Rainfordia opercularis, a liopropomin serranid (Teleostei: Serranidae: Epinephelinae): corroborative evidence from settlement-stage larvae

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Abstract *Rainfordia opercularis* was described in 1923 from a single specimen taken in Edgecumbe Bay, Queensland, Australia. The species is rare in museum collections, and the larvae have not been described. In 1999, two settlement-stage larvae (20–21 mm in standard length) were collected in light traps set off Lizard Island, Great Barrier Reef, Queensland. The smaller of the two has one thin, flexible, extremely elongate dorsal-fin spine encased in a pigmented sheath. The larger specimen lacks an elongate dorsal-fin spine and exhibits caudal-fin pigment characteristic of adults. A combination of features in one or both of the settlement-stage larvae support the placement of *Rainfordia* in the epinepheline-serranid tribe Liopropomini: presence of an elongate, filamentous dorsal-fin spine serially associated with the first dorsal-fin pterygiophore; presence of a spine on the inner preopercular ridge; presence of dense pigment on the frontals; absence of an elongate spine at the angle of the preopercle; and absence of supraorbital spination.

Key words *Rainfordia opercularis* · Settlement-stage larvae · Relationships · Epinephelinae · Liopropomini

Supplementary material A color photograph of *Rainfordia opercularis*, AMS I. 39081-001, 21.4 mm SL, in alcohol, is available on Springer's server at springerlink.com

Rainfordia opercularis McCulloch, 1923, the flathead perch, inhabits caves in inshore coral reefs in Western Australia and Queensland, where it is considered endemic. The unusual morphology of the species has led to uncertainty about the family to which it belongs. When first described, the monotypic *Rainfordia* was placed in its own family, the Rainfordiidae, based on its "subcylindrical form, spinate suboperculum, and depressed and partially naked head" (McCulloch, 1923: 119). Norman (1957) and Woodland and Slack-Smith (1963) also classified *Rainfordia* as a monotypic family. McCulloch (1923) considered the Rainfordiidae to be closely related to *Grammistes*, Greenwood et al. (1966) recognized *Rainfordia* as a serranid, and Schultz (1966) assigned it to the Grammistidae. Randall et al. (1971) excluded *Rainfordia* from their Grammistidae (*Aulacocephalus*, *Diploprion*, *Grammistes*, *Grammistops*, *Pogonoperca*, *Rypticus*, and *Belonoperca*, the last added to the family by Randall et al., 1980). Kendall (1976) recognized osteological similarities between *Rainfordia* and *Liopropoma*, and Johnson (1983) placed *Rainfordia* in his epinepheline-serranid tribe Liopropomini (which also included *Jeboehlkia*, *Liopropoma*, and *Pikea*).

Baldwin and Johnson (1993) redefined the Liopropomini to include *Liopropoma*, *Rainfordia*, and, possibly, *Bathyanthias*, but not *Jeboehlkia*, which they assigned to the epinepheline tribe Grammistini. Baldwin and Johnson (1993) used larval and adult characters in their cladistic analysis of epinepheline phylogeny, and concluded that the tribe Liopropomini is a member of three clades within the subfamily (Fig. 1): the Epinephelini + Diploprionini + Liopropomini + Grammistini; the Diploprionini + Liopropomini + Grammistini; and the Liopropomini + Grammistini. Larvae of *Rainfordia* were not known at the time. Randall et al. (1990) and Heemstra and Randall (1993) recognized a serranid subfamily Grammistinae, equivalent in rank with a subfamily Epinephelinae [Johnson's (1983) tribe Epinephelini], subfamily Niphoninae (tribe Niphonini), subfamily Anthiinae, and subfamily Serraninae. Randall et al. (1990) assigned four tribes to their Grammistinae: Liopropomini, including *Rainfordia*, Diploprioni [sic], Grammistini, and Pseudogrammini. Heemstra and Randall (1993) recognized three tribes in their Grammistinae: Diploprionini, Liopropomini, and Grammistini (including *Pseudogramma* and relatives). Those classifications do not conflict with the phylogenetic relationships proposed by Baldwin and Johnson (1993), but they do not reflect the monophyly of Johnson's (1983) subfamily Epinephelinae, and the Randall et al. (1990) classification does not reflect the mono-

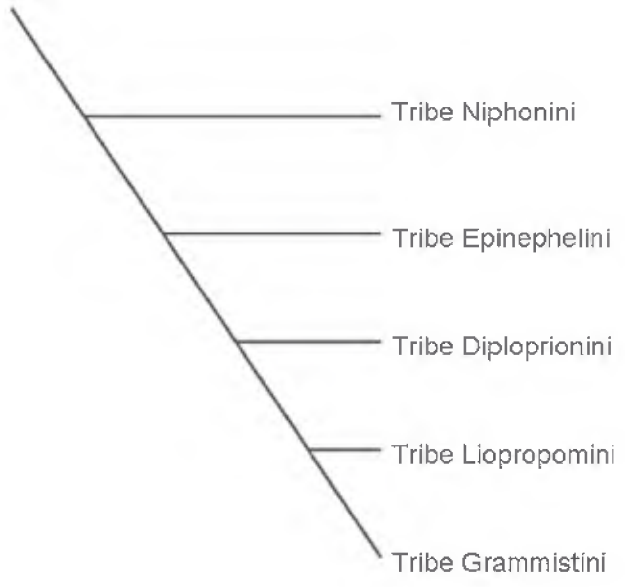

Fig. 1. Relationships of the tribes of the serranid subfamily Epinephelinae as proposed by Baldwin and Johnson (1993). Their tribe Liopropomini consists of *Rainfordia*, *Liopropoma*, and, possibly, *Bathyanthias*

phyly of Baldwin and Johnson's (1993) epinepheline tribe Grammistini. The purposes of this article are to describe two settlement-stage larvae of *Rainfordia opercularis* and to interpret the morphology of those larvae in light of current hypotheses of epinepheline phylogeny.

Materials and Methods

Specimens are deposited in AMS (Australian Museum, Sydney) and USNM (National Museum of Natural History, Washington, DC). Settlement-stage larvae: *Rainfordia opercularis*, AMS I.39080-001, 20.4 mm in standard length (SL) and AMS I.39081-001, 21.4 mm SL; light traps off Coconut Beach, Lizard Island, Great Barrier Reef, Queensland, Australia (14°41′ S, 145°28′ E); collected by J.M Leis and Peter Nangle, respectively, 17 February 1999. Adults: AMS I.24986009, 69 mm SL; I.21894-003 (1, 72 mm SL, radiograph); I.23708-020 (1, 68 mm SL, radiograph); I.19641-010 (2, 82 and 92 mm SL, radiographs); USNM 203247 (1, 110 mm SL, cleared and stained).

Larvae were collected in light traps similar to those described by Stobutzki and Bellwood (1997). The traps were attached to a surface float and set so that the entry slots into the traps were within the top 1–1.5 m of the water column. Water depth was 10–15 m over sand bottom, and the nearest coral reefs were 200 m away. Measurements of larvae were made with the aid of an ocular micrometer in a Zeiss dissecting microscope. Illustrations were made with the aid of a camera lucida. Photographs were made with a Fujifilm FinePix S3 Pro digital camera. Counts of vertebrae were made from digital radiographs made with a PXS5-724EA Thermo Kevex X-Ray source with CU017 controller, and images were captured by a Flat Panel Amorphous Silicon Digital X-Ray Detector–PaxScan 4030. Counts of median fins were made from microscopic examination and confirmed on digital radiographs. Counts of pectoral-fin rays were made by slipping a small square of developed X-ray film beneath the fin to highlight the rays. Scale morphology was investigated by removing several scales from the right side and staining them with Alizarin red S mixed into 95% ethanol. Characterizations of body shape, head size, and eye size follow the categories of Leis and Carson-Ewart (2000). Outer preopercular spines are those on the distal margin of the preopercle, inner preopercular spines are those on the ridge proximal to the distal margin; the latter are also sometimes referred to as the lateral preopercular spines (e.g., Baldwin and Johnson, 2003).

Results and Discussion

Diagnostic characters.—Dorsal fins widely separated, the second dorsal-fin spine (the first visible one) greatly elongate in the 20.4-mm SL specimen (ca. 330% SL); head large (length 36–37% SL), slightly depressed; body only slightly deeper at origin of dorsal fin (19–20% SL) than at anus (18–19% SL); body covered with tiny scales, head naked; frontals heavily pigmented; 21.4-mm SL specimen with caudal spot characteristic of adults; dorsal and ventral midlines of body with grooves or depressions at various locations along length of body (Figs. 2, 3).

Morphology.—Dorsal fin V-I, 9, the first spine tiny, buried, and visible only in radiographs (Fig. 4), fourth and fifth spines lying in longitudinal groove and not visible without lifting them out of the groove; anal fin II, 8; pectoral fin 15–16 (15 left, 16 right in 21.4-mm SL specimen, 16 on both sides in 20.4-mm SL specimen); vertebrae 10 + 14. Body elongate, body depth at origin of dorsal fin 19–20% SL. Head depressed and large, length 36–37% SL. Eye small to moderate, diameter 22–26% head length (HL). Snout length 26% HL. Body depth at anus only slightly less than depth at origin of dorsal fin, 18–19% SL. Caudal peduncle strongly compressed, depth 12–13% SL. Second dorsal-fin spine (the first visible spine) greatly elongate in the 20.4-mm SL specimen, ca. 330% SL. This spine only 16% SL in the 21.4-mm SL specimen (unclear whether it is broken or has been lost naturally as part of the transformation to the juvenile stage). Other fin spines intact and not elongate. Pectoral and pelvic fins approximately equal in length, 19–20% SL.

Most of body covered with small scales, scales poorly developed anteriorly and lacking on head. Scales tiny, each approximately 0.1 mm in length, and bearing one to three spiny projections posteriorly.

Dorsal midline with several longitudinal depressions, the most anterior one extending from frontal bones to origin of dorsal fin, another posterior to the anterior dorsal-fin spines (fourth and fifth dorsal spines lying in this groove and difficult to see), and the last on caudal peduncle posterior to second dorsal fin. Ventral midline with similar grooves, one beneath pelvic fins and another posterior to anal fin on anterior portion of caudal peduncle (last anal-fin ray lying partially or completely in this groove and difficult to see).

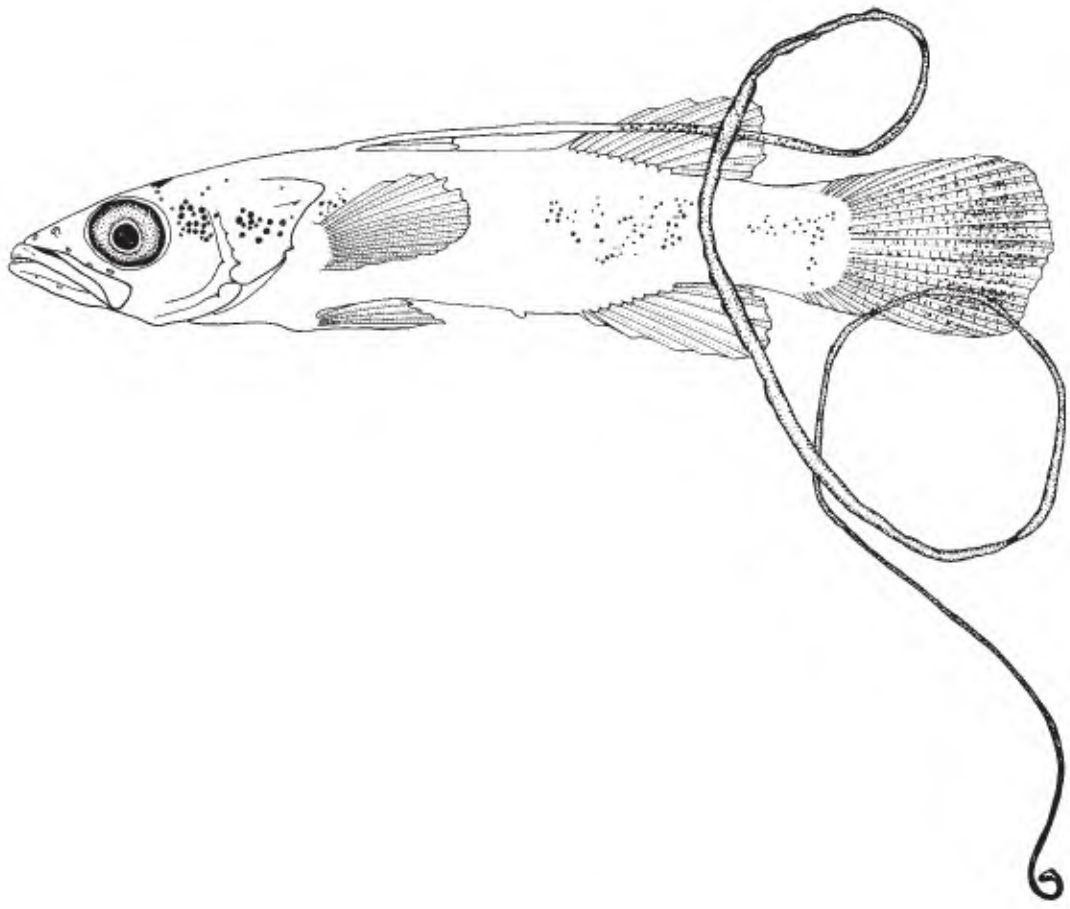

Fig. 2. Settlement-stage larva of *Rainfordia opercularis*, AMS I.39080-001, 20.4 mm SL, Lizard Island, Queensland, Australia

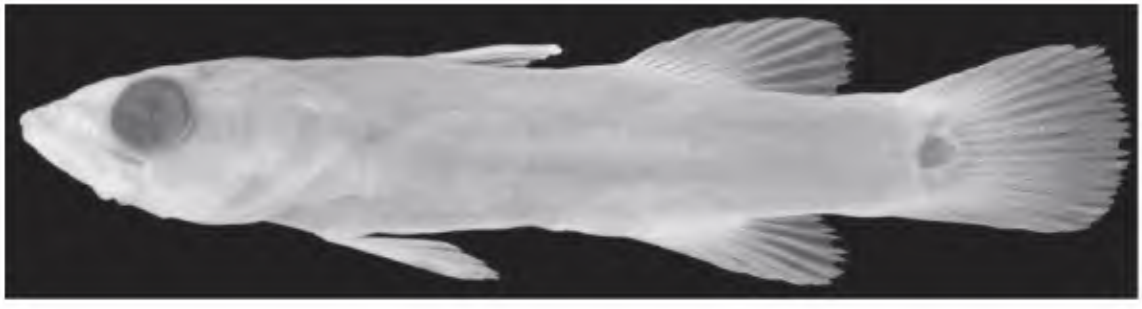

Fig. 3. Settlement-stage larva of *Rainfordia opercularis*, AMS I. 39081-001, 21.4 mm SL, Lizard Island, Queensland. The semicircular band of pigment on the distal third of the caudal fin, which did not show well in the original black-and-white photograph, was enhanced using Adobe Photoshop. The natural pigment is best seen in a color photograph of this preserved specimen, which is available on Springer's server at springerlink.com

Head spines.—Smaller specimen with five small spines on outer preopercular ridge (four in 21.4-mm SL specimen), one on inner preopercular ridge (none), and two on subopercle (three). Three spines present on the opercle, the central one the largest. No other spines present on head, and none are present on bones of the pectoral-fin girdle.

Pigment.—Frontals with dense melanophores in both specimens, the smaller also with a few melanophores on upper lip but none on snout, lower jaw, cheek, or gular region. Larger specimen with scattered spots on anterior portion of upper lip, lacrimal, and cheek. Both specimens with scattered spots on dorsal portion of preopercle and on opercle. Smaller specimen with scattered melanophores along central portion of trunk from beneath upper base of pectoral fin posteriorly to bases of central caudal-fin rays. Principal- and posteriormost procurrent-caudal rays with melanophores from approximately midpoint of each ray to a point near the distal tip. Elongate dorsal-fin spine without pigment proximally, heavily pigmented along most of length, and nearly black distally. Larger specimen with more melanophores on trunk and with spot on base of caudal fin typical of adults. This spot surrounded by pale

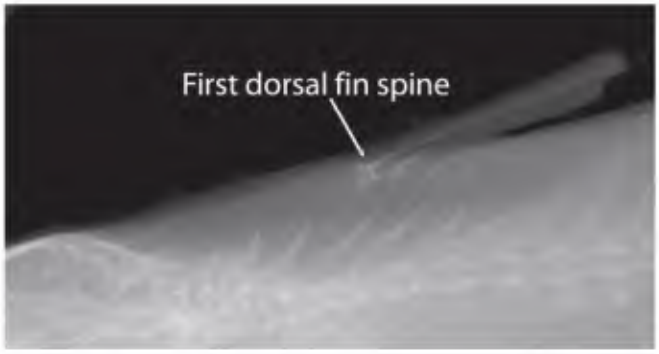

Fig. 4. Digital radiograph of anterior dorsal-fin pterygiophores and spines in larval *Rainfordia opercularis*, AMS I. 39081-001, 21.4 mm SL

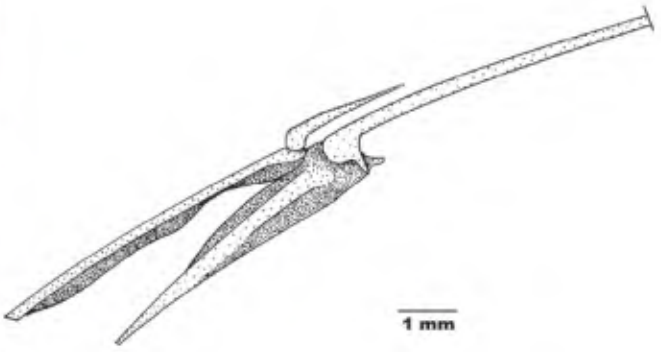

Fig. 5. Anterior dorsal-fin pterygiophores and spines in adult *Rainfordia opercularis*, USNM 203247, 110 mm SL (cleared and stained)

halo in preserved specimen, an area that is blue in life in adults. The pale halo bordered dorsally, posteriorly, and ventrally by semicircular band of melanophores (Fig. 3). Another semicircular band of pigment present on distal third of fin, presumably a coalescence of the melanophores on distal portion of caudal fin of smaller specimen. Other fins without pigment. Both specimens with overall bright red pigmentation when fresh (before preservation).

Remarks.—As the common name suggests, the flathead perch is characterized by a depressed head as an adult. There is little indication of this condition in either of the larvae, and although it is clear the 21.4-mm SL specimen is in the process of metamorphosis, its head is no more depressed than that of the 20.4-mm SL specimen. The smallest settled specimen we have examined is 68 mm SL, and it has a fully depressed head and other features typical of the species, including a deep caudal peduncle and widely separated, short-based dorsal fins that give it a rather gobiid-like appearance. It also has the adult trunk pigmentation, which in preservative consists of several longitudinal, dark-edged, pale stripes on a pale background. The larvae lack stripes, but two appear to be beginning to form in the 21.4-mm SL specimen. Adults have a series of spines at the edge of the opercle, subopercle, and interopercle. Apparently after settlement, the preopercular spines disappear, spines develop on the interopercle, and the opercular and subopercular spines are retained.

Relationships.—Johnson (1983) diagnosed the Serranidae on the basis of several reductive internal features and one innovative specialization, the presence of three spines on the opercle. He included *Rainfordia* in the Serranidae based on those features, and the familial placement of *Rainfordia* is not in question. Johnson (1983) did not identify any larval characters that diagnose the Serranidae, but we note that the settlement-stage larvae of *Rainfordia* have three opercular spines. The classification of *Rainfordia* in the Epinephelinae also is well supported, as *Rainfordia* has the diagnostic features of that subfamily: absence of an autogenous distal radial on the first dorsal-fin pterygiophore (Johnson, 1983) and the presence of only two supraneurals (Kendall, 1976). Furthermore, in all known epinepheline larvae for which the osteology of the anterior dorsal fin has been investigated, the first dorsal-fin pterygiophore serially supports an elongate spine (Johnson, 1983; Baldwin and Johnson, 1993). In *Rainfordia*, the first dorsal-fin pterygiophore supports a tiny spine in supernumerary association (Figs. 4, 5), which is visible only in radiographs or cleared and stained specimens. [Note: Previous authors have given the dorsal-fin count of *R. opercularis* as IV-I, 9, but they overlooked the tiny first spine, which renders the correct count V-I, 9.] The first visible spine in whole specimens is the second dorsal-fin spine, which is in serial association with the first dorsal-fin pterygiophore. It is this spine that is greatly elongated in the smaller of the two, settlement-stage *Rainfordia* larvae (see Fig. 2), and its presence corroborates the placement of the genus in the Epinephelinae.

In their cladistic analysis of epinepheline relationships, Baldwin and Johnson (1993) identified larval and adult characters that are synapomorphic for various clades within the subfamily. In the following, we assess the conditions in the settlement-stage larvae of *Rainfordia* for the derived larval characters presented in that study.

Clade: tribe Epinephelini + tribe Diploprionini + tribe Liopropomini + tribe Grammistini (the spine serially associated with the first dorsal-fin pterygiophore is extremely elongate in larvae and encased in a fleshy sheath).—The spine serially associated with the first dorsal-fin pterygiophore in the 20.4-mm SL specimen of *Rainfordia* is extremely elongate, more than three times the length of the fish (ca. 330% SL), and is encased in a pigmented sheath.

Clade: tribe Diploprionini + tribe Liopropomini + tribe Grammistini [(1) the elongate dorsal-fin spine(s) in larvae is (are) filamentous and (2) larvae lack an elongate spine at the angle of the preopercle].—The elongate dorsal-fin spine of the 20.4-mm SL specimen is thin, flexible, and filamentous, not robust as in larval *Niphon spinosus* and epinephelins (groupers). The spine at the angle of the preopercle is the largest of the preopercular spines in larval *Rainfordia*, but it is not greatly produced or elongate as in larval *Niphon* and epinephelins.

Clade: tribe Liopropomini + tribe Grammistini [(1) Larvae lack supraorbital spination and (2) the pelvic fins develop late].—The settlement-stage larvae of *Rainfordia* lack supraorbital spination. The absence could be attributable to

the advanced development of the larvae, but the presence of larval specializations in the form of preopercular and subopercular spines suggests otherwise. All fins, including the pelvic, are well developed in the *Rainfordia* larvae, so we cannot assess the order of fin formation.

Clades: tribe Liopropomini and tribe Grammistini.— Baldwin and Johnson (1993) did not identify any larval characters that diagnose liopropomins, but they proposed two that diagnose the tribe Grammistini: (1) larvae lack melanophores on the frontal bones and (2) larvae lack spines on the lateral (inner) preopercular ridge. Both larval specimens of *Rainfordia* have dense pigment on the frontals, and the smaller specimen has one spine on the outer preopercular ridge.

In summary, the morphology of the settlement-stage larvae of *Rainfordia opercularis* corroborates the inclusion of *Rainfordia* in the epinepheline tribe Liopropomini. Further study is needed to determine relationships within the tribe. As noted by Baldwin and Johnson (1993), it is unclear if *Liopropoma* includes *Pikea* and *Bathyanthias*, which are currently considered synonyms of *Liopropoma*, or if *Bathyanthias is* a valid genus that includes *Pikea cubensis* and *Pikea mexicanus*. A study to assess the limits and relationships of liopropomin genera is in progress by the first author.

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