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EARLY DEVELOPMENT OF THE HITCH, LAVINIA EXILICAUDA, OF CLEAR LAKE, CALIFORNIA [1]

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In 1962 and 1963, eggs were collected from hitch during their spawning in tributaries of Clear Lake. The eggs were hatched using improvised hatchery apparatus. Observations of the stages of development of both eggs and larvae are described and shown in drawings up to the juvenile stage.

Information on the early development of fishes can make valuable contributions to life history and ecological studies (Balinsky, 1948; Winn and Miller, 1954). This information can also be useful in establishing systematic relationships (Orton, 1953).

This report describes the early development of the hitch, a cyprinid native to California, inhabiting the Pajaro-Salinas, Sacramento-San Joaquin, and Russian River systems, as well as Clear Lake, Lake County. Miller (1945) thought it best to retain the Pajaro-Salinas form, *Lavinia exilicauda harengus,* as a subspecies distinct from *L. e. exilicauda* of the Sacramento-San Joaquin drainage, on the basis of the former's slender body, but stated more specimens of *L. e. exilicauda*-especially from tributaries of San Francisco Bay—are needed to determine the validity of this difference. On the basis of preliminary studies, the hitch of Clear Lake probably represents a third geographic subspecies (John D. Hopkirk, pers. commun.).

Murphy (1948) made extensive observations on the biology of hitch in Clear Lake. He found that, unlike most cyprinids, the hitch must lay its demersal nonadhesive eggs in flowing water. He surmised that eggs hatch in 10 days and become free-swimming larvae in 20 days at 62° F. Kimsey (1960) observed the spawning of Clear Lake hitch in the wave-washed gravel of the lakeshore. Murphy (1948) compiled age and growth tables for the hitch from the juvenile stage onward. But before the present study, there has been no detailed description of the development of the hitch from spawning to the juvenile stage.

METHODS AND MATERIALS

On April 7, 1962, I took spawning fish from Seigler Canyon Creek, and on April 12, 1963, from an unnamed ditch swollen with rainwater near Lakeport. Both sources are Clear Lake tributaries.

I mixed freshly-stripped eggs and milt for 1 minute in a quart jar and then washed them by filling the jar with creek water. After 1 hour I transferred them to a gallon jar, and 6 hours later to a deep enameled dishpan having an air supply. The pan was immersed in a bath of tap

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water and maintained at 60 to 64° F. for 7 days, until the eggs hatched. Occasionally, methylene blue was added to prevent growth of fungus. On the 24th day, I transferred the prolarvae to an aerated 5-gallon aquarium. Here the temperature fluctuated from 63° to 73° F., paralleling daily air temperatures. The prolarvae were fed finely ground tropical fish food daily.

All observations and drawings were made from live or freshly killed specimens. Specimens were measured against millimeter-graph paper lining the bottom of a petri dish. All measurements are averages from 5 to 10 individuals. I made observations at 15X, 30X, and 45X, and based the drawings on 15X views. I gave the time sequences of development, because I believed that in early stages the temperature range could well have been a natural one. But growth from free-swimming stages onward lagged behind that of wild stock the same age (Murphy, 1948).

The terminology for larval stages follows Hubbs (1943) as defined for cyprinids by Winn and Miller (1954). Stages of development follow Balinsky (1948). The terminology for pigmentation follows Balinsky (1948), as further subdivided by Winn and Miller (1954).

RESULTS

Eggs and Embryos

In 1962 the eggs were subjected to wide temperature fluctuations (61° to 74° F.), and all the prolarvae died within 2 days after hatching.

In 1963 the hitch were raised through the juvenile stage. The eggs were collected from fish spawning in water at 55° F. Transporting them to the laboratory involved a 2.5-hour delay, but the temperature rose to only 61° F. The temperature remained at 61° F. until the eggs reached the dishpan used as an incubator. The time sequence of development is based on this 1963 work.

The freshly stripped eggs appear pale orange. Twenty minutes after fertilization the vitelline membrane lifts and an individual egg appears light yellow (Figure 1A). The fertilized egg's diameter is between 2.00 and 2.25 mm. The diameter of the yolk sphere is 1.25 mm. The eggs are considerably heavier than water and do not adhere to themselves or other objects. No oil globules are visible. Figure 1, B through J, omits the egg shell for clarity and to save space.

A high, rounded blastodisc forms in 1 hour (Figure 1B). In 2 hours the first cleavage appears (Figure 1C). The second cleavage appears at 2.5 hours (Figure 1D). The 8-cell stage can be seen at 3.5 hours. At 5.5 hours, there is a blastoderm with 16 or more cells (Figure 1E). In 12 hours the yolk becomes elongated as the blastoderm begins to migrate around it. At this time the yolks have various oblong shapes, the most common of which is shown (Figure 1F).

The blastopore is closed, and the thickened keel of the embroyo can be seen at 35 hours (Figure 1G). The higher, thicker head region can be seen at 39 hours. At 45 hours, there are 4 to 6 somites centered about halfway between the head and tail ends, and the splitting of the internal cavity of the optic cup is visible (Figure 1H). At 54 hours, there are 15 to 17 somites (Figure 1I). At 69 hours, there are 20 to 22 somites; the otic placode is visible; and the tail begins to undulate slowly as it

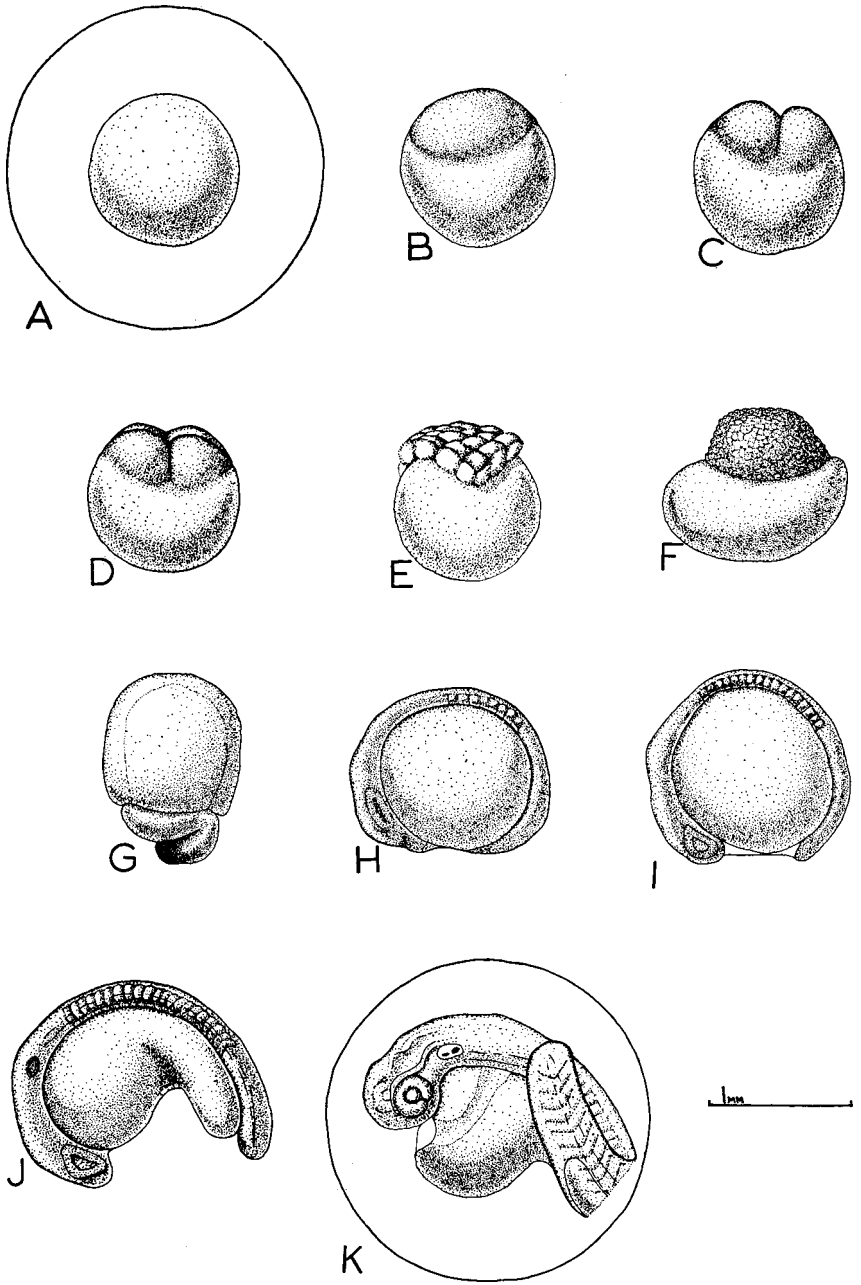

FIGURE 1. Early stages of development of the hitch before hatching: (A) stage 2, 20 minutes; **(B)** stage 3, 1 hour; (C) stage 4, **2½** hours; (D) stage 5, **3½** hours; (E) between stages 6 and 7, **5½** hours; (F) stage 11, 12 hours; (G) stage 14, 30 hours; **(H)** stage 18, 45 hours; (I) stage 19, 50 hours; (J) stage 20, 69 hours; (K) stage 22, 108 hours.

frees itself from the yolk, carrying an extension of the yolk sac with it (Figure 1J). At 99 hours the otic capsule, which now his two otoliths, has moved closer to the eye with the straightening of the head region, and the first irregular heart beats can be seen ventral and lateral to the left eye. The beginnings of the vitelline vein appear laterally on the yolk sac at 108 hours, and the embryo is almost constantly undulating (Figure 1K). At 120 hours the heart is a distinct red spot anterior to the yolk sac and ventral to the eye and has a constriction between the auricle and ventricle. There are dorsal, anal, and caudal fin folds. Pigment granules are visible in the eyes, giving them a sooty appearance. On the 6th day the embryo is crowded in the egg membrane and its movements have become vigorous lashings. At 120 hours an embryo is 5 mm long. At 15X it is light grey, with dark grey eyes, and has a light yellow yolk sac. Grossly, embryos appear light yellow with black eyes.

Larvae

Hatching occurs on the 7th day (Figure 2A). The tail breaks through and a few lashes of it free the prolarva, which is 6 mm long. The prolarva lies motionless on its side, unless disturbed. If disturbed, it swims erratically like a tadpole and settles back to the bottom.

The dosal pigment line extends from the interorbital region posteriorly half the length of the body. The posterior cardinal veins and the dorsal aorta appear as two distinct red lines ventral and parallel to the notochord. To the naked eye, the prolarvae appear yellow with two black eyes—the postcardinal veins and the dorsal aorta appearing as a single red line.

Lengths

On the 10th day the prolarvae are 7 mm long. Postlarvae 32 days old are 8.5 mm long, and juveniles 58 days old are 13 mm long.

Eyes and Lateral Line

The eyes are dark grey on the 8th day, becoming black with visible lenses on the 10th. On the 26th day the eyes are iridescent gold with black pupils, the adult condition. On the 22nd day the transparent, filamentous lateral-line organs can be seen at 45X projecting from the sides of the body and the dorsal and lateral sides of the head. These organs are still visible on juveniles 65 days old.

Digestive System Derivatives

On the 10th day the upper and lower jaw bars are visible (Figure 2B). The single-lobed air sac contains air on the 14th day. By the 15th day, gill filament buds are visible on the four gill bars, and the liver is encroaching on the anterior end of the yolk sac. On the 20th day the yolk sac has disappeared, marking the beginning of the postlarval stage. The bright yellow interior of the gut is visible ventral to the anterior end of the air sac on the 27th day. By the 32nd day the gut is constricted about halfway along its length at the future site of the pelvic fins, and the liver now obscures the anterior fourth of the gut. At 46 days the air sac is bilobed, the anterior lobe comprising about one-third the total air sac volume.

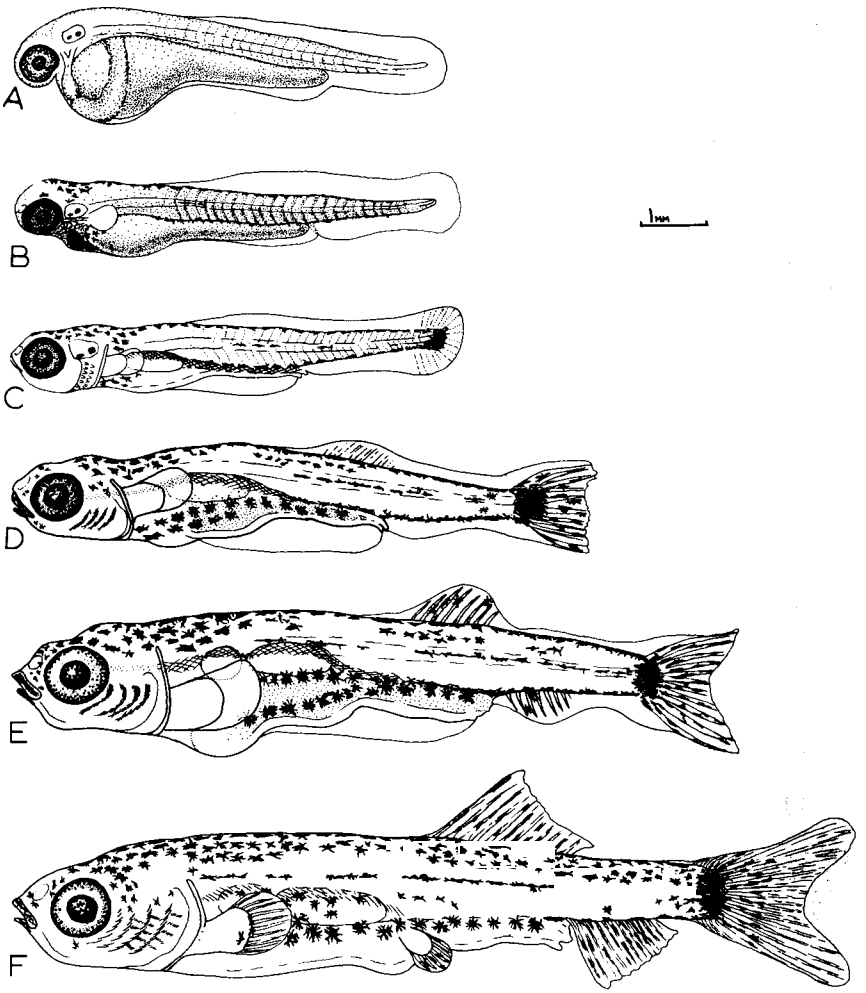

FIGURE 2. Early stages of development of the hitch after hatching: (A) stage 26 (hatching), 7 days; (B) stage 30, 10 days; (C) stage 32, 26 days; (D) stage 35, 36 days; (E) stage 37, 46 days; (F) stage 43, 65 days.

Fins and Activity

On the 10th day, there is some spontaneous swimming, there are slight jaw movements, and the pectoral fins appear as small paddles. By the 14th day the air sac enables the prolarva to swim and rest upright. There are strong breathing and feeding movements of the jaws ; and the pectoral fins, now with a definitive muscular lobe, can be moved backward and forward. The vertical, rod-like cleithrum can be seen along the origin of the pectoral fin on the 21st day. By the 36th day, there is an outline of the dorsal fin, and 8 to 10 caudal fin rays are ossified (Figure 2D). By the 46th day 8 to 10 dorsal, 6 to 8 anal, and 16 to 18 caudal fin rays are ossified (Figure 2E). By the 65th day the fins have a full complement of ossified rays (Figure 2F).

Pigmentation

On the 8th day the dorsal and ventral pigment lines extend posteriorly to the caudal peduncle. The ventral aorta and dorsal and lateral sides of the pericardium are pigmented. On the 9th day the dorsal edge of the myotomes has a greenish tinge in contrast to the rest of the embryo. On the 11th day, there are 6 to 8 melanophores along the lateral pigment line. There are 2 to 4 melanophores on each tip of the upper and lower lips by the 26th day and a concentration of melanophores on the ventral aspect of the tail (Figure 2C). All the gill bars are pigmented, the lateral pigment line has 10 to 14 melanophores, and the dorsal and ventral pigment lines are denser by the 29th day. By the 32nd day, there are silvery guanophores on the dorsal lateral aspects of the stomach and intestine, and the pectoral fins have one or two melanophores on each. By the 36th day the concentration of melanophores in the tail region forms a spot covering the base of the caudal fin, and many melanophores have migrated onto the caudal rays. By the 41st day the anal and dorsal fins each have 1 to 4 melanophores. There is a patch of guanophores on the opercles by the 46th day; these cells, along with those of the stomach and intestine, produce the adults' dark-above, light-below appearance. On the 65th day the gill filaments are pigmented. The ventral pigment line never has more than 3 or 4 dispersed melanophores in the trunk region, and no melanophores are seen on the ventral side of the pericardium.

DISCUSSION

The development of the hitch followed the stages of Balinsky (1948) very closely through stage 43. Stages from 44 onward were not seen, because scales were never observed on hitch in the laboratory. Hatching took place at stage 26. The hatching and free-swimming times of 7 and 14 days, respectively, are considerably shorter than Murphy's 1943 estimates. He reported 10 and 20 days, respectively, at similar temperatures.

The large spot at the base of the caudal fin distinguishes young hitch from young carp *(Cyprinus carpio)* and also from young Venus roach *(Hesperoleucus venustus)*, which have only a small spot at the base of the caudal fin (Fry, 1936).

SUMMARY

In the spring of 1962 and 1963, *eggs* of the Clear Lake hitch were raised under laboratory conditions. The temperature averaged 62° F. The pale yellow, fertilized eggs are 2.25 mm in diameter, and the yolk sphere is 1.25 mm in diameter. There are no oil globules. The eggs are eyed in 5 days and the prolarvae become free-swimming and feed on day 14. They have a full complement of ossified fin rays by day 65. The large caudal spot distinguishes them from the young of most other cyprinids.

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