1978 and 1982. A commercial fishery had existed in the Central Valley (Rutter, 1908; Skinner, 1962) before populations declined by the end of the 1980s. Sacramento perch has not been recorded in the CVP/TFCF since 1986 and from the SWP/SDFPF since 1979. Moyle (2002) suggested several hypotheses to explain the decline, with habitat loss and heavy competition from non-native centrarchids as major reasons. Sacramento perch can tolerate alkaline waters and has been restocked outside of California (*e.g.*, Nevada and Colorado) and outside its original range in the Delta, with approximately 28 locations in California reported in the 1990s (Moyle, 2002). Introduced species have been found with the Sacramento perch such as green sunfish in Lake Anza in the mid-1980s (Wang, 1986) and the fathead minnow (*Pimephales promelas*) in the Lagoon Valley Regional Park Pond (City of Vacaville) in the 1990s. In the latter example, declining numbers of Sacramento perch and Sacramento blackfish (*Orthodon microlepidotus*) in the early 2000s (Wang and Reyes, 2007) are most likely attributed to competition with fathead minnow. Contra Costa County Mosquito and Vector Control District (CCMVCD) has released cultured Sacramento perch in different private and public ponds as a mosquito control alternative (Miller, 2005). Reintroduction has also taken place in areas such as Wood Duck Slough at Cosumnes River Preserve

(Miller, 2005) and throughout the Delta (M. Dege, 2000–2005, personal communication). However, because of the wide distribution of introduced centrarchids in California watersheds, the future of this native centrarchid is still uncertain.

Centrarchids share similar reproductive behavior and early life characteristics. The majority of centrarchids are nest builders with the male often guarding the eggs and sometimes, as with *Micropterus* spp., the larvae. Eggs, although easily dislodged, are demersal or negatively buoyant and are often observed attached to a variety of substrates. Newly hatched larvae initially do not have pigments, remain motionless on their sides at the bottom, and disperse to nearby vegetation when disturbed. Pigmentations start appearing usually at the late prolarval and early postlarval stages. Juveniles at some point in their development (ontogeny) exhibit vertical bands of pigment. Mabee (1993, 1995) described and developed a phylogeny of centrarchids using melanistic pigment ontogeny.

Members of the centrarchidae family also share similarities in feeding, habitat preference, and value as sport fish. Adult centrarchids in California are both piscivorous and insectivorous. They are valued as sport fishes for all ages, from children learning to catch “panfish” to adults competing for prize money in bass tournaments. They have been widely introduced outside of North America.

METHODOLOGY

Study Area

A detailed map of the study area identifies the Sacramento and San Joaquin Rivers and their tributaries and all adjacent lakes, reservoirs, ponds, and rivers (inset) mentioned in this report (Figure 1). The Delta, located east of the Suisun Bay, is arbitrarily divided into four general regions: west, central, south, and north (not circled in the map). North Delta is the region north of the Mokelumne River. The Delta, consisting of over 1000 km of waterways with a drainage area encompassing approximately 40 percent of California’s surface area (Nichols, *et al.*, 1986), is currently a network of dredged sloughs, channels, and canals connected to the Sacramento and San Joaquin Rivers. It was once an enormous tule marsh dissected by meandering river channels but has been transformed into islands of farmlands protected by earthen levees (Moyle, 2002). The earthen levees were mostly constructed by Chinese laborers in the 19th century and most are protected by riprap. Throughout the Delta, dead-end sloughs and agricultural barriers provide stagnant warm waters while agricultural runoffs create eutrophic environments, especially in the south Delta.

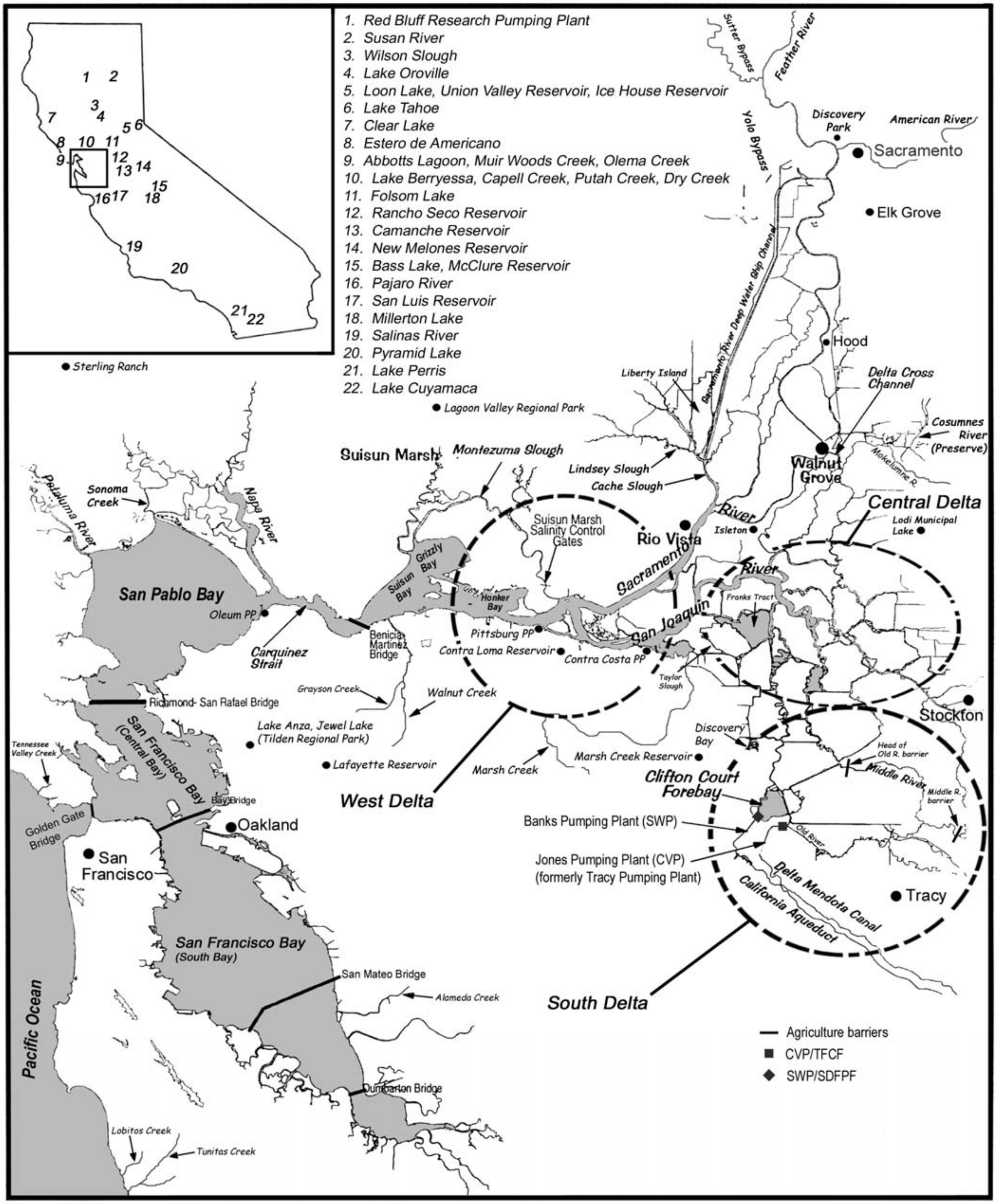


FIGURE 1.—Map of study area.

The Delta, managed mostly as a freshwater ecosystem, relies heavily on freshwater input from the upper elevation coming from snowmelt and reservoir releases. Dams and reservoirs were constructed by the CVP and the SWP during the 1940s to the 1960s to catch most of this water mainly for irrigation and urban uses. Reservoirs in California's lower elevation such as Contra Loma Reservoir are warm and host several species of centrarchids while the upper elevation reservoirs have salmonids but often have centrarchids at the epilimnion and edge waters. Located at the south Delta are the two large water diversion projects (owned by the SWP and CVP) which divert water from the Delta to mostly agricultural lands in the central and southern region of the state. The pumps are capable of reversing the waterflow of the entire Delta by moving water through the Delta rather than downstream towards the San Francisco Bay (Moyle, 2002). Saltwater intrusion from the bay (San Francisco, San Pablo, and Suisun Bays) is an issue for the south Delta pumps especially during dry years.

Specimens Observed

Live eggs, solely collected for this study, were obtained directly from centrarchid nests both from the wild and from the laboratory. Eggs of the redear sunfish, largemouth bass, bluegill, and green sunfish were collected from the levee shoreline of Delta sloughs and reservoirs using small, fine-mesh dip nets and bare hands. Substrates were often collected to minimize destroying the attached eggs. Live eggs of Sacramento perch, green sunfish, and warmouth were obtained through laboratory manipulation (temperature and photoperiod). Additional Sacramento perch eggs were obtained from the CCMVCD. Neither strip spawning nor hormone injections were conducted because centrarchids readily spawn in laboratory environment. Eggs were collected between 2002 and 2005.

Larval specimens collected for this study were obtained using light traps, fine mesh seines, and through the salvage operations at the CVP/TFCF. Postlarval stage and juvenile centrarchids were caught using light traps and fine mesh dip nets. To verify species, these larvae were raised to juvenile stage. Prejuvenile and juvenile life stages were collected from salvage operations at the CVP/TFCF. Additional preserved specimens were obtained from various agencies and their programs such as California Department of Fish and Game (CDFG) Fish Egg and Larval (E & L) Survey and the USFWS unpublished beach seine data, 2000–2006. Descriptions of pigmentation patterns are from wild specimens because pigments from laboratory-raised fishes differ from its wild counterparts. Larvae were euthanized and preserved in 5-percent formalin for reference. Larval and juvenile specimens were collected between 2002 and 2006.

Laboratory Equipment

Adequate magnification is imperative in identifying the early life stages. Because the body structures of the prolarval to postlarval stages of centrarchids are transparent or translucent and low-contrast, transmitted light (bright field) is best for counting myomeres and for observing internal structures and pigmentation. For photography and observation, larvae were anaesthetized using very low concentration of MS-222 (Tricaine Methanesulfonate, Argent Laboratories, Redmond, Washington). We observed and recorded the morphological development of each species and their life stages using Leica MZ8 and MZ7 stereomicroscopes (Leica Microsystems, Inc., Bannockburn, Illinois) with a Polaroid digital camera (Polaroid Corporation, Concord, Massachusetts). Digital images were analyzed using Image Pro© image analysis software reference (Image-Pro© version 6.2, Media Cybernetics, Inc., Bethesda, Maryland) and were archived for future reference. Additional images were obtained using Hitachi and Sony Color Video Printer (Hitachi America, Ltd., Brisbane, California, and Sony Corporation of America, New York, respectively). Drawings and images were of wild specimens whenever possible, however, cultured specimens were used when wild specimens were lacking.

For centrarchid prejuveniles and juveniles, reflected light from above with little or no light from below the specimen (dark field) is necessary for observing structures since they are more opaque except for the fins. For all but the larger postlarvae and juveniles, a magnification range of 10-12.5X is suitable for measuring fish length and structures, however, for detailed observations, a higher magnification range is needed (*e.g.,* 30–50X).

Species Accounts

The species accounts provide spawning information, taxonomic characteristics for each life stage, life histories, and illustrations of development including schematic drawings and digital images. The illustrations and images immediately follow the life history section of each species. Lengths, descriptions, comments, and other information without citation are from this study. Figures 2a and 2b show selected anatomical terms used in the report. 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 buoyant.

LARVAE

Length at 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 fin folds.
Distribution:	Both general geographic distribution and specific range are described.

JUVENILES

Dorsal fin:	The number of spiny rays or hardened rays in Roman numerals; soft rays in Arabic numerals (Example III, 10).
Anal fin:	As for dorsal fin.
Pectoral fin:	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.

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.

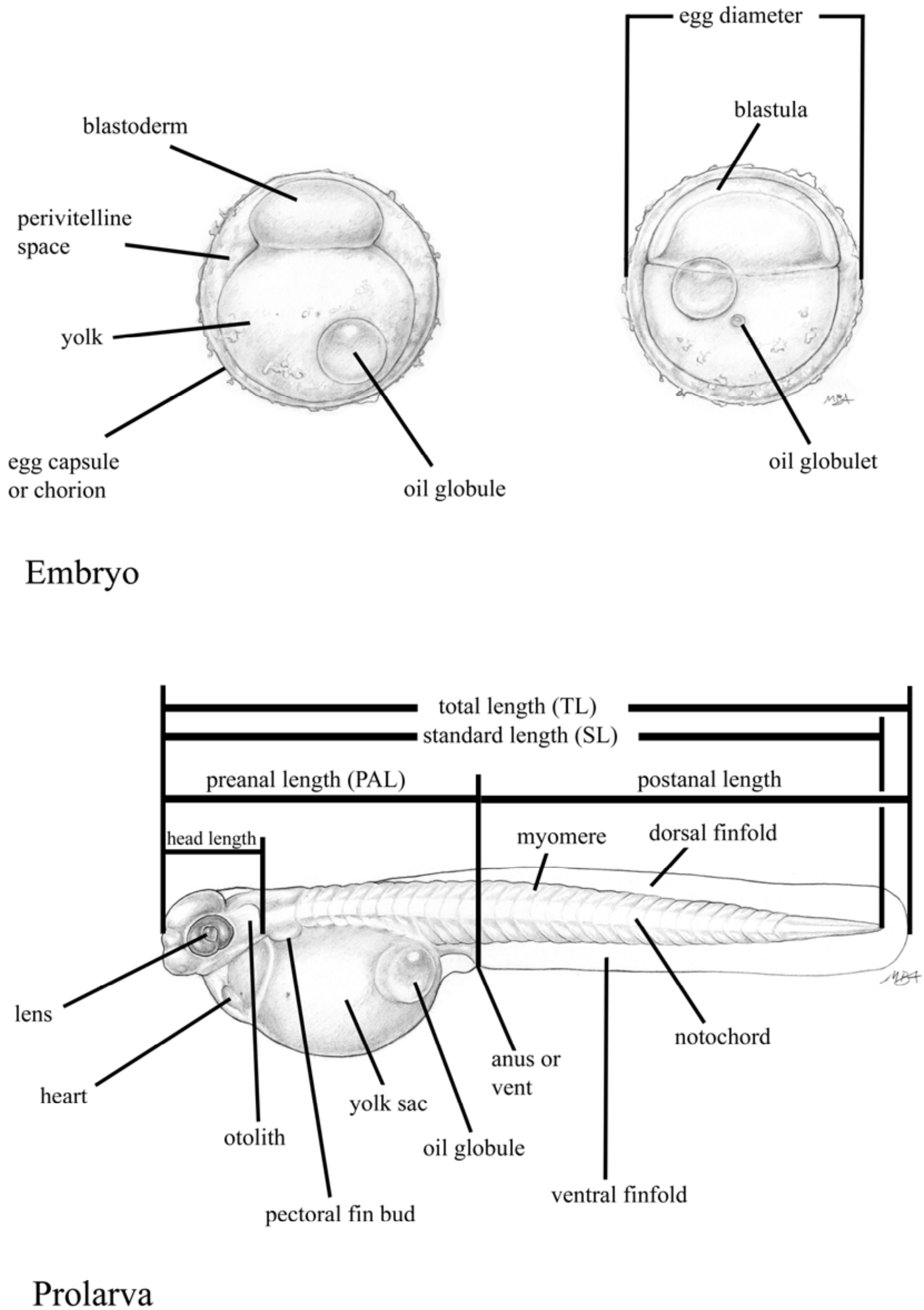
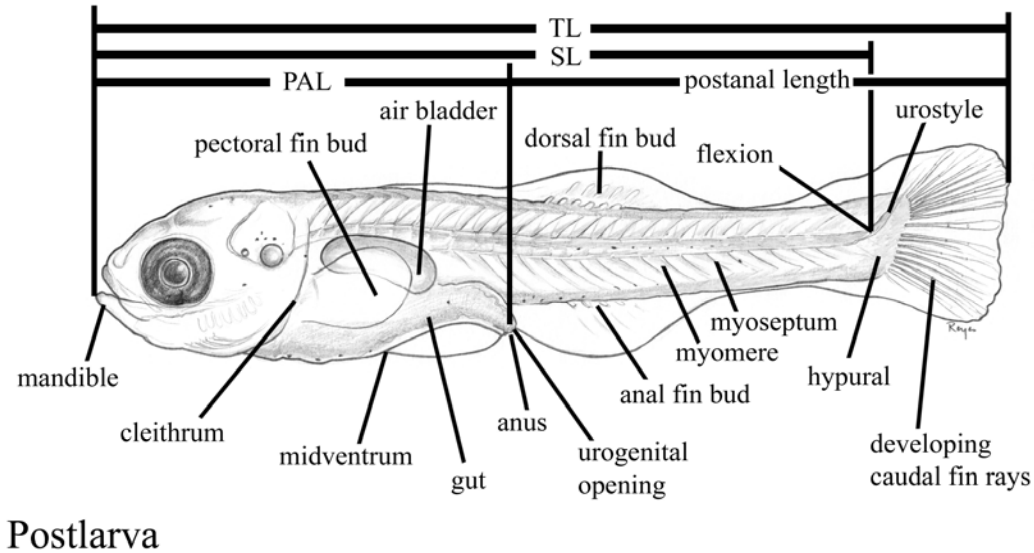


FIGURE 2a.—Anatomical features of centrarchid embryo and prolarva.



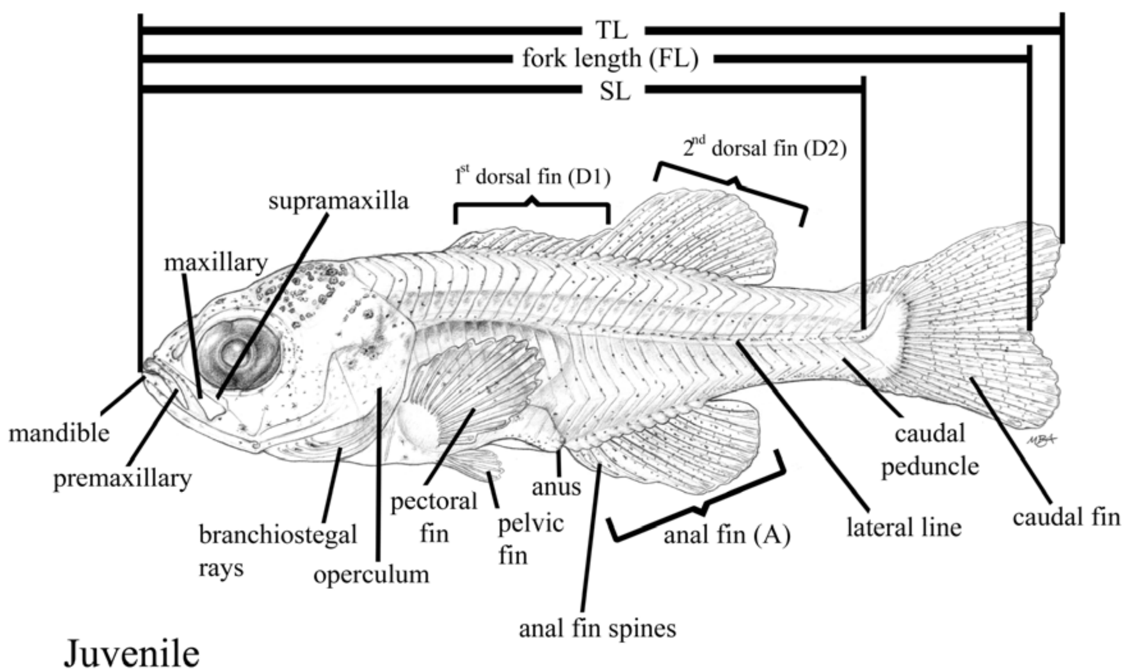


FIGURE 2b.—Anatomical features of centrarchid postlarva and juvenile.

RESULTS

Species Accounts

SACRAMENTO PERCH, *Archoplites interruptus* (Girard)

SPAWNING

Location:	In weedy ponds and lakes such as Lake Anza and Jewel Lake (Tilden Regional Park, Contra Costa County), Sterling Ranch (near Sonoma Mountain Road, Sonoma County), Lagoon Valley Regional Park (City of Vacaville, Solano County), and Abbotts Lagoon (Point Reyes National Seashore, Marin County).
Season:	April through August (Murphy, 1948; Johnson, 1958; Mathews, 1962, 1965) and peaking in May and June (Mathews, 1962; Aceituno and Vanicek, 1976; Moyle, 1976); January through October in laboratory/temperature controlled conditions (Miller, 2003); April through June in Lagoon Valley Regional Park.
Temperature:	24.2 °C (Murphy, 1948); 21.7–23.9 °C (Mathews, 1962); 21–29 °C (McCarraher and Gregory, 1970); 23–29 °C (Miller, 2005); 20–24 °C when the eggs were collected at Lagoon Valley Regional Park; 25.4–25.6 °C (Leon, *et al*., 2008).
Salinity:	Freshwater (Murphy, 1948; Mathews, 1962; Wang, 1986; Miller, 2005) or mesohaline at alkalinities of 800 ppm (McCarraher and Gregory, 1970).
Substrates:	Filamentous algae, rocks with heavy algal growth, potted plants (Murphy, 1948; Mathews, 1962); submerged vegetation (Mathews, 1965); Spawn Tex™ commercial spawning substrate (Miller, 2003, 2005; sandy bottom at Lagoon Valley Region Park, Spawn Tex™ in the laboratory.
Fecundity:	84,000 from one female (Murphy, 1948); 8,400–16,000 for 120–157 mm TL specimens from Lake Anza (Mathews, 1962); 9,700–125,000 for 196–337 mm TL specimens from Pyramid Lake (Mathews, 1962); 8,000–9,000 prolarvae hatched out from a female ca. 120 mm standard length (SL; Miller, 2003); larger females averaged larger numbers of larvae, e.g., 14,680 larvae for a 162 mm SL female, 20,383 larvae for a 168 mm SL female (Miller, 2006); 4,006–16,260 larvae/brood (Leon, *et al*., 2008).

EGGS

Shape:	Spherical, some irregular.
Diameter:	0.9–1.1 mm (Wang, 1986); 850 microns (Miller, 2003); 0.8–1.0 mm.
Yolk:	Yellowish, granular (Wang, 1986); yellowish white (Miller, 2003): colorless to pale yellow.
Oil globule:	Single, large, ca. 0.3–0.4 mm in diameter.
Chorion:	Transparent, elastic.
Perivitelline space:	Narrow in all stages.
Egg mass:	Deposited singly or in small clusters.
Adhesiveness:	Moderately adhesive, attached to gravel and each other (Murphy, 1948); adhesive (Mathews, 1962); adhesive to slightly adhesive; eggs easily detached from the substrates (Wang, 1986; Miller, 2003).
Buoyancy:	Demersal or negatively buoyant (Murphy, 1948; Mathews, 1962).

LARVAE

Length at hatching:	< 4.0 mm TL (Wang, 1986); 3.4–4.0 mm for specimens collected at Lagoon Valley Regional Park by Michael Dege with CDFG; 2.9–3.2 mm TL (Leon, *et al*., 2008); 2.5–3.2 mm TL (from eggs obtained from Chris Miller, CCMVCD and from TFCF laboratory).
Snout to anus length:	ca. 36–44% of TL for prolarvae and postlarvae from 4.0–9.8 mm TL (Wang, 1986). For prolarvae: 50–57% (often, 51–54%) for 0 days post hatch (dph), 43–47% (often, 44–46%) for 1 dph, and decreasing to 35–46% (often 37–39%) before complete yolk sac absorption. For postlarvae: 36–41% of TL at 4.3–8.8 mm TL.
Oil globule(s):	Single, large, ca. 0.25–0.30 mm in diameter, variously located in the yolk sac (Wang, 1986); 0.3–0.4 mm in diameter.

Air Bladder:	Small, oval, midway between pectoral and anus in late prolarvae; large, oval to elongate in postlarvae.
Teeth:	Small, pointed, appear in postlarvae.
Size at absorption of yolk sac:	ca. 4.7–4.9 mm TL (Wang, 1986); 4.5–5.5 mm TL.
Total myomeres:	31–34, usually 32 (Wang, 1986); up to 33 (Leon, *et al*., 2008); 27–31, often 27–30.
Preanal myomeres:	10–12 (Wang, 1986); 8–11, often 9.
Postanal myomeres:	21–22 (Wang, 1986); 17–22, often 18–21.
Last fin(s) to complete development:	Pelvic.
Pigmentation:	Prolarvae have large stellate melanophores scattered dorsally on head trunk and tip of caudal region; large stellate melanophores are also found midventrally on dorsal surface of gut, and in the postanal region; dashed melanophores are present along lateral line. Pigmentation patterns for postlarvae are similar to those of prolarvae, but heavier on the snout, head, and in the postanal regions.
Distribution:	Planktonic (Mathews, 1962); in the wild, larvae swim in shallow inshore waters among or near vegetation or shaded areas created by trees; in aquaria, larvae swim near the bottom and up to mid-water column. In the laboratory, newly hatched larvae adhered by their snouts to substrate. These newly hatched larvae sometimes exhibited quick bursts of swimming to the surface and then attaching again to substrate. They become planktonic and feed exogenously at 4–5 dph.

JUVENILES

Dorsal fin:	XII–XIII; I, 10–11 (Moyle, 1976).
Anal fin:	VI–VIII, 10–11 (Moyle, 2002).
Pectoral fin:	14–16 (Wang, 1986); 13–15 (Moyle, 2002).
Mouth:	Large, oblique (Moyle, 1976); terminal to slightly superior (Wang, 1986); large and slightly superior.
Vertebrae:	31–34 (Wang, 1986); 31–32 (Moyle, 2002).
Distribution:	Ponds and reservoirs (Murphy, 1948; Mathews, 1962; Aceituno and Nicola, 1976); among aquatic plants or congregating in shallow waters (Moyle, 1976); in shallow water near vegetation or tree shade and avoiding open water (Wang, 1986); large juveniles become more solitary; in the laboratory environment, juveniles sometimes show aggressiveness toward each other and swim near bottom and up to the midlevel of the water column.

Life History

The Sacramento perch is the only centrarchid native to the waters west of the Rocky Mountains (Moyle, 2002). Sacramento perch is the last surviving member[1] of the genus *Archoplites*. This genus is morphologically primitive among centrarchids (Smith, *et al.*, 2000) and is a sister group to *Centrarchus* (Mabee, 1995) and *Amboplites* (Near, *et al.*, 2004; Bolnick and Miller, 2006). Prior to introduction of other sunfishes into California, Sacramento perch were abundant in the Sacramento-

[1] From fossil records, there were three more species of *Archoplites* known to the lakes and river basins west of the Rocky Mountains from Utah toward Washington during the late Miocene to Pliocene periods:

(1) *Archoplites taylori* was recorded in Utah, Idaho, and Washington (Gustafson, 1978; Hearst and Smith, 2002; Smith and Cossel, Jr., 2002),
(2) *A. clarki* was recorded in Idaho (Smith and Miller, 1985),
(3) *A. molarus* was recorded in Washington (Smith, *et al.*, 2000).

An additional record, tentatively named *Archoplites* spp., was found in Oregon (Van Tassell, *et al.*, 2001, 2007). The *Archoplites* group is still being investigated by geologists and archeologists.

San Joaquin River system. They were also found in Pajaro and Salinas Rivers and Clear Lake (Evermann and Clark, 1920; Aceituno and Nicola, 1976). Hubbs (1947) questioned the native status of the Sacramento perch to Salinas River; however, recent archeological studies have shown that Sacramento perch are native to both the Salinas River (Gobalet, 1990b, 1993) and Alameda Creek (Gobalet, 1990a). In recent years, Sacramento perch have been restricted to a few locations, principally in ponds and reservoirs where they were stocked (McCarraher and Gregory, 1970; Moyle, 1976). Approximately 29 known locations in California were reported in the 1990s by Moyle (2002). In some locations, such as in Abbotts Lagoon at the Point Reyes National Seashore, they dominate the fish species assemblage (Saiki and Martin, 2001). Sacramento perch have been successfully introduced outside of California, especially in Nevada and Nebraska (McCarraher and Gregory, 1970) and to other Rocky Mountain States (McCarraher and Gregory, 1970; Imler, *et al.*, 1975; Becker, 1983; Moyle, 2002) although their status in these states is undetermined. Although Sacramento perch typically inhabit freshwater habitats, they can survive and reproduce in chloride-sulfate waters with salinities as high as 17,000 mg/L (McCarraher and Gregory, 1970). Few juvenile and adult Sacramento perch were collected at the intake screens of Contra Costa Power Plant in the late 1970s to early 1980s (Wang, 1986). In this study, most of the wild specimens were collected from Sterling Ranch pond near Sonoma Mountain Road (Sonoma County), Lake Anza and Jewel Lake of Tilden Regional Park (Contra Costa County), and Lagoon Valley Regional Park pond (Solano County).

Spawning has been reported to extend from April (Murphy, 1948; Mathews, 1962) through August (Johnson, 1958), depending on location and water temperature. In Lake Anza, spawning occurs from April through July (Mathews, 1962) but usually April through May. In Sterling Ranch, a small pond about 1 m deep with weeds, spawning mostly occurred April through May (Wang, 1986). At Lagoon Valley Regional Park, larvae were collected from early April through July (Moyle, 2002). In this study, Sacramento perch nesting sites were observed from April to July (mid-1990s to early 2000s) near the park's south shore (near the boat ramp) at depths less than 1 m over substrates of sand and debris. However, no larvae have been observed since 2002. In laboratory conditions, spawning can be as early as January and extend to October at temperatures of 23–29 °C (Miller, 2005).

Spawning activities were described by Murphy (1948) and Mathews (1962, 1965). Males become darker than females, especially along the ventral surfaces and gill covers (Mathews, 1965). Spawning males congregate in depths of less than 1 m (Mathews, 1965; this study). Murphy (1948) reported that Sacramento perch show no nest building behavior and no parental care. However, Mathews (1962, 1965) observed nest-like sites with male fish guarding the site until a few days after hatching. Furthermore, underwater video recording of Sacramento perch showed that males guard their nests (C. Miller, 2006–2007, personal communication). In this study, Sacramento perch eggs and larvae were collected on a spawning site of Lagoon Valley Regional Park, where a male fish was observed in nesting behavior (M. Dege, 1995–2005, personal communication). Wang (1986) reported Sacramento perch eggs and larvae near a white, circular spot (~ 15 cm in diameter, very likely a nest) at the Sterling Ranch site in early May 1980, where various early life stages were collected in subsequent years. Eggs adhere on substrates such as filamentous algae and submerged vegetation (Murphy, 1948; Mathews, 1962, 1965). Fine debris, detritus, and sand particles adhered to eggs found at the Lagoon Valley site. In the laboratory, eggs were deposited on Spawn Tex™ (Blocksom & Co., Michigan City, Indiana) artificial substrate. The male fish drove the female away when all eggs were spawned (Miller, 2003). Eggs hatched within 19–36 hours at 25.4–25.6 °C (Leon, *et al*., 2008).

Newly hatched larvae ranged in size from 3.4–4.9 mm total length (TL) in the wild (M. Dege, 1995–2005, personal communication) and 2.5–3.2 mm TL in the laboratory. They have light pigmentation on the dorsum and are swimming in the water column at 4 dph. In the laboratory, exogenous feeding began at 5 dph on small marine rotifers (*Brachionus* spp.). In about 14 days, the larvae fed on larger zooplankton such as artemia (*Artemia* spp.). In the wild, Sacramento perch larvae have been collected with other species. At Sterling Ranch pond, Sacramento perch larvae were found in a plant bed with Sacramento blackfish larvae; in Lake Anza, Sacramento perch larvae were found in plant beds with green sunfish, largemouth bass, and golden shiner (*Notemigonus crysoleucas*); and in the Lagoon Valley Regional Park, Sacramento perch larvae were swimming under a wooden boat ramp with Sacramento blackfish, golden shiner, and fathead minnow.

Small juveniles venture into deeper water in schools of their own species, seeming to prefer shade created by overhanging trees. In the laboratory, juveniles exhibited vertical bars as early as 15 mm TL. The vertical bars are commonly disjunct at the lateral line, as the species name “interruptus” implies (Mabee, 1995). As juveniles develop and schools gradually disperse, individuals begin inhabiting near shore plant beds and are seldom observed in the open water. The diet of juvenile Sacramento perch includes amphipods, cladocerans, ostracods, copepods, and chironomids (Moyle, *et al*., 1974; Aceituno and Vanicek, 1976). In the laboratory, small juveniles consumed amphipods, sliced mysid shrimps, and live and dried artemia. Large juveniles consumed small live fish, small pieces of sliced fish, and commercial trout feed.

Sacramento perch reach sexual maturity at 2–3 years, and some may live up to 9 years (Mathews, 1962). This species readily spawn in the laboratory. For example, a pair of Sacramento perch collected as juveniles (10–15 mm TL) from Lake Anza, spawned 2 years later soon after being donated to the Lindsay Wildlife Museum (Walnut Creek, California). The female was 24 cm TL at time of spawning. At the CVP/TFCF laboratory, Sacramento perch spawned in spring and summer months, however, at the CCMVCD, Sacramento perch have successfully spawned in the laboratory almost year round with photoperiod manipulation. Multiple spawning from a single female has been observed as many as seven times in 73 days (C. Miller, 2006, personal communication).

Sacramento perch was a food fish for Native Americans (Skinner, 1972; Moyle, 1976) and was abundant throughout the lowland areas, growing to lengths of about

300–600 mm (Jordan and Evermann, 1896–1900). Today, this species is rarely found in its native range, and efforts have been directed toward its recovery (Schwartz and May, 2004). They were last recorded at the CVP/TFCF in 1986. Currently, the stocked population at Lagoon Valley Regional Park has decreased drastically, perhaps due to the introduction of fathead minnow. Fathead minnow may have outcompeted the Sacramento perch for resources and may have preyed on their eggs if not defended (Wang and Reyes, 2007). The less aggressive nature of the Sacramento perch suggests the species would also be dominated by other more aggressive centrarchids (Vanicek, 1980); therefore, coexistence may not be possible with any introduced centrarchid (Marchetti, 1999). The population of Sacramento perch in Lake Anza has declined since the introduction of Florida strain largemouth bass, and the population in Jewel Lake has declined drastically in 2006 when large quantities of silt runoff reduced the lake volume significantly (Leidy, 2007). Sacramento perch have been successfully cultured by the CCMVCD and released into several private and public ponds and Delta sloughs with mixed success (Miller, 2005). Reintroduction of Sacramento perch should target stream reaches where other centrarchids are not abundant (Leidy, 2007). The Sacramento perch will likely prevail in alkaline lakes and ponds where they have been introduced, however, it is unlikely that this species will be successfully reintroduced to its native range where it has to compete with introduced centrarchids. The future ecological status of the Sacramento perch remains uncertain.

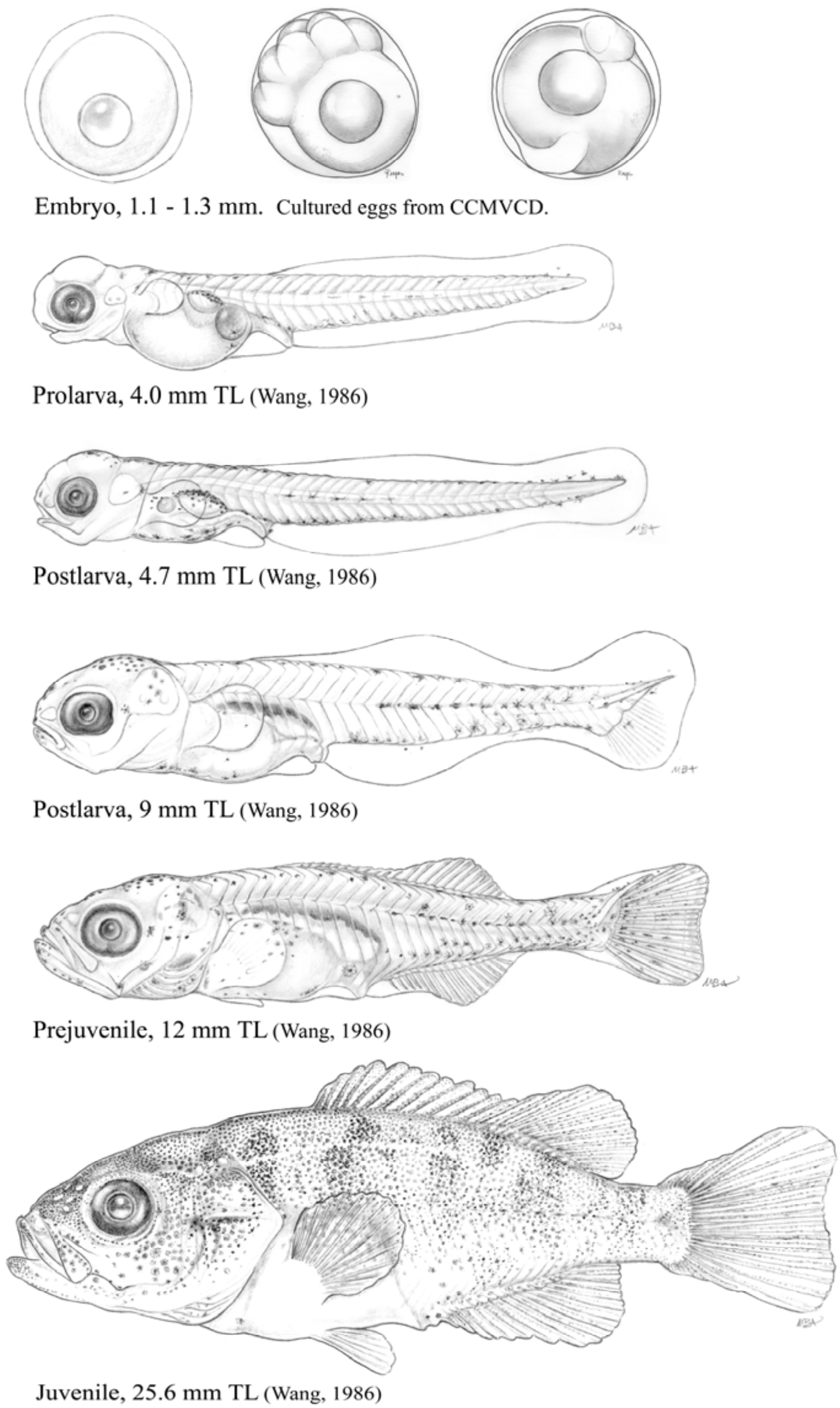


FIGURE 3a.—Sacramento perch (*Archoplites interruptus*).

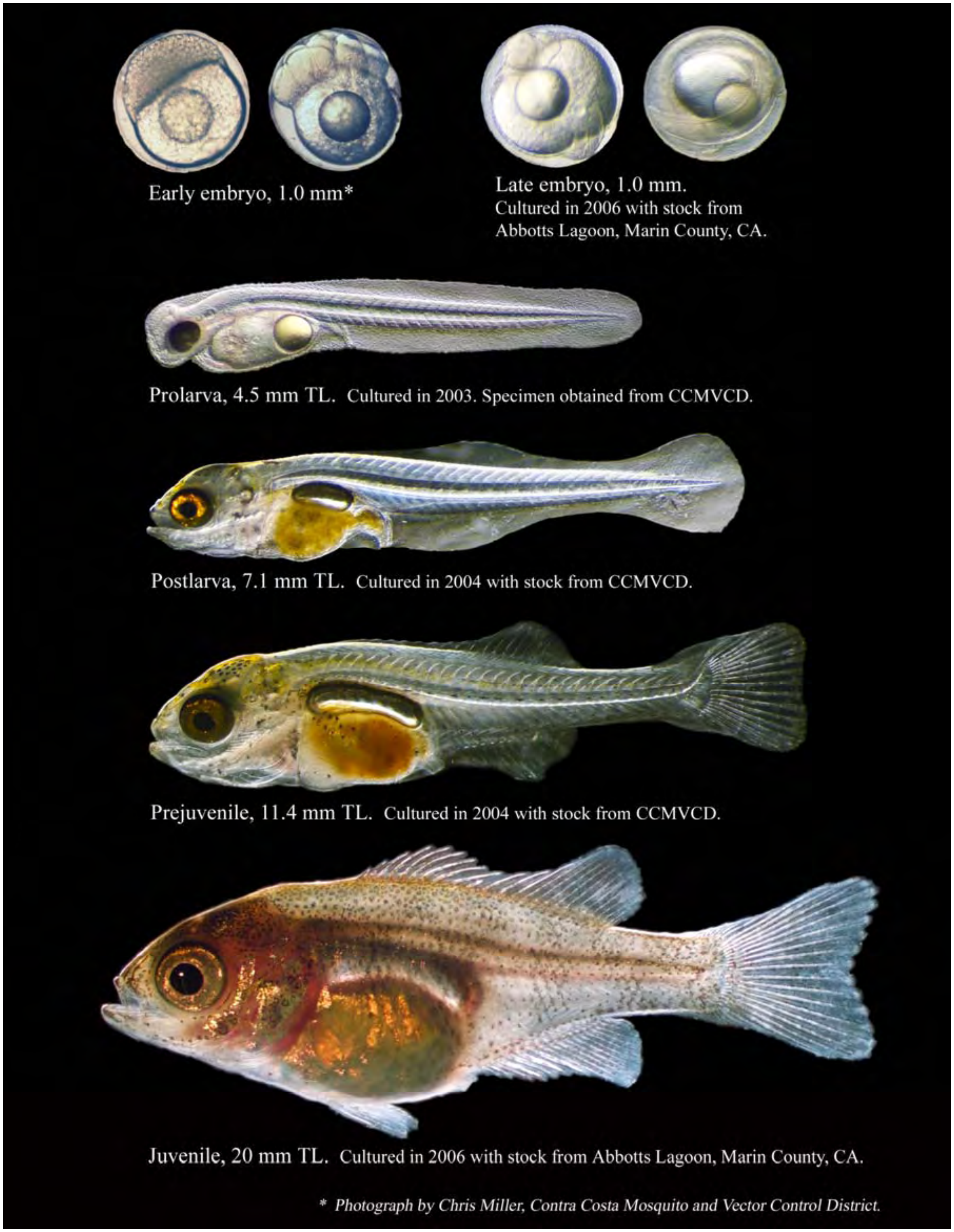


FIGURE 3b.—Sacramento perch (*Archoplites interruptus*).

GREEN SUNFISH, *Lepomis cyanellus* (Rafinesque)

SPAWNING

Location: Near shore (Hubbs, 1919) in shallow water often near overlapping bushes or other cover (Moyle, 1976). In the study area, spawning has been observed in sunlit pool water in creeks, ponds, ditches, sluggish sloughs, and in coves of reservoirs, such as lower portion of Walnut Creek, upper Napa River, upper Sonoma Creek, Lake Anza, inshore of Marsh Creek Reservoir, Discovery Bay (Contra Costa County), Mosher Creek, and Bear Creek (in north Stockton, San Joaquin County). In the foothill regions, green sunfish have been observed spawning in coves at the Millerton Lake and Union Valley Reservoir.

Season: May through August (Moyle, 1976; Wang, 1986); early May to mid-August in the laboratory.

Temperature: 20–28 °C (Scott and Crossman, 1973); in excess of 19 °C (Moyle, 1976); eggs collected in the field at 19–24 °C (Wang, 1986); 23.9–24.5 °C in the laboratory.

Salinity: Freshwater.

Substrates: Gravel (Beckman, 1952); clumps of vegetation or rock (Scott and Crossman, 1973); among the branches of fallen trees, gravel, and sand (Wang, 1986); sand, filamentous algae on rocky jetties, gravel, stones, and wood.

Fecundity: 2,000–10,000 (Beckman, 1952).

EGGS

Shape: Spherical (Meyer, 1970); mostly spherical to slightly irregular.

Diameter: 1.0–1.4 mm (Meyer, 1970); 1.1–1.3 mm (Wang, 1986); 1.0–1.3 mm.

Yolk: Yellowish (Scott and Crossman, 1973); granular (Wang, 1986); colorless to pale yellow, granular.

Oil globule: Single oil globule 0.3–0.5 mm in diameter (Wang, 1986); 0.3–0.4 mm in diameter (eggs at 0 days post spawn (dps) have several oil globulets that consolidate into one by 1 dps).

Chorion: Transparent, elastic, not smooth because of adhering substrates (Wang, 1986); transparent when not covered by detritus and other debris.

Perivitelline space: Narrow to wide, 6–25% of egg diameter (Wang, 1986); mostly narrow.

Egg mass: Deposited singly or in small clusters in the nest (Wang, 1986); singly to small clusters in nest and attaching strongly to wood and gravel.

Adhesiveness: Very adhesive to each other and to substrates.

Buoyancy: Demersal or negatively buoyant.

LARVAE

Length at hatching: 3.6–3.7 mm TL (Taubert, 1977); 3.2–3.9 mm TL (Wang, 1986); eggs hatched in the incubator undisturbed (2 dps) as small as 2.7 mm TL and as large as 4.0 mm TL, but usually between 3.3–3.9 mm TL.

Snout to anus length: 39–49% TL for prolarvae at 3.3 mm TL and postlarvae at 11.1 mm TL (Wang, 1986). For prolarvae: 48–55% TL at 0 dph, 45–56% (often 47–50%) TL at 3.1–3.9 mm TL (1 dph), decreasing to 40–51% (often 40–42%) TL at 3.6–5.7 mm TL (≥ 2 dph). For postlarvae: 41–46% (often, 42–43%) TL at 5.3–6.9 mm TL.

Yolk sac: Spherical to oval, large, extends from jugular to abdominal region (Wang, 1986); large, oval extends from snout to anus in newly hatched larvae, reduced to the thoracic to abdominal regions within 48 hours.

Oil globule(s): Single, usually located posteriorly in yolk sac; 0.3–0.4 mm in diameter.

Gut: Short, straight, and bent ventrally in anal region in prolarvae; twisted in postlarvae.

Air Bladder: Shallow, large, near pectoral fins (Wang, 1986); large, oval, sometimes “tear-drop” shaped, located midway between pectoral fins and anus, becomes visible as early as 4.8 mm TL during prolarval stage.

Teeth: Small, pointed, developed in postlarvae (Wang, 1986).

Size at absorption of yolk sac: ~ 4.5–5.0 mm TL (Wang, 1986); 5.3–6.4 mm TL or as early as 4 dph.

Total myomeres: 27–28 (Taubert, 1977); 26–29, often 26–27.

Preanal myomeres: 11 (Taubert, 1977); 12–14 (Wang, 1986); 9–12, often 10–12.

Postanal myomeres: 16–17 (Taubert, 1977); 14–16 (Wang, 1986); 14–18, often 15–17.

Last fin(s) to complete development: Pelvic (Wang, 1986).

Pigmentation: Prolarvae have large stellate melanophores on cephalic, middorsal, midventral, dorsal surface of gut, and postanal regions. Postlarvae have dashed melanophores along

	lateral line, heavier concentrations of cephalic melanophores, and more melanophores scattered in thoracic regions (Wang, 1986). In laboratory conditions, newly hatched prolarvae do not have pigment on eyes or body; first stellate pigment appears at 2 dph ventrally in the postanal region; a few pigments are visible ventrally and dorsally in the caudal peduncle region. Heavy pigmentation on “ceiling” of the air bladder is present in both prolarval and postlarval; eyes are pigmented by 3 dph, pigment on cephalic and dorsal surface of gut and postanal regions become heavier during the postlarval stage; sometimes there are dash-shaped melanophores located above and below vertebrae.
Distribution:	Newly hatched prolarvae stay on the bottom near nesting area (eyes are initially unpigmented). By 4 dph or about 5 mm TL, air bladder is pigmented and inflated and the larvae (now postlarvae) become free swimming in the water column of shallow waters with vegetation.

JUVENILES

Dorsal fin:	IX–XI, 10–12 (Beckman, 1952; Scott and Crossman, 1973; Moyle, 2002).
Anal fin:	III, 8–10 (Beckman, 1952; Moyle, 2002); III, 9–10 (Scott and Crossman, 1973).
Pectoral fin:	12–13 (Scott and Crossman, 1973); 13–15 (Moyle, 1976).
Mouth:	Terminal and large (Moyle, 1976); terminal, oblique, maxillary reaching anterior edge of eye (Scott and Crossman, 1973; Wang, 1986).
Vertebrae:	28 or 29 (Scott and Crossman, 1973); usually 28.
Distribution:	Usually found in the shallow, still or low-velocity waters in rivers, creeks, ditches, and impoundments.

Life History

The green sunfish is a freshwater fish native to eastern and central North America (Scott and Crossman, 1973); specifically, in most of the Mississippi River drainages and Great Lakes in the United States (Moyle, 2002). This species has been introduced to several Western States such as Utah, Nevada, and California (Scott and Crossman, 1973). The green sunfish is known almost everywhere in the United States and in some countries around the world (Moyle, 2002). In a study of stream tributaries of the San Francisco Estuary, green sunfish was the most common non-native fish encountered (Leidy, 2007). In the study area, green sunfish were among the most widespread centrarchids, ranging from coastal lagoons, such as Rodeo Lagoon, to inland mid-elevation Sierra water bodies, such as Union Valley Reservoir on the upper American River (Wang, 1986). Green sunfish are common in Delta tributaries and are occasionally caught in the south Delta (CVP/TFCF salvage records) and as far north as Red Bluff (Red Bluff Research Pumping Plant entrainment records), however, they are uncommon in the tidal Delta waters.

Spawning takes place from May through August (Moyle, 2002). Dominant males exhibit a two-tone color with a darkening head with green hue on the operculum and a lighter grayish hue on the body. There are two black blotches on the fins: one on the soft dorsal fin and the other on the soft anal fin. Males build nests near protected coves or at the lower end of pools (near sandbars) where the water is less than 0.5 m in depth. Several nests constructed in close proximity to each were observed near shore in Marsh Creek Reservoir. Solitary nests were observed in Walnut Creek and upper Napa River. During the spawning season, a male mates with numerous females in his nest (Hunter, 1963).

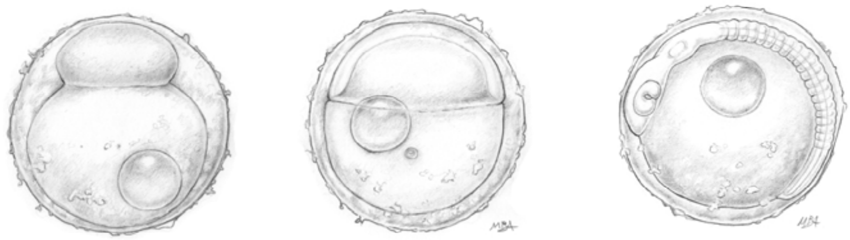
In laboratory conditions, only one male green sunfish is dominant. In this study, more than 10 green sunfish were kept in a 75.7-L aquarium. Only the largest male exhibited active spawning color while the other males showed partial coloration (or none at all) and stayed near the surface of the aquarium. The dominant male may inhibit the other males from showing their true spawning color while in his territory. Once a dominant male shows weakness, one or more males start showing coloration. A dominant male will guard the eggs vigorously. When eggs were being collected for this study, a nesting male nipped the intruding hand.

Scott and Crossman (1973) reported an incubation period of 3–5 days at an unspecified temperature. Wang (1986) reported an incubation period of 3–4 days at 19–23 °C. In the current study, eggs hatched 2–3 days after fertilization at 23.9–24.5 °C. Newly hatched larvae are unpigmented including the eye and lie motionless among the crevices of the gravel for 1–2 days. The guarding male stays near the nest until the larvae become planktonic, about 3–4 days after hatching. Larvae begin exogenous feeding about 5–7 days after hatching, feeding initially on smaller invertebrates such as rotifers. Larvae school in laboratory aquariums, however, in the wild, they probably disperse into inshore vegetation since large numbers of individuals have not been collected. Male nesting time (incubation and caring of larvae) is estimated at 5–7 days (Moyle, 2002).

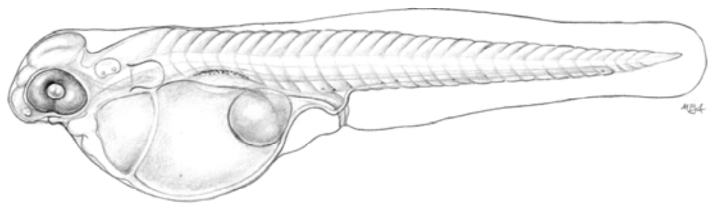
Juveniles are abundant in various lentic habitats such as small ponds with dense vegetation, ditches with filamentous algae, and shallow coves of large reservoirs. They are less abundant in lotic environments. In the laboratory, juvenile stage is reached around 12 mm TL but vertical bars on the body were not observed until 17 mm TL. Mabee (1995) counted 11–14 vertical bars visible in juveniles 14.8–23.2 mm standard length (SL). Juvenile green sunfish feed on crustaceans, aquatic insects, and terrestrial insects (Applegate and Mullan, 1967), zooplankton, benthic invertebrates, and fish larvae (Becker, 1983). In the laboratory, juveniles are aggressive feeders, readily taking TetraMin® (Spectrum Brands Company, Blacksburg, Virginia) and other commercially made dry fish food. Of all the centrarchids found in California, only juvenile green sunfish have been shown to possess a chemical alarm signal similar to those found in cyprinids. When alarm pheromones (released because of mechanical damage to skin) are detected, juvenile green sunfish remain still with dorsal fins erect (Brown and Brennan, 2000).

The minimum age at maturity is less than 6 months (White, 1971); usually 3 years (Scott and Crossman, 1973); in California mostly 1–2 years or 5–7 cm SL (Moyle, 1976). In laboratory conditions, green sunfish matured in less than a year and readily spawned 10 months after hatching. The life expectancy is 7–9 years (Scott and Crossman, 1973). Green sunfish in California have little sport value since they are small, have a slow growth rate, and have stunted populations (Moyle, 1976).

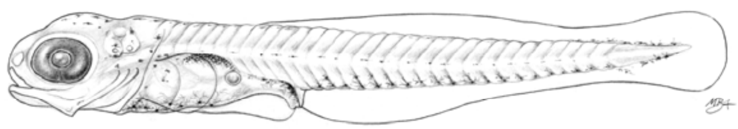
The green sunfish was introduced to San Diego County in 1891 (Dill and Cordone, 1997). It has since expanded its territory successfully northward to California's coastal streams and to the Sierra foothills. It is found almost everywhere in the Sacramento-San Joaquin River system. The green sunfish adapts well to various environmental changes (McCarraher, 1972). It has an aggressive territorial behavior and can outcompete other species for food. Its geographic expansion includes creek habitats where it threatens the native California roach (Moyle, 1976). Green sunfish nests have been found in polluted and channelized rivers and creeks (with dissolved oxygen levels as low as 4 ppm) that run through cities, such as Petaluma River (city of Petaluma), Napa River (below the city of Napa), Walnut Creek (city of Walnut Creek), Grayson Creek (city of Concord; Wang, 1986), and Bear and Mosher Creeks (city of Stockton). Some spawning adults in the Napa River carried nematode cysts on their body; however, their larvae emerged uninfected.



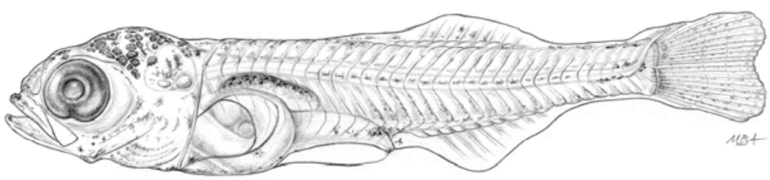
Morula, 1.1 mm Gastrula, 1.3 mm Late embryo, 1.3 mm (Wang, 1986)



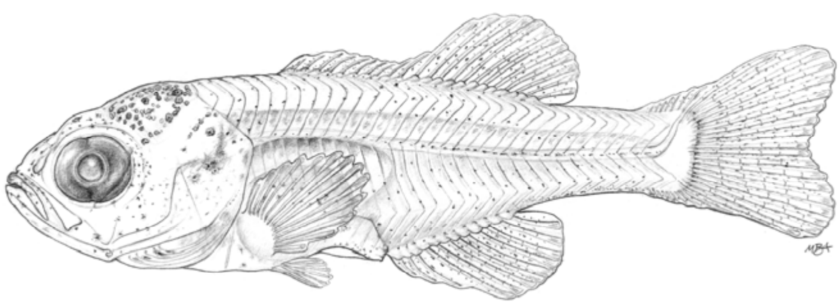
Prolarva, 4.5 mm TL (Wang, 1986)



Postlarva, 5.5 mm TL (Wang, 1986)



Postlarva, 9 mm TL (Wang, 1986)



Juvenile, 11.6 mm TL (Wang, 1986)

FIGURE 4a.—Green sunfish (*Lepomis cyanellus*).

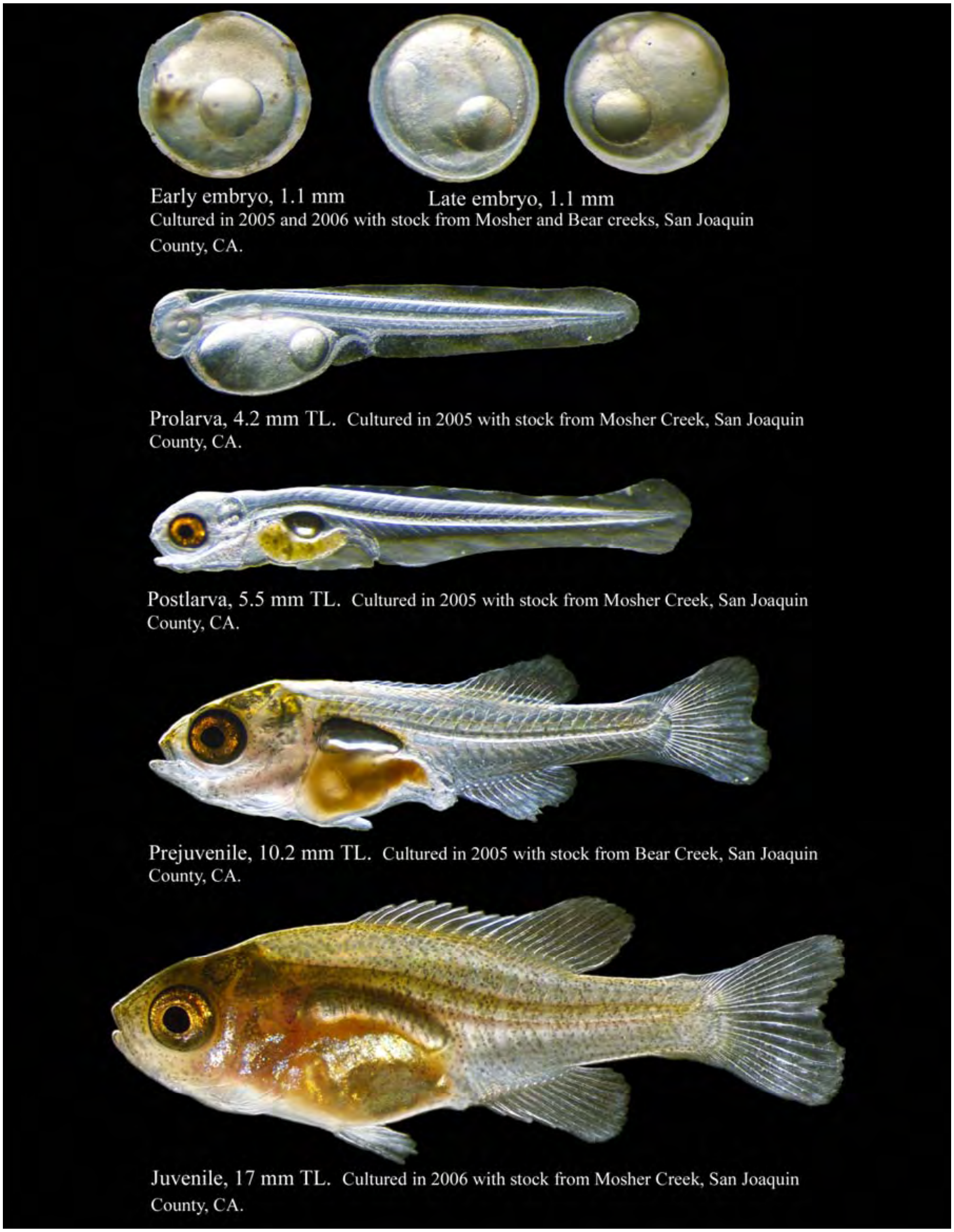


FIGURE 4b.—Green sunfish (*Lepomis cyanellus*).

PUMPKINSEED, *Lepomis gibbosus* (Linnaeus)

SPAWNING

Location:	Lakes, reservoirs, ponds, and creeks (Breder, 1936); Walnut Creek (Leidy, 1983); in Walnut Creek near Las Lomas High School (Wang, 1986); in Walnut Creek near the Hilton Hotel at Concord (N. Cuevas, 2006, personal communication).
Season:	May through August in mid-Atlantic region (Smith, 1971; Wang and Kernehan, 1979); judging by the breeding color, estimated in June and July in Walnut Creek (Wang, 1986; April to June in California (Moyle, 2002); in the TFCF laboratory, males built nests in April.
Temperature:	~ 20 °C (Scott and Crossman, 1973); optimum temperature 21–24 °C (Anjard, 1974); 17.5–20 °C in Delaware River, Delaware (Wang and Kernehan, 1979); in the laboratory, males built nests at 20 °C.
Salinity:	Freshwater; tidal freshwater to brackish water (Smith, 1971; Wang and Kernehan, 1979).
Substrates:	Sand and gravel (Carbine, 1939); debris such as broken glass, freshwater clam shells, sticks, and dead leaves (Wang and Kernehan, 1979); firm substrates such as sand and gravel to soft substrates such as silt (Danylchuk and Fox, 1996); coarse gravel (available aquarium substrate).
Fecundity:	~ 8,000 larvae harvested from a nest (Bean, 1903); 600–2,900 for females at ages 2–5 (Scott and Crossman, 1973).

EGGS

Shape:	Spherical.
Diameter:	0.8–1.2 mm (Anjard, 1974); ~ 1.0 mm (Scott and Crossman, 1973); 0.9–1.2 mm (Wang and Kernehan, 1979).
Yolk:	Pale amber (Scott and Crossman, 1973); granular (Wang and Kernehan, 1979).
Oil globule:	Single, large, with several extremely small ones (Hardy, 1978); single, large ~ 0.3 mm in diameter, occasionally with small oil globules on the periphery of the large one, amber color (Wang and Kernehan, 1979).
Chorion:	Transparent, thick (Hardy, 1978; Wang and Kernehan, 1979).
Perivitelline space:	Narrow, 0.05 mm in width (Balon, 1959); fairly wide in early developmental stages, ~ 5–22% of egg diameter (Wang and Kernehan, 1979).
Egg mass:	Deposited singly or in clusters or clumps and can be very dense in the center of the nest (Wang and Kernehan, 1979).
Adhesiveness:	Adhesive (Gill, 1906), attaches to substrates such as sand, debris, sticks and each other (Fish, 1932; Scott and Crossman, 1973; Anjard, 1974; Wang and Kernehan, 1979).
Buoyancy:	Demersal.

LARVAE

Length at hatching:	As small as 2.6 mm TL (Breder, 1926) and up to 3.1 mm TL (Balon, 1959); 2.4–2.9 mm TL (Wang and Kernehan, 1979).
Snout to anus length:	~ 45–50% TL for prolarvae; 40–45% TL for postlarvae (Wang and Kernehan, 1979); 40–43% for postlarvae.
Yolk sac:	Large, spherical to oval, extending from head or jugular to abdominal region (Balon, 1959; Anjard, 1974).
Oil globule(s):	Single, 0.2–0.3 mm in diameter in newly hatched larvae usually located posterior to midpoint of yolk sac (Hardy, 1978).
Gut:	Short and straight in prolarvae (Wang and Kernehan, 1979); coiled in postlarvae (Anjard, 1974).
Air Bladder:	Small, oval, behind pectoral fins or midway between nape and anus.
Teeth:	Small and pointed, appear in postlarval stage.
Size at absorption of yolk sac:	~ 4.0–5.0 mm TL (Delaware River specimens, Wang and Kernehan, 1979): ~ 5 mm TL (specimens provided by Brent Bridges from Christina Lake, a natural lake fed by the Columbia River in Canada).
Total myomeres:	27–35 (Hardy, 1978); 33 (Anjard, 1974); 27–30.
Preanal myomeres:	10–13 (Fish, 1932; Hardy, 1978); 10–12.
Postanal myomeres:	17–21 (Hardy, 1978); 16–19.
Last fin(s) to complete development:	Pelvic.

Pigmentation:	Newly hatched larvae lack pigmentation on body and eyes. Stellate melanophores develop on cephalic, eyes, dorsal surface of gut, air bladder, and occasionally in postanal region. Pumpkinseed larvae have little pigmentation in general.
Distribution:	In study area, larval pumpkinseed are found in shallow weedy waters of creeks and ponds, and in reservoirs such as Lafayette Reservoir.

JUVENILES

Dorsal fin:	X–XI, 10–12 (Scott and Crossman, 1973); X, 10–12 (Moyle, 1976); IX–X, 10–11 (Wang and Kernehan, 1979).
Anal fin:	II–III, 8–11 (Sterba, 1959); III, 8–11 (Scott and Crossman, 1973); III, 9–12 (Wang and Kernehan, 1979); III, 10–11 (Moyle, 1976); III–IV, 9–11 (Moyle, 2002).
Pectoral fin:	12–14 (Carbine, 1939; Scott and Crossman, 1973); 12–13 (Moyle, 2002).
Mouth:	Terminal, small, oblique (Scott and Crossman, 1973); very small oblique mouth (Moyle, 2002).
Vertebrae:	28–29 (Scott and Crossman, 1973).

Life History

The pumpkinseed is native to the freshwaters of eastern and central North America. It was introduced to California in the early 1890s (Curtis, 1949; Scott and Crossman, 1973; Dill and Cordone, 1997) and has been introduced throughout the United States and Canada (Moyle, 2002). There are four populations known to California: Klamath Basin, Susan River, Sacramento-San Joaquin drainage (Moyle, 2002), and possibly in southern California (William, *et al.*, 1955; Moyle, 2002). In the study area, the pumpkinseed has been observed in Walnut Creek and reported in the lower San Joaquin River, however, it has not been collected from the south Delta (Feyrer and Healey, 2002) or in the Delta since the 1980s (Brown and Michniuk, 2007), and from the CVP/TFCF since 1992.

In the study area, spawning is estimated to occur in June and July judging from the males' brilliant green to orange coloration. Males construct nests in close proximity to each other with large nests built in deeper water and small nests in the periphery (Breder, 1936; Wang and Kernehan, 1979). Larger and older males nest earlier (Danylchuk and Fox, 1996). In east coast populations, nesting pumpkinseeds are associated with golden shiners (Shao, 1997). Pumpkinseeds aggressively chase away other nesting males, juvenile pumpkinseeds, and other fishes while showing little or no aggression toward golden shiners (Shao, 1997). Details of courtship behavior of the pumpkinseed have been summarized by Breder and Rosen (1966). Eggs are deposited at the center of the nest on substrates of gravel, sand, sticks, or hard clay. Males guard the nests and, sometimes, a single male may guard two nests simultaneously. Egg incubation time varies: 2 days at 19–25 °C (Balon, 1959) or 3 days at 22 °C (Wang and Kernehan, 1979) or 28 °C (Scott and Crossman, 1973).

Newly hatched larvae are transparent, have unpigmented eyes for the first 48 hours after hatching, and remain at the bottom of the nest for a short period (Wang and Kernehan, 1979). The male continues to guard the larvae against predators until they are free-swimming. However, some larvae are eaten by hydras, which are commonly found in the centrarchid nest. When larvae leave the nest and form a school, they inhabit dense vegetation or may be found under the shade of trees in shallow water. Some may also venture out into open waters for dispersal (Faber, 1967). Juveniles can be solitary or form small schools near or among aquatic vegetation. Some move into deeper pools, but rarely remain in lotic environments such as at Walnut Creek near the Concord Hilton Hotel. In the laboratory, juvenile stage is reached at about 13 mm TL, however, vertical pigmentations in juvenile pumpkinseeds were not observed until ~ 30 mm TL. Mabee (1995) observed 9–10 primary vertical bars on the body. Larvae and early juveniles feed on zooplankton (Faber, 1967), with aquatic insects and snails becoming the food items for large juveniles (Reid, 1930; Seaburg and Moyle, 1964). In the laboratory, large juveniles readily feed on *Gammarus* spp., frozen artemia, live worms, and chopped fish meat. Pumpkinseed have small mouths but strong jaws to crush snail shells (Lauder, 1983) and other heavy bodied mollusks (Gross and MacMillan, 1981). They have a series of short gill rakers to excrete indigestible items.

Pumpkinseed mature in about 2 years in Canada (Scott and Crossman, 1973), and 2 or 3 years in California (Moyle, 1976). Some pumpkinseed live up to 12 years (Becker, 1983). Pumpkinseed provide minor sport value at the Walnut Creek and Lafayette Reservoir sites. Hybrids between pumpkinseed and redear sunfish, bluegill, and green sunfish were common in the Walnut Creek watershed (Leidy, 2007). Details of its life history and ecological status in the study area are limited.

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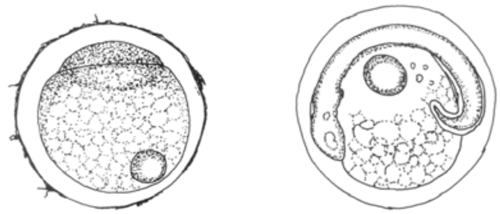
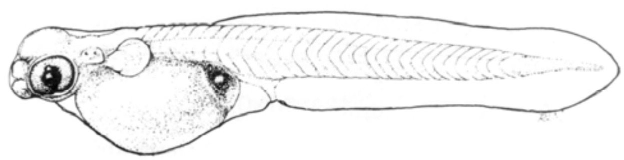
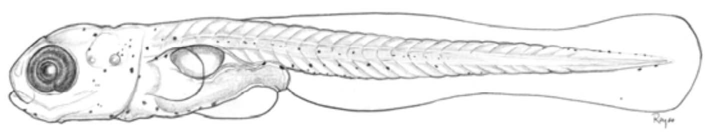


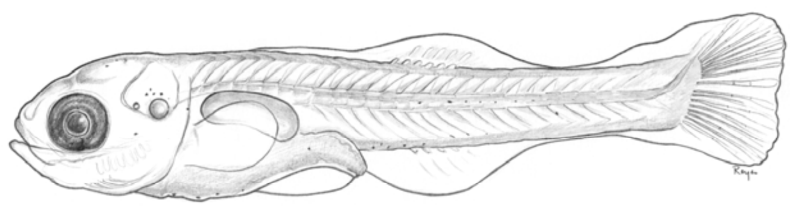
Morula and late embryo (Wang & Kernehan, 1979)



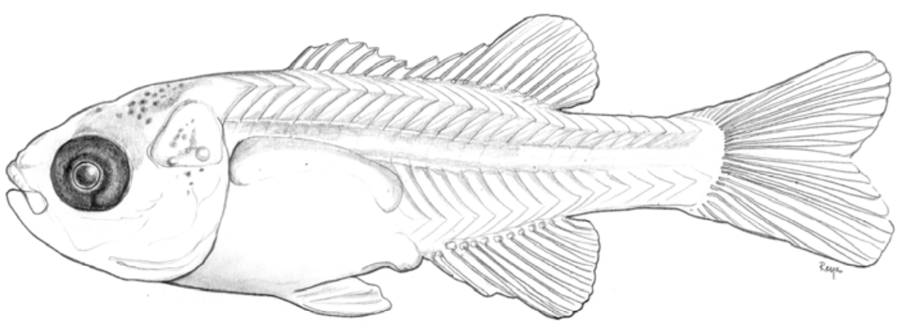
Prolarva, 4.0 mm TL (Wang & Kernehan, 1979)



Postlarva, 5.4 mm TL, cultured with stock from Christina Lake, Canada.



Late postlarva, 8.9 mm TL, cultured with stock from Christina Lake, Canada.



Juvenile, 13 mm TL. Walnut Creek, Contra Costa County, CA.

FIGURE 5a.—Pumpkinseed (*Lepomis gibbosus*).

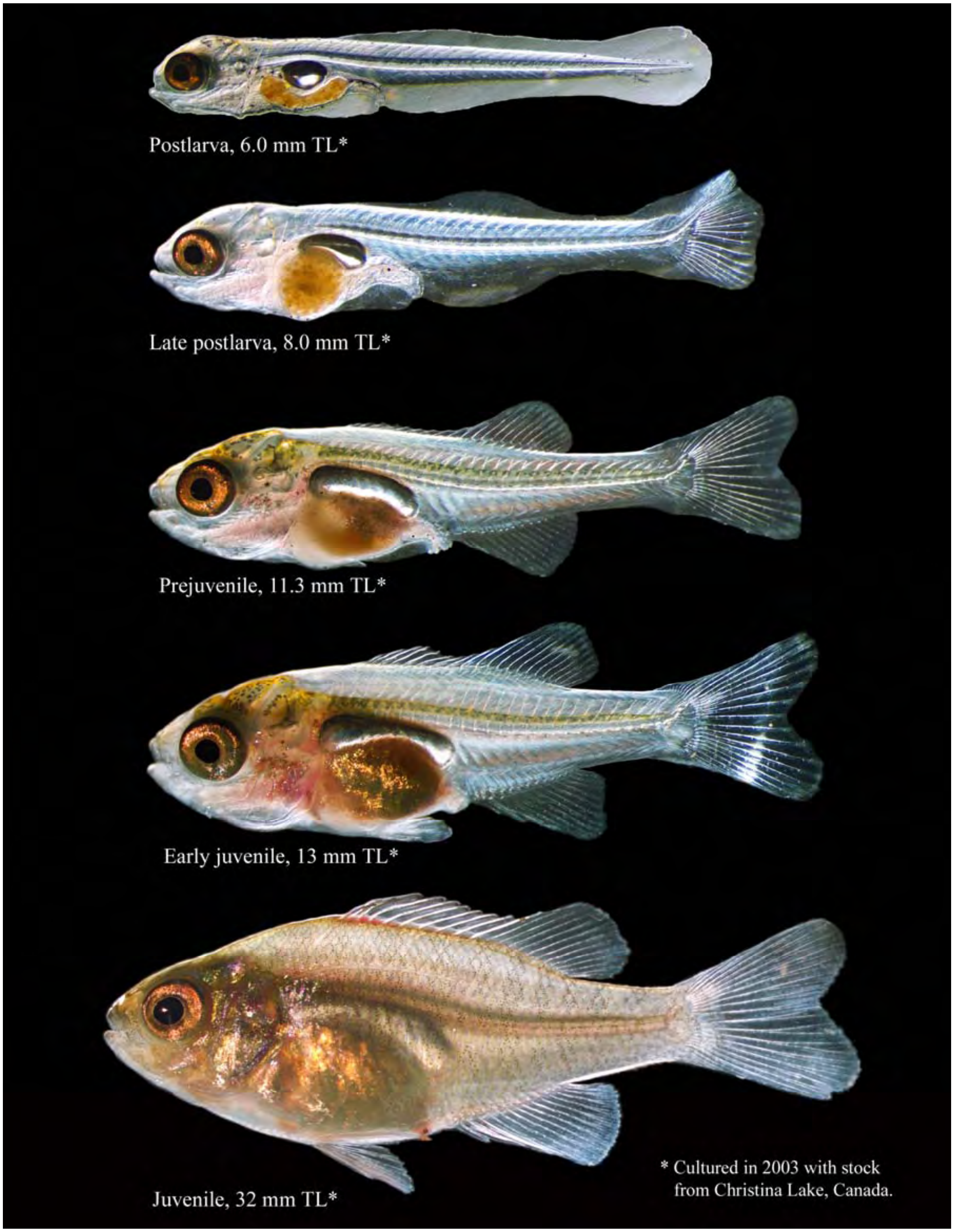


FIGURE 5b.—Pumpkinseed (*Lepomis gibbosus*).

WARMOUTH, *Lepomis gulosus* (Cuvier)

SPAWNING

Location: Ponds and lakes (Larimore, 1957); Bass Lake and Delta (Moyle, 1976); lentic, dead-end areas of Delta sloughs, such as the abandoned intake channel at CVP/TFCF.

Season: Varies in latitude, May to August in Illinois (Larimore, 1957); April to October in Texas (Larimore, 1957); in late spring and early summer (Moyle, 1976); in spring and summer months in the study area, eggs were observed in July 2003 and June 2005.

Temperature: Minimum at 21.1 °C (Larimore, 1957); 21.9–23.3 °C.

Salinity: Freshwater.

Substrates: Mud, silt, sand, rubble, detritus, leaves, and sticks associated with tree roots, stumps, and vegetation (Hubbs, 1919; Carr, 1939; Larimore, 1957); near dense cover of vegetation (Moyle, 2002); in the study area, spawning males have been collected from riprap; laboratory-spawned eggs were attached mostly to gravel, but also to small sticks, branches, and pebbles.

Fecundity: 4,500–63,000 (Larimore, 1957); ovarian eggs count up to 126,000 (Buss, 1965); 3,029–22,850 mature or nearly mature ova (Germann, *et. al*., 1974); 798–34,257 (Panek and Cofield, 1978).

EGGS

Shape: Spherical (Larimore, 1957); usually spherical but sometimes oblong-shaped.

Diameter: Mature, unfertilized eggs, ~ 1.1 mm or larger (Larimore, 1957); fertilized eggs, 1.0–1.1 mm (Carr, 1939); unfertilized (naturally deposited) eggs were 0.9 mm, fertilized eggs were 0.9–1.0 mm.

Yolk: Light amber (Larimore, 1957); granular, eggs that had bright yellow oil globule had faint yellow yolk; eggs that had clear oil globule had colorless yolk.

Oil globule: Single (Larimore, 1957); ~ 0.35 mm in diameter (Carr, 1939); ~ 0.2 mm in diameter in unfertilized eggs, 0.30–0.36 mm in diameter in fertilized eggs.

Chorion: Clear (Carr, 1939); transparent, thick.

Perivitelline space: Thin (Larimore, 1957); narrow.

Egg mass: Small clusters (Carr, 1939); in small clusters or single layer attached to woody substrate.

Adhesiveness: Adhesive (Carr, 1939); adhesive but easily dislodged.

Buoyancy: Demersal (Carr, 1939), negatively buoyant.

LARVAE

Length at hatching: 2.30–2.85 mm TL (Larimore, 1957); 3.4 mm TL (Trautman, 1957); 3.1–3.8 mm TL.

Snout to anus length: ~ 50% TL for 3.4 mm TL prolarvae, 42–45% TL for 5.3–12.0 mm TL postlarvae (Larimore, 1957). For prolarvae: 48–55% TL (often, 48–50%) for 0 dph at 3.1–3.8 mm TL, 47–50% TL (often, 48–49%) at 3.4–3.8 mm TL, decreasing to 40–42% TL (often, 41–42%) for late prolarvae at 4.4–5.0 mm TL. For postlarvae: 43–46% TL (often, 43–45%) at 5.1–8.7 mm TL.

Yolk sac: Oval, large, extends from jugular to abdominal region (Larimore, 1957); large and oval, extends from head to anus for newly hatched larvae, reduced to the abdominal region within 2–3 days, fully absorbed ~ 5.5 mm TL.

Oil globule(s): Single, 0.35 mm in diameter for newly hatched larvae (Larimore, 1957).

Total myomeres: 29–30 (Larimore, 1957); 25–30 (Taubert, 1977); 26–29, usually 26–28.

Preanal myomeres: 8–11 (Larimore, 1957): 9–11, usually 10–11.

Postanal myomeres: 17–19 (Larimore, 1957); 15–19, usually 15–17.

Pigmentation: Newly hatched larvae have no pigmentation. In postlarvae measuring 5.3–7.6 mm TL, stellate melanophores were observed on cephalic, thoracic, operculum, base of pectorals, and postanal region while dashed melanophores were observed midlaterally (Larimore, 1957). In this study, newly hatched larvae lack pigments on body or eyes. Eyes pigmented at 4.5 mm TL. Late prolarvae and early postlarvae have pigment on ceiling of air bladder, stellate melanophores dorsally on gut, a series of postanal melanophores on ventrum running from the anus to hypural; dorsum is pigment-free except for a short series of melanophores located at the caudal region; dashed melanophores present midlaterally. A few large melanophores are present at cephalic at 6 mm TL and greater.

Distribution: Sloughs of the Delta, such as Taylor Slough, Franks Tract, and lower reaches of San Joaquin River (Wang, 1986); they are seen occasionally at the CVP/TFCF, often caught individually.

JUVENILES

Dorsal fin:	X for spiny dorsal (Beckman, 1952), and 9–11 for the soft dorsal (Trautman, 1957); X–XI, 9–11 (Moyle, 1976).
Anal fin:	III, 8–9 (Beckman, 1952); III, 9–10 (Moyle, 1976).
Pectoral fin:	12–14 (Moyle, 2002).
Mouth:	Large (Moyle, 1976); terminal, large, oblique.
Vertebrae:	29 (Bean, 1903).
Distribution:	Scattered in sloughs throughout the Delta, west of Delta as far as the vicinity of the currently inoperative Oleum Power Plant in San Pablo Bay (Wang, 1986).

Life History

Warmouth is a freshwater fish native to the eastern United States from the Great Lakes region southward to the Mississippi River drainage and throughout the Atlantic and Gulf States (Eddy, 1957; Hubbs and Lagler, 1958). This species was introduced to parts of Washington, Oregon (Bond, 1973; Wydoski and Whitney, 1979), and California. The exact date of their introduction into California waters is not known (Moyle, 2002) although they may have been introduced into Central Valley waters as early as 1891 (Dill and Cordone, 1997; Moyle 2002). Warmouth are known to tolerate brackish water (Renfro, 1960; Swingle, 1971). They are widely distributed in the Delta (Turner, 1966; Moyle, 1976), from the south Delta (Feyrer and Healey, 2002) to the San Pablo Bay; however, they are rarely collected at the CVP/TFCF. They are shy and elusive in the laboratory, hiding behind artificial reefs most of the time. The slow-growing warmouth can reach 300 mm TL (Trautman, 1957). In California, the angling record for warmouth weighed 340 g, caught in the American River (Moyle, 2002). No stunted populations have been observed in the study area.

Spawning takes place in spring and summer in shallow waters with aquatic vegetation or tree roots (Larimore, 1957). Male warmouth construct solitary nest (Childers, 1965) or may nest in colonies (Richardson, 1913; Carr, 1939). In this study, a solitary nest was observed at the tidal riprap of the abandoned intake channel at the CVP/TFCF. In the laboratory, a male and a female were observed spawning. The male built a small depression on the gravel. The male, swimming around the female as she dropped eggs, released milt near the dropped eggs. The female's head gyrated as she slightly tapped the male's side of the body. The couple was observed spawning irregularly for 3 hours. When the female left, the male was observed fanning the nest using the anal and caudal fins, sometimes positioned vertically to the nest. Details of the reproductive biology have been described in Illinois by Larimore (1957). Many aspects of parental care are very similar to those of green sunfish (Moyle, 1976). However, unlike the green sunfish and the redear sunfish, the male warmouth did not vigorously defend the nest when eggs were collected. Most eggs have a clear oil globule and a few were observed with bright yellow oil globules. Eggs hatched within 35 hours at 25–26.4 °C (Larimore, 1957); in our current study, eggs hatched in less than 2 days after spawning at 21.9 °C. Egg development is hindered or stalled at 13 °C (Carr, 1939).

Newly hatched larvae remained in the nest and are guarded by the male until they swim freely, in about 10 days (Carr, 1939). In the laboratory, newly hatched larvae remained near the nest and on their sides until 5 dph (~ 5.0 mm TL) when the air bladder started developing. By ~ 5.5 mm TL, the yolk sac is absorbed and the larvae were in the water column. These postlarvae readily fed on artemia nauplii. In the wild, schooling larvae use submerged plant beds as shelters (Larimore, 1957). In the laboratory, they schooled near bottom to mid-level similar to green sunfish and redear sunfish.

Juveniles become more solitary and prefer protected shallow waters (Carr, 1939; Larimore, 1957). In the laboratory, warmouth reached juvenile stage in 4 weeks when they are 13 mm fork length (FL). Eight vertical bars appeared on the body at ~ 19 mm FL; however, Mabee (1995) observed 7–8 primary vertical bars earlier at 10–16 mm SL. Juvenile warmouth are found in low numbers and scattered in various sections of the Delta and estuary and as far as San Pablo Bay. Juveniles are ambush feeders; early juveniles start with small crustaceans, and then feed on aquatic insects, amphipods, and mysid shrimp as they grow (Turner, 1966). In the laboratory, they also fed on chopped fish (such as juvenile threadfin shad, *Dorosoma petenense*, and American shad, *Alosa sapidissima*), frozen artemia, and were trained to feed on dry feed.

Warmouth breed for the first time at 1–2 years of age (Larimore, 1957) or mature in their second or third summer (Moyle, 1976). Although established in the Delta, they grow slowly (Moyle, 2002) and are seldom sought by anglers because of their small size and uncommonness. Their role in the Delta's ecology is poorly understood (Moyle, 2002).

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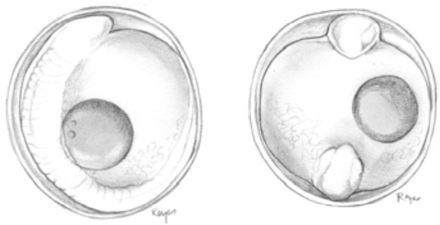
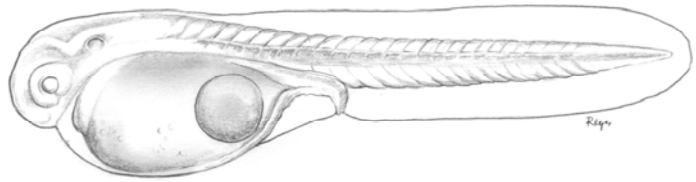
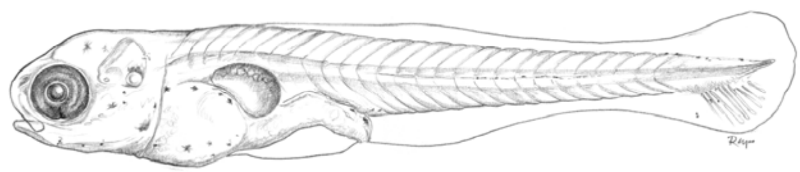


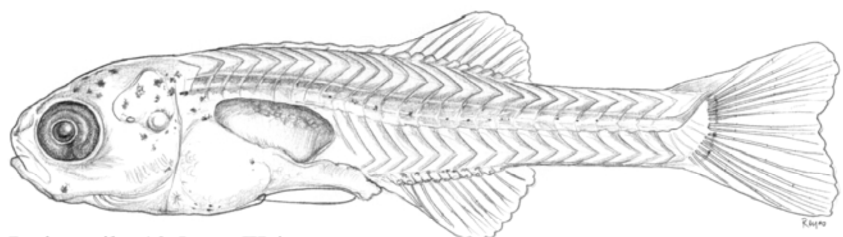
Late embryo, 1.0 - 1.1 mm*



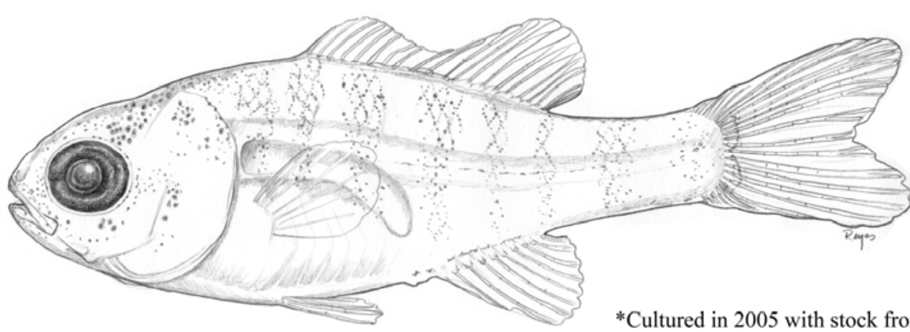
Prolarva, 3.8 mm TL, 0 dph*



Postlarva, 7.2 mm TL*



Prejuvenile, 10.5 mm TL*



Juvenile, 20.8 mm TL*

*Cultured in 2005 with stock from Old River, San Joaquin County, CA.

FIGURE 6a.—Warmouth (*Lepomis gulosus*).

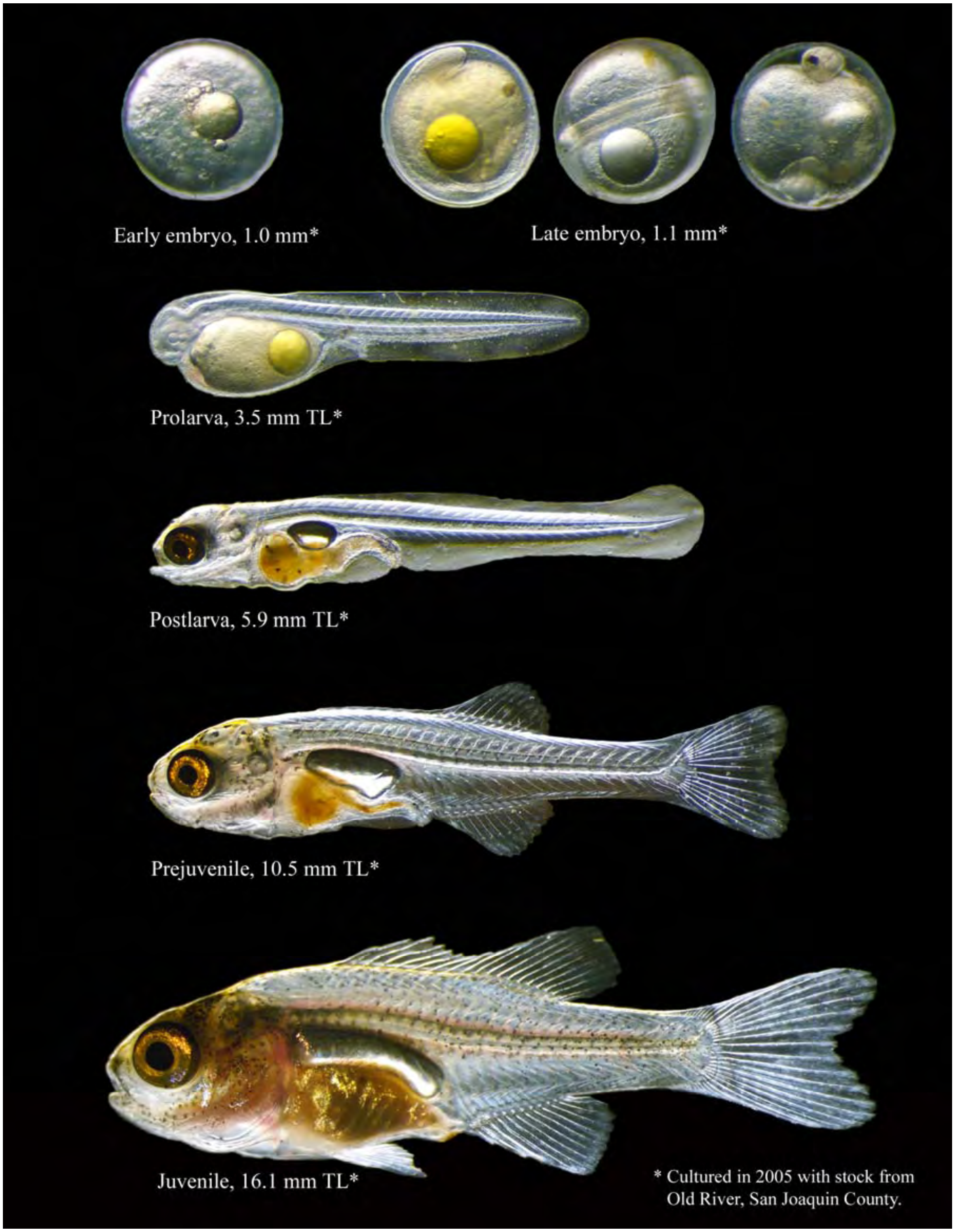


FIGURE 6b.—Warmouth (*Lepomis gulosus*).

BLUEGILL, *Lepomis macrochirus* (Rafinesque)

SPAWNING

Location: Near shore in areas shaded by overhanging trees (Breder, 1936). Some spawn in colonies of 5–150 nests in waters 0.4–1.4 m deep (Gross, 1982), sluggish shallow waters of sloughs, ponds, coves of lakes and reservoirs, and Delta-fed reservoirs such as the Contra Loma Reservoir and the San Luis Reservoir. Bluegill nest in colonies in areas of the Delta that are stagnant such as lagoons or dead-end sloughs (*e.g.*, the old abandoned intake channel of the CVP/TFCF, the pool created by the Old River barrier).

Season: Throughout the summer in California (Moyle, 1976); from the breeding colors of males collected from the Delta, estimated spawning occurs from May through August (Wang, 1986); larvae are abundant in June and July in the Delta (Wang and Reyes, 2007); eggs have been collected in the Delta and reservoirs from June to August, spawning colors last all year under laboratory conditions.

Temperature: 17–27 °C (Morgan, 1951); beginning at 18–21 °C (Moyle, 1976); spawning at the CVP/TFCF abandoned intake channel occurred at 23 °C; spawning in the laboratory often occurred at temperatures > 20 °C.

Salinity: Freshwater; may spawn in tidal freshwater with very low salt content such as in west Delta and Suisun Bay.

Substrates: Nests are constructed in gravel, sand, or mud interspersed with debris, twigs, or dead leaves (Moyle, 1976); on sand or hard clay with eggs deposited on sticks or dead leaves (Wang, 1986); on crevices of riprap, filamentous algae, on floating canopies of dense vegetation in a muddy pond, and on clay and sand with debris in shallow water.

Fecundity: Fecundity increases with size and age of female fish (Carbine, 1939); 2,500–64,000 (Morgan, 1951; Snow, 1960); 2,000–18,000 per nest (Emig, 1966); 2,500–50,000 (Moyle, 1976); 571–27,027 (Panek and Cofield, 1978); actual fecundity may vary since bluegill is an intermittent spawner.

EGGS

Shape: Spherical, some are slightly irregular.

Diameter: Average 1.04 mm (Toetz, 1965); 1.1–1.3 mm in Delaware (Wang and Kernehan, 1979); 0.8–1.3 mm.

Yolk: Pale yellow (Toetz, 1965); amber (Scott and Crossman, 1973); granular (Hardy, 1978); pale yellow to colorless, granular, and in small clusters.

Oil globule: Single (Morgan, 1951; Toetz, 1965); 0.3–0.6 mm in diameter (Wang, 1986); usually single, may have globulets surrounding the large oil globule (Nakamura, *et al*., 1971); some eggs have large oil globule 0.2–0.4 mm in diameter, some have small oil globule < 0.1 mm (collected from the CVP/TFCF abandoned intake channel), but eggs usually have single oil globule with a few oil globulets.

Chorion: Noticeably thick (Carver, 1976); thick and often covered with detritus but still transparent.

Perivitelline space: Slightly wide for newly fertilized eggs and becomes narrow as embryo develops, ~ 10–20% of egg diameter.

Egg mass: Deposited in small clusters, singly, and sometimes in layers, often at the center of the nest.

Adhesiveness: Adhesive (Adams and Hankinson, 1928; Morgan, 1951).

Buoyancy: Demersal or negatively buoyant.

LARVAE

Length at hatching: 2.2–3.2 mm TL (Morgan, 1951; Nakamura, *et al*., 1971); 2–3 mm TL (Scott and Crossman, 1973); ~ 3.0–4.0 mm TL (laboratory sample obtained from Michael Dege with CDFG); 2.7–3.8 mm TL, may hatch prematurely (~ 2.0 mm TL) if disturbed.

Snout to anus length: ~ 42–46% of TL for prolarvae, ~ 40% of TL for postlarvae (Wang, 1986). For prolarvae: 49–58% TL (often 50–51%) for newly hatched (0 dph), 42–50% TL (often 44–47%) for older prolarvae. For postlarvae: 40–41% TL.

Yolk sac: Large, spherical to oval; extending from head to abdominal region (Wang, 1986); large, oval, extending from head to anus for newly hatched larvae, and reduced to the abdominal region within 1–2 days.

Oil globule(s): Single, located in the posterior portion of the yolk sac (Carver, 1976; Wang and Kernehan, 1979).

Gut:	Straight in prolarvae and coiled in single loop in postlarvae (Anjard, 1974); gut depressed (by inflated air bladder) in early postlarvae, twisted and looped in late prolarvae and early postlarvae.
Air Bladder:	In prolarvae, air bladder is oval, small, and located midway between pectoral fins and anus; appears in prolarvae as early as 4 mm TL but is usually present by ~ 5 mm TL. In postlarvae, air bladder becomes large and elongate.
Teeth:	Small, pointed, appears in postlarval stage.
Size at absorption of yolk sac:	4.92–5.84 mm TL (Toetz, 1966); 4.8–5.0 mm TL (Wang and Kernehan, 1979); 5.5–6.5 mm TL.
Total myomeres:	31 (Taber, 1969); 27–31 (Wang, 1986); 29–32, often 30–31.
Preanal myomeres:	10 (Taber, 1969); 9–11 (Wang, 1986); 10–12, often 10–11.
Postanal myomeres:	21 (Taber, 1969); 17–20 (Wang, 1986); 19–21, often 19–20.
Last fin(s) to complete development:	Pelvic.
Pigmentation:	No pigmentation on newly hatched larvae (Hardy, 1978; Wang and Kernehan, 1979); in postlarvae a row of chromatophores is visible along posterior margin of head at ~ 7 mm TL (Meyer, 1970). Stellate melanophores are visible on cephalic, dorsal surface of gut, and postanal regions and there are three rows of large melanophores in mosaic arrangement in postanal and above postanal regions in postlarvae (Wang, 1986); pigmentation concentrates in the lower half of body in postanal region.
Distribution:	Newly hatched larvae remain in the nesting area (Hardy, 1978; Wang, 1986); free-swimming larvae inhabit shallow water with vegetation (Taber, 1969). Larvae have been collected in the shallow shorelines of reservoirs such as the Contra Loma Reservoir (Contra Costa County) and the O'Neill Forebay (Merced County) as well as in the open waters of the Delta (Wang and Reyes, 2007) such as the Suisun Bay, University of California at Davis sampling and south Delta (CVP/TFCF sampling).

JUVENILES

Dorsal fin:	X, 10–12 (Moyle, 1976); X–XI, 10–12 (Scott and Crossman, 1973).
Anal fin:	III, 11–12 (Moyle, 2002); III, 8–11 (Scott and Crossman, 1973).
Pectoral fin:	13–14 (Moyle, 2002; Scott and Crossman, 1973).
Mouth:	Terminal, small, oblique (Scott and Crossman, 1973).
Vertebrae:	28 or 29 (Scott and Crossman, 1973); 28–30 (Stokely, 1952).
Distribution:	Limnetic to littoral zone (Werner, 1967); mostly in the sluggish backwaters of sloughs throughout the Delta, above the Old River barrier, Delta-fed reservoirs and ponds, and also in oligohaline water such as Suisun Bay and Napa River.

Life History

The native range of the bluegill is in freshwaters of central and eastern North America (Scott and Crossman, 1973) and south to Florida and northeastern Mexico (Moyle, 1976; Hardy, 1978). Bluegill was introduced into California in 1908 (Dill and Cordone, 1997). Populations are established throughout most of the state except in the Sierras. This species is abundant in the Delta (Nichols, 1943; Turner, 1966; Moyle, 2002; Brown and Michniuk, 2007), the most abundant centrarchid in the south Delta (Feyrer and Healey, 2003), and is the most salvaged centrarchid at the CVP/TFCF. Their numbers have increased in the littoral fish assemblages of the Delta, which is probably due to the spread of Brazilian elodea (*Egaria densa*; Brown and Michniuk, 2007). However, they are absent in some small coastal streams such as Lobitos, Tunitas, and Tennessee Valley Creeks where pool habitats are lacking.

Spawning takes place in shallow, shaded waters with vegetation and tree roots from May through August, peaking in June and July (Wang, 1986). Spawning also occurs along riprap found throughout the Delta, such as at the abandoned intake channel of the

CVP/TFCF and above the barrier of the Old River. Spawning males become darker on the dorsum and rusty orange in the abdomen. They excavate depressions on sand, gravel, or hard clay bottoms, and then add sticks and dead leaves. Filamentous algae that grows on rocks is also used as spawning substrate. A male builds and defends a nest in close proximity to a few or several other nests (Scott and Crossman, 1973; Moyle, 1976; Gross, 1982). Nesting in colonies may be beneficial since a collective defense is more effective against predators. Nests that are solitary and nests that are located on the periphery of colonies experience heavier losses from predation than nests located near the center of the colony (Gross and MacMillan, 1981). Colonial males can also devote less time to defending eggs and more time to fanning them, reducing fungal infection (Côté and Gross, 1993). Males occasionally remove diseased eggs from nests (Côté and Gross, 1993). During spawning, there may be one or more satellite males or sneaker males involved with the parental fishes (Dominey, 1981; Gross, 1982, 1991). Satellite males can mimic females in color and behavior giving them the ability to position themselves in the nest, often between the spawning female and parental male. Sneaker males usually hide themselves behind plants or other objects and dart into the nest during spawning. These two types of males do not build nests (Gross, 1982). More than one pair of fish remains in the nesting area during the spawning period. Males continually fan the eggs during the 2–4 day egg stage (Coleman and Fischer, 1991). Often, incubation takes 2–3 days at 20 °C in the field (Wang and Kernehan, 1979) or less than 2 days at 23 °C in the laboratory. A male bluegill will guard and clean his nest after spawning season is over if water temperature remains 20 °C and above (laboratory observation).

Newly hatched larvae remain in the nest (Morgan, 1951; Hardy, 1978) until the eyes become pigmented and the yolk is completely absorbed (Scott and Crossman, 1973). Parental males guard and fan the nest until hatching, and guard the larvae until they become free-swimming (Gross, 1982). Survival of young was greatest in nests with coarse substrate (Bain and Helfrich, 1983). Clady and Ulrichson (1968) reported that fry were free-swimming 6 days after hatching. Newly hatched larvae are active in the nesting area and are preyed upon by nearby fishes, and sometimes by hydras. Taber (1969) found larvae at all depths, but mostly near the bottom. In this study, larvae had a very short planktonic (drifting) life stage. Few larvae collected by plankton nets were greater than 10 mm TL and most larvae greater than 10 mm TL were found in shallow waters near or among vegetation, while some ventured out into the open waters (Wang and Reyes, 2007). Others switch from nesting area into plant beds when the larvae become densely pigmented (Moyle, 1976).

Juveniles swim in small schools near or among plant beds (Morgan, 1951); in the Delta, particularly in the south Delta, juveniles are always associated with aquatic vegetation such as rooted *Egaria densa* and floating water hyacinth (*Eichhornia crassipes*). In the laboratory, bluegill reached juvenile stage at 14 mm TL and vertical pigmentation bars appeared at ~ 17 mm TL. Mabee (1995) observed 7–8 primary vertical bars in juveniles. Bluegill juveniles are often observed in great numbers at the CVP/TFCF soon after agricultural barriers, such as at the head of Old River, are breached. Some juveniles were observed as far as San Pablo Bay during high freshwater flows, tolerating salinities of

1–2 parts per thousand (ppt; Moyle, 2002). Juveniles feed on copepods and cladocerans (Siefert, 1972), planktonic crustaceans, aquatic insects, and insect larvae (Moyle, 1976; 2002). Juveniles can be trained to eat dry feed.

The spawning age of the bluegill ranges from 1–3 years (Morgan, 1951; Moyle, 1976). Their maximum lifespan is 8–10 years (Scott and Crossman, 1973), but a few may live more than 6 years (Moyle, 2002). Bluegill is an abundant freshwater game fish sought by fishermen in California.

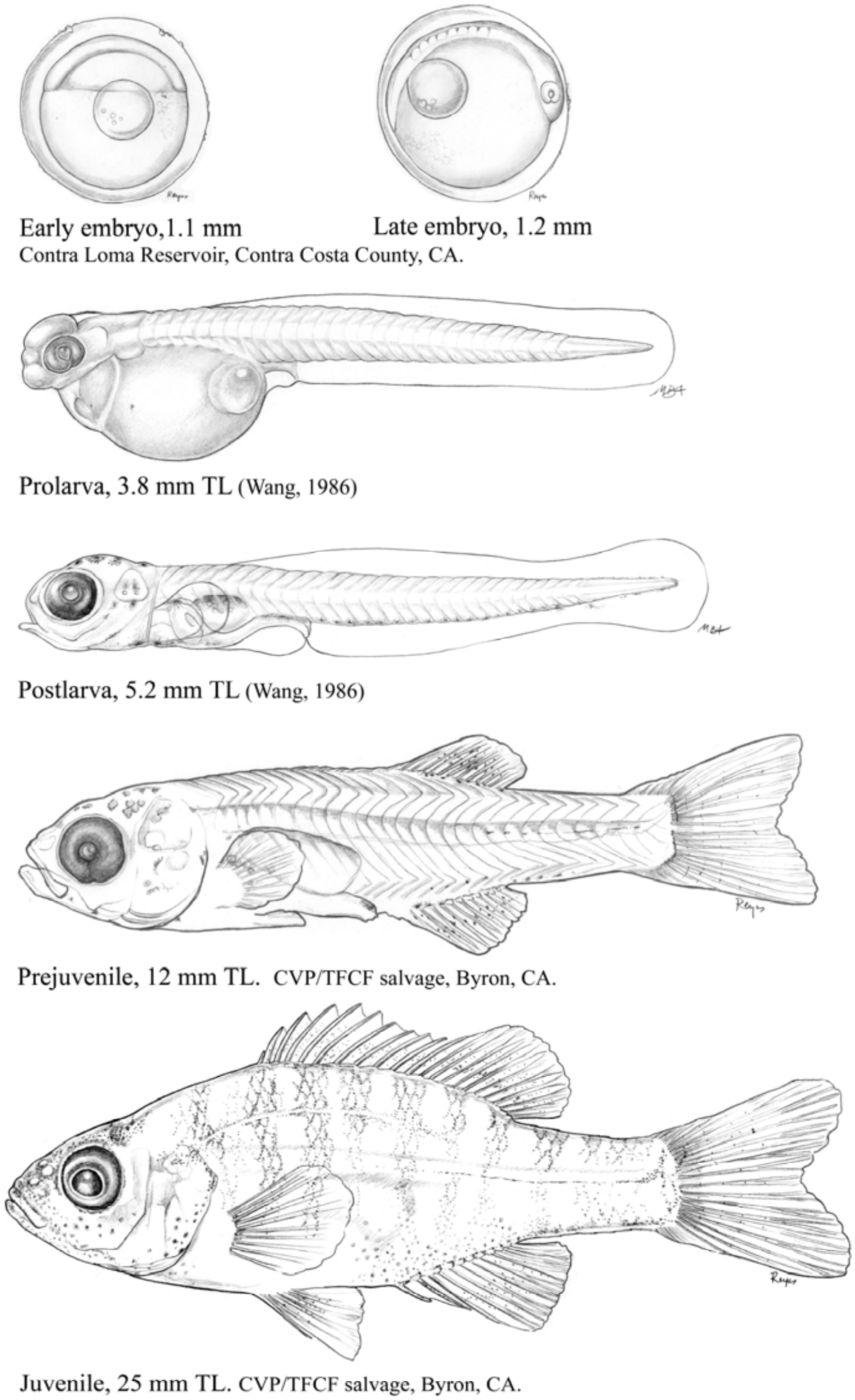


FIGURE 7a.—Bluegill (*Lepomis macrochirus*).

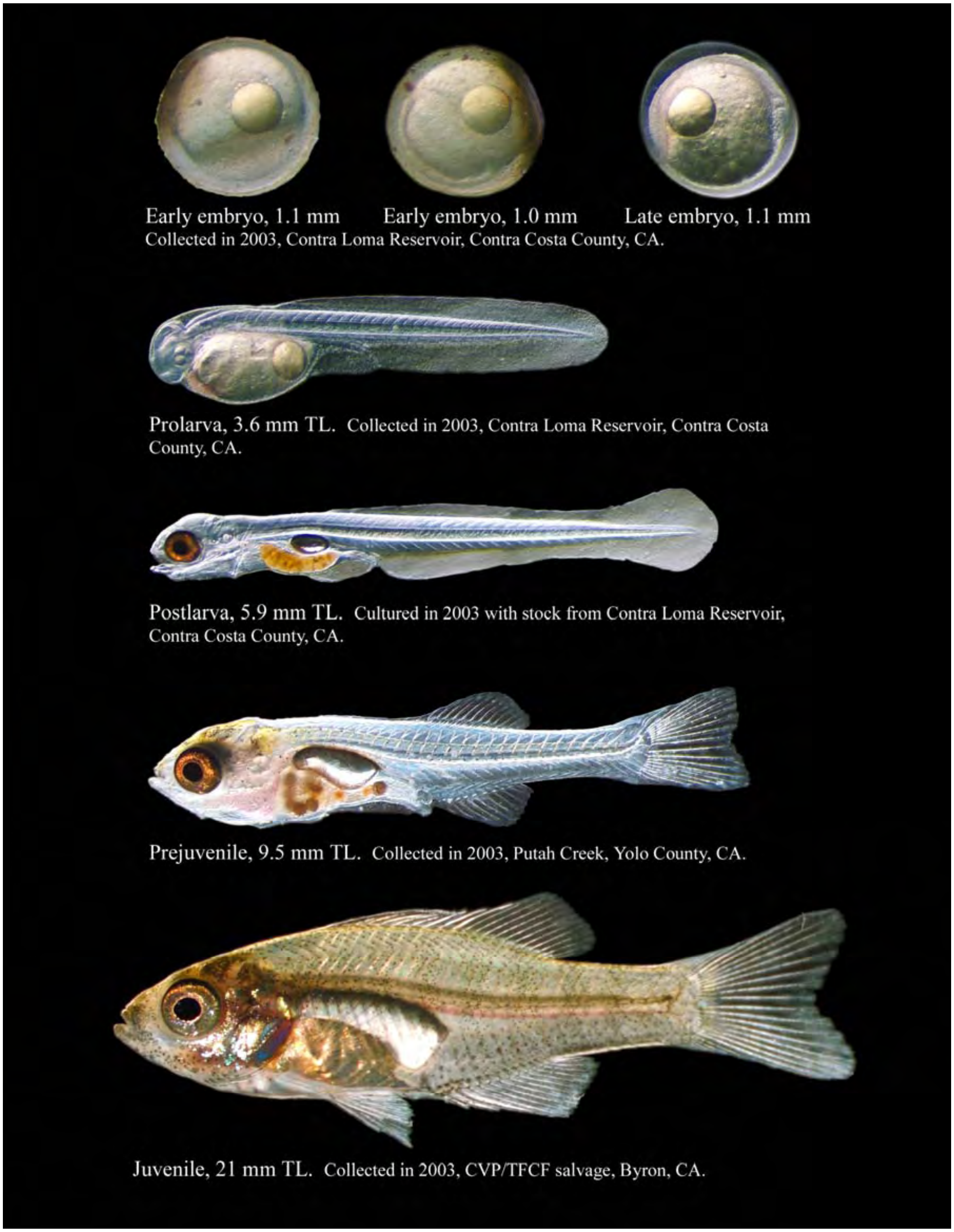


FIGURE 7b.—Bluegill (*Lepomis macrochirus*).

REDEAR SUNFISH, *Lepomis microlophus* (Guenther)

SPAWNING

Location:	Shallow region of ponds and reservoirs, such as Rancho Seco Park pond, Lake Berryessa, Putah Creek, the abandoned intake channel of CVP/TFCF, pool above the barrier of Old River, and Contra Loma Reservoir (Contra Costa County).
Season:	May through September in Tennessee (Schoffman, 1939); spring to fall in Alabama (Swingle, 1946); March and as late as September in Florida (Moody, 1957); throughout the summer in California (Emig, 1966); estimated April to August (Wang, 1986); mid-April to mid-August in Rancho Seco Reservoir (Christophel, 1988); from late-April to August, peaking in late-May to mid-July.
Temperature:	Approaching 21.1 °C (Clugston, 1966); 22–24 °C (Emig, 1966); larvae collected at 22.5 °C (Wang, 1986); eggs collected at 22–23 °C.
Salinity:	Freshwater.
Substrates:	Gravel, sand, and hard clay in areas such as at Putah Creek (Marchetti, 1998), Lake Berryessa, and Millerton Lake (Wang, 1986); in the Delta, often in riprap interspersed with stone, gravel, small rocks, and filamentous algae.
Fecundity:	Average fecundity of 25,000 eggs per female (Wilbur, 1969); by stripping, fecundity ranged from 120 –3,977 (Smitherman and Hester, 1962); 9,655–79,286 eggs per female from Rancho Seco Reservoir, Sacramento County (Christophel, 1988); 9,000–80,000 estimated (Moyle, 2002).

EGGS

Shape:	Mostly spherical, some slightly irregular.
Diameter:	1.3–1.6 mm in diameter (Meyer, 1970); 1.2–1.5 mm in diameter.
Yolk:	Whitish, pale yellow, granular, some eggs have oil globulets.
Oil globule:	Single, very large, ~ 0.4–0.5 mm in diameter, most are bright yellow or golden but a few are pale yellow.
Chorion:	Transparent and thick, often covered with debris.
Perivitelline space:	Narrow, ~ 0.1–0.2 mm in morula and early embryo.
Egg mass:	Deposited singly and sometimes in small clusters of 3–5 eggs.
Adhesiveness:	Adhesive, attaching to detritus, sand grains, small rocks, stones, gravel, and especially filamentous algae.
Buoyancy:	Demersal or negatively buoyant.

LARVAE

Length at hatching:	Maximum 5.0 mm TL (Hardy, 1978); ~ 3.0–4.6 mm TL.
Snout to anus length:	~ 40–41% TL of larvae at 6.1–6.5 mm TL (Wang, 1986). For prolarvae: 49–59% TL at 0 dph, 44–57% TL at 3.1–4.6 mm TL (eyes unpigmented), and 38–44% TL at 4.8–6.6 mm TL (eyes pigmented). For postlarvae: 39–46% TL at 5.9–7.9 mm TL.
Yolk sac:	Initially large and oval extending from lower jaw to anus, then becoming spherical; located in abdominal region in late prolarvae.
Oil globule(s):	Single, large, bright yellow or gold to pale yellow located posteriorly in yolk sac.
Gut:	Straight in prolarvae; becomes more arched during postlarvae development (~ 6.0 mm TL).
Air Bladder:	Spherical, oval, sometimes “tear-drop” shaped; located midway between pectoral fins and anus; dorsal surface of air bladder covered with pigmentation at 5.0 mm TL (May and Gassaway, 1967), or 4–5 days after hatching.
Teeth:	Very small and pointed, appear in postlarvae.
Size at absorption of yolk sac:	6.5–7.0 mm TL (Wang, 1986); ~ 6.0 mm TL but remnants of yolk and oil globule may be visible up to 6.5 mm TL.
Total myomeres:	30–32 (Wang, 1986); 29–32, often 29–30.
Preanal myomeres:	10–13 (Wang, 1986); 10–13, often 10–11.
Postanal myomeres:	17–20 (Wang, 1986); 17–21, often 18–20.
Pigmentation:	In prolarvae, small melanophores present on head, in thoracic region and on dorsal surface of gut; a series of melanophores in postanal region extends to dorsal region of caudal area. In postlarvae, a series of intermittent melanophores are visible along the midlateral region (Meyer, 1970; Wang, 1986); at 10.0–15.0 mm TL, a conspicuous line of melanophores is present on breast and belly and there is a double line of pigment in postanal region (Werner, 1966).

Distribution:	In shallow water near vegetation, such as the old abandoned intake channel of the CVP/TFCF, Contra Loma Reservoir, and Putah Creek. Larval redear sunfish are commonly collected in the sloughs of the south Delta.

JUVENILES

Dorsal fin:	X, 10–12 (Carr and Goin, 1955); X, 11–12 (Moyle, 1976).
Anal fin:	III, 9–11 (Carr and Goin, 1955); III, 10–11 (Moyle, 1976).
Pectoral fin:	13 (Moyle, 1976; Wang, 1986).
Mouth:	Terminal, small, and oblique.
Vertebrae:	32–33 (Wang, 1986).
Distribution:	Shallow coves of ponds, reservoirs, and sloughs, near or among vegetation and the crevices of levees and riprap.

Life History

The redear sunfish is native to the Mississippi River drainage including the Southern United States from the Rio Grande to the Florida Peninsula (Eddy, 1957; Hubbs and Lagler, 1958; Wilbur, 1969). This species was introduced to the lower Colorado River during the 1950s (Beland, 1953) and probably in the same period into southern California (Shapovalov, *et al*., 1959; Dill and Cordone, 1997). Redear sunfish is the second most common centrarchid (behind bluegill) in the south Delta (Feyrer and Healey, 2003) and has increased its presence in the Delta littoral fish assemblage (Brown and Michniuk, 2007). In this study, redear sunfish were observed throughout the Delta and its adjacent waters.

Reported spawning depths vary: 0.4–6 m in Rancho Seco Reservoir (Christophel, 1988); > 1.8 m deep (Swingle and Smith, 1950); to 3 m (Emig, 1966). In this study, redear sunfish nests were found close to shore in quiet waters (ponds and reservoir) as deep as 1 m. Their eggs have been collected from nests in riprap about 1 m below the high tide mark at the CVP/TFCF abandoned intake channel. Males construct nests in close proximity to each other (Christophel, 1988; this study). Eggs are deposited on sand, gravel, small rocks, and on filamentous algae. Redear sunfish are multiple spawners and larger females do not necessarily produce more eggs (Christophel, 1988). In this study, eggs were harvested from several nests located at the abandoned intake channel of the CVP/TFCF. Males aggressively defended nests from intruders by flaring their opercula and fins. Spawning occurred in water ranging from 21–24 °C with incubation periods lasting about 2 days (Emig, 1966; Childers, 1967; this study). In Rancho Seco Reservoir, use of deep littoral habitats by spawning adults was highest in mid-summer (Christophel, 1988). Similar to bluegill colonies (Gross and MacMillan, 1981), eggs from nests located on the periphery of colonies are heavily preyed upon (Christophel, 1988). Christophel (1988) observed as many as 100 young-of-the-year largemouth bass simultaneously preying on eggs in a single nest in situations where a male redear sunfish was frightened off or removed from the nest.

Newly hatched redear sunfish larvae are transparent, including the eyes. The large, oval-shaped yolk sac extends from the snout to near the anus and has an oil globule (bright yellow to pale yellow) located posteriorly. Prolarvae swim sideways or dart upwards for a short distance. It takes at least 4–5 days before eyes are pigmented and the air bladder is inflated enabling the larvae to swim freely in the water column. Larvae school with hitch (*Lavinia exilicauda*) and bluegill of a similar age near or in weedy inshore areas (Wang, 1986). In the laboratory, the larvae swim in large schools near the bottom and mid-level of the aquarium. Among the *Lepomis* spp., redear sunfish larvae are the most robust. They have the largest oil globule (comparable only with the largemouth bass), largest eggs (up to 1.5 mm compared to 1.3 mm for the bluegill), and the largest hatching size (up to 4.6 mm TL compared to 3.9 mm TL for the green sunfish).

Redear sunfish juveniles are found alone and in schools in vegetated, shallow waters (Hellier, 1967; Wang, 1986). In the laboratory, redear sunfish reached juvenile stage as early as 14 mm FL; however, vertical bars were not visible until ~ 19 mm FL. Mabee (1995) observed 9–10 primary vertical bar pigmentations in 23 mm SL juveniles. Those juveniles that venture deeper into open water remain close to vegetation. They are more often captured in clear water than murky water. In laboratory conditions, juveniles swim close to the bottom and seldom on the surface.

Moyle (2002) suggested that redear sunfish require warm, clear water near plant beds to grow. In recent years, the Delta has become more clear (Lehman, 2004), and the south Delta has experienced an explosion of introduced aquatic vegetation (CVP/TFCF, unpublished debris data). Redear sunfish are generally less abundant than bluegill in waters where the two species co-exist (Yeh, 1977). However, in the abandoned intake channel of the CVP/TFCF, redear sunfish are more abundant than bluegill (author's personal observation). Small juvenile redear sunfish feed primarily on insect larvae and small crustaceans; larger juveniles may include snails in their diet, hence their popular common name "shell-cracker" (Wilbur, 1969). It is possible that redear sunfish are benefiting from the successful introduction of the Asiatic clam (*Corbicula fluminea*) in the Delta.

In their native range, redear sunfish mature as early as 8 months (Dineen, 1968), in 1–2 years (Wilbur, 1969), or in their second summer (Schoffman, 1939; Pflieger, 1975). In California, maturity of this species may be delayed to 3–4 years. Stunted populations in California are seldom observed (Moyle, 1976). This characteristic, along with fast growth rate and tendency not to overpopulate, make the redear sunfish popular in intensively managed small impoundments (Christophel, 1988). In the laboratory, redear sunfish is easy to culture and grows fast on commercial feed making it a potentially viable farmed panfish. Individual redear sunfish collected at the CVP/TFCF can easily weigh 500 g or more.

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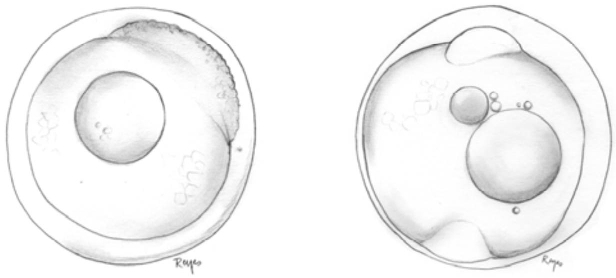
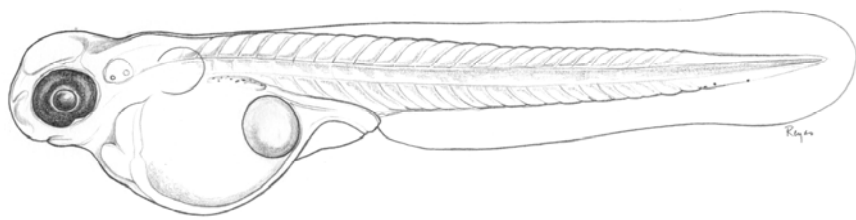
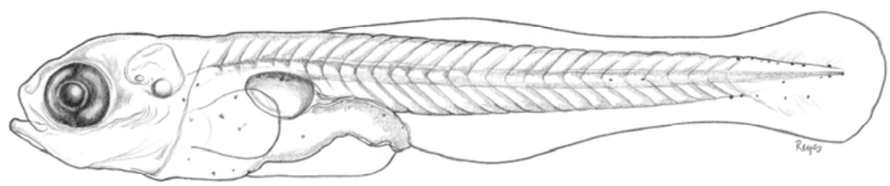


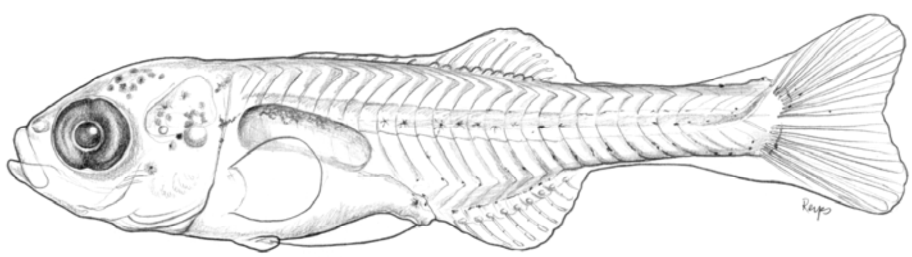
Embryo, 1.3 mm. CVP/TFCF abandoned intake canal, Byron, CA.



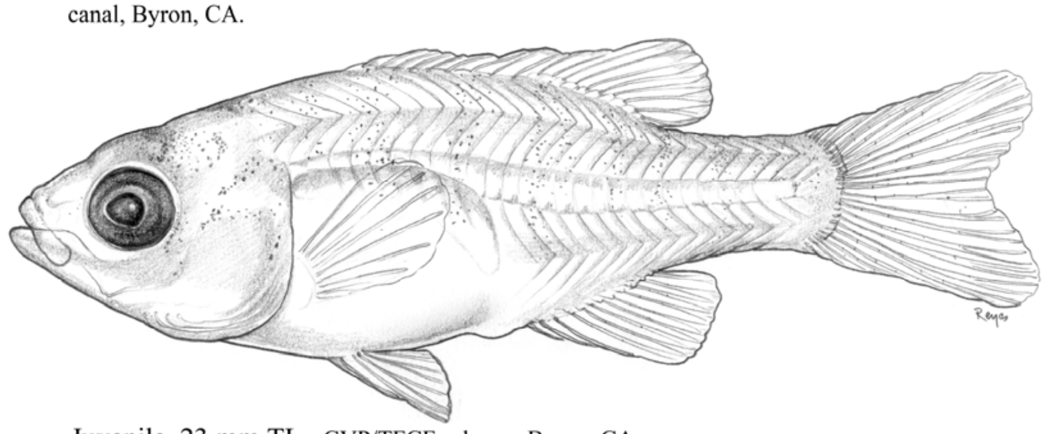
Prolarva, 6.2 mm TL. Contra Loma Reservoir, Contra Costa County, CA.



Postlarva, 7.2 mm TL. CVP/TFCF abandoned intake canal, Byron, CA.



Prejuvenile, 9.5 mm TL. Cultured with stock from CVP/TFCF abandoned intake canal, Byron, CA.



Juvenile, 23 mm TL. CVP/TFCF salvage, Byron, CA.

FIGURE 8a.—Redear sunfish (*Lepomis microlophus*).

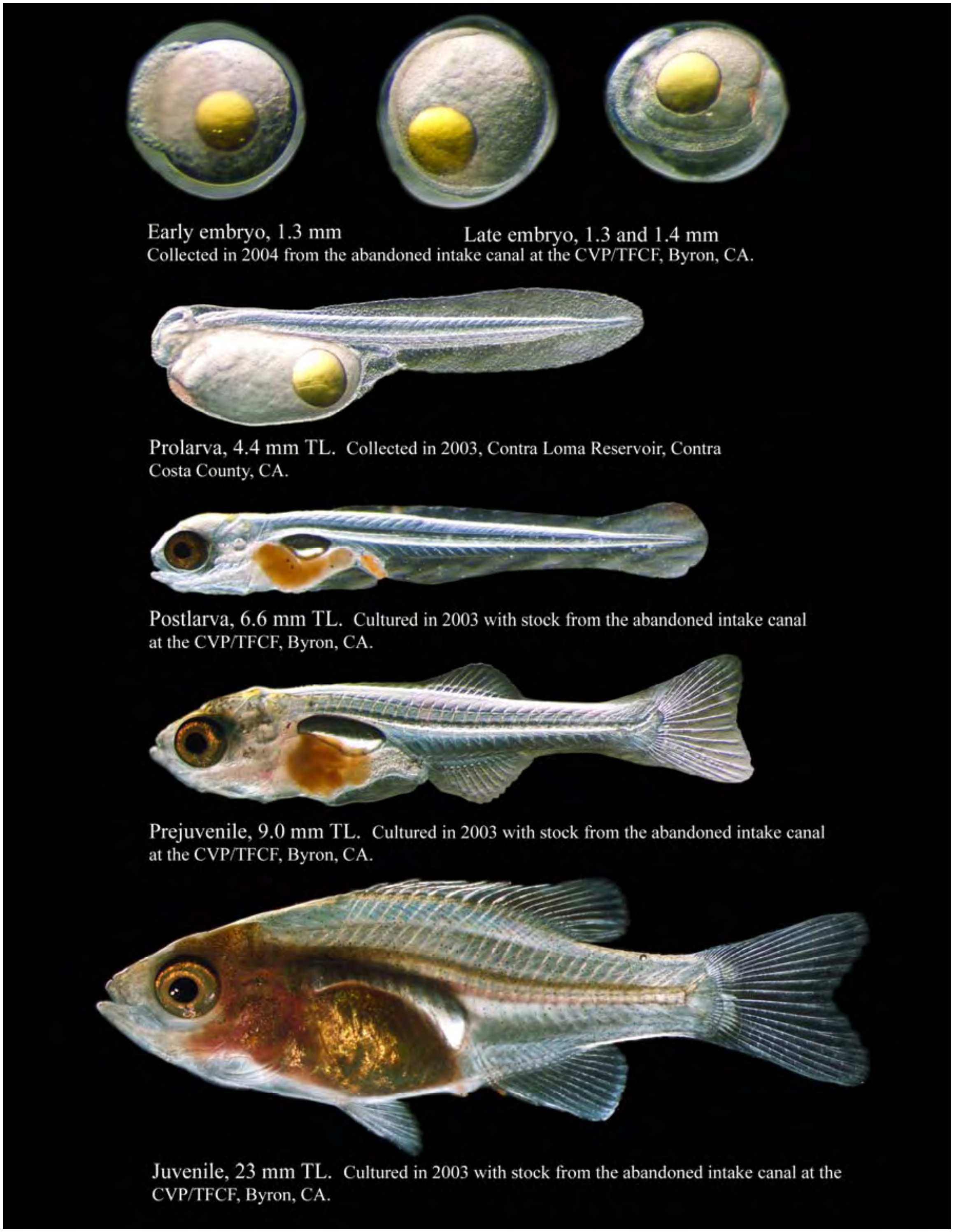


FIGURE 8b.—Redear sunfish (*Lepomis microlophus*).

SMALLMOUTH BASS, *Micropterus dolomieu* (Lacépède)

SPAWNING

Location:	In streams (Trautman, 1957; Pflieger, 1975) to lakes (Webster, 1954); most move from reservoirs or lakes to tributaries to spawn (Wang, 1986); quiet water near shore or below boulders with little or no current (Pflieger, 1975) such as Capell Creek, Dry Creek, and Putah Creek and possibly downstream of Putah Diversion Dam, vicinity of Reclamation's Red Bluff Research Pumping Plant at the Sacramento River, tributaries of Folsom Lake, and upper San Joaquin River of Millerton Lake (Wang, 1986).
Season:	As early as March (Hogan, 1934) and as late as August (Henderson and Foster, 1957); late spring (Moyle, 1976), May–July (Fish, 1932; Pflieger, 1975); judging by larvae collected from Capell Creek, estimated in April and May (Wang, 1986).
Temperature:	13–16 °C (Moyle, 1976); 12.8 °C (Henderson and Foster, 1957); 16.1–18.3 °C (Scott and Crossman, 1973); started at 15–16 °C (Pflieger, 1975); 12.5–23.5 °C (Graham and Orth, 1986); 15 °C (Ridgway, *et al.*, 1991; Lukas and Orth, 1995); larvae collected at 14–15 °C from Capell Creek.
Salinity:	Freshwater.
Substrates:	Sand and stone (Beeman, 1924); sand, gravel, rubble, or combination of these substrates (Mraz, 1964); gravel and rock rubble (Emig, 1966; Scott and Crossman, 1973); sometimes vegetation or woody debris (Goff, 1984); rocks and pebbles (Wiegmann, *et al.*, 1992); rocky rivers and creek beds with sandbars.
Fecundity:	Varies from 4,964 (Reynolds, 1965) to 20,825 (Fajen, 1975); average of 2,500 (Pflieger, 1975); 2,000–21,000 (Moyle, 1976).

EGGS

Shape:	Spherical.
Diameter:	Fertilized eggs are 1.2 mm in diameter (Scott and Crossman, 1973) to 2.8 mm (Reighard, 1906); average 2.0 mm (Meyer, 1970).
Yolk:	Amber (Fish, 1932; Coble, 1975); golden yellow (Pflieger, 1975); pale yellow (Hardy, 1978).
Oil globule:	Single, large (Fish, 1932).
Chorion:	Outer membrane adhesive and inner membrane transparent (Hardy, 1978).
Perivitelline space:	Narrow, ~ 0.2 mm in width (Reighard, 1906).
Egg mass:	Small cluster, becoming loose during incubation and falling into crevices of substrates (Coble, 1975); circular mass of eggs (Goff, 1984).
Adhesiveness:	Adhesive initially after fertilization (Coble, 1975).
Buoyancy:	Demersal (Scott and Crossman, 1973) or negatively buoyant.

LARVAE

Length at hatching:	4.6 mm TL (Reighard, 1906); ranged 5.6–5.9 mm TL 1 day after hatching (Tester, 1930); ~ 5.0 mm TL (Coble, 1975).
Snout to anus length:	~ 48–53% TL at 6.75–11.1 mm TL (Reighard, 1906); ~ 46% TL at 8.8 mm TL (Fish, 1932); ~ 46% TL at 10.2 mm TL (Meyer, 1970); ~ 48.7–52.3% TL for postlarvae and prejuveniles 13.2–16.4 mm TL (Yakima, Washington specimens provided by Reclamation's Mark Bowen).
Yolk sac:	Spherical to oval, very large, extending from head to abdominal region (Reighard, 1906).
Oil globule(s):	Single, bright golden (Reighard, 1906).
Gut:	Initially straight; coiled at 8.0 mm TL (Anjard, 1974) or at 9.5 mm TL (Fish, 1932).
Air Bladder:	Develops at 9.3 mm TL (Piscator, 1950); near pectoral fins (Anjard, 1974).
Total myomeres:	29–33 (Fish, 1932).
Preanal myomeres:	10–11 (Fish, 1932).
Postanal myomeres:	19–22 (Fish, 1932).
Last fin(s) to complete development:	Pelvic (Hardy, 1978).
Pigmentation:	No pigmentation at hatching, pigmentation appears on head, trunk, and in thoracic and postanal regions at about 7.5 mm TL (Reighard, 1906). Larger specimens (~ 8–9 mm TL) have dense pigmentation covering the entire body (Reighard, 1906; Fish, 1932; Hardy, 1978). Pigmentation pattern can be patchy on body (such as light small melanophores/dense large melanophores) and no bars.

Distribution:	Newly hatched larvae remain in the nesting area for about a week then swim in a tight swarm for a couple more days before dispersing into shallow inshore waters (Reighard, 1906; Pflieger, 1975). In this study, smallmouth bass were found in pools and oxbows of lower Capell Creek, upper Putah Creek, and upper Millerton Lake.

JUVENILES

Dorsal fin:	Spiny dorsal IX–X (Hildebrand and Schroeder, 1928; Moyle, 1976); X, 14 (Fish, 1932); soft dorsal 12–15 (Scott and Crossman, 1973) and 13–15 (Moyle, 1976).
Anal fin:	III, 12 (Fish, 1932); III, 10–12 (Moyle, 1976; Scott and Crossman, 1973); spiny anal II–III (Hardy, 1978).
Pectoral fin:	Up to 18 (Moore, 1957); 13–15 (Scott and Crossman, 1973); 16–18 (Moyle, 1976).
Mouth:	Terminal, large, slightly oblique maxillary reaching to the middle of the eye in juveniles and past the middle of the eye in young adults, but not going beyond the hind margin of the eye (Scott and Crossman, 1973; Moyle, 1976).
Vertebrae:	Up to 33 (Bean, 1903); 31–32 (Scott and Crossman, 1973).
Distribution:	Sandy shoals (Webster, 1942), rocky area (Coble, 1975); shallow stream pools with sandy, rock bottoms, and sandbars with vegetation, such as at Capell Creek, and in shallow inshore areas with loose granite granules such as at Millerton Lake.

Life History

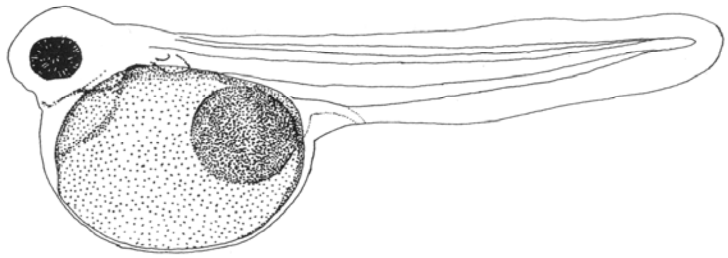
The smallmouth bass is native to the freshwaters of eastern and central North America, covering most of the upper Mississippi River drainages north to the Great Lakes and the United States–Canadian border (Scott and Crossman, 1973). This species has been introduced throughout most of the United States and in many other countries (Emig, 1966; Scott and Crossman, 1973; Coble, 1975). The smallmouth bass was introduced to California waters in 1874 (Curtis, 1949). In this study, smallmouth bass was observed in the San Joaquin River at Millerton Lake, Folsom Lake, Red Bluff Research Pumping Plant, Capell Creek of Lake Berryessa, and Putah Creek. It is rarely observed at the CVP/TFCF.

Numerous smallmouth bass postlarvae and juveniles were collected in Capell Creek in spring and summer months (Wang, 1986); therefore, spawning was estimated to have occurred in April and May. In the San Joaquin River at Millerton Lake, spawning may be variable because of the water temperature variation between the upper basin and the lower lake. Smallmouth bass may migrate to the lower lake where water is warmer and more suitable for spawning. Potamodromy has been documented for smallmouth bass populations (Robbins and MacCrimmon, 1977; Schmidt and Stillman, 1998). The optimum temperature for egg deposition is 16.1–18.3 °C (Scott and Crossman, 1973). Courtship of smallmouth bass found in California has been described by Emig (1966) and Moyle (1976). Both males and females are generally monogamous (Raffetto, 1987; Wiegmann, *et al.*, 1992), although polygynous mating has been documented (Webster, 1954; Coble, 1975). Large individuals of both sexes tend to spawn earlier in the season (Turner and MacCrimmon, 1970; Ridgway, *et al.*, 1991; Wiegmann, *et al.*, 1992; Lukas and Orth, 1995). Males generally construct nests 30–60 cm in diameter in shallow water with sandy to rocky substrate. Smallmouth bass nests have been found in water as deep as 6 m (Mraz, 1964). In Millerton Lake, some nesting sites were observed close to spotted bass nests (D. Mitchell, 1979–1991, personal communication). A single male may excavate several nests in close proximity to each other; however, spawning occurs in only one nest (Mraz, 1964). Generally, a male builds nests greater than 1 m from neighboring males (Mraz, 1964). Smallmouth bass eggs are ~ 2 mm in diameter and larger than largemouth bass and spotted bass eggs. They are initially adhesive with some falling into crevices of gravel and rocks. The male guards and aerates the nest during incubation (Hinch and Collins, 1991). Nocturnal activity of smallmouth bass occurs only during spawning season (Hinch and Collins, 1991). Larger males guarded nests containing larger eggs, which suggest that larger males mated with large females (Lukas and Orth, 1995). Eggs hatch in 2–10 days depending on water temperature (Webster, 1948) or specifically, in 10 days at 12.8 °C and 2.5 days at 25.6 °C (Emig, 1966). Among the black basses, smallmouth bass appear to be the most attentive parents, defending the eggs most actively and caring for the larvae longer (Emig, 1966). Larvae are continuously guarded by the male parent for 1–3 weeks (Moyle, 1976) or until they reach 25 mm TL. Survival of young was greater in nests consisting of predominantly rock substrate than in nests constructed of other substrate types (Wiegmann, *et al.*, 1992; Lukas and Orth, 1995). Large substrate might provide a better incubation environment for eggs and larvae by being more stable in strong currents (Reynolds and O'Bara, 1991). It may also provide better concealment for the developing larvae (Bain and Helfrich, 1983). Early spawners, which tend to be larger males (preferred by females) are able to spawn a second time in the season. Larvae from early spawnings have a longer growing period, produce larger fry, and have greater survival (Moyle, 2002).

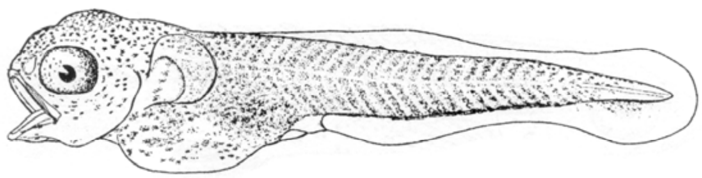
Newly hatched smallmouth bass larvae remain in the nest for several days (Reighard, 1906; Emig, 1966). Larvae are active during the day, increasing their distance from the nest site approximately 5–10 m after 2–3 weeks in the fry stage (Ridgway, 1988). The range of movement of guarding males appears to increase also as larvae grow and move further from the nest (Ridgway, 1991). Dispersal of free-swimming larvae (7–9 mm SL larvae) from nest sites occurs at low velocities (Simonson and Swenson, 1990); high water velocities and high flows are responsible for most nest failures (Lukas and Orth, 1995). Initially, larvae school in a tight ball (Coble, 1975). Agonistic behavior (conflicts within a cohort) is observed within 50 days of hatching and is probably an important mechanism for initiating dispersal (Sabo, *et al*., 1995). When the school breaks up, the juveniles disperse into shallow waters seeking vegetation and rock crevices for shelter.

As the water recedes in summer months, juvenile smallmouth bass have been observed solitary in rocky and sandy pools near the mouth of Capell Creek of Lake Berryessa. They were also observed at the Temperance Flat of upper Millerton Lake (Wang, 1986) and at Reclamation's Red Bluff Research Pumping Plant. Juvenile smallmouth bass initially feed on crustaceans and aquatic insects, and then prey on small fish and crayfish as they grow larger (Moyle, 1976). In Millerton Lake, small threadfin shad are often found in the stomachs of juvenile smallmouth bass (Wang, 1986). Juvenile smallmouth bass can be easily distinguished from largemouth bass and spotted bass by the presence of dorsoventrally elongated primary bars on the body (Mabee, 1995). In addition, the caudal fin of the juvenile smallmouth bass is tricolored: opaque pale yellow to yellow-orange before the band and iridescent white behind (Ramsey and Smitherman, 1971).

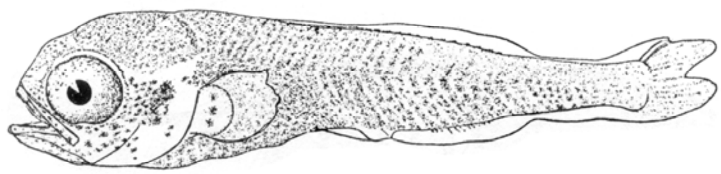
Smallmouth bass reportedly mature in their third or fourth year (Pflieger, 1975; Moyle, 1976) or may mature at 2 years (Webster, 1954; Emig, 1966; Coble, 1975). They occasionally live 10 to 12 years (Pflieger, 1975). In the Columbia River basin, introduced smallmouth bass prey on juvenile salmonids and have impacted populations of native sand roller (*Percopsis transmontana*; Zimmerman, 1999). In California, smallmouth bass coexist with native fishes as long as the densities of bass remain low (Moyle, 2002). Smallmouth bass may have negative effects on hardhead (*Mylopharodon conocephalus*) in streams where they occur (Brown and Moyle, 2003). In reservoirs, smallmouth bass can invade rivers upstream such as at the Merced River above the McClure Reservoir (Brown and Short, 1999). Smallmouth bass is sparsely distributed in some lakes and reservoirs and is uncommon in the Delta (Brown and Michniuk, 2007). Occasionally caught in very low numbers, young smallmouth bass are collected with beach seines in the Sacramento River (*e.g.*, Discovery Park at Sacramento, California and in Isleton, California) and in the San Joaquin River (*e.g.*, Mossdale near Manteca, California), usually from July to October (USFWS unpublished beach seine data, 2000–2006). Smallmouth bass probably play a minor role in California's sport fishing industry (Moyle, 1976).



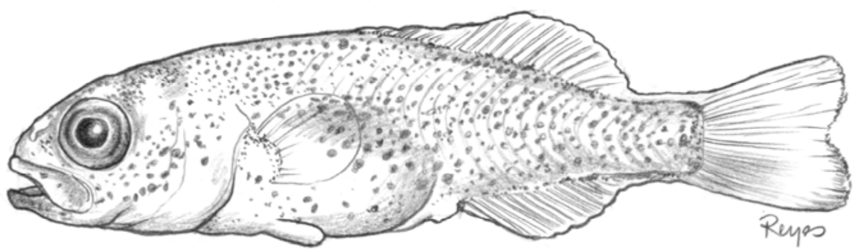
Prolarva, 3 dph, 6.75 mm TL (Reighard, 1906)



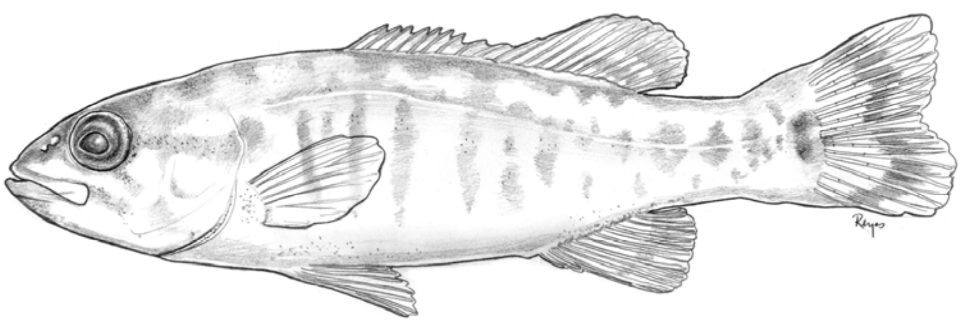
Prolarva, 8.8 mm TL (Fish, 1932)



Postlarva, 9.5 mm TL (Fish, 1932)



Prejuvenile, 13.2 mm TL. Yakima, WA.



Juvenile, 35 mm TL. Sacramento River, CA.

FIGURE 9.—Smallmouth bass (*Micropterus dolomieu*).

SPOTTED BASS, *Micropterus punctulatus* (Rafinesque)

SPAWNING

Location:	In the flats of Millerton Lake, from shallow water up to 6 m (D. Mitchell, 1979–1991, personal communication); pools of small streams (Pflieger, 1975); along the south shore of Camanche Reservoir in Calaveras County (P. Miklos, 2007, personal communication).
Season:	Mid-April to early June (Pflieger, 1975); through late May to early June (Aasen and Henry, 1981); late March to June, peaking in late April and early May (D. Mitchell, 1979–1991, personal communication), estimated from April to June (Wang, 1986).
Temperature:	18 °C (Howland, 1931); in southern states, between 13.8–23.3 °C (Smitherman and Ramsey, 1972; Vogele, 1975); ~ 18 °C (Pflieger, 1975); 14–15 °C (Aasen and Henry, 1981); 12.0–12.5 °C at Millerton Lake (D. Mitchell, 1979–1991, personal communication).
Salinity:	Freshwater.
Substrates:	Rock or gravel and usually near cover (Vogele, 1975); mud to gravel (Moyle, 1976); mud, sand (D. Mitchell, 1979–1991, personal communication), and rocky shoreline (P. Miklos, 2007, personal communication).
Fecundity:	2,000–2,500 at each nest (Howland, 1931); up to 47,000 for 5-year-old females (Towery, 1964); 1,150–26,555 for females weighing 0.08–0.95 kg (Hurst, 1969); 1,150–26,500 eggs from females 190–390 mm (Robbins and MacCrimmon, 1974); length-age correlated from 3,806 eggs for a 269 mm, 3-year-old female to 30,586 eggs for a 444 mm, 6-year-old female (Vogele, 1975).

EGGS

Shape:	Spherical.
Diameter:	Less than one-third the size of smallmouth bass eggs (Pflieger, 1975); 1.6–2.3 mm (Vogele, 1975); estimated spotted bass eggs ~ 1.0 mm and less.
Adhesiveness:	Adhesive.
Buoyancy:	Demersal or negatively buoyant.

LARVAE

Distribution:	Newly hatched larvae remain in the nesting area (Pflieger, 1975); near the nest in the shallow flats of Millerton Lake (D. Mitchell, 1979–1991, personal communication).

JUVENILES

Dorsal fin:	X, 12 (Cross, 1967); IX–XI, 9–11 (Moyle, 1976); soft dorsal, 12 or 13 (Pflieger, 1975).
Anal fin:	III, 10 (Cross, 1967); spiny anal ranges II to IV, and mainly III (Pflieger, 1975); III, 9–11 (Moyle, 1976).
Pectoral fin:	15–16 (Cross, 1967); 14–17 (Moyle, 1976).
Mouth:	Large, maxillary extends past the middle of the eye in juveniles (Pflieger, 1975; Moyle, 1976) and beyond the posterior margin of the eye in adult (Pflieger, 1975).
Vertebrae:	Usually 32 (Cross, 1967).
Distribution:	Millerton Lake, and upper San Joaquin River below Kerkhoff Dam; introduced to Lake Berryessa in 1981 and 1982 (D. Mitchell, 1979–1991, personal communication); collected in the Delta by USFWS with beach seine between August and October (A. Bourandas, 2007, personal communication).

Life History

The original distribution of the spotted bass is from southern Illinois, Missouri, and Ohio, southward to eastern Texas and the Gulf Coast to Florida, covering the major drainages of the Mississippi River (Eddy, 1957; MacCrimmon and Robbins, 1975; Pflieger, 1975; Lee, *et al*., 1980). A subspecies of the spotted bass, the northern spotted bass (*M. p. punctulatus*), was introduced from Ohio to California's foothill rivers in 1933 (McKechnie, 1966). They are now present in the Cosumnes River and in Lake Oroville of the Feather River. In 1973, California Fish and Game Commission authorized the introduction of a subspecies Alabama spotted bass (*M. p. henshalli*) as part of an "experimental" management program to improve fishing in California reservoirs (Dill and Cordone, 1997). It was introduced to reservoirs as far south as Lake Perris, Riverside County (Moyle, 1976). Origins of spotted bass in the Delta are not clear. It is possible that they descended from foothill tributaries such as Cosumnes River or from reservoirs such as Lake Oroville where they were originally stocked. They may have been introduced by fishermen also. The spotted bass stocked in Millerton Lake had two origins: the Central Valley Hatchery (Elk Grove, California) and Perris Reservoir stocked in 1974 and 1975, respectively (Dill and Cordone, 1997). Spotted bass seem to utilize environments intermediate between those preferred by largemouth bass and smallmouth bass (Miller, 1975).

Spotted bass start spawning late spring when water temperatures rise to 15–18 °C (Aasen and Henry, 1981). Judging from the small juvenile spotted bass collected in this study, spawning was estimated to occur from April to June. In Millerton Lake, spawning started as early as late March and peaked in late May and early June. Nesting areas include most of the peripheral regions of Millerton Lake with concentrations in the shallow flats near the Madera boat ramp. The nests were constructed in colonies, and range in depth from 1–6 m, 40–80 cm in diameter, and often near cover (D. Mitchell, 1979–1991, personal communication). More than one female has been observed attempting to spawn with a single male (Vogele, 1975). Male spotted bass guard the eggs and larvae (up to about 30 mm) in the nest, however, they are a less attentive parent compared to largemouth bass and smallmouth bass, moving away from the nest quickly when threatened (Pflieger, 1975; Vogele, 1975). The Alabama spotted bass spawn successfully in deeper waters and are less affected by lake level fluctuations (Aasen and Henry, 1981).

Spotted bass larvae are pale green or translucent (Pflieger, 1975) or almost transparent (D. Mitchell, 1979–1991, personal communication). They disperse from the nest 8–9 days after hatching (Pflieger, 1975). Male spotted bass do not guard their larvae as long as smallmouth bass and largemouth bass. The larvae of a spotted bass and smallmouth bass were observed schooling together guarded by a male smallmouth bass (D. Mitchell, 1979–1991, personal communication) and by both male parents (Vogele, 1969).

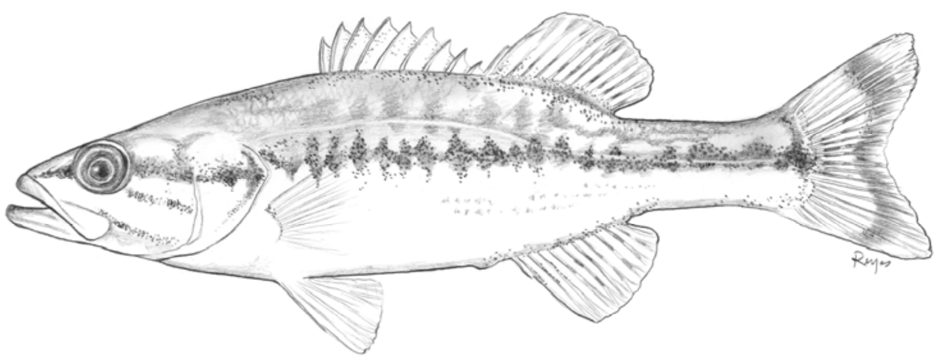
Spotted bass juveniles look very similar to largemouth bass. The primary pigmentation bars are initially visible as 11–14 midlateral patches (10–12 for largemouth bass) that are more dorsoventrally elongated than those of largemouth bass (Mabee, 1995). Looking at the internal anatomy, small juvenile spotted bass can be distinguished from largemouth bass by the 10–13 pyloric caeca in spotted bass compared to 20–33 in largemouth bass (Carlander, 1977). In larger juveniles, the caudal fin is tricolored with pale tips, black band in middle, and orange at the base; largemouth bass do not have orange in the caudal fin (Moyle, 2002).

After leaving the nest, juvenile spotted bass school in coves and in backwater near cover (Sublette, *et al*., 1990). They are often observed near boat ramps at Millerton Lake in the summer months. Although rarely observed in the Delta, juveniles have been collected with beach seines as far north as Knights Landing (~ 40 km northwest of Sacramento) and as far south as Mossdale (~ 20 km south of Stockton), from May to November but peaking between June and August (USFWS unpublished beach seine data, 2000–2006). Small juveniles feed on zooplankton, small insects (Moyle, 1976), and then on aquatic insects, crustaceans, and small fish as they get larger (Smith and Page, 1969). In Millerton Lake, threadfin shad were often in the stomachs of large juvenile spotted bass (D. Mitchell, 1979–1991, personal communication).

Maturity is reached at ages of 2 or 3 (Howland, 1931). Maximum TL is about 51 cm (McKechnie, 1966) and the life expectancy is about 6 years, shorter than that of a largemouth bass (Pflieger, 1975). In Millerton Lake, where a single fish weighing more than 3 kg was landed (D. Mitchell, 1979–1991, personal communication), the spotted bass is gaining popularity after the decline of largemouth bass.

The early life histories of the spotted bass in California have not been observed in depth although unpublished observations have been made from foothill reservoirs (D. Mitchell, 1979–1991, personal communication). Spotted bass became more abundant than the largemouth bass in Millerton Lake during the early 1980s and the 1990s (Ecological Analysts unpublished data; Wang, 1986). This abundance is due to the spotted bass strategy of nesting in deeper waters less affected by water fluctuations. In the Delta, distribution and life history information is not well-documented. Their impact on native fishes in the Delta is still unknown but is probably minimal since they mainly inhabit reservoirs (Moyle, 2002).

Juvenile, 50 mm TL. Collected in 2002 from Discovery Park at Sacramento River, CA.



Juvenile, 56 mm TL. Camanche Reservoir, Calaveras County, CA.

FIGURE 10.—Spotted bass (*Micropterus punctulatus*).

LARGEMOUTH BASS, *Micropterus salmoides* (Lacépède)

SPAWNING

Location:	Shallow inshore waters of lentic bodies such as ponds, lakes, reservoirs, creeks with pools, and some irrigation ditches; Delta sloughs with backwaters such as the abandoned intake channel of the CVP/TFCF and behind agricultural barriers such as at the head of Old River and Middle River in the south Delta.
Season:	April (Emig, 1966) to June (Moyle, 1976); mid-April to late May (Von Geldern, 1971); April through June, peaking in early May (Wang, 1986); mid-March to early June.
Temperature:	15–24 °C (Swingle, 1956; Kramer and Smith, 1962); starts at 14–16 °C (Emig, 1966; Miller and Kramer, 1971); eggs collected at 14–18.2 °C (Wang, 1986); eggs collected at 20–21 °C.
Salinity:	Up to oligohaline (Emig, 1966); non-tidal and tidal freshwaters (Wang and Kernehan, 1979).
Substrates:	Mud (Webster, 1942); mostly over gravel (Emig, 1966; Miller and Kramer, 1971); in shallow sandy cove with gentle slope, small rocks, gravel, and riprap with filamentous algae.
Fecundity:	2,000–145,000 (Carlander, 1977); 2,000–110,000 (Scott and Crossman, 1973); 2,000–94,000 (Moyle, 1976); up to 145,000 (Heidinger, 1975); fecundity increases with size and weight (Latta, 1975; Moyle, 1976).

EGGS

Shape:	May have oval shaped eggs (Perche, 1964); spherical.
Diameter:	As small as 0.75 mm in diameter (Emig, 1966), and maximum 1.95 mm in diameter (Merriner, 1971); usually 1.5–1.7 mm (Kelley, 1962); 1.4–1.8 mm (Meyer, 1970); 1.63–1.71 mm (Wang and Kernehan, 1979); 1.4 to 1.7 mm.
Yolk:	Yellowish, light yellow, clear (Saiki, 1973); may have orange color (Heidinger, 1975); granular, yellowish (Wang and Kernehan, 1979); faint yellow and granular.
Oil globule:	Single, dark amber (Carr, 1942) to yellow (Saiki, 1973); single, 0.52–0.55 mm in diameter, bright yellow (Wang and Kernehan, 1979); single, 0.50–0.64 mm in diameter, bright yellow.
Chorion:	Transparent, thin (Hardy, 1978); transparent to translucent, elastic (Wang, 1986); translucent, thin.
Perivitelline space:	Narrow, ~ 0.16–0.24 mm in width (Wang and Kernehan, 1979); 0.11–0.16 mm.
Egg mass:	Deposited mainly in center of the nest (Hardy, 1978). In the south Delta, eggs are concentrated at the center but some are also found as far as 0.7 m from the center. Sometimes, eggs are mixed with cyprinid (usually golden shiner or Sacramento blackfish) eggs, usually at the periphery.
Adhesiveness:	Adhesive, attached to stones (Fish, 1932); sticky when first deposited then lose their adhesiveness after water hardening (Carr, 1942); eggs are often covered with debris and are easily dislodged from substrate.
Buoyancy:	Demersal or negatively buoyant.

LARVAE

Length at hatching:	3–5.5 mm TL (Carr, 1942; Meyer, 1970); as small as 2.3 mm TL (Perche, 1964); recently hatched field specimens, 4.8–5.1 mm TL (CDFG Fish E & L survey); 4.6–5.1 mm TL.
Snout to anus length:	~ 46–50% TL for prolarvae and postlarvae (Wang, 1986, CDFG E & L survey). For prolarvae: 51–53% TL for 0 dph at 4.6–5.1 mm TL, decreasing to 42–51% TL (often 44–48%) for older prolarvae at 5.2–7.7 mm TL. For postlarvae: 44–51% TL at 6.4–10.3 mm TL.
Yolk sac:	Large, spherical to oval, extends from head to abdominal region; head slightly recessed and yolk sac protruded or head pointed downward over anterior margin of yolk sac (Wang and Kernehan, 1979).
Oil globule(s):	Short and straight in prolarvae, coiled in postlarvae (Anjard, 1974).
Gut:	Large, spherical to oval, above and behind the base of pectoral fins; air bladder becomes evident (pigmented and inflated) at ~ 5.0 mm TL (Carr, 1942) or between 6.5–7.0 mm TL.
Teeth:	Sharp and pointed, develop in postlarval stage.
Size at absorption of yolk sac:	~ 6.5–8.5 (with residual of oil globule) (Wang, 1986); 6.5–7.5 mm TL.
Total myomeres:	30 (Carr, 1942); 28–34; usually 32 (Wang, 1986); 29–32, often 29–31.
Preanal myomeres:	11 (Carr, 1942); 11–13 (Wang, 1986); 11–14, often 12–14.

Postanal myomeres:	19 (Carr, 1942); 17–21 (Wang, 1986); 15–20, often 17–18.
Last fin(s) to complete development:	Pelvic.
Pigmentation:	Tadpole-like newly hatched larvae have no pigmentation on body or eye; then dense pigment appears on head and yolk sac regions, small melanophores appear middorsally on the operculum and in the postanal region. Postlarvae have small melanophores on entire posterior half of body, with a dark horizontal band formed midlaterally.
Distribution:	Newly hatched larvae remain in the nest (Carr, 1942) guarded by the male parent for 5–8 days (Moyle, 2002). In the laboratory, postlarvae remain in a tight swarm in the corner of the aquarium. In the wild, postlarvae swim in small schools near the bottom and eventually disperse into shallow, weedy waters in lakes, reservoirs, rivers, and streams with pools, and backwaters of Delta sloughs. Larvae are seldom observed (Wang and Reyes, 2007).

JUVENILES

Dorsal fin:	X, 12–14 (Scott and Crossman, 1973); IX, 12–14 (Moyle, 2002).
Anal fin:	Spiny anal fin, II–III (Beckman, 1952); III, 10–12, usually 11 (Scott and Crossman, 1973); III, 11–12 (Moyle, 2002).
Pectoral fin:	13–17, usually 14–15 (Moyle, 1976); 13–15 (Hardy, 1978).
Mouth:	Terminal, large, oblique, maxillary reaching to posterior margin of the eye (Scott and Crossman, 1973); mouth slightly superior, maxillary extends to middle of the eye in juveniles less than 10 cm TL (Moyle, 2002).
Vertebrae:	33 (Bean, 1903); 30–32 (Scott and Crossman, 1973); mostly 32 (Ramsey, 1975); 30–31.
Distribution:	Juvenile largemouth bass are associated with vegetation (Carbine, 1939; Carlander, 1975); school near edge of pond or near vegetation with golden shiners of same age (Kramer and Smith, 1962); shallow water with vegetation found throughout the study area.

Life History

The native range of the largemouth bass is from the lower Great Lakes to the Mississippi River drainages, the Gulf Coast, Florida, parts of the Rio Grande, and along the Atlantic slope as far north as Virginia (Scott and Crossman, 1973) extending northward to Ontario and Quebec, however, they are absent from the Atlantic seaboard north of South Carolina (MacCrimmon and Robbins, 1975; Jenkins and Burkhead, 1994). Because of the tremendous sport fisheries demand for this species, it has been stocked all over the United States and parts of Canada (Moyle, 2002). Largemouth bass also have been introduced to many countries in South America, Asia, Europe, and Africa (Robbins and MacCrimmon, 1974; Hardy, 1978; Lever, 1996). The introduction to California waters was in 1874 (Skinner, 1962). In 1891, largemouth bass brought in from Quincy, Illinois, were introduced into Lake Cuyamaca (San Diego County) and the Feather River (Dill and Cordone, 1997). Most of California's population is believed to be from the northern subspecies (*Micropterus salmoides*) also known as the Illinois largemouth bass. A fast-growing subspecies, the Florida largemouth bass (*M.s. floridanus*) was also introduced to California in 1959 (Moyle, 1976; Shapovalov, *et al.*, 1981).

In this study, largemouth bass were observed in freshwaters and in some small coastal streams, such as Tunitas Creek, Olema Creek, and Tennessee Valley Creek in Marin County (Wang, 1986). In recent years, their distribution has been expanding to higher elevations, such as Lake Tahoe (Moyle, 2002). Unlike east coast populations, the largemouth bass from the Sacramento-San Joaquin Estuary seldom move into the oligohaline portion of the estuary where they have been recorded in salinities of 5 ppt (Emig, 1966; Smith, 1971; Christmas and Waller, 1973). They are rarely collected from Napa River (CDFG 20-mm fish survey) and Suisun Marsh of Suisun Bay (Matern, *et al*., 2002).

Spawning of the largemouth bass in the study area occurs as early as March and April when water warms to 14 °C (Emig, 1966; Miller and Kramer, 1971; this study). Spawning can also occur with temperatures as low as 12.2 °C (Allen and Romero, 1975). Largemouth bass spawn at the same time or slightly later than *Pomoxis* spp. and 2–4 weeks before the *Lepomis* spp. Larger adults spawn earlier than smaller fish (Goodgame and Miranda, 1993). At the abandoned intake channel of the CVP/TFCF, male largemouth bass often build their nests very far from each other. Bluegills are also often seen near the nest. Largemouth bass males construct a nest, usually a depression near the shore, in substrate with submerged vegetation, sand, gravel, or mud (Emig, 1966). A nest with eggs has also been observed on the top surface of a submerged plastic barrel suggesting that largemouth bass do not always build nest depressions. Some nests become exposed to air when the nesting location is too close to the shoreline. For example, at Millerton Lake, nests have been observed dry when the lake water is diverted for irrigation. Largemouth bass never build nests in areas with current or wave action (Pflieger, 1975); however, some nests were observed at the low tide marks of Delta sloughs. During low tide when the nest is more exposed, the male is vulnerable to predation by birds but their body coloration that blends with their surrounding environment provides some protection. A female may mate with several males at short intervals (Reighard, 1906; Breder and Rosen, 1966). The male guards the nest and the subsequent brood. A single nest can contain as many as 43,000 eggs (Kramer and Smith, 1962; Snow, 1960). Occasionally, eggs of cyprinid species, such as the golden shiner (Kramer and Smith, 1960; Scott and Crossman, 1973) and the Sacramento blackfish (Wang and Reyes, 2007) are observed in the nest. This relationship or association probably benefits both the largemouth bass and the cyprinid in that the cyprinid eggs are cared for and hatch and then some become forage for largemouth bass fry. Kramer and Smith (1960) observed that male largemouth bass tolerated golden shiners 1 year but showed aggression toward them in another year.

Eggs hatch in 5 days at 18.9 °C and 2 days at 22.2 °C (Emig, 1966). In this study, eggs hatched in 4–5 days at 19 °C. Newly hatched larvae are unpigmented and remain in the nest for several days before rising to the surface and forming a tight school near the spawning ground (Carr, 1942). Larger adults produced eggs with greater diameter (Laurence, 1969); however, larger adults do not inevitably produce larger larvae (Goodgame and Miranda, 1993). In the laboratory, larvae swim up in the water column when their air bladder starts to develop, about 5–8 days after hatching. Schools of largemouth bass postlarvae have been observed in both clear and murky stagnant waters with lots of cover. Postlarvae feed on zooplankton such as daphnia, artemia, and copepods. The male guards the school another 2–7 days after the fry swim up (Davis and Lock, 1997). The male stops guarding when smaller schools are formed which is a behavior similar to that of bullheads (*Ameiurus* spp.).

Small, fully pigmented juvenile largemouth bass remain near the bottom in tight schools (Carr, 1942; Kramer and Smith, 1960). They may swim with golden shiner juveniles at the edge of ponds, reservoirs, or sloughs, always close to plant beds. Juveniles are quick to seek cover in deeper water or plant beds when disturbed, regrouping again when safe.

Major food items for the small juveniles are cladocerans, chironomid larvae, amphipods, copepods, and small invertebrates (Kramer and Smith, 1960). Largemouth bass hatched earlier in the season obtain an initial length advantage over those that hatched later (Shelton, *et al.*, 1979). This advantage enables age-0 juveniles to shift diet sooner from a mainly invertebrate to a piscivorous one (Gutreuter and Anderson, 1985), attaining faster first year growth and higher survival rates than smaller juveniles (Aggus and Elliot, 1975). In the Delta, largemouth bass heavily prey on near shore fishes, including native fishes, and become predominantly piscivorous at 115 mm (Nobriga and Feyrer, 2007).

In the laboratory, small juveniles from the same cohort have different growth rates, creating different sizes. Cannibalism, observed in Sacramento perch, was observed with largemouth bass as the juveniles grew larger, however, this may have been due to the enclosed environment. Large juveniles, caught individually at the CVP/TFCF in the summer months and placed in aquaria, became solitary.

Large juveniles take mainly aquatic insects, small fish such as golden shiner and threadfin shad (Goodson, 1965), bluegill (McCammon, *et al.*, 1964), and their own species (Keast, 1966; Moyle and Holzhauser, 1978). Juvenile largemouth bass are aggressive predators, utilizing strategies such as lie-and-wait and high-speed chase of prey. Largemouth bass have been known to utilize green sunfish more than other prey, including bluegills (Lewis and Helms, 1964; Savitz and Janssen, 1982).

Largemouth bass mature in 1 year in southern states and 2–4 years in northern states (Emig, 1966). In California, largemouth bass mature during their second or third season (Moyle, 1976). Maximum lifespan is about 13–15 years (Scott and Crossman, 1973). The largemouth bass is the most sought after game fish in California (Moyle, 1976) and supports a significant sport fishery (Lee, 2000). In reservoirs, largemouth bass population declines occur due to overfishing, resource competition, and productivity of aging reservoirs (Moyle, 2002). More recently, largemouth bass numbers in the Delta have been increasing, associated with increasing water quality and abundance of submerged aquatic vegetation (Brown, 2003; Brown and Michniuk, 2007).

The largemouth bass, labeled as California bass, was introduced from southern California into China in the mid-1990s. Recently, with China's rapid economic development, the largemouth bass became a major warm water fish farming species in southern China, competing with the traditional non-carnivorous *Cyprinus* spp. Oddly, some largemouth bass raised in China are re-labeled as "California black bass," and are sold in U.S. markets, particularly in California's Asian fish markets (author's experience/trip to China).

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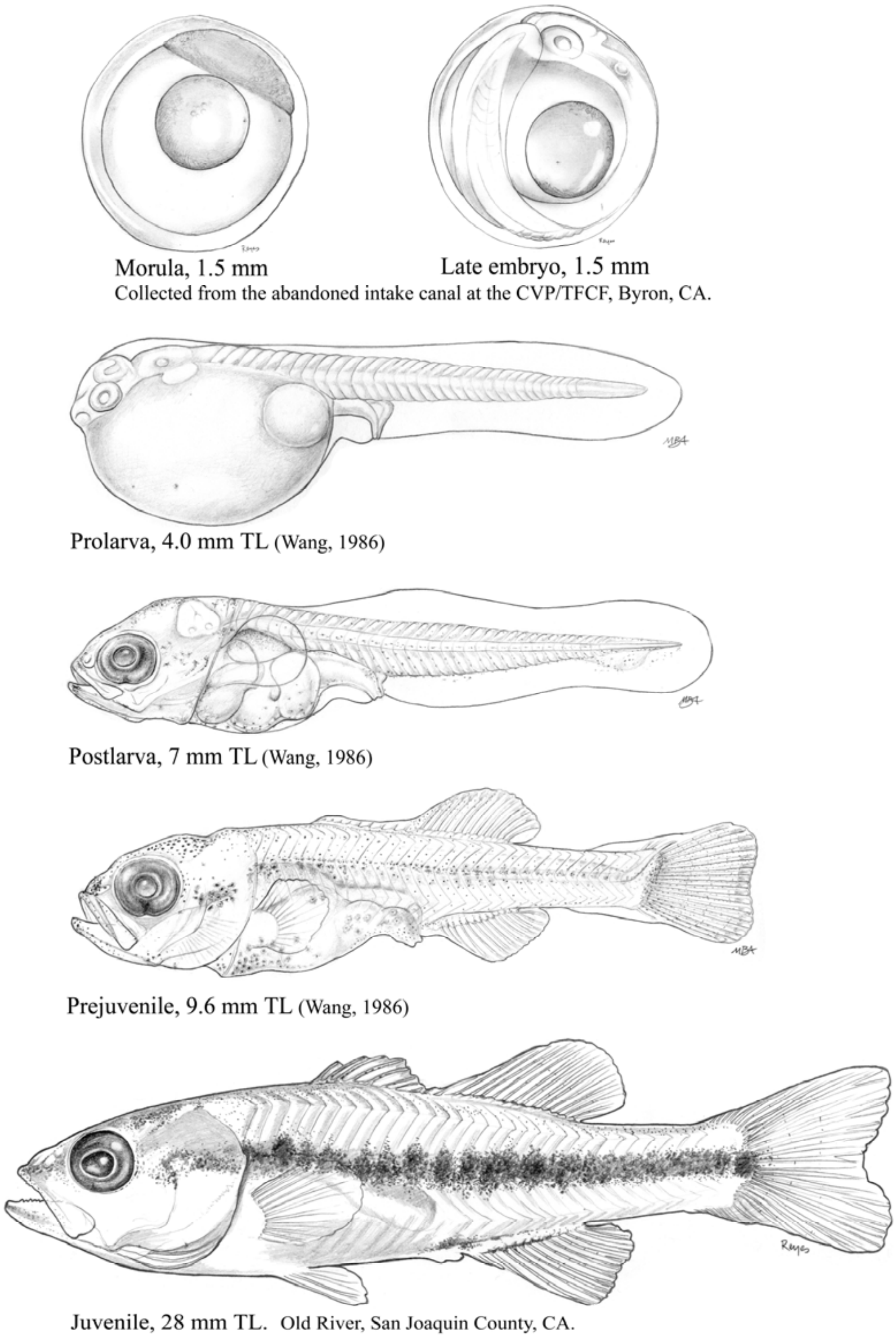


FIGURE 11a.—Largemouth bass (*Micropterus salmoides*).

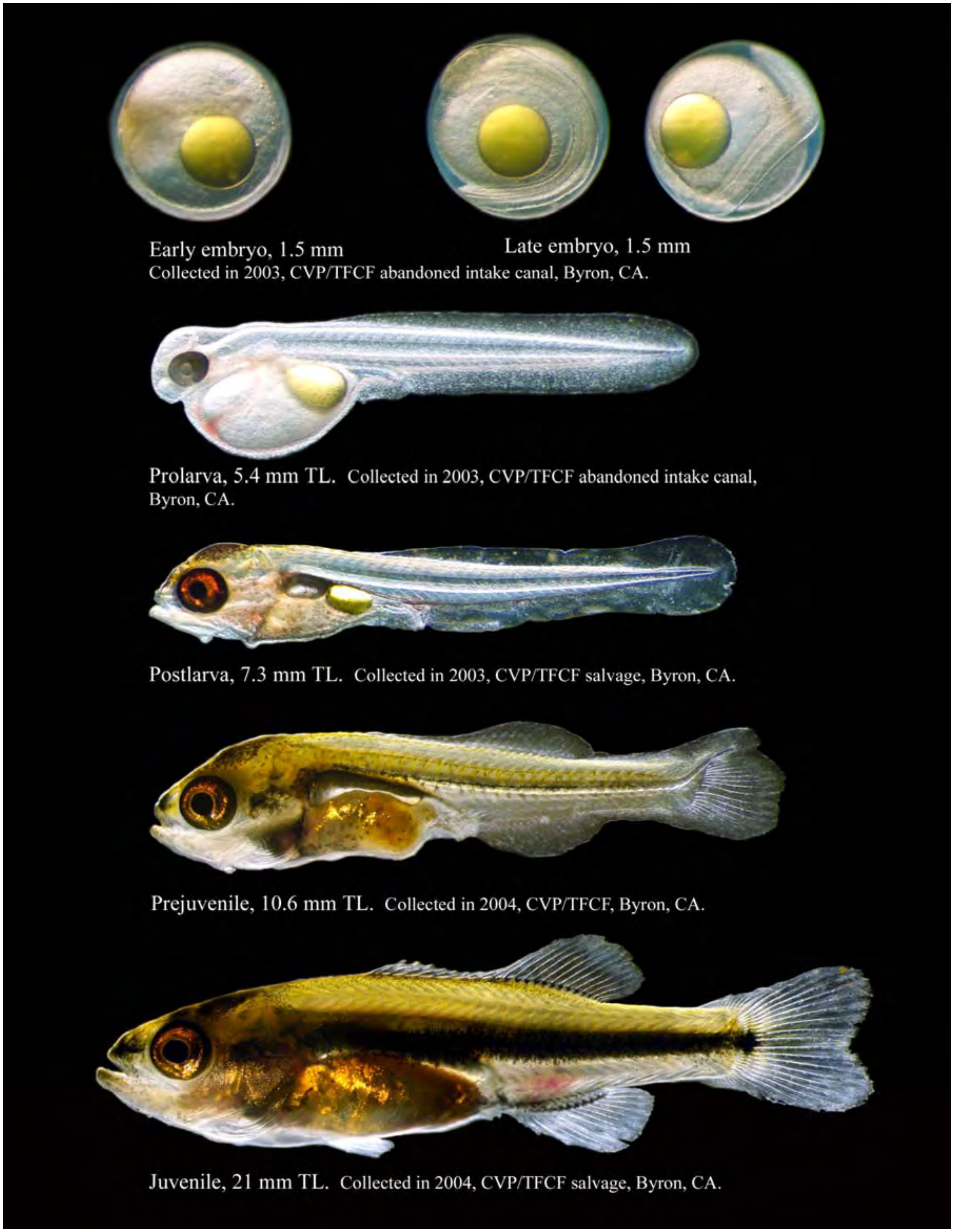


FIGURE 11b.—Largemouth bass (*Micropterus salmoides*).

WHITE CRAPPIE, *Pomoxis annularis* (Rafinesque)

SPAWNING

Location:	Inshore areas of ponds, lakes, and reservoirs (Hansen, 1943, 1951, 1965; Morgan, 1954; Whiteside, 1964); nest in depths of less than 1 m (Hansen, 1951, 1965; Siefert, 1968) to 3 m (Pflieger, 1975), and as deep as 6–7 m (Moyle, 1976); Cache Slough, Montezuma Slough (Wang, 1986); mainly they spawn in the peripheral regions of the Delta (*e.g.*, northern reaches of the Sacramento River at Red Bluff Research Pumping Plant and Colusa, a town 110 km north of Sacramento).
Season:	May–June in Illinois (Hansen, 1965) and South Dakota (Siefert, 1968); April–June in Missouri (Pflieger, 1975); April or May in California (Moyle, 1976); judging by the small juveniles taken, spawning was estimated from April–June in the study area.
Temperature:	17.8–20 °C (Curtis, 1949; Sigler, 1959); 16–20 °C (Siefert, 1968); 17–20 °C (Moyle, 1976).
Salinity:	Freshwater.
Substrates:	Eggs deposited on plant materials, boulders, submerged brush, and submerged trees, gravel, sand, clay, or mud (Hansen, 1943, 1951, 1965; Whiteside, 1964); algae, dead leaves (Hansen, 1965); aquatic vegetation (Siefert, 1965); areas near objects or bottom vegetation (Siefert, 1968).
Fecundity:	325,677 (Morgan, 1954); average at 53,000 (Bailey and Allum, 1962); 970–213,213 (Goodson, 1966); 21,300 (Moyle, 1976).

EGGS

Shape:	Spherical.
Diameter:	0.82–0.92 mm with an average of 0.89 mm (Hansen, 1943; Whiteside, 1964).
Yolk:	Granular (Morgan, 1954); colorless (Scott and Crossman, 1973).
Oil globule:	Single, large (Morgan, 1954).
Chorion:	Transparent and elastic for newly fertilized eggs (Morgan, 1954).
Perivitelline space:	1/7 of yolk diameter (Morgan, 1954).
Egg mass:	Single to small clumps (Siefert, 1968).
Adhesiveness:	Adhesive (Hansen, 1943; Morgan, 1954; Siefert, 1968).
Buoyancy:	Demersal (Morgan, 1954).

LARVAE

Length at hatching:	1.22–1.89 mm TL (Morgan, 1954); at least 2.54 mm TL (Siefert, 1968); yolk-sac larvae ~ 3.0 mm TL were collected from Sacramento River (Wang and Reyes, 2007).
Snout to anus length:	~ 37–38% TL larvae at 3.72–8.3 mm TL (Siefert, 1968); ~ 38–40% TL of larvae at 4.3–11.2 mm TL (Taber, 1969); gut short for postlarvae, ~ 35–40% TL (Wang and Kernehan, 1979).
Yolk sac:	Spherical to oval, large, extending from head or jugular to abdominal region (Morgan, 1954).
Oil globule(s):	Single, variably positioned in yolk sac (Morgan, 1954); generally in the posterior half of the yolk sac (Chatry, 1977).
Gut:	Straight in prolarvae, becoming folded at 3.9 mm TL (Morgan, 1954); body cavity very short, gut coiled in postlarval stage (Anjard, 1974).
Air Bladder:	Oval, large near anal region (Anjard, 1974).
Total myomeres:	28–31 (Siefert, 1969b).
Preanal myomeres:	10–13 (Siefert, 1969b).
Postanal myomeres:	17–20 (Siefert, 1969b).
Last fin(s) to complete development:	Pelvic (Taber, 1969).
Pigmentation:	Newly hatched larvae are unpigmented; at 3.9 mm TL melanophores become evident along postanal region (Morgan, 1954); postanal melanophores diminished at 13.5 mm TL and a few melanophores on the cephalic region (Taber, 1969).
Distribution:	In shallow water near the spawning area (Taber, 1969).

JUVENILES

Dorsal fin:	Ranged IV–VIII (Trautman, 1957); usually IV (Hubbs and Lagler, 1958); V–VI, 13–15 (Moyle, 1976).
Anal fin:	V–VII (Siefert, 1965); 16 (Scott and Crossman, 1973) to 19 (Beckman, 1952); VI–VII, 16–18 (Moyle, 2002).
Pectoral fin:	13 (Scott and Crossman, 1973); 13–14 (Moyle, 2002).

Mouth:	Mouth large and oblique, lower jaw longer than upper jaw and maxillary reaches to the posterior margin of the eye (Scott and Crossman, 1973; Moyle, 1976).
Vertebrae:	30–32 (Scott and Crossman, 1973).
Distribution:	In the study area, white crappie juveniles were usually found in turbid waters of the Sacramento River, near boat docks, in lentic ponds associated with the upper Sacramento River, in sloughs and ditches of the Delta, occasionally observed at the CVP/TFCF in winter, and uncommon everywhere else. Also reported in shallow waters (1–2 m deep) depending on the tides, mostly tule marsh with lots of vegetative and woody cover, and in very turbid, still waters sometimes associated with fathead minnow and red shiner (*Cyprinella lutrensis* ; J. Pedretti, 2007, personal communication).

Life History

The native range of white crappie extends from the Mississippi River drainage to the Gulf Coast, along the eastern seaboard to North Carolina, and northward to most of the Great Lake Basin (Scott and Crossman, 1973). However, Pflieger (1975) indicated that the eastern range of this species is restricted to the western slope of the Appalachians. Similar to largemouth bass, white crappie has been introduced throughout the United States and northern Mexico for sport fishing. Goodson (1965, 1966) reported the initial introduction of white crappie in southern California in 1917 and in northern California in 1951. However, due to confusion in identification of black and white crappie, the introduction to southern California may have been as early as 1908 (Dill and Cordone, 1997). In this study, white crappie were found to be rare in the tidal estuary and the Delta and patchy in the Sacramento River. Some white crappie were found in some sloughs and irrigation ditches (T. Woods, 1994–1995, personal communication). White crappie, along with other centrarchids, temporarily move into Suisun Marsh when freshwater conditions prevail (Matern, *et al.*, 2002). Moyle (2002) reported white crappie abundant in Clear Lake, but the population fluctuated greatly in the late 1970s with no apparent reason. In lakes and reservoirs where both white crappie and black crappie occur, one species usually dominates (Ellison, 1984).

Spawning was estimated to be from April to June or early July in the study area (Wang, 1986). In the Sacramento River, spawning occurs mainly in April and May and extends to June and July (Wang and Reyes, 2007). Unlike male black crappie, male white crappie develop spawning colors: dark pigmentation on the sides of their head, lower jaw, and breast (Hansen, 1951; Whiteside, 1964; Goodson, 1966). Nests are constructed by males in shallow water usually less than 1 m in depth (Hansen, 1951) but as deep as 6–7 m (Moyle, 1976). In reservoirs where water depth often fluctuates, white crappie spawn in deeper waters. Spawning often occurs in areas near objects or bottom vegetation such as brush piles, stumps, or rock outcroppings (Toole, 1950; Hansen, 1951; Siefert, 1968). Nests are constructed on hard bottom, using gravel, clay, and plant materials although sometimes the nests do not have depressions (Hansen, 1965; Pflieger, 1975) and are not well-defined (Siefert, 1968). Colony nesting has been observed (Hansen, 1965). Females participate to a limited extent in vigorous fanning of the nest area (Siefert, 1968).

Larger white crappie females tend to produce higher quality, energy-rich eggs than smaller females (Bunnell, *et al.*, 2005). Females release only a few eggs at each interval and may mate with different males (Siefert, 1968; Scott and Crossman, 1973). Eggs are deposited more around the perimeter than in the center (Siefert, 1968). Although not good nest builders, the males guard the nest. Incubation takes 43–51 hours at 18.3–19.4 °C (Siefert, 1968) or 24–27.5 hours at 21.1–22.0 °C (Morgan, 1954). At 14.4 °C, incubation took 93 hours (Siefert, 1968). Both white and black crappie spawn earlier (as early as April) than some centrarchids (slightly earlier than *Micropterus* spp.). Spawning period may be influenced more by photoperiod than water temperature (Siefert, 1968). After spawning, white crappie move into deeper water and are found predominantly over steeper gradients with structure (Markham, *et al.*, 1991).

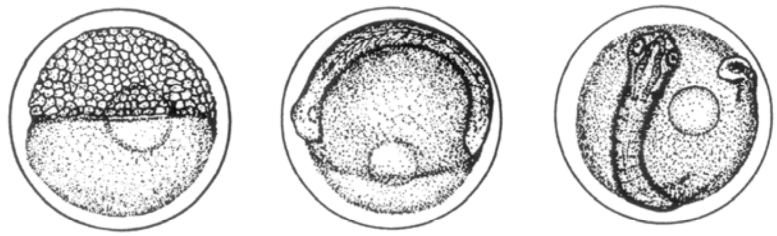
Newly hatched white crappie larvae are transparent and remain in the guarded nest until they can swim freely and disperse into adjacent plant beds. The oil globule is most often in the posterior half of the yolk sac. Once the swim bladder is distinct (~ 4.0 mm TL), white crappie can be distinguished from black crappie by measuring the distance from the posterior margin of the eye to the anteriormost portion of the swim bladder. The distance, in relation to total length, is > 15% in white crappie and < 15% in black crappie (Chatry, 1977). Yolk is absorbed when larvae are about 4.5 mm TL. Copepod nauplii were the principal food eaten immediately after yolk sac absorption (Siefert, 1968). The smaller larvae concentrate at the surface of the water column at night and are evenly distributed in the water column during daytime; larger larvae (5–10 mm TL) stay on the bottom (Siefert, 1968).

White crappie juveniles school in ponds and reservoirs near weedy shores. They are common in Lindsey and Cache Sloughs and adjacent irrigation ditches (Wang, 1986). Their distribution in the Delta and Suisun Bay is scattered, *i.e.*, they are found everywhere but not in great numbers (Wang, 1986; Matern, *et al*., 2002; CVP/TFCF salvage records). White crappie juveniles were collected near the northern portion of Liberty Island, north of Rio Vista, and often with beach seines near boat ramps in the Sacramento River (J. Pedretti, 2007, personal communication). Collections often come from shallow (1–2 m deep) turbid waters with lots of tule (*Scirpus* spp.) and other vegetative cover. Juveniles of both crappie species are often collected together.

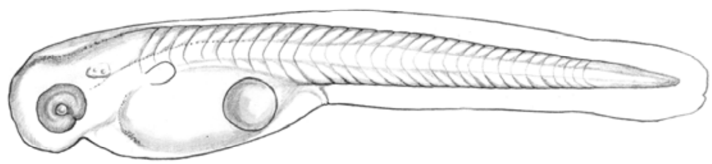
Diet of small juvenile (~ 30–35 mm TL) white crappie consists mainly of planktonic crustaceans, such as *Daphnia* spp. and *Cyclops* spp. (Goodson, 1965; Nelson, *et al*., 1967; Siefert, 1968). Larger juveniles (~ 50–60 mm TL) feed on insects and small fishes, such as threadfin shad and inland silverside, *Menidia beryllina* (Moyle, 1976). Juvenile white crappie are mostly limnetic, preferring deeper water, and have diel feeding patterns (Ridenhour, 1960; O'Brien, *et al.*, 1984), usually feeding in the morning and in the early afternoon (Mathur and Robbins, 1971).

White crappie reach sexual maturity at 2–3 years (Hansen, 1951; Morgan, 1954; Goodson, 1965; Pflieger, 1965). Maximum life expectancy has been reported at

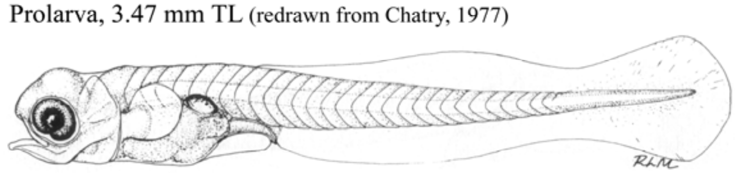
8–10 years (Scott and Crossman, 1973), but few live more than 3–4 years (Pflieger, 1975). Though white crappie are considered an excellent and tasty panfish, their low numbers in the Delta probably limit their value as a sport species.



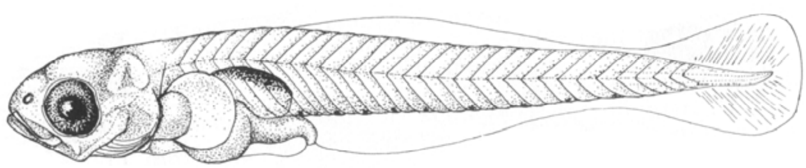
Embryo, morula and advanced embryo (Morgan, 1954)



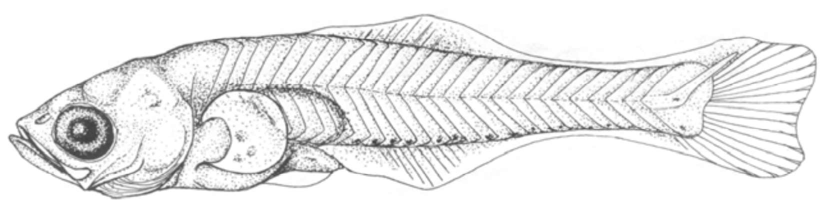
Prolarva, 3.47 mm TL (redrawn from Chatry, 1977)



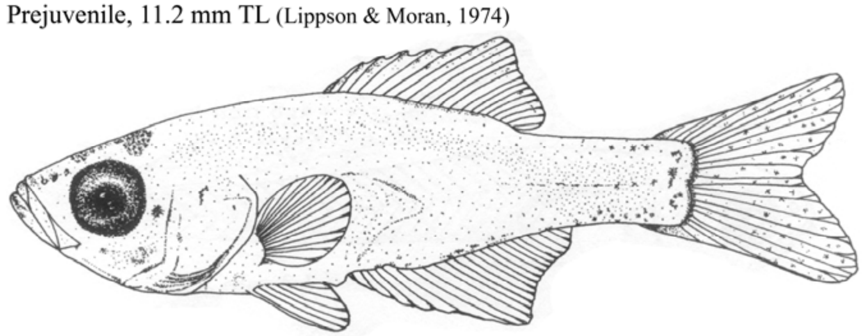
Postlarva, 3.7 mm TL (Lippson & Moran, 1974)



Postlarva, 7.2 mm TL (Lippson & Moran, 1974)



Prejuvenile, 11.2 mm TL (Lippson & Moran, 1974)



Juvenile, 25.5 mm TL (Lippson & Moran, 1974)

FIGURE 12.—White crappie (*Pomoxis annularis*).

BLACK CRAPPIE, *Pomoxis nigromaculatus* (Lesueur)

SPAWNING

Location:	In the study area, black crappies spawn in backwaters of sloughs and tributaries associated with the Delta, such as Lindsey Slough, Wilson Slough, Montezuma Slough, Putah Creek, Old River by River's End Marina (Byron, California), and possibly in the waterways of Discovery Bay; outside of the Delta, spawning occurs in rivers, ponds, and reservoirs, such as Cosumnes River, Folsom Lake, and Millerton Lake.
Season:	March to July (Goodson, 1966); March or April through July (Moyle, 1976); April through June or July (Wang, 1986); judging by the small larvae collected in the Delta, mainly in April and May in 2004–2006 (L. Grimaldo, 1998–2007, personal communication); mainly in April based on postlarvae collections with light traps.
Temperature:	14.4–17.8 °C (Goodson, 1966); at temperatures exceeding 14 °C (Moyle, 1976); 16–21 °C (Siefert, 1969a); exceeding 15 °C (Smith, 1971); black crappie is the first centrarchid to spawn in the season.
Salinity:	Freshwater; possibly tidal freshwater (Wang and Kernehan, 1979).
Substrates:	On leaves of submerged vegetation (Richardson, 1913); gravel or sand in 1–2 m water near or among vegetation (Evermann and Clark, 1920); over clay, sand, and fine gravel (Breder, 1936); gravel areas or on bottom materials softer and muddier than acceptable to other sunfishes (Eddy and Surber, 1947). In the Delta, spawning occurred in a slough near inshore vegetation; postlarvae were collected in light traps set near mud and submerged vegetation.
Fecundity:	Maximum of 158,000 (Buss, 1965); 11,000–188,000 (Goodson, 1966); 26,700–65,520, with an average of 37,796 (Scott and Crossman, 1973); 33,000–42,000, and up to 1,888,000 (Becker, 1983).

EGGS

Shape:	Spherical.
Diameter:	0.93 mm in diameter (Merriner, 1971).
Yolk:	Whitish (Scott and Crossman, 1973).
Oil globule:	Centrally or anteriorly placed in the yolk sac (Chatry, 1977); single (Hardy, 1978); judging by the newly hatched prolarvae, single and small.
Chorion:	Unfertilized eggs: transparent, elastic and smooth.
Egg mass:	Presumably single or small clumps similar to white crappie.
Adhesiveness:	Adhesive (Scott and Crossman, 1973).
Buoyancy:	Demersal.

LARVAE

Length at hatching:	2.32 mm TL (Siefert, 1969a) to > 3.0 mm TL (Anjard, 1974); estimated at 3.0 mm TL from field collections.
Snout to anus length:	~ 38–40 % TL for larvae at 10.8–11.4 mm TL (Wang, 1986); ~ 36–39% (less than 40% as a rule) TL for larvae at ~ 3.5–5.5 mm TL.
Oil globule(s):	Single (Faber, 1963); single, small, ~ 0.1 mm for larvae less than 5.0 mm TL.
Gut:	Straight to slightly twisted for prolarvae; coiled at 6–9 mm TL (Anjard, 1974).
Air Bladder:	Large and near anal region (Anjard, 1974); large, tear-drop shaped, slanting toward anus.
Teeth:	Fine, pointed, on both jaws, appears in postlarval stage.
Size at absorption of yolk sac:	~ 5.0 mm TL (Siefert, 1969a); ~ 5–6 mm TL, field specimens from the Delta a 7.7 mm TL specimen with remnants of yolk was collected from Old River at the CVP/TFCF.
Total myomeres:	29–32 (Siefert, 1969a); 31–34, mean 32 (Faber, 1963); 31–32 (Wang, 1986); 30–32.
Preanal myomeres:	10–14 (Siefert, 1969a); 9–10 (Faber, 1963); 13–14 (Wang, 1986); 9–12.
Postanal myomeres:	21–24 (Faber, 1963); 18–21 (Siefert, 1969a); 18–19 (Wang, 1986); 19–22.
Last fin(s) to complete development:	Pelvic.
Pigmentation:	Transparent (Adams and Hankinson, 1928); usually no pigmentation visible before 8 mm TL (Faber, 1963); small melanophores appear on head and isthmus, and a series of sparse melanophores develops along the postanal and above postanal regions in late postlarval stage (Wang, 1986). Postlarvae have very few melanophores overall on the body, few small melanophores on the head, few ventral melanophores preanally, a few melanophores in the ventral postanal region; dorsal surfaces lack pigment.

Distribution:	In the study area, black crappie larvae are found usually in shallow weedy sloughs, such as Lindsey Slough, Wilson Slough, and Montezuma Slough (Wang, 1986); sloughs in the central and south Delta (Feyrer and Healey, 2003); Putah Creek, Cosumnes River, and Lodi Municipal Lake (A. Rockriver, 1996–1997, personal communication). Postlarvae and prejuvenile black crappie were collected with light traps from Old River in front of the CVP/TFCF near a boat dock surrounded with weeds.

JUVENILES

Dorsal fin:	Spiny dorsal various from VI–X (Forbes and Richardson, 1920); soft dorsal, 14–16 (Scott and Crossman, 1973; Anjard, 1974); VII–VIII, 15–16 (Moyle, 1976).
Anal fin:	Spiny anal, VI–VII (Scott and Crossman, 1973); VI, 17–19 (Moyle, 2002).
Pectoral fin:	14–15 (Moyle, 1976); 13–15 (Hardy, 1978).
Mouth:	Large, oblique, lower jaw slightly protruding (Scott and Crossman, 1973); large, oblique, and flexible.
Vertebrae:	31–33 (Scott and Crossman, 1973).
Distribution:	Juvenile black crappie are widely distributed in Delta sloughs (Turner, 1966); also in rivers and creeks with pools and quiet waters, such Cosumnes River and Putah Creek; in lakes and reservoirs, such as Lodi Municipal Lake, Millerton Lake; also in oligohaline habitats such as Suisun Marsh and San Pablo Bay.

Life History

Black crappie is native to eastern and central North America, including the Great Lakes, the Gulf Coast including Florida and Alabama, and north along the Atlantic Coast to Virginia (Scott and Crossman, 1973). In the Great Lakes region, their range apparently extends to southern Canada (Eddy, 1957; Hubbs and Lagler, 1958). Black crappie was unsuccessfully introduced to California in 1891 and 1908 (Vogelsang, 1931; Goodson, 1966). The exact introduction date into California is unclear because of early workers' confusion in distinguishing between a white crappie and black crappie (Dill and Cordone, 1997).

Black crappie is one of the most abundant centrarchids in the Delta (Turner, 1966). This species is found in most sloughs and many oxbow lakes of the Delta (Goodson, 1966), Suisun Marsh (Matern, *et al.*, 2002), south Delta (Feyrer and Healey, 2003), man-made canals of Discovery Bay (B. Wu, 2005, personal communication), and waters adjacent to the Delta, such as Cosumnes River and Lodi Municipal Lake (Rockriver, 1998). Black crappie is well established in rivers, lakes, and low elevation reservoirs in California. They are not found in small coastal streams that lack deep pools such as Walker Creek, Muir Wood Creek, and Estero de Americano. They are also not present in high elevation lakes and reservoirs, such as Ice House Reservoir, Union Valley Reservoir, and Loon Lake of upper American River systems, probably due to lack of cover and low water temperatures (Wang, 1986).

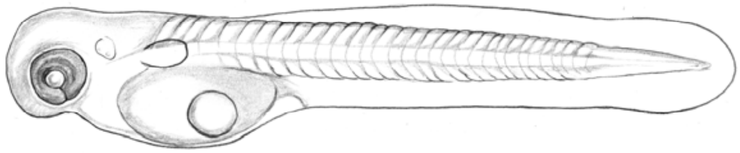
Moyle (1976) reported black crappie spawning from March through July. Spawning time for black crappie is similar to the white crappie in the Delta, occurring as early as March. However, judging by the larvae collected in the Delta in recent years (2004–2006; L. Grimaldo, 1998–2007, personal communication), spawning usually occurs in April and May. Judging by the location and size of the larvae collected, it is possible that spawning may occur in tidal and non-tidal sloughs of the Delta and westward to the Suisun Marsh.

Male black crappie excavate nests in gravel, sand, or mud near shore with vegetation (Breder, 1936; Eddy and Surber, 1947; Scott and Crossman, 1973), usually in water 0.9–2.4 m deep (Goodson, 1966). Males guard their nest during incubation and after hatching, and in general, the spawning behavior of black crappie is similar to that of white crappie (Scott and Crossman, 1973; Pflieger, 1975).

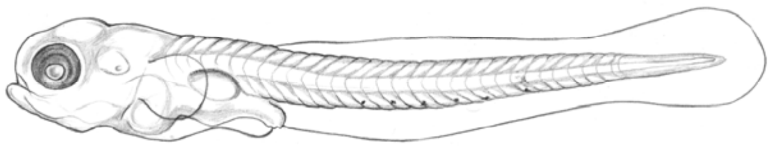
Information on the early life histories of black crappie is sparse in the literature (Hardy, 1978); however, comparative development morphology of black crappie and white crappie larvae from Louisiana has been documented by Chatry (1977). Black crappie and white crappie have overlapping ranges of myomere count and have sympatric characteristics. Prolarval (2.5–3.8 mm TL) white and black crappie can be distinguished by the position of the oil globule. In white crappie, the oil globule is in the posterior half of the yolk sac; in black crappie, the oil globule is centrally or anteriorly placed (Chatry, 1977). Postlarval (4.0–13.0 mm TL) white and black crappie can be distinguished by the distance from the posterior margin of the eye to the anteriormost portion of the swim bladder. The distance, in relation to total length, is > 15% in white crappie and < 15% in black crappie (Chatry, 1977).

Juveniles prefer quiet, shallow water with patchy to heavy vegetation. Many of them were taken with beach seines in Wilson Slough and Montezuma Slough in summer months and in mesohaline waters at the Oleum Power Plant of San Pablo Bay (Wang, 1986). Apparently, black crappie can tolerate moderately high salinity better than white crappie (Lebida, 1969; Smith, 1982; Moyle, 2002). Small young (< 10 cm FL) feed on zooplankton (Faber, 1967) and large individuals take mostly amphipods, mysid shrimps, other planktonic crustaceans and small fish (Keast and Webb, 1966; Moyle, 1976). Their long and closely spaced gill rakers enable retention of very small prey (Keast, 1968; Brooks, 1968; Loshbaugh, 1978). Compared with white crappie, black crappie consume fewer fish and more benthic invertebrates, especially insects that are found in greatest abundance in aquatic vegetation (Mitchell, 1941; Finkelstein, 1960; Ball and Kilambi, 1973; McDonough and Buchanan, 1991). Juvenile black crappie prefer heavy vegetation and feed readily on organisms associated with it (Ridenhour, 1960) and are collected in great numbers at the CVP/TFCF during summer months when aquatic macrophytes are most abundant (CVP/TFCF, unpublished debris data).

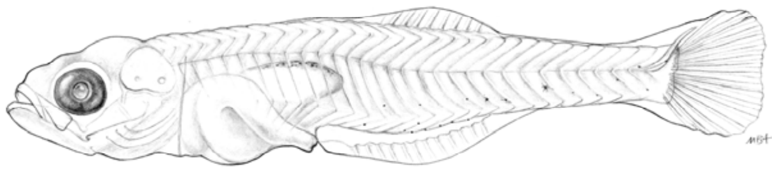
Black crappie become sexually mature in 2–4 years. Maximum life expectancy has been reported as 8–10 years (Scott and Crossman, 1973). In California, black crappie reach maturity in 2–3 years and live up to 13 years (Moyle, 2002). Black crappie is an important game fish sought by sport fishermen. Its flesh has a good quality and farm-raised crops (along with bluegill and largemouth bass) have been occasionally sold in Asian markets in the Bay Area.



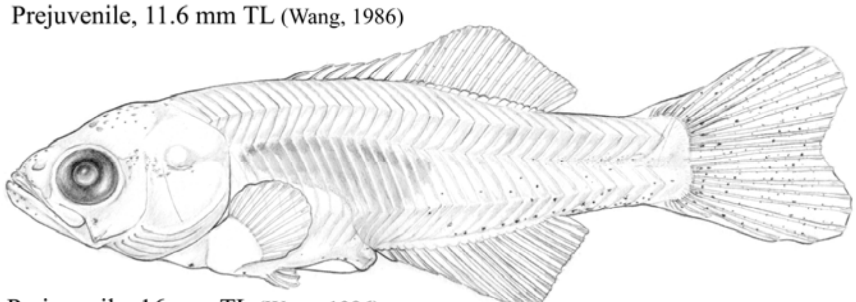
Prolarva, 3.42 mm TL (redrawn from Chatry, 1977)



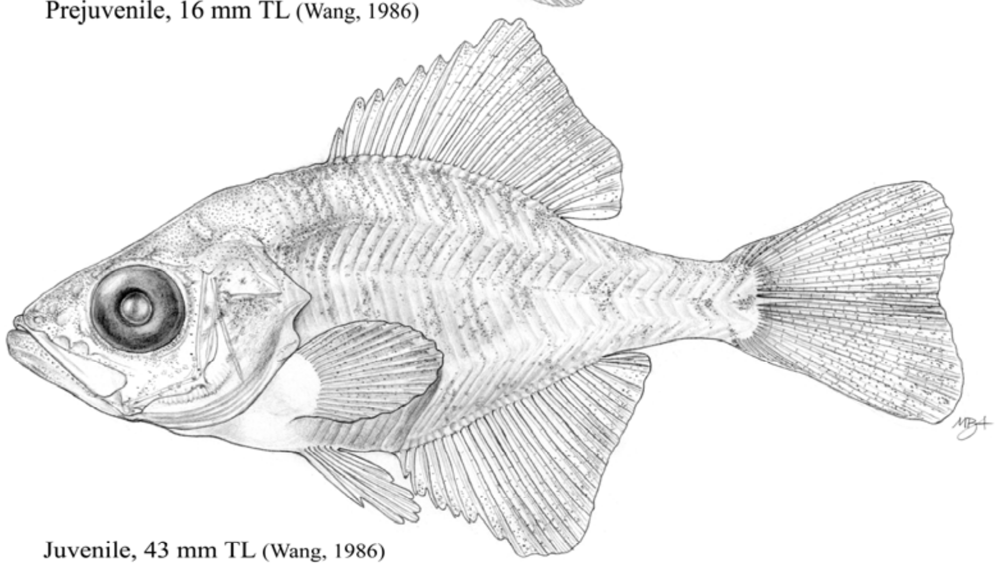
Postlarva, 4.85 mm TL (redrawn from Chatry, 1977)



Prejuvenile, 11.6 mm TL (Wang, 1986)



Prejuvenile, 16 mm TL (Wang, 1986)



Juvenile, 43 mm TL (Wang, 1986)

FIGURE 13a.—Black crappie (*Pomoxis nigromaculatus*).

FIGURE 13b.—Black crappie (*Pomoxis nigromaculatus*).

Summary of Developmental Characteristics for Prolarval Centrarchids (~ 2.5–6.0 mm TL yolk sac larvae) Refer to Figures 2a and 14a.

	Archoplites interruptus	**Lepomis spp.**	**Micropterus spp.**	**Pomoxis spp.**
Newly hatched size (mm TL)	2.5–4.0	2.4 (pumpkin-seed)–4.6 (redear sunfish)	~ 4.6	2.0– ~ 3.0 mm
Yolk sac position (Figure 14a)	Small, thoracic	Small, circular, thoracic	Large, thoracic	Very small, very thoracic
Newly hatched larva's adhesiveness to substrates	Adheres, then free	Remains in nest	Remains in nest	Free from nest

Summary of Developmental Characteristics for Postlarval Centrarchids (~ 6.0 –10 mm TL) Refer to Figures 2b and 14b–14c.

	Archoplites interruptus	**Lepomis spp.**	**Micropterus spp.**	**Pomoxis spp.**
Body pigmentation (Figure 14b)	All over, but sparse	Postanal-ventral	Head, dorsum, postanal	None, few at the postanal-ventral
PAL/TL (%) at size (mm TL)	36–41 at 4.3–8.8	39–46 at 5.0–8.0	44–51 at 6.4–10.3	36–39 at ~ 3.0–3.5
Air bladder: shape, position from base of pectoral fin and anus (Figure 14c)	Oval, midway	Roundish oval, midway	Roundish oval, near pectoral	Tear drop-shape, near anus
Myomere ranges:				
Total	27–34	25–35	28–34	28–32
Preanal	8–12	8–14	10–14	9–14
Postanal	17–22	14–21	15–22	17–24

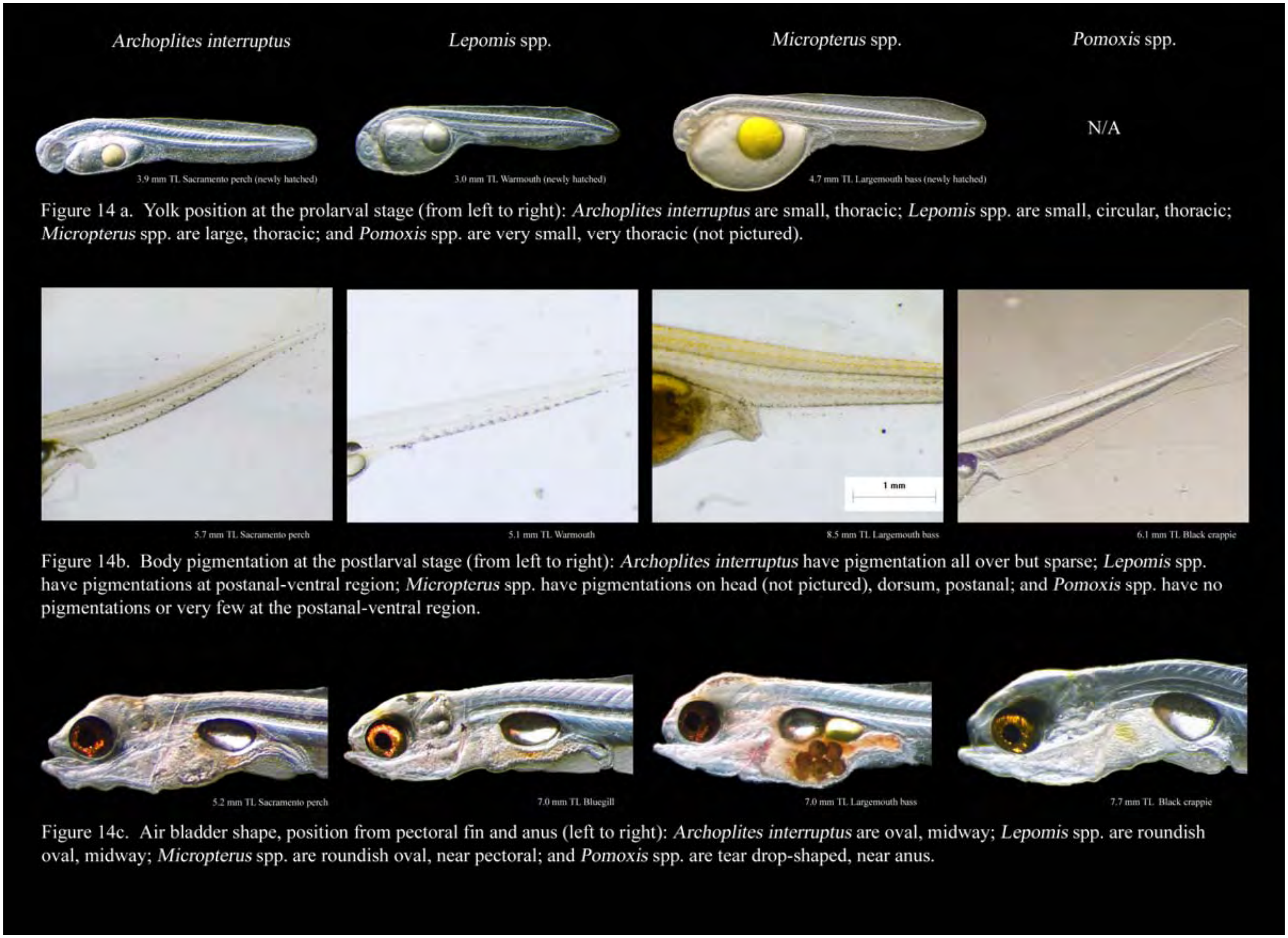


Figure 14 a. Yolk position at the prolarval stage (from left to right): *Archoplites interruptus* are small, thoracic; *Lepomis* spp. are small, circular, thoracic; *Micropterus* spp. are large, thoracic; and *Pomoxis* spp. are very small, very thoracic (not pictured).

Figure 14b. Body pigmentation at the postlarval stage (from left to right): *Archoplites interruptus* have pigmentation all over but sparse; *Lepomis* spp. have pigmentations at postanal-ventral region; *Micropterus* spp. have pigmentations on head (not pictured), dorsum, postanal; and *Pomoxis* spp. have no pigmentations or very few at the postanal-ventral region.

Figure 14c. Air bladder shape, position from pectoral fin and anus (left to right): *Archoplites interruptus* are oval, midway; *Lepomis* spp. are roundish oval, midway; *Micropterus* spp. are roundish oval, near pectoral; and *Pomoxis* spp. are tear drop-shaped, near anus.

FIGURE 14a–14c.—Figures for summary of characteristics for prolarval and postlarval centrarchids.

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KEY for the Juvenile Centrarchids (~ 15–50 mm TL) Refer to Figures 2b and 15a–15j.

1a	Body elongate, bass-like (Figure 15a)	2
1b	Body round, panfish-like (Figure 15b)	4
2a	Mouth small (jaw extends to middle of the eye, but not beyond the eye), body with random dense or sparse spots or with vertical bars (Figure 15c)	**Smallmouth bass**
2b	Mouth large, body with no vertical bars but with diamond-shaped blotches (Figure 15d)	3
3a	Mouth very large (jaw extends to middle of the eye or past the middle of eye), body deep and compressed, diamond-shaped blotches closely connected along the lateral region, deep notch between D1 and D2, orange absent at caudal fin base	**Largemouth bass**
3b	Mouth large (jaw rarely extends beyond rear margin of eye), body less deep, near cylindrical, diamond-shaped blotches loosely connected, shallow notch between D1 and D2, orange present at caudal fin base	**Spotted bass**
4a	Dorsal fin spines 12–13 (Figure 15e), anal fin spines 6–7	**Sacramento perch**
4b	Dorsal fin spines less than 12, anal spines 3–7	5
5a	Anal fin with 3 spines (Figure 15f)	6
5b	Anal fin with 6–7 spines (Figure 15f)	10
6a	Teeth on tongue (for larger juveniles), ca. 4 radiated stripes behind the eye (Figure 15g), and supramaxilla present	**Warmouth**
6b	No teeth on tongue, no radiated stripes behind the eye, and no supramaxilla	7
7a	Mouth large, maxillary extends beyond anterior margin of the eye (Figure 15h)	**Green sunfish**
7b	Mouth small, maxillary does not extend beyond the anterior margin of the eye	8
8a	Color of ear flap black, body with dark vertical bars (some in pairs), dark spot on D2 (Figure 15i), long gill rakers	**Bluegill**
8b	Color of ear flap black with orange-red border, no dark spot on D2, short gill rakers	9
9a	Mouth very small and less protruding; body deeper (Figure 15j); larger juveniles have body with bright yellow, orange and blue mosaic color, ear flap stiff	**Pumpkinseed**
9b	Mouth moderate and more protruding; body less deep (Figure 15j); larger juveniles have body with silvery yellow, olive, and orange mosaic color, ear flap stiff to flexible	**Redear sunfish**
10a	Dorsal fin with 7–8 spines, body high and strongly mottled, with dark green to black spots and with vertical bars	**Black crappie**
10b	Dorsal fin with 5–6 spines, body low and less mottled near silvery with vertical bars and some with broken vertical bars	**White crappie**

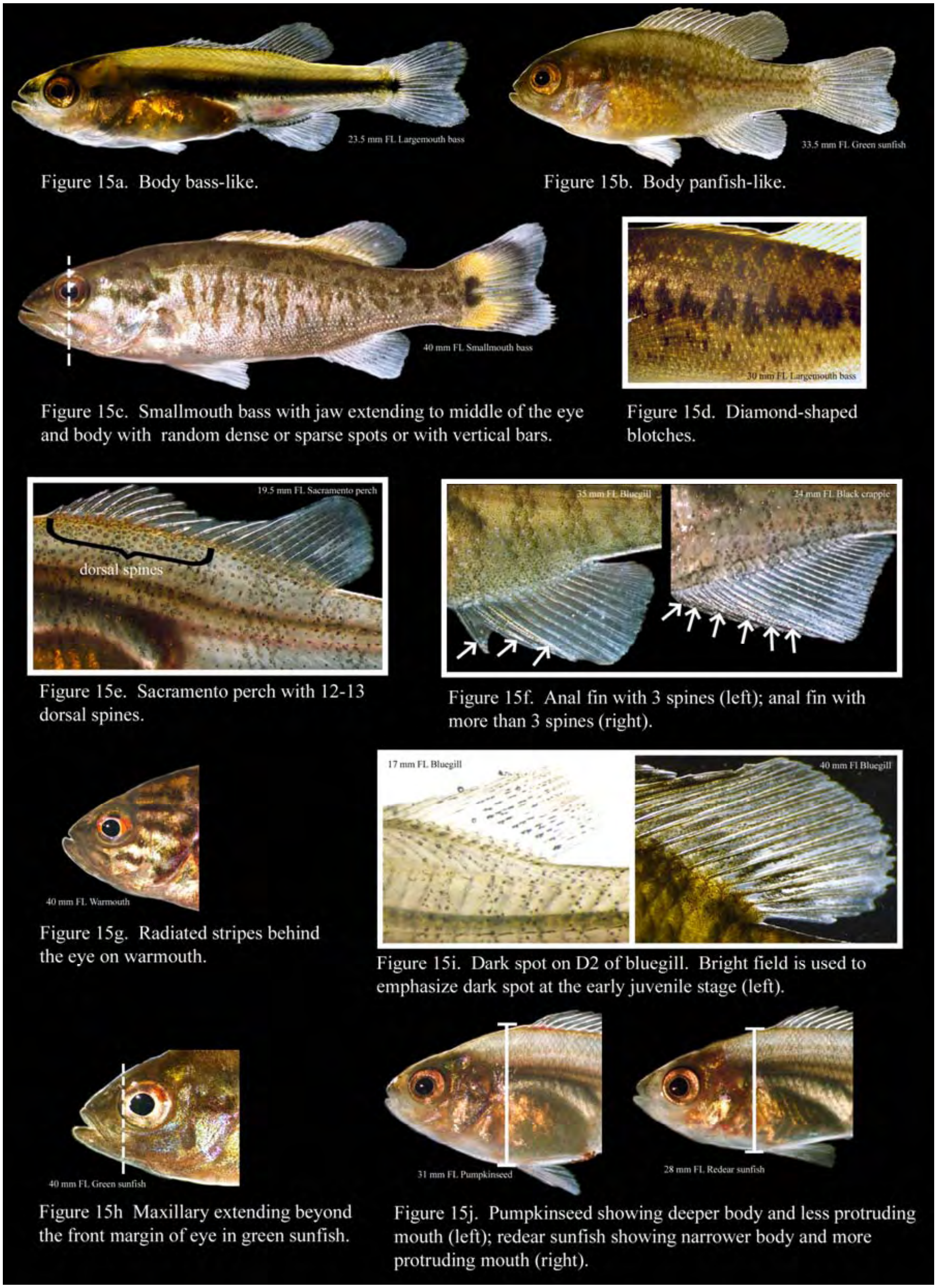

FIGURE 15a–15j.—Figures for Key for the Juvenile Centrarchids.

Summary of Characteristics of Adult Centrarchids

1. Sacramento perch (*Archoplites interruptus*)

   High dorsal fin spine count: XII–XLV (more than any *Lepomis* spp.)

   High anal fin spine count: VI–VIII (more than any *Lepomis* spp.)

   Body with broken blotches laterally reduced from ~ 10 to ~ 8 while developing from juvenile to adult

   Vertebrae: 31–34 (slightly more than *Lepomis* spp.)

2. Panfish or sunfish, *Lepomis* spp.

	Green sunfish	**Pumpkinseed**	**Warmouth**	**Bluegill**	**Redear sunfish**
Mouth	Large	Small	Large	Small	Small
Teeth on tongue	No	No	Yes	No	No
Gill rakers	Long	Short	Long	Long	Short
Opercle stripes	None	Yes	Yes	None	None
Ear lobe	Black	Orange/red	Black	Black	Orange/red
Spot on D2	Yes	No	No	Yes	No
Spot on A	Yes, (breeding males only)	No	No	No	No
Body lateral pigmentation	Vertical, large blotches	Mosaic	Vertical, irregular blotch	Vertical bar, double	Vertical blotches to mosaic
Pectoral fin with pointed tip	No	Yes	No	No	Yes
Dorsal fin	IX–XI, 10–12	X, 10–12	X–XI, 9–11	X, 10–12	X, 11–12
Anal fin	III, 8–10	III–IV, 9–11	III, 9–10	III, 11–12	III, 10–11
Vertebrae	28–30	28–29	29	28–30	32–33

3. Black bass, *Micropterus* spp.

	Smallmouth bass	**Spotted bass**	**Largemouth bass**
Mouth	Small	Large	Large
Bars or band on body	Vertical bars (~10)	Loose lateral band (1)	Connected lateral band (1)
Body/pigmentation on lower half of body	Bars separated	Black spots on scales of lower body, in rows, dense	Few spots
Notch in D1 and D2	Shallow	Shallow	Deep
Dorsal fin	IX–X, 12–15	IX–XI, 9–12	IX–X, 12–14
Anal fin	III, 10–12	II–V, 9–11	II–III, 10–12
Vertebrae	31–32	32	30–33
Body depth	Deep	Slightly deep	Very deep

4. Crappie, *Pomoxis* spp.

	White crappie	**Black crappie**
Mouth/Snout	Moderately large	Moderately large
Length from eye to origin of dorsal fin/ length of dorsal fin base	> (dorsal fin further back)	= (equal distance)
Dorsal fin	V–VI* /13–15	VII–VIII* /15–16
Anal fin	VI–VII, 16–18	VI, 17–19
Body pigmentation	Vertical and broken bars, body color greenish, black, silver, white, overall lighter	Vague bars, mostly mottled and mosaic, body color deep greenish, black, silvery white, overall darker
Ear lobe darkspot	Large, distinctive	Small, vague
Occiput, upper jaw	Noticeable, very short	Less noticeable, short
Body morphology	Very compressed, body tapering off gradually	Compressed, body tapering off abruptly
Vertebrae	30–32	31–33

* A key characteristic separation.

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REFERENCES

Aasen, G.A. and F.D. Henry, Jr. 1981. *Spawning behavior and requirements of Alabama spotted bass, Micropterus punctulatus henshalli, in Lake Perris, Riverside County, California.* California Fish and Game 67:118–125.

Aceituno, M.L. and S. Nicola. 1976. *Distribution and status of the Sacramento perch, Archoplites interruptus (Girard), in California.* California Fish and Game 62:246–254.

Aceituno, M.L. and C.D. Vanicek. 1976. *Life history studies of the Sacramento perch, Archoplites interruptus (Girard), in California.* California Fish and Game 62:5–20.

Adams, C.C. and T.L. Hankinson. 1928. *The ecology and economics of Oneida Lake fishes.* Roosevelt Wildlife Annual (3/4):235–548.

Aggus, L.R. and G.V. Elliott. 1975. *Effects of cover and food on year-class strength of largemouth bass.* Pages 317–322 *in* H. Clepper (editor). Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

Allen, C. and J. Romero. 1975. *Underwater observations of largemouth bass spawning and survival in Lake Mead*. Pages 104–112 *in* H. Clepper (editor). Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

Anjard, C.A. 1974. *Centrarchidae–sunfishes.* Pages 178–195 *in* A.J. Lippson and R.L. Moran (editors). Manual for Identification of Early Developmental Stages of Fishes of the Potomac River Estuary. Prepared for Maryland Department of Natural Resources, Power Plant Siting Program, PPSP-MP-13.

Applegate, R.L. and J.W. Mullan. 1967. *Food of young largemouth bass, Micropterus salmoides, in a new and old reservoir.* Transactions of the American Fisheries Society 96:74–77.

Bailey, R.M. and M.O. Allum. 1962. *Fishes of South Dakota.* Miscellaneous Publications of the Museum of Zoology, University of Michigan 119:1–132.

Bain, M.B. and L.A. Helfrich 1983. *Role of male parental care in survival of larval bluegills.* Transactions of the American Fisheries Society 112:47–52.

Ball, R.L. and R.V. Kilambi. 1973. *The feeding ecology of the black and white crappies in Beaver Reservoir, Arkansas, and its effect on the relative abundance of the crappie species.* Proceedings of the Annual Conference Southeastern Association of Game and Fish Commissioners 26:557–590.

Balon, E. 1959. *Spawning of Lepomis gibbosus (Linnaeus 1758) acclimatized in the back waters of the Danube and its development during the embryonic period.* Acta Societatis Zoologicae Bohemicae 23:1–22.

Bean, T.H. 1903. *Catalogue of fishes of New York.* New York State Museum Bulletin 60 (zool. 9):1–784.

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

Beckman, W.C. 1952. *Guide to the fishes of Colorado.* University of Colorado Museum Leaflet 11, 110 pp.

Beeman, H.W. 1924. *Habits and propagation of smallmouth black bass*. Transactions of the American Fisheries Society 54:92–107.

Beland, R.D. 1953. *The occurrence of two additional centrarchids in the lower Colorado River, California.* California Fish and Game 39:139–151.

Bolnick, D.I. and C.E. Miller. 2006. *Intergeneric spawning between captive female Sacramento perch (Archoplites interruptus) and male rock bass (Amboplites rupestrus), Teleostei: Centrarchidae.* American Midland Naturalist 156:299–304.

Bond, C.E. 1973. *Occurrence of the reticulate sculpin, Cottus perplexus, in California, with distributional notes on Cottus gulosus in Oregon and Washington.* California Fish and Game 59:93–94.

Bourandas, A. 2007. Data Lab Manager. U.S. Fish and Wildlife Service. Stockton, California.

Breder, C.M., Jr. 1926. *Sunfish nests.* New York Zoological Society Bulletin 29:221–222.

Breder, C.M., Jr. 1936. *The reproductive habits of the North American sunfishes (family Centrarchidae).* Zoologica (New York) 21:1–48.

Breder, C.M., Jr. 2003. *Will tidal wetland restoration enhance populations of native fishes?* San Francisco Estuary and Watershed Science. Vol. 1, Issue 1 (October 2003), Article 2. http://repositories.cdlib.org/jmie/sfews/vol1/iss1/art2.

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

Brooks, J.L. 1968. *The effects of prey size selection by lake zooplanktivores.* Systematic Zoology 17:272–291.

Brown, L.R. 2000. *Fish communities and their association with environmental variables, lower San Joaquin River drainage, California.* Environmental Biology of Fishes 57:251–269.

Brown, L.R. 2003. *Will tidal wetland restoration enhance populations of native fishes?* San Francisco Estuary and Watershed Science. Vol. 1, Issue 1 (October 2003), Article 2. http://repositories.cdlib.org/jmie/sfews/vol1/iss1/art2.

Brown, G.E. and S. Brennan. 2000. *Chemical alarm signals in juvenile green sunfish (Lepomis cyanellus, Centrarchidae).* Copeia 2000:1079–1082.

Brown, L.R. and J. May. 2006. *Variation in spring near shore resident fish species composition and life histories in the lower Sacramento-San Joaquin watershed and Delta (California).* San Francisco Estuary and Watershed Science. Vol. 4, Issue 1 (July 2006), Article 1. http://repositories.cdlib.org/jmie/sfews/vol4/iss2/art1.

Brown, L.R. and D. Michniuk. 2007. *Littoral fish assemblages of the alien-dominated Sacramento-San Joaquin Delta, California 1980–1983 and 2001–2003*. Estuaries and Coasts 30:186–200.

Brown, L.R. and P.B. Moyle. 2003. *Distribution, ecology, and status of the fishes of the San Joaquin drainage, California*. California Fish and Game 79:96–114.

Brown, L.R. and P.B. Moyle. 2005. *Native fish communities of the Sacramento-San Joaquin watershed, California: a history of decline.* Pages 75–98 *in* F. Rinne, R. Hughes, and R. Calamusso (editors). Fish Communities of Large Rivers of the United States. American Fisheries Society. Bethesda, Maryland.

Brown, L.R. and T.M. Short. 1999. *Biological, habitat, and water quality conditions in the upper Merced River drainage, Yosemite National Park, California, 1993–1996*. U.S. Geological Survey, Water Resources Investigations Report 99-4088, Sacramento, California.

Bunnell, D.B., M.A. Scantland, and R.A. Stein. 2005. *Testing for evidence of maternal effects among individuals and populations of white crappie.* Transactions of the American Fisheries Society 134:607–619.

Buss, K. 1965. *Black crappie, Pomoxis nigromaculatus; Pumpkinseed, Lepomis gibbosus; Redear sunfish, Lepomis microlophus; Warmouth, Lepomis gulosus.* Pages 112, 702–703, 716–717, 979–980 *in* McClane's Standard Fishing Encyclopedia. Holt, Rinehart, and Winston, New York.

Carbine, W.F. 1939. *Observations on the spawning habits of centrarchid fishes in Deep Lake, Oakland County, Michigan.* Transactions of the North American Wildlife and Natural Resources Conference 4:275–287.

Carlander, K.D. 1975. *Community relations of bass, large natural lakes*. Pages 125–130 *in* H. Clepper (editor). Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

Carlander, K.D. 1977. *Handbook of Freshwater Fishery Biology*. Volume 2. Iowa State University Press. Ames, Iowa, 431 pp.

Carr, A.F., Jr. 1939. *Notes on the breeding habits of the warmouth bass*. Proceedings of the Florida Academy of Sciences 4:108–112.

Carr, A.F., Jr. and C.J. Goin. 1955. *Guide to the Reptiles, Amphibians, and Fresh-water Fishes of Florida.* University of Florida Press, Gainesville, Florida, 353 pp. plus plates.

Carr, M.H. 1942. *The breeding habits, embryology, and larval development of the largemouth black bass in Florida.* Proceedings of the New England Zoological Club 20:43–77.

Carver, D.M. 1976. *Early life history of the bluegill, Lepomis macrochirus.* University of Maryland CEES, Chesapeake Biological Laboratory Reference 76-40, 8 pp. plus illustrations.

Chatry, M.F. 1977. *Comparative Developmental Morphology of the Crappies, Pomoxis annularis Rafinesque and P. nigromaculatus (LeSueur).* Master's thesis. Louisiana. State University, Baton Rouge.

Childers, W.F. 1965. *Hybridization of four species of sunfishes (Centrarchidae).* Doctoral dissertation. University of Illinois, Urbana.

Childers, W.F. 1967. *Hybridization of four species of sunfishes (Centrarchidae).* Illinois Natural History Survey Bulletin 29:159–214.

Christmas, J.Y. and R.S. Waller. 1973. *Estuarine vertebrates, Mississippi, Section 5.* Pages 320-434 *in* J.Y. Christmas (editor). Cooperative Gulf of Mexico Estuarine Inventory and Study–Mississippi. Publication of the Gulf Coast Research Laboratory, 434 pp.

Christophel, D.B. 1988. *Contributions to the life history of the redear sunfish (Lepomis microlophus) in Rancho Seco Reservoir, Sacramento County, California*. Master's thesis. California State University, Sacramento.

Clady, M.D. and G.U. Ulrichson. 1968. *Mortality of recently hatched bluegill fry as a result of hydra.* Progressive Fish-Culturist 30:39–40.

Clugston, J.P. 1966. *Centrarchid spawning in the Florida Everglades*. Quarterly Journal of the Florida Academy of Sciences 29:137–143.

Coble, D.W. 1975. *Smallmouth bass*. Pages 21–23 *in* H. Clepper (editor). Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

Coleman, R.M. and R.U. Fischer. 1991. *Brood size, male fanning effort and the energetics of a non-shareable parental investment in bluegill sunfish, Lepomis macrochirus (Teleostei: Centrarchidae)*. Ethology 87:177–188.

Côté, I.M. and M.R. Gross. 1993. *Reduced disease in offspring: a benefit of coloniality in sunfish.* Behavioral Ecology and Sociobiology 33:269–274.

Cross, F.B. 1967. *Handbook of Fishes of Kansas*. University of Kansas Museum of Natural History Miscellaneous Publications 45, 357 pp.

Cuevas, N. 2006. Biological Science Technician, California Department of Fish and Game, Bay-Delta Region, Stockton, California.

Curtis, B. 1949. *The warm water game fishes of California*. California Fish and Game 35:255-273.

Danylchuk, A.J. and M.G. Fox. 1996. *Size and age-related variation in the seasonal timing of nesting activity, nest characteristics, and female choice of parental male pumpkinseed sunfish (Lepomis gibbosus).* Canadian Journal of Zoology 74:1834–1840.

Davis, J.T. and J.T. Lock. 1997. *Largemouth bass biology and life history*. Southern Regional Aquaculture Center (SRAC) Publication 200.

Dege, M. 1995–2005. Fisheries Biologist, California Department of Fish and Game, North Central Region, Rancho Cordova, California.

Dill, W.A. and A.J. Cordone. 1997. *History and status of introduced fishes of California. 1871–1996*. California Fish and Game Fish Bulletin 178, 414 pp.

Dineen, W.J. 1968. *Determination of the effects of fluctuating water levels on the fish population of Conservation Area III*. Florida Federal Aid Project F-16; Job 1-E; Complete Report,15 pp.

Dominey, W.J. 1981. *Anti-predator function of bluegill sunfish nesting colonies.* Nature 290:586–588.

Eddy, S. 1957. *How to Know the Freshwater Fishes*. Wm. C. Brown Company, Dubuque, Iowa, 259 pp.

Eddy, S. and T. Surber. 1947. *Northern Fishes*. Second Edition. University of Minnesota Press, Minneapolis, Minnesota, 276 pp.

Ellison, D.G. 1984. *Trophic dynamics of a Nebraska black crappie and white crappie population*. North American Journal of Fisheries Management 4:355–364.

Emig, J.W. 1966. *Largemouth bass*; *smallmouth bass*; *redear sunfish*; *brown bullhead*. Pages 332–353, 354–365, 392–398, and 463–475 *in* A. Calhoun (editor). Inland Fisheries Management. California Fish and Game.

Evermann, B.W. and H.W. Clark. 1920. *Lake Maxinkuckee, a physical and biological survey*. Indiana Department of Conservation. Publication 7, Volume 1, 660 pp. and 36 plates.

Faber, D.J. 1963. *Larval fish from the pelagial region of two Wisconsin lakes*. Doctoral dissertation. University of Wisconsin, Madison.

Faber, D.J. 1967. *Limnetic larval fish in northern Wisconsin lakes*. Journal of the Fisheries Research Board of Canada 24:927–938.

Fajen, O. 1975. *Population dynamics of bass in rivers and streams*. Pages 195–203 *in* H. Clepper (editor). Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

Feyrer, F. and M. Healey. 2002. Structure, sampling gear and environmental associations, and historical changes in the fish assemblage of the southern Sacramento-San Joaquin Delta. California Fish and Game 88:126–138.

Feyrer, F. and M. Healey. 2003. *Fish community structure and environmental correlates in the highly altered southern Sacramento-San Joaquin Delta*. Environmental Biology of Fishes 66:123–132.

Feyrer, F., T.R. Sommer, S.C. Zeug, G. O'Leary, and W. Harrell. 2004. *Fish assemblages of perennial floodplain ponds of the Sacramento River, California (USA), with implications for the conservation of native fishes.* Fisheries Management and Ecology 11:335–344.

Feyrer, F., T.R. Sommer, and W. Harrell. 2006. *Importance of flood dynamics versus intrinsic physical habitat in structuring fish communities: evidence from two adjacent engineered floodplains on the Sacramento River, California*. North American Journal of Fisheries Management 26:408–417.

Finkelstein, S.L. 1960. *A food study of four centrarchidae of Lake Forth Smith, Crawford County, Arkansas*. Master's thesis. University of Arkansas, Fayetteville.

Fish, M.P. 1932. *Contributions to the early life histories of sixty-two species of fishes from Lake Erie and its tributary waters*. U.S. Bureau of Fisheries Bulletin 47:293–398.

Forbes, S.A. and R. E. Richardson. 1920. *The Fishes of Illinois*. Second Edition. Illinois Natural History Survey, Springfield, Illinois, 493 pp.

Germann, J.F., L.E. McSwain, D.R. Holder, and C.D. Swanson. 1974. *Life history of the warmouth in the Suwannee River and Okefenokee Swamp, Georgia*. Proceedings of the Annual Conference of the Southeast Association Game and Fish Commission 28:259–278.

Gill, T. 1906. *Parental care among freshwater fishes*. Annual Report of the Smithsonian Institute 1905:403–531.

Gobalet, K.W. 1990a. *Native status of Sacramento perch (Archoplites interruptus) in Alameda Creek, Alameda County, California: Evidence from archaeological site California-ALA-483*. California Fish and Game 76:244–247.

Gobalet, K.W. 1990b. *Prehistoric status of freshwater fishes in the Pajaro-Salinas River system of California*. Copeia 1990:680–685.

Gobalet, K.W. 1993. *Additional archaeological evidence for endemic fishes of California's Central Valley in the coastal Pajaro-Salinas basin*. The Southwestern Naturalist 38:218–223.

Goff, G.P. 1984. *The reproductive behaviour and ecology of smallmouth bass (Micropterus dolomieui) in Long Point Bay, Lake Erie*. Doctoral dissertation. University of Western Ontario, London, Canada.

Goodgame, L.S. and L.E. Miranda. 1993. *Early growth and survival of age-0 largemouth bass in relation to parental size and swim-up time*. Transactions of the American Fisheries Society 122:131–138.

Goodson, L.F. 1965. *Diets of four warmwater fishes in a fluctuating steep-sided California reservoir*. California Fish and Game 51:259–269.

Goodson, L.F. 1966. *Crappie*; *landlocked striped bass*. Pages 312–332 and 402–411 *in* A. Calhoun (editor). Inland Fisheries Management. California Fish and Game.

Graham, R.J. and D.J. Orth. 1986. *Effects of temperature and streamflow on time and duration of spawning by smallmouth bass*. Transactions of the American Fisheries Society 115:693–702.

Grimaldo, L. 1998–2007. Biologist/Environmental Specialist, California Department of Water Resources, Sacramento, California.

Gross, M.R. 1982. *Sneakers, satellites and parentals: Polymorphic mating strategies in North American Sunfishes*. Zeitschrift für Tierpsychologie 60:1–26.

Gross, M.R. 1991. *Evolution of alternative reproductive strategies: frequency-dependent sexual selection in male bluegill sunfish*. Philosophical Transactions of the Royal Society of London B 332:59–66.

Gross, M.R. and A.M. MacMillan. 1981. *Predation and the evolution of colonial nesting in bluegill sunfish (Lepomis macrochirus)*. Behavioral Ecology and Sociobiology 8:163–174.

Gustafson, E.P. 1978. *The vertebrate faunas of the Pliocene Ringold Formation, south-central Washington*. University of Oregon Museum of Natural History Bulletin 23:1–62.

Gutreuter, S.J. and R.O. Anderson. 1985. *Importance of body size to the recruitment process in largemouth bass populations*. Transactions of the American Fisheries Society 114:317–327.

Hansen, D.F. 1943. *On nesting of the white crappie, Pomoxis annularis*. Copeia 1943:259–260.

Hansen, D.F. 1951. *Biology of the white crappie in Illinois*. Illinois Natural History Survey Bulletin 25:209–265.

Hansen, D.F. 1965. *Further observations on nesting of the white crappie, Pomoxis annularis*. Transactions of the American Fisheries Society 94:182–184.

Hardy, J.D., Jr. 1978. *Development of fishes of the mid-Atlantic Bight: an atlas of egg, larval, and juvenile stages*. Volume 3. Aphredodderidae through Rachycentridae. FWS/OBS-78/12. U.S. Fish and Wildlife Service, Office of Biological Services. Fort Collins, Colorado, 394 pp.

Hearst, J.M. and G.R. Smith. 2002. *Fish of the late Pleistocene Duck Point local fauna, Power County, Idaho; equitable climate indicator or reworked assemblage?* Idaho Museum of Natural History Occasional Papers 37:131–140.

Heidinger, R.C. 1975. *Life history and biology of the largemouth bass*. Pages 11–20 *in* H. Clepper (editor). Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

Hellier, T.R., Jr. 1967. *The fishes of the Santa Fe River system*. Florida State Museum Biological Sciences Bulletin 2:1-37.

Henderson, C. and R.F. Foster. 1957. *Studies of smallmouth black bass (Micropterus dolomieui) in the Columbia River near Richland, Washington*. Transactions of the American Fisheries Society 86:112–127.

Hildebrand, S.F. and W.C. Schroeder. 1927 (1928). *Fishes of Chesapeake Bay*. Bulletin U.S. Bureau of Fisheries 43, 366 pp.

Hinch, S.G. and N.C. Collins. 1991. *Importance of diurnal and nocturnal nest defense in the energy budget of male smallmouth bass: insights from direct video observations*. Transactions of the American Fisheries Society 120:657–663.

Hogan, J. 1934. *Rearing largemouth black bass at Lonoke*. Transactions of the American Fisheries Society 64:127–131.

Howland, J.W. 1931. *Studies on the Kentucky black bass* (*Micropterus pseudoaplites Hubbs*). Transactions of the American Fisheries Society 61:89–94.

Hubbs, C. 1947. *Mixture of marine and freshwater fishes in the lower Salinas River, California.* Copeia 1947:147–149.

Hubbs, C.L. 1919. *The nesting habits of certain sunfishes as observed in a park lagoon in Chicago*. Aquatic Life 4:143–144.

Hubbs, C.L. and K.F. Lagler. 1958. *Fishes of the Great Lake Region*. Revised edition. Cranbrook Institute of Science Bulletin 26, 186 pp. and plates.

Hunter, J.R. 1963. *The reproductive behavior of the green sunfish* (*Lepomis cyanellus).* Zoologica (New York) 48:13–24.

Hurst, H.N. 1969. *Comparative life history of the redeye bass, Micropterus coosae, (Hubbs and Bailey), and the spotted bass, Micropterus p. punctulatus (Rafinesque), in Halawakee Creek, Alabama*. Master’s thesis, Auburn University, Alabama.

Imler, R.L., D.T. Weber, and O.L. Fyock. 1975. *Survival, reproduction, age, growth, and food habits of Sacramento perch, Archoplites interruptus (Girard), in Colorado*. Transactions of the American Fisheries Society 2:232–236.

Jenkins, R.E. and N.M. Burkhead. 1994. *Freshwater Fishes of Virginia*. American Fisheries Society. Bethesda, Maryland.

Johnson, V.K. 1958. *Lakes Pyramid, Walker, and Tahoe investigations: life history of Sacramento perch, Pyramid Lake*. Nevada Department of Fish and Game Project Report D-JF-4-R, 7 pp.

Jordan, D.S. and B.W. Evermann. 1896–1900. *The Fishes of Middle and North American*. U.S. Natural Museum, Bulletin 47, 3313 pp. and plates.

Keast, A. 1966. *Trophic interrelationships in the fish fauna of small streams*. Proceedings of the 9th Conference on Great Lakes Research. University of Michigan 15:51–79.

Keast, A. 1968. *Feeding biology of the black crappie, Pomoxis nigromaculatus*. Journal of the Fisheries Research Board of Canada 25:285–297.

Keast, A. and D. Webb. 1966. *Mouth and body form relative to feeding ecology in the fish fauna of a small lake, Lake Opinicon, Ontario*. Journal of the Fisheries Research Board of Canada 23:1845–1874.

Kelley, J.W. 1962. *Sexual maturity and fecundity of the largemouth bass, Micropterus salmoides (Lacépède), in Maine*. Transactions of the American Fisheries Society 91:23–28.

Kramer, R.H. and L.L. Smith, Jr. 1960. *Utilization of nests of largemouth bass, Micropterus salmoides, by golden shiners, Notemigonus crysoleucas*. Copeia 1690:73–74.

Kramer, R.H. and L.L. Smith, Jr. 1962. *Formation of year classes in largemouth bass*. Transactions of the American Fisheries Society 91:29–33.

Larimore, R.W. 1957. *Ecological life history of the warmouth (Centrarchidae*). Bulletin Illinois Natural History Survey 27, 83 pp.

Latta, W.C. 1975. *Dynamics of bass in large natural lakes*. Pages 175–182 *in* H. Clepper (editor). Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

Lauder, G.V. 1983. *Functional and morphological bases of trophic specialization in sunfishes (Teleostei, Centrarchidae)*. Journal of Morphology 178:1–21.

Laurence, G.C. 1969. *The energy expenditure of largemouth bass larvae, Micropterus salmoides, during yolk absorption*. Transactions of the American Fisheries Society 98:398–405.

Lebida, R.C. 1969. *The seasonal abundance and distribution of eggs, larvae, and juvenile fishes in the Weweantic River Estuary, Massachusetts, 1966*. Master's thesis. University of Massachusetts, Amherst.

Lee, D.P. 2000. *The Sacramento-San Joaquin Delta largemouth bass fishery.* Interagency Ecological Program for the San Francisco Estuary Newsletter 13:37–40.

Lee, D.S., C.R. Gilbert, C.H. Hocutt, R.E. Jenkins, D.E. McAllister, and J.R. Stauffer, Jr. 1980. *Atlas of North American freshwater fishes*. Raleigh, North Carolina State Museum of Natural History, 854 pp.

Lehman, P.W. 2004. *The influence of climate on mechanistic pathways that affect lower food web production in Northern San Francisco Bay estuary*. Estuaries 27:311–324.

Leidy, R.A. 1983. *Distribution of fishes in streams of the Walnut Creek basin, California.* California Fish and Game 69:23–32.

Leidy, R.A. 2007. *Ecology, assemblage structure, distribution, and status of fishes in streams tributary to the San Francisco Estuary, California*. SFEI Contribution 530. San Francisco Estuary Institute. Oakland, California.

Leon, A., C.E. Miller, and S.J. Teh. 2008. *Early development of Sacramento perch*. North American Journal of Aquaculture 70:27–37.

Lever, C. 1996. *Naturalized Fishes of the World*. Academic Press, San Diego, California.

Lewis, W.M. and D.R. Helms. 1964. *Vulnerability of forage organisms to largemouth bass.* Transactions of the American Fisheries Society 93:315–318.

Loshbaugh, D.F. 1978. *Prey selection by the black crappie (Centrarchidae: Pomoxis nigromaculatus*). Master’s thesis. University of California, Santa Barbara.

Lukas, J.A. and D.J. Orth. 1995. *Factors affecting nesting success of smallmouth bass in a regulated Virginia stream*. Transactions of American Fisheries Society 125:726–735.

Mabee, P.M. 1993. *Phylogenetic interpretation of ontogenetic change: sorting out the actual and artefactual in an empirical case study of centrarchid fishes*. Zoological Journal of the Linnean Society 107:175–291.

Mabee, P.M. 1995. *Evolution of pigment pattern development in centrarchid fishes*. Copeia 1995:586–607.

MacCrimmon, H.R. and W.H. Robbins. 1975. *Distribution of the black basses in North America*. Pages 56–66 *in* H. Clepper (editor). Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

Marchetti, M.P. 1998. *Biological effects of non-native species in low elevation streams of the Central Valley, California.* Doctoral dissertation, University of California, Davis.

Marchetti, M.P. 1999. *An experimental study of competition between native Sacramento perch (Archoplites interruptus) and introduced bluegill* (*Lepomis macrochirus*). Biological Invasions 1:55–65.

Marchetti, M.P. and P.B. Moyle. 2001. *Keeping alien fishes at bay: effects of flow regime and habitat structure on fish assemblages in a regulated California stream*. Ecological Applications 11:75–87.

Markham, J.L., D.L. Johnson, and R.W. Petering. 1991. *White crappie summer movements and habitat use in Delaware Reservoir, Ohio*. North American Journal of Fisheries Management 11:504–512.

Matern, S.A., P.B. Moyle, and L.C. Pierce. 2002. *Native and alien fishes in a California estuarine marsh: twenty-one years of changing assemblages*. Transactions of the American Fisheries Society 131:797–816.

Mathews, S.B. 1962. *The ecology of the Sacramento perch, Archoplites interruptus, from selected areas of California and Nevada.* Master's thesis. University of California, Berkeley.

Mathews, S.B. 1965. *Reproductive behavior of Sacramento perch, Archoplites interruptus*. Copeia 1965:224–228.

Mathur, D. and T.W. Robbins. 1971. *Food habits and feeding chronology of young white crappie, Pomoxis annularis Rafinesque, in Conowingo Reservoir*. Transactions of the American Fisheries Society 100:307–311.

May, E.B. and C.R. Gassaway. 1967. *A preliminary key to the identification of larval fishes of Oklahoma, with particular reference to Canton Reservoir, including a selected bibliography.* Oklahoma Department of Wildlife Conservation Bulletin 5, 35 pp.

May, J.T. and L.R. Brown. 2002. *Fish communities of the Sacramento River basin: implications for conservation of native fishes in the Central Valley, California.* Environmental Biology of Fishes 63:373–388.

McCammon, G.W., D.L. Faunce, and C.M. Seeley. 1964. *Observation on the food of fingerling largemouth bass in Clear Lake, Lake County, California.* California Fish and Game 50:158–169.

McCarraher, D.B. 1972. *Survival of some freshwater fishes in the alkaline eutrophic waters of Nebraska.* Journal of the Fisheries Research Board of Canada 28:1811–1814.

McCarraher, D.B. and R.W. Gregory. 1970. *Adaptability and current status of introductions of Sacramento perch, Archoplites interruptus, in North America.* Transaction of the American Fisheries Society 99:700–707.

McDonough, T.A. and J.P. Buchanan. 1991. *Factors affecting abundance of white crappies in Chickamauga Reservoir, Tennessee, 1970–1989*. North American Journal of Fisheries Management 11:513–524.

McKechnie, R.J. 1966. *Logperch*. Pages 530–531 *in* A. Calhoun (editor). Inland Fisheries Management. California Department of Fish and Game, Sacramento, California.

Merriner, J.V. 1971. *Egg size as a factor of intergeneric hybrid success of centrarchids*. Transactions of the American Fisheries Society 100:29–32.

Meyer, F.A. 1970. *Development of some larval centrarchids*. The Progressive Fish-Culturist 32:130–136.

Miklos, P. 2007. Biological Science Technician, U.S. Fish and Wildlife Service, Stockton, California.

Miller, C. 2003. *Embryonic development of the Sacramento perch, Archoplites interruptus: A preliminary report*. *Unpublished report.* Mosquito and Vector Control Division, Contra Costa County, Concord, California.

Miller, C. 2005. *Evaluation of stocking success of Sacramento perch using three life history stages, adult, juvenile, and larvae. Unpublished report.* Contra Costa Mosquito and Vector Control District, Concord, California.

Miller, C. 2006. *Preliminary Report on feed trials of Sacramento perch (Archoplites interruptus). Unpublished report.* Contra Costa Mosquito and Vector Control District, Concord, California.

Miller, C. 2006–2007, Biologist, Contra Costa Mosquito and Vector Control District, Concord, California.

Miller, K.D. and R.J. Kramer. 1971. *Spawning and early life history of largemouth bass (Micropterus salmoides) in Lake Powell*. Pages 73–83 *in* G.E. Hall (editor). Reservoir Fisheries and Limnology. American Fisheries Society Special Publication 8, Bethesda, Maryland.

Miller, R.J. 1975. *Comparative behavior of centrarchid basses*. Pages 85–94 *in* H. Clepper (editor). Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

Mitchell, D. 1979–1991. Fisheries Biologist, California Department of Fish and Game, Central Region, Fresno, California.

Mitchell, G.C. 1941. *Food habit analysis of the two species of Texas crappie*. Master's thesis. North Texas State Teacher's College, Victoria.

Moody, H.L. 1957. *A fisheries study of Lake Panasoffkee, Florida*. Quarterly Journal of the Florida Academy of Sciences 20:21–88.

Moore, G.A. 1957. *Fishes*. Pages 31-210 *in* W.F. Blair, A.P. Blair, P. Brodkorb, F.R. Cagle, and G.A. Moore (editors). Vertebrates of the United States. McGraw-Hill Book Company, New York.

Morgan, G.D. 1951. *The life history of the bluegill sunfish, Lepomis macrochirus, of Buckeye Lake (Ohio)*. Journal of Science Laboratory, Denison University 42(4):21-59.

Morgan, G.D. 1954. The life history of the white crappie (*Pomoxis annularis*) of Buckeye Lake, Ohio. Journal of Science Laboratory, Denison University 43(618):113–144.

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, California, 502 pp.

Moyle, P.B., F.W. Fisher, and H.W. Li. 1974. Mississippi silversides and logperch in the Sacramento-San Joaquin River system. California Fish and Game 60:144-147.

Moyle, P.B. and N.J. Holzhauser. 1978. *Effects of the introduction of Mississippi silverside (Menidia audens) and Florida largemouth bass (Micropterus salmoides floridanus) on the feeding habits of young-of-year largemouth bass in Clear Lake, California*. Transactions of the American Fisheries Society 107:575–582.

Moyle, P.B., P.K. Crain, and K. Whitener. 2007. *Patterns in the use of a restored California floodplain by native and alien fishes*. San Francisco and Estuary Watershed Science. Volume 5, Issue 3 (July 2007). Article 1. http://repositories.cdlib.org/jmie/sfews/vol5/iss3/art1

Moyle, P.B., P.K. Crain, K. Whitener, and J.F. Mount. 2003. *Alien fishes in natural streams: fish distribution, assemblage structure, and conservation in the Cosumnes River, California, USA*. Environmental Biology of Fishes 68:143–162.

Mraz, D. 1964. *Observations on large and smallmouth bass nesting and early life history*. Wisconsin Conservation Department Report 11:1–13.

Murphy, G.I.. 1948. *A contribution to the life history of the Sacramento perch (Archoplites interruptus) in Clear Lake. Lake County, California*. California Fish and Game 34:93–100.

Nakamura, N., S. Kasahare, and T. Yada. 1971. *Studies on the usefulness of the bluegill sunfish, Lepomis machrochirus (Rafinesque), as an experimental standard animal II. On the developmental stages and growth from egg through one year.* Journal of the Faculty of Fisheries and Animal Husbandry, Hiroshima University, Japan 10:139–151.

Near, T.J., D.I. Bolnick, and P.C. Wainwright. 2004. *Investigating phylogenetic relationships of Centrarchidae (Actinopterygii: Perciformes) using DNA sequences from mitochondrial and nuclear genes.* Molecular Phylogenetics and Evolution 32:344–357.

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. American Fisheries Society Special Publication 29. Bethesda, Maryland.

Nelson, W.R., R.E. Siefert, and D.V. Swedberg. 1967. *Studies of the early life history of reservoir fishes*. Pages 374–385 *in* C.E. Lane, Jr. (editor). Reservoir Fishery Resources Symposium. American Fisheries Society, Bethesda, Maryland.

Nichols, F.H., J.E. Cloern, S.N. Luoma, and D.H. Peterson. 1986. *The modification of an estuary*. Science 231:567–573.

Nichols, J.T. 1943. *The fresh-water fishes of China*. Natural History of Central Asia, Vol. 9. The American Museum of Natural History, New York, New York, 322 pp.

Nobriga, M., F. Feyrer, R. Baxter, and M. Chotkowski. 2005. *Fish community ecology in an altered river delta: spatial patterns in species composition, life history strategies, and biomass.* Estuaries 28:776–785.

Nobriga, M.L. and F. Feyrer. 2007. *Shallow-water piscivore-prey dynamics in California's Sacramento-San Joaquin Delta*. San Francisco Estuary and Watershed Science. Volume 5, Issue 2 (May 2007). Article 4. http://repositories.cdlib.org/jmie/sfews/vol5/iss2/art4

O'Brien, W.J., B. Loveless, and D. Wright. 1984. *Feeding ecology of young white crappie in a Kansas reservoir.* North American Journal of Fisheries Management 4:341–349.

Panek, F.M., and C.R. Cofield. 1978. *Fecundity of bluegill and warmouth from a South Carolina blackwater lake.* The Progressive Fish-Culturist 40:67–68.

Pedretti, J. 2007. Fish Biologist, U.S. Fish and Wildlife Service, Stockton, California.

Perche, G. 1964. *El Black-bass de boca grande*. Montes 20:483–489.

Pflieger, W.L. 1965. *Reproductive behavior of the minnows, Notropsis spilopterus and Notropsis whipplii.* Copeia 1965:1–8.

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

Piscator. 1950. *Bass sent from the cape to Mauritus breed at one year old*. Piscator 4(13):6–7.

Raffetto, N. 1987. *The reproductive ecology of smallmouth bass (Micropterus dolomieui) in Nebish Lake, Wisconsin.* Doctoral dissertation. University of Wisconsin, Madison.

Ramsey, J.S. and R.O. Smitherman. 1971. *Development of color pattern in pond-reared young of five Micropterus species of southeastern U.S.* Proceedings of the Twenty-fifth Annual Conference of the Southeastern Association of Game and Fish Commissioners 25:348–356.

Ramsey, L.D. 1975. *Taxonomic history and systematic relationships among species of Micropterus.* Pages 67–75 *in* H. Clepper (editor). Black Bass Biology and Management. Sport Fishing Institute, Washington, D.C.

Reid, H. 1930. *A study of Eupomotis gibbosus (L.) as occurring in the Chamcook Lakes, N.B.* Contributions to Canadian Biology and Fisheries 5:457–466.

Reighard, J.E. 1906. *The breeding habits, development and propagation of the black bass (Micropterus dolomieui Lacépède and Micropterus salmoides Lacépède).* Michigan Fish Commission Bulletin 7, 73 pp. plus plates.

Renfro, W.C. 1960. *Salinity relations of some fishes in the Arkansas River, Texas*. Tulane Studies in Zoology 8:83–91.

Reynolds, C.R. and C.J. O'Bara. 1991. *Reproductive ecology and spawning habitat of smallmouth bass in two small streams of the Tennessee River system*. Pages 61–65 *in* D.C. Jackson (editor). The First International Smallmouth Bass Symposium. Mississippi Agriculture and Forestry Experiment Station, Mississippi State University, Starkville.

Reynolds, J.B. 1965. *Life history of smallmouth bass, Micropterus dolomieui Lacépède, in the Des Moines River, Boone County, Iowa.* Iowa State Journal of Science 30:417–436.

Richardson, R.E. 1913. *Observations on the breeding habits of fishes at Havana, Illinois, 1910 and 1911.* Illinois State Laboratory Natural History Bulletin 9:405–416.

Ridenhour, R.L. 1960. *Abundance, growth, and food of young game fish in Clear Lake, Iowa, 1949 to 1957*. Iowa State Journal of Science 35:1–23.

Ridgway, M.S. 1988. *Developmental stage of offspring and brood defense in smallmouth bass* (*Micropterus dolomieui*). Canadian Journal of Zoology 66:1722–1728.

Ridgway, M.S. 1991. *The relative influence of body size and territorial behaviour on nesting asynchrony in male smallmouth bass, Micropterus dolomieui (Pisces: Centrarchidae)*. Journal of Animal Ecology 60:665–681.

Ridgway, M.S., J.A. MacClean, and J.C. MacLeod. 1991. *Nestside fidelity in a centrarchid fish, the smallmouth bass (Micropterus dolomieui).* Canadian Journal of Zoology 69:3103–3105.

Robbins, W.H. and H.R. MacCrimmon. 1974. *The black bass in America and overseas.* Biomanagement Research Enterprises, Sault Ste. Marie, Ontario, Canada, 196 pp.

Robbins, W.H. and H.R. MacCrimmon. 1977. *Vital statistics and migratory patterns of a potamodromous stock of smallmouth bass, Micropterus dolomieui.* Journal of the Fisheries Research Board of Canada 34:142–147.

Rockriver, A. 1996–1997. Fisheries Biologist, California Department of Fish and Game, Bay-Delta Region, Stockton, California.

Rockriver, A.K.C. 1998. *Spatial and temporal distribution of larval fish in littoral habitats of the Central Valley, California*. Master's thesis. California State University, Sacramento.

Rutter, C. 1908. *The fishes of the Sacramento-San Joaquin Basin with a study of their distribution and variation*. U.S. Bureau of Fisheries Bulletin 27:103–152.

Sabo, M.J., E.J. Pert, and K.O. Winemiller. 1995. *Agonistic behavior of juvenile largemouth bass and smallmouth bass.* Journal of Freshwater Biology 11:115–118.

Saiki, M.K. 1973. *The life history and ecology of largemouth bass in Parker Canyon Lake*. Master's thesis. University of Arizona, Tucson.

Saiki, M.K. 1984. *Environmental conditions and fish faunas in low elevation rivers on the irrigated San Joaquin Valley floor.* California Fish and Game 70:145–157.

Saiki, M.K. and B.A. Martin. 2001. *Survey of fishes and environmental conditions in Abbotts Lagoon, Point Reyes National Seashore, California*. California Fish and Game 87:123–138.

Savitz, J. and J. Janssen. 1982. *Utilization of green sunfish and bluegills by largemouth bass: influence of ingestion time*. Transactions of the American Fisheries Society 111:462–464.

Schmidt, R.E. and T. Stillman. 1998. *Evidence of potamodromy in an estuarine population of smallmouth bass (Micropterus dolomieu).* Journal of Freshwater Ecology 13:155–163.

Schoffman, R.J. 1939. *Age and growth of the redear sunfish in Reelfoot Lake*. Journal of Tennessee Academy of Sciences 14:61–70.

Schwartz, R.S. and B. May. 2004. *Characterization of microsatellite loci in Sacramento perch (Archoplites interrruptus).* Molecular Ecology Notes 4:694–697.

Scott, W.B. and E.J. Crossman. 1973. *Freshwater Fishes of Canada*. Fisheries Research Board of Canada Bulletin 184, 966 pp.

Seaburg, K.G. and P.B. Moyle. 1964. *Feeding habits, digestion rates, and growth of some Minnesota warmwater fishes.* Transactions of the American Fisheries Society 93:269–285.

Shao, B. 1997. *Nest association of pumpkinseed, Lepomis gibbosus, and golden shiner, Notemigonous crysoleucas.* Environmental Biology of Fishes 50:41–48.

Shapovalov, L., A.J. Cordone, and W.A. Dill. 1981. *A list of the freshwater and anadromous fishes of California.* California Fish and Game 67:4–38.

Shapovalov, L., W.A. Dill, and A.J. Cordone. 1959. *A revised check list of the fresh-water and anadromous fishes of California*. California Fish and Game 45:155–180.

Shelton, W.L., W.D. Davies, T.A. King, and T.J. Timmons. 1979. *Variation in the growth of the initial year class of largemouth bass in West Point Reservoir, Alabama and Georgia*. Transactions of the American Fisheries Society 108:142–148.

Siefert, R.E. 1965. *Early scale development in the white crappie*. Transactions of the American Fisheries Society 94(2): 182 pp. plus 1 figure.

Siefert, R.E. 1968. *Reproductive behavior, incubation and mortality of eggs, and postlarval food selection in the white crappie*. Transactions of the American Fisheries Society 97:252–259.

Siefert, R.E. 1969a. *Characteristics for separation of white and black crappie larvae*. Transactions of the American Fisheries Society 98:326–328.

Siefert, R.E. 1969b. *Biology of the white crappie in Lewis and Clark Lake*. Bureau of Sport Fisheries and Wildlife, Technical Paper 22, 16 pp.

Siefert, R.E. 1972. *First food of larval yellow perch, white sucker, bluegill, emerald shiner, and rainbow smelt*. Transactions of the American Fisheries Society 101:219–225.

Sigler, W. 1959. *The taxonomy and life history of some freshwater fish*. Utah State University, Department of Wildlife Management, Logan, Utah.

Simonson, T.D. and W.A. Swenson. 1990. *Critical stream velocities for young-of-year smallmouth bass in relation to habitat use.* Transactions of the American Fisheries Society 119:902–909.

Skinner, J.E. 1962. *An historical review of the fish and wildlife resources of the San Francisco Bay area.* California Fish and Game, Water Projects Branch Report 1. 226 pp.

Skinner, J.E. 1972. *Ecological studies of the Sacramento-San Joaquin estuary*. California Department of Fish and Game. Delta Fish Wildlife Protection Study Report 8, 94 pp.

Smith, B.A. 1971. *The fishes of four low-salinity tidal tributaries of the Delaware River Estuary.* Master's thesis. Cornell University, Ithaca, New York.

Smith, G.R. and J. Cossel, Jr. 2002. *Fishes from the Late Miocene Poison Creek and Chalk Hills Formation, Owyhee County, Idaho.* Idaho Museum of Natural History Occasional Papers 37:23–35.

Smith, G.R., N. Morgan, and E. Gustafson. 2000. *Fishes of the Mio-Pliocene Ringold Formation, Washington: Pliocene capture of the Snake River by the Columbia River.* University of Michigan Papers on Paleontology 32:1–47.

Smith, G.R. and R.R. Miller. 1985. *Taxonomy of fishes from Miocene Clarkia lake beds*. Pages 75-83 *in* C.J. Smith (editor). Late Cenozoic History of Pacific Northwest. Pacific Division of the American Association Advancement of Science, San Francisco, California.

Smith, J.J. 1982. *Fishes of the Pajaro River system*. University of California Publication of Zoology 115:83–170.

Smith, P.W. and L.M. Page. 1969. *The food of spotted bass in streams of Wabash River drainage*. Transactions of the American Fisheries Society 98:647–651.

Smitherman, R.O. and J.S. Ramse. 1972. *Observations on spawning and growth of four species of bass (Micropterus) in ponds.* Proceedings of Annual Conference of the Southeast Association of Game Fish Commissioners 25:357–365.

Smitherman, R.O. and R.E. Hester. 1962. *Artificial propagation of sunfishes, with meristic comparisons of three species of Lepomis and five of their hybrids.* Transactions of the American Fisheries Society 91:333–341.

Snow, J.R. 1960. *An exploratory attempt to rear largemouth blackbass fingerlings under controlled environment.* Proceedings of Annual Conference of the Southeast Association of Game Fish Commissioners 14:253–257.

Sparks, R.E., J.C. Nelson, and Y. Yin. 1998. *Naturalization of the flood regime in regulated rivers.* Bioscience 48:707–720.

Sterba, G. 1959. *Freshwater Fishes of the World*. Longacre Press, London, England, 878 pp.

Stokely, P.S. 1952. *The vertebral axis of two species of centrarchid fishes*. Copeia 4:255–261.

Sublette, J.E., M.D. Hatch, and M. Sublette. 1990. *The Fishes of New Mexico*. University New Mexico Press, Albuquerque, New Mexico, 393 pp.

Swingle, H.S. 1946. *Experiments with combinations of largemouth black bass, bluegills, and minnows in ponds*. Transactions of the American Fisheries Society 76:46–62.

Swingle, H.S. 1956. *Appraisal of methods of fish population study. Part IV: Determination of balance in farm fish ponds*. The 21st North American Wildlife Conference Transactions 298–322.

Swingle, H.S. 1971. *Biology of Alabama estuarine area–Cooperative Gulf of Mexico estuarine inventory.* Alabama Marine Resources Bulletin 5, 123 pp.

Swingle, H.S. and E.V. Smith. 1950. *Management of farm fish ponds*. Alabama Polytechnic Institute. Agriculture Experiment Station Bulletin 254, 23 pp.

Taber, C. 1969. *The distribution and identification of larval fishes in the Buncombe Creek arm of Lake Taxoma with observations on spawning habitats and relative abundance.* Doctoral dissertation. University of Oklahoma, Norman.

Taubert, B.D. 1977. *Early morphological development of the green sunfish, Lepomis cyanellus, and its separation from other Lepomis species.* Transactions of the American Fisheries Society 106:445–448.

Tester, A.L. 1930. *Spawning habits of the small-mouthed black bass in Ontario waters.* Transactions of the American Fisheries 60:58–61.

Toetz, D.W. 1965. *Factors affecting the survival of bluegill sunfish larvae.* Doctoral dissertation. Indiana University, Bloomington.

Toetz, D.W. 1966. *The changes from endogenous to exogenous sources of energy in bluegill sunfish larvae*. Investigations of Indiana Lake and Streams 7:115–146.

Toole, M. 1950. *Utilizing stock tanks and farm ponds for fish*. Texas Game and Fish Commission Bulletin 24, 53 pp.

Towery, B.A. 1964. *Age and size at maturity of spotted bass.* Completion report F-6-R. Mississippi Game and Fish, Jackson, Mississippi.

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

Turner, G.E. and H.R. MacCrimmon. 1970. *Reproduction and growth of smallmouth bass, Micropterus dolomieui, in a Precambrian lake*. Journal of the Fisheries Research Board of Canada 27:395–400.

Turner, J.L. 1966. *Distribution and food habits of ictalurid fishes in the Sacramento-San Joaquin Delta.* Pages 130–143 *in* J.L. Turner and D.W. Kelley (editors). *Ecological studies of the Sacramento-San Joaquin Delta, Part II.* California Fish and Game Fish Bulletin 136, Sacramento, California.

Vanicek, C.D. 1980. *Decline of the Lake Greenhaven Sacramento perch population*. California Fish and Game 66:178–183.

Van Tassell, J., E. Bergey, C. Davis, M. Davis, B. Grimshaw, J. Kisselburg, R. Ledgerwood, S. Miller, C. Morris, J. Steele, C. Wehymiller, M.L. Ferns, G.R. Smith, H.G. McDonald, J.I. Mead, and R.A. Martin. 2007. *Early Pliocene (Blancan) Always Welcome Inn local fauna, Baker City, Oregon*. Oregon Geology 68:3–23.

Van Tassell, J., M. Ferns, V. McConnell, and G.R. Smith. 2001. *The mid-Pliocene Imbler fish fossils, Grande Ronde Valley, Union County, Oregon, and the connection between Lake Idaho and Columbia River*. Oregon Geology 63:77–84, 89–96.

Vogele, L.E., 1969. *Underwater observations*. U.S. Bureau of Sport Fishery and Wildlife Resources Publication 77:75–56.

Vogele, L.E. 1975. *Reproduction of spotted bass, Micropterus punctulatus, in Bull Shoals Reservoir, Arkansas.* U.S. Fish and Wildlife Service Technical Paper 84, 21 pp.

Vogelsang, C.A. 1931. *Early history of introduction and distribution of spiny-rayed fishes in California waters*. California Fish and Game 31:238–240.

Von Geldern, C.E., Jr. 1971. *Abundance and distribution of fingerling largemouth bass, Micropterus salmoides, as determined by electrofishing, at Lake Nacimiento, California.* California Fish and Game 57:303.

Wang, J.C.S. 1986. *Fishes of the Sacramento-San Joaquin estuary and adjacent waters, California: A guide to the early life histories*. Interagency Ecological Program (IEP) Technical Report 9, 612 pp.

Wang, J.C.S. and R.C. Reyes. 2007. *Early life stages and early life histories of cyprinids in Sacramento-San Joaquin Delta, California: With emphasis on splittail, Pogonichthys macrolepidotus, spawning in the Suisun Bay and Delta.* Tracy Volume 32, 114 pp. plus appendix.

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

Webster, D.A. 1942. *The life history of some Connecticut fishes*. Pages 122-227 *in* A Fishery Survey of Important Connecticut Lakes. Connecticut Geological and Natural History Survey Bulletin 63.

Webster, D.A. 1948. *Relation of temperature to survival and incubation of the eggs of smallmouth bass (Micropterus dolomieui).* Transactions of the American Fisheries Society 75:43–47.

Webster, D.A. 1954. *Smallmouth bass, Micropterus dolomieui in Cayuga Lake. Part I. Life history and environment.* Cornell University Agricultural Experiment Station Memoir 327:1–39.

Werner, R.G. 1966. *Ecology and movements of bluegill sunfish fry in a small northern Indiana Lake*. Doctoral dissertation. Indiana University, Bloomington.

Werner, R.G. 1967. *Intralacustrine movements of bluegill fry in Crane Lake, Indiana*. Transaction of the American Fishery Society 96:416–420.

White, G.E. 1971. *The Texas golden green: A color mutation of the green sunfish*. The Progressive Fish-Culturist 33:155.

Whiteside, B.G. 1964. *Biology of the white crappie, Pomoxis annularis, in Lake Texoma, Stillwater, Oklahoma.* Master's thesis. Oklahoma State University, Stillwater.

Wiegmann, D.D., J.R. Baylis, and M.H. Hoff. 1992. *Sexual selection and fitness variation in a population of smallmouth bass, Micropterus dolomieui (Pisces: Centrarchidae).* Evolution 46:1740–1753.

Wilbur, R.L. 1969. *The redear sunfish in Florida*. Florida Game and Fresh Water Fish Commission Fishery Bulletin 5, 64 pp.

William, A.D., M. Coots, and P.A. Douglas. 1955. *The status of the pumpkinseed, Lepomis gibbosus (Linne), in California.* California Fish and Game 41:157–159.

Woods, T. 1994–1995. Biologist/Environmental Specialist, California Department of Water Resources, Sacramento, California.

Wu, B. 2005. Fish Biologist, U.S. Bureau of Reclamation, Tracy Fish Collection Facility, Byron, California.

Wydoski, R.S. and R.R. Whitney. 1979. *Inland Fishes of Washington*. University of Washington Press, Seattle.

Yeh, C.F. 1977. *Relative selectivity of fishing gear used in a large Texas reservoir*. Transactions of the American Fisheries Society 106:309–313.

Zimmerman, M.P. 1999. *Food habits of smallmouth bass, walleyes, and northern pikeminnow in the Lower Columbia River Basin during outmigration of juvenile anadromous salmonids*. Transactions of the American Fisheries Society 128:1036–1054.

GLOSSARY AND ABBREVIATIONS

Abdominal On or pertaining to the belly or abdomen.

Agonistic behavior Any behavior associated with conflict between two individuals from a cohort.

Air bladder Membranous gas-filled sac present in the dorsal portion of the body cavity.

Alkaline/alkalinity Reference to water having pH of more than 7.

Anus The posterior opening of the digestive tract.

Bay Area Common term for San Francisco Bay Area, a geographical region that surrounds the San Francisco Bay and San Pablo Bay.

Black bass A common name for *Micropterus* spp. of the Centrarchidae family. The term originates from the stage of larval development of smallmouth bass where soon after yolk absorption, the larvae become progressively darker, and then becoming black.

Caudal peduncle The slender portion of the body that is between the anal and caudal fins.

CCMVCD An abbreviation of Contra Costa County Mosquito and Vector Control District.

CDFG An abbreviation of California Department of Fish and Game.

Central Valley The fertile, flat valley dominating the central part of California where the Sacramento-San Joaquin River Delta is located.

Centrarchids Any fishes from the family Centrarchidae including the Sacramento perch and several species of sunfish, black bass, and crappie.

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.

Cyprinid Any member of the carp and minnow family, Cyprinidae.

CVP/TFCF An abbreviation of Central Valley Project/Tracy Fish Collection Facility.

Delta A tidally influenced body of water comprising of the Sacramento and the San Joaquin Rivers and their tributaries.

Demersal Living on or close to the bottom substrate.

Detritus Decomposing organic material and debris that includes small pieces of dead and decomposing plants and animals.

Dorsal Pertaining to the back or the upper part of the body. Opposite of ventral.

Dorsoventrally Extending from the dorsal region to the belly.

Dorsum The back side of a structure (the back).

dph. Days post hatch or the number of days after the egg hatched. The day of hatching is counted as 0 dph.

dps Days post spawn or the number of days after the egg was fertilized. The day of fertilization is counted as 0 dps.

DWR An abbreviation of the California Department of Water Resources.

D1 Abbreviation for the first dorsal fin (spines).

D2 Abbreviation for the second dorsal fin (rays).

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.

Exogenous/exogenously Feeding method of larvae where nutrients are taken from the environment and less or none from the yolk sac.

E & L Survey Fish Eggs and Larvae sampling conducted by the California Department of Fish and Game.

Fresh water or freshwater Salinities less than 0.3 ppt.

Gut Digestive tract from the mouth to anus.

Hydra A genus of simple, freshwater invertebrate possessing radial symmetry that attach themselves to substrate and mainly feed on other invertebrates and small larval fish. It is distinguished from the free-living medusa or jellyfish form.

Hypural A serial bony structure below the urostyle which supports the caudal fin.

Incubation period The elapsed time between fertilization and hatching of the egg.

Intermittent spawner Fish that spawn several times during the season.

Isthmus The narrow area between the sets of branchiostegal rays across the jugular.

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 prolarva Stage of larval development when air bladder becomes visible and the yolk sac is not yet fully absorbed.

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.

Limnetic A description of the body of water where the lake bottom is too deep to support rooted aquatic plants due to insufficient sunlight

Lotic A description of running water such as a river or a stream.

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.

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.

Monogamous (Monogamy) Description of a mating system where each member of a heterosexual pair spawns only with the other member of that pair.

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.

Nape The area along the middorsum just behind the cephalic region.

Newly hatched prolarvae Fish larvae at 0 dph.

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 A bony flap covering the gills.

Panfish A common name for sunfish species (*Lepomis* spp.) of the Centrarchidae family.

Perivitelline space Vitreous space between the chorion and yolk.

Planktonic Floating or drifting in the water column.

Phylogeny The evolutionary descent and interrelationships of a group of organisms.

Polygynous (Polygyny) Description of a mating system where a male mates with more than one female.

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 (Potamodromy) Migrating within freshwater.

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.

Prolarva (Yolk-sac larva) The stage of larval development when yolk sac is not yet absorbed, finfolds are present, and notochord is straight.

Pyloric caecum (*pl.* caeca) Finger-like pouches of the intestine connected with the stomach which aids in digestion.

Riprap A collection of rocks used to stabilize the shore such as those that line the sloughs and rivers of the Delta.

Satellite males Smaller, sub-dominant males that exploit a resource such as an undefended nest or female.

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.

South Delta The southern region of the Sacramento-San Joaquin Delta where the State (State Water Project) and Federal (Central Valley Project) water diversion projects are located.

Spawning Release or deposition of spermatozoa and/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.

Stellate Pertaining to the star-shape of a melanophore.

Sunfish A common name for fishes in the Centrarchidae family.

Superior mouth Position of the mouth where the mouth is located on the dorsal side of the snout; lower jaw extends beyond upper jaw.

Supramaxilla A small bone (or bones) lying immediately above or partially overlapping the posterior end of the maxillary bone in some fishes.

SWP/SDFPF An abbreviation for State Water Project/Skinner Delta Fish Protective Facility.

Terminal mouth Jaws meet at the tip of the snout.

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.

UC Davis An abbreviation for University of California at Davis.

USFWS An abbreviation of the U.S. Fish and Wildlife Service.

Ventral Pertaining to the underside or lower part of the fish. Opposite of dorsal.

Width of the perivitelline space The distance between the yolk and the chorion.

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.