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HAWAIIAN FRESHWATER FISHES (OSTEICHTHYES, GOBIOIDEI) A FIELD KEY TO THE SPECIES OF LARVAE AND POSTLARVAE DURING RECRUITMENT INTO FRESH WATERS

By David C. Tate, J. Michael Fitzsimons, and Richard P. Cody

"Ai wale i ka hinana, ka i'a kaulana o ka aina." - eat freely of the *hinana*, the well known fish of the land (Pukui 1940). The ancient Hawaiians knew that at certain times of the year vast numbers of larval gobioid fishes (*hinana*) moved from the ocean into fresh water where they could be collected for food in fine-meshed nets. The Hawaiians recognized adults of the five species of endemic freshwater fishes (*'o'opu wai)* by assigning each a descriptive name (Titcomb 1972), but, understandably, they did not attempt to distinguish species among larvae and postlarvae, referred to collectively as *hinana.* These young animals are quite small (13-22 mm TL) and usually do not resemble adults except in the general placement and shape of the fins. Only recently biologists have begun to discover characteristics with which these fishes can be identified. However, there are disagreements about which features go with which species and whether or not a feature useful in identifying a certain larva also can be used to distinguish a postlarva of the same species. In preparing this key, we have examined series of specimens from the islands of Hawaii, Kauai, and Maui and have incorporated ideas from conversations and correspondence with Robert Nishimoto (Division of Aquatic Resources, State of Hawaii), Skippy Hau (DAR), Wade Ishikawa (DAR), Arnold Suzumoto (B. P. Bishop Museum), and Amadeo Timbol (Kauai Community College). Our intent is to provide the simplest possible field key for the identification of both larval and postlarval gobioid fishes from Hawaiian fresh waters. No special equipment other than a millimeter ruler and 10-power hand lens is required. If a fish is to be returned to the water after examination, it should be

held loosely in a wet dipnet or soft, water-soaked cloth. The use of dry fingers, netting, or cloth will rub off the mucous coat and eventually may kill the fish.

Material Examined

Awaous stamineus.- Island of Hawaii: LSUMZ 9435 (32 specimens), 9437(3), 9442(21), 9445(5), 9448(3), 9450(3), 9453 (4), 9458(4), 9461(8), 9487(36), 9495(12), 9496(6), 9500(27), 9518(2), 9527(1), 9534(1), 9537(3), 9540(1), 9543(6); Maui: 9466(5), 9470(2), 9476(5), 9482(1), 9509(8), 9510(2), 9515(1); Kauai: 9501(8), 9504(7), 9521(50), 9525(3).

Eleotris sandwicensis.- Hawaii: 9459(1), 9488(1), 9490(1), 9530(2); Maui: 9508(3); Kauai: 9503(2), 9523(4).

Lentipes concolor.- Hawaii: 9436(64), 9439(8), 9440(1), 9443(12), 9446(1), 9449(3), 9451(2), 9454(2), 9456(3), 9462(6), 9464(4), 9475(24), 9491(7), 9493(6), 9498(4), 9506(2), 9516(25), 9519(2), 9526(2), 9528(41), 9532(2), 9536(8), 9539(3), 9542(2); Maui: 9467(4), 9471(11), 9472(6), 9477(6), 9481(5), 9483(4), 9484(11), 9485(13), 9512(13), 9513(8); Kauai: 9505(1).

Sicyopterus stimpsoni.- Hawaii: 9434(16), 9438(4), 9441(12), 9444(1), 9447(20), 9452(14), 9455(4), 9457(5), 9460(10), 9463(4), 9474(13), 9489(1), 9492(8), 9497(15), 9517(4), 9520(1), 9529(2), 9531(21), 9535(5), 9538(2), 9541(2). Maui: 9465(1), 9468(4), 9469(8), 9511(4). Kauai: 9502(1), 9507(14), 9524(1).

Stenogobius hawaiiensis.- Hawaii: 9494(2), 9499(1). Maui: 9514(5). Kauai: 9522(5).

Localities.- Hawaii: Hakalau, Pahoehoe, and Kolekole Streams, Wailoa River. Maui: Iao, Piinaau, Palauhulu, Honolewa, Palikea, Paukukalo, and Maliko Streams, Waialohe Pond. Kauai: Manoa and Hanapepe Streams, Wainiha River.

Principal collectors.- Hawaii: D. C. Tate, R. T. Nishimoto, D. G. K. Kuamoo, J. M. Fitzsimons, and B. Nishimoto; Maui: S. Hau, D. C. Tate, R. T. Nishimoto, and J. M. Fitzsimons; Kauai: D. C. Tate, R. T. Nishimoto, W. Ishikawa, J. M. Fitzsimons, and G. W. Barlow.

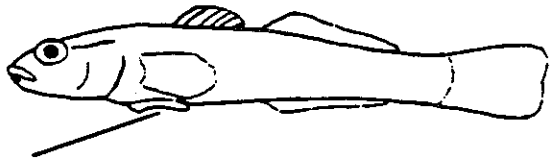
Collection dates.- Larval and postlarval fishes were collected during 1990 and 1991 during the following months. Hawaii: March through August; Maui: February, April, May, July through September; Kauai: July.

KEY TO HINANA

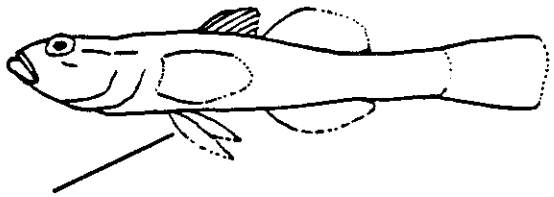
1A Hinana transparent (live fish) or milky white (preserved); pigment usually restricted to isolated melanophores, not forming conspicuous patterns .....(larva)....2

1B Hinana opaque; pigment well developed on head, nape, and back; light to dark pigment on sides of body.....(postlarva).....6

2A Pelvic (ventral) fins fused on midline to form sucking disk ....(Family Gobiidae)....3

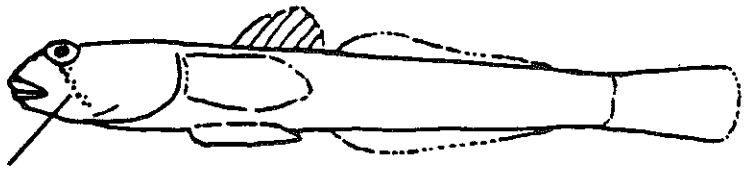


2B Pelvic (ventral) fins separate.....(Family Eleotrididae)..... .....*Eleotris sandwicensis* ('o'opu akupa or 'o'opu o'au)



3A No melanophores (small dark spots) extend from bottom of eye across cheek 4

3B Series of melanophores extend obliquely from bottom of eye toward base of operculum (lower edge of gill cover)..... .....*Stenogobius hawaiiensis* ('o'opu naniha)

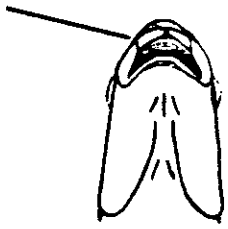


4A One or three notches usually visible in upper lip; no c-shaped "beard" formed by spots on chin.....5

4b No notches in upper lip; faint spots form c-shaped "beard" on chin ....*Awaous stamineus* ('o'opu nakea)

5 A Dark spots (melanophores) form "goatee" on chin; single median notch in upper lip sometimes present..... .....*Lentipes concolor* ('o'opu hi'ukole or 'o'opu alamo'o)

5B Three notches (one medial and two lateral) in upper lip..... .....*Sicyopterus stimpsoni* ('o'opu nopili)

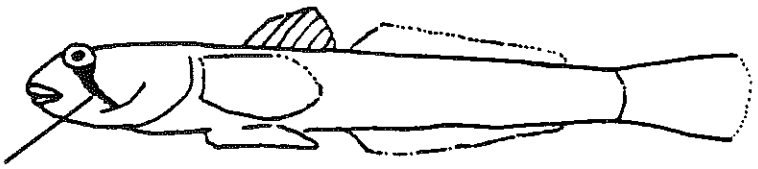


6A Pelvic (ventral) fins fused on midline to form sucking disk .....
.....(Family Gobiidae)....7

6B Pelvic (ventral) fins separate.....(Family Eleotrididae).....
.....*Eleotris sandwicensis* ('o'opu akupa or 'o'opu o'oau)

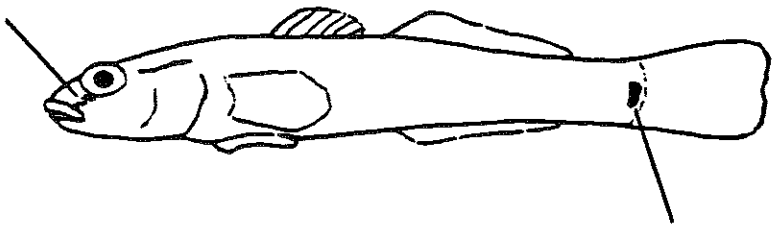
7A No dark bar extending obliquely back from bottom of eye across cheek.....8

7B Dark, tear-drop shaped bar extends obliquely from bottom of eye toward base of operculum (lower edge of gill cover).....
.....*Stenogobius hawaiiensis* ('o'opu naniha)



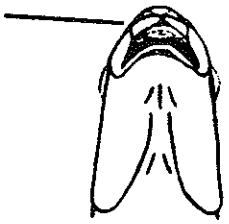
8A One or three notches in upper lip.....9

8B No notches in upper lip; large spot at base of caudal fin; faint bar extending forward from bottom of eye toward upper lip.....
.....*Awaous stamineus* ('o'opu nakea)



9A Single median notch in upper lip.....
.....*Lentipes concolor* ('o'opu alamo'o or 'o'opu o' hi'ukole)

9B Three notches (one medial and two lateral) in upper lip.....
.....*Sicyopterus stimpsoni* ('o'opu nopili)



Species Descriptions

Eleotris sandwicensis.- Larvae, postlarvae, and adults of the 'o'opu akupa are readily distinguished from other native freshwater fishes by having separate rather than fused pelvic fins. Incoming larvae are 12-14 mm SL, and any pigmentation is confined to scattered melanophores near the caudal peduncle and along the ventral midline. Postlarvae (>16 mm SL) are a uniform dark brown on the sides and light brown to tan dorsally. The base of the caudal (tail) fin has a prominent dark spot. A black band occurs on the first dorsal fin, and two bands are present on the second dorsal fin. In addition to being darker, akupa postlarvae differ conspicuously from other species by having the body flattened dorsoventrally and by exhibiting pronounced prognathony (lower jaw extending beyond the upper jaw).

Stenogobius hawaiiensis.- The black "tear drop" below each eye is a diagnostic feature of postlarvae and adults of the 'o'opu naniha. In larvae 15-16 mm SL, the suborbital bar is represented by a row of discrete melanophores. Melanophores along the midside of the body form 7 to 8 short, faint, vertical bars. Ten to 11 indistinct "saddles" occur on the back. Melanophores form an indistinct band and a diffuse basal spot on the first dorsal fin. The tail is slightly forked in larvae and truncated (squared off) in postlarvae 18 mm and larger. In postlarvae 16-19 mm SL, the suborbital bar, midlateral bars on the body, and bands in each dorsal fin are more heavily pigmented and distinct, but the basal spot on the first dorsal fin of larvae is not evident in postlarvae.

Awaous stamineus.- Incoming larvae of the 'o'opu nakea, 14-16 mm SL, have a distinct dark but thin vertical line formed by melanophores at the caudal-fin base and a faint "beard" of melanophores on the anterior margin of the lower jaw. In these small fish, 4-6 indistinct wedge-shaped lateral bars extend from below the dorsum to just below the midline on the anterior two-thirds of the body. Eleven to 13 faint dorsal saddles are formed by clusters of melanophores. In postlarvae 16-22 mm, there is a distinct dark spot at the

base of the caudal fin and a suborbital bar that extends forward and down toward the upper lip. Seven to 8 vertical bars, sometimes discontinuous, occur along the midside of the body. Nine to 13 saddles or broad bands, often

diffuse in larger postlarvae, produce a mottled effect when viewed from above. A black spot is conspicuous at the posterior base of dorsal fin in postlarvae 16 -18 mm SL. In addition to the basal spot, larger postlarvae (18-22 mm) have a distinct red spot or band and a black terminal band on the middle and upper membranes of the dorsal fin.

Lentipes concolor.- In larval fishes 13-15 mm SL, a single melanophore produces a distinct spot on the tip of the chin, and a median notch in the upper lip is beginning development. Melanophores are randomly distributed along the sides and give preserved specimens an overall dusky appearance. Melanophores are concentrated in the axils of pectoral fins, and they form a triangular patch at the base of the operculum or gill cover. The mouth is subterminal, and the upper jaw does not project beyond the snout. The tail is forked. A distinct sensory canal extends from behind the eye posteriorly to just past the operculum on a line parallel to the long axis of the body. In fish 18 mm and larger, discrete pores are visible in the postorbital canal. In postlarvae 16-20 mm SL, the median notch in the upper lip is better developed. Melanophores forming the chin spot on larvae occur as a cluster of smaller spots in 16-18 mm postlarvae. By 19 mm, the submental spot is diffuse, and, by 20 mm, it is no longer visible. In some specimens, melanophores along the sides of the body are less evenly distributed and may form a diffuse pattern of 7-9 vertical blotches; in other fish the sides have an overall grayish hue without distinct patterns. In 20 mm fish, the tail has become truncated rather than forked.

Sicyopterus stimpsoni.- Larvae and postlarvae of the 'o'opu nopili are most easily separated from other Hawaiian freshwater fishes by the presence of three distinct notches in the posterior margin of the upper lip. Larvae and postlarvae of this species can be distinguished by degree of pigmentation but not by size as in the other gobioids. Both the larvae and postlarvae ranged from 20-24 mm SL in our samples. Incoming nopili are larger than the larvae of the other four species, but an individual nopili larva actually loses length during metamorphosis as its subterminal mouth rotates down and back to the inferior (ventral) position seen in postlarvae and adults. Larvae of *S. stimpsoni* may have 7 or 8 faint v-shaped bars on the sides and 7-9 dorsal saddles. The body is cigar-shaped with a forked tail. The snout projects beyond the upper jaw. The open postorbital canal extends past the operculum and is parallel to the long axis of the body. In transformed postlarvae, the reddish distal third of the first dorsal fin is separated from the proximal

portion of the fin by a broad black band. A dark spot is present posteriorly near the base of the first dorsal fin. The second dorsal fin has three bands - black, red, and black again - from the edge of the fin toward its base. Red coloration occurs also on the membranes of the caudal fin. The lateral v-shaped bars seen in larvae become more diffuse in transforming postlarvae. With an increase in size, postlarvae become more tapered (vs cigar-shaped), acquire pigment patterns resembling those of adults, develop discrete pores in the postorbital canal, and gradually obtain a truncate caudal fin.

Discussion

Amphidromy.- The collections of larvae and postlarvae listed above confirm the assumption that all five species comprising Hawaii's native freshwater fishes are amphidromous (having two migrations during an animal's lifetime). The eggs hatch in fresh water, and larvae are washed out to sea where they remain in the plankton for as long as five months (Radtke et al. 1988) before returning to fresh water. Although descriptions of behavior involve adults of each species (Nishimoto and Fitzsimons 1986; Fitzsimons and Nishimoto 1990 and in press), studies of the movements and interactions of young fishes during recruitment have been initiated only recently.

Recruitment.- Times of recruitment into fresh water have been inferred for *A. stamineus*, *L. concolor*, and *S. stimpsoni* from random collections of hinana, from the occurrence of gravid females, and from the reproductive behavior of adults in streams and aquaria (Ego 1956; Kinzie and Ford 1982; Tomihama 1972; Yuen 1987; Fitzsimons and Nishimoto in press). However, these studies provide only tentative estimates of recruitment times and must be confirmed by the identification of specimens taken at regularly scheduled, year-round intervals.

According to local fishermen (W. Ishikawa, pers. comm.), movements of hinana from the ocean into fresh water often occur after freshets or flash floods produced by mountain storms. R. T. Nishimoto (pers. comm.) has suggested that floodwaters may have two effects - one related to the behavior of the fishes while still in the ocean and the other related to changes in the configuration of a stream bottom at its mouth. A plume of turbid fresh water extending into the sea during storm floods may provide a chemical or olfactory cue for orientation movements of marine larvae. At low water, the mouth of a stream is often partially plugged by a sand and gravel berm that continues to build from the action of ocean waves. Immigrating larvae must pass through a narrow, deep channel where predatory fishes (primarily aholehole *Kuhlia sandvicensis* and 'o'opu akupa *E. sandwicensis*) are concentrated. During floods, high water washes out the berm and allows the young fishes to be carried passively inland by ocean waves that produce

counter-current pulses along stream margins where the water is often sufficiently shallow to reduce exposure to predators. Preliminary observations (Nishimoto and Kuamoo in press; this study) indicate that glass-clear larvae enter estuaries in midwater schools of one or more species. Within a short period of time (probably 48 hours), the larvae settle to the bottom as they metamorphose into well-pigmented postlarvae that more closely resemble adults. Postlarvae of three species (*A. stamineus*, *L. concolor*, and *S. stimpsoni*) are capable of moving farther inland against swift currents by using the pelvic-fin sucker to cling to the stream bottom or to the surface of waterfalls. Postlarvae of these same species are highly aggressive toward individuals of their own and other species. Their behavior tends to space individuals and promote upstream movement. Observations for all five species indicate that the behavior of postlarvae and juveniles may play a significant role in determining the instream distribution of adults.

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