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Nurseryfish, *Kurtus gulliveri* (Perciformes: Kurtidae), from northern Australia: redescription, distribution, egg mass, and comparison with *K. indicus* from southeast Asia

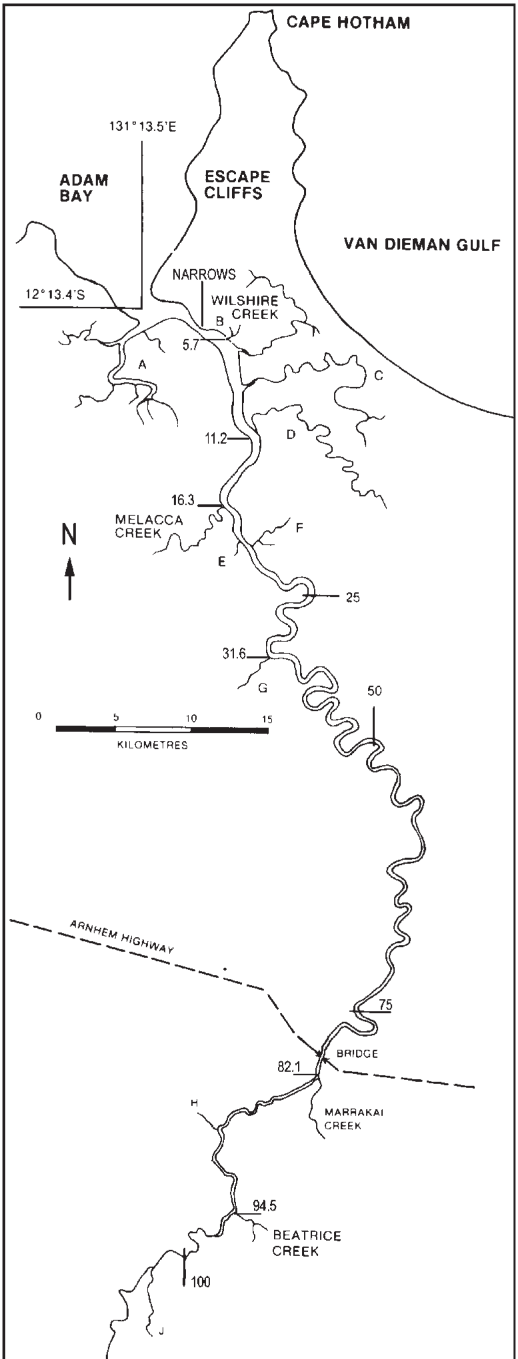
Tim M. Berra*

Kurtus gulliveri is remarkable in that males carry the eggs on a hook formed from the supraoccipital crest of the skull. Principal components analysis of meristic and morphometric characters of populations of nurseryfish from northern Australia and southern New Guinea indicate that they belong to the same species. *Kurtus gulliveri* has a higher anal fin ray count than *K. indicus* (39-49 vs. 30-35), and the caudal peduncle is narrower (6.8-9.9 % SL vs. 9.3-12.2). The living colors of *K. gulliveri* are described for the first time. The dorsal and ventral surfaces, the anal and caudal fins and base of the dorsal fin are covered with an irridescent violet wash. The violet wash gives way to a rosy pink and brassy yellow along the anterior half of the dorsal-lateral surface. The head, operculum and thorax are silvery with greenish blue highlights. *Kurtus gulliveri* is known from large, turbid, coastal rivers of northern Australia from Wyndham, Western Australia to the Saxby River in Queensland, and there are scattered records throughout southern New Guinea. Photographs of a complete egg mass containing late-stage embryos, yolk-sac fry, and larval nurseryfish are presented.

Introduction

The family Kurtidae is usually placed in its own suborder, Kurtoidei, of the Perciformes (Lauder & Liem, 1983; Nelson, 1994; Eschmeyer, 1998). Johnson (1993), however, wrote that "there is nothing in the osteology of *Kurtus* to exclude it from the suborder Percoidei". There are two described species, *K. gulliveri* Castelnau, 1878 from northern Australia-southern New Guinea and *K. indicus* Bloch, 1786 from India to Borneo (Berra, 2001). The most distinctive feature of *K. gulliveri* is the presence in males of a hook projecting from the dorsal surface of the head with which the eggs are carried like a cluster of grapes on the forehead. Until recently virtually nothing was known of the biology of this bizarre fish, and the few papers that exist are 90 years old. Its unique parental care system was first reported by Weber (1910, 1913), and termed "forehead brooding" by Balon (1975). Guitel (1913) described early-stage eggs, and de Beaufort (1914) depicted aspects of its skeletal anatomy. In order to learn some of the details of the natural history of *K. gulliveri*, a study was begun in the Adelaide River near Darwin, Northern Territory, Australia in 2001. Papers resulting from this study include Berra & Wedd (2001) who reported on the anatomy of the ali-

* Department of Evolution, Ecology & Organismal Biology, The Ohio State University, Mansfield, OH 44906, USA. E-mail: berra.1@osu.edu



mentary canal and showed that nurseryfish consume crustaceans, isopods, insect larvae and small fishes. Berra & Humphrey (2002) described the anatomy and histology of the male's hook. They speculated that engorgement of vascular tissue in the dermis may clamp the egg mass in place, and that oxygen and / or nutrients might be provided to the egg mass via the blood supply of the hook. They also showed that the skin in the cleft of the hook is devoid of secretory and neurosensory cells and is folded into crypts which may be an adaptation for adhesion of the egg mass. Berra & Neira (2003) described the development of larval stages of nurseryfish and presented evidence that spawning is a dry season (May-November) phenomenon. The present paper compares *K. gulliveri* and *K. indicus*, presents a color description, distribution map, and photograph of an egg mass and larvae.

Methods

Fish were collected weekly between April-November 2001 using 100 and 130 mm mesh gill nets 2.5 m deep and 24 m long set in tributaries of the Adelaide River and, occasionally, cast nets thrown from the boat or bank onto shallow mud flats. The gill nets were set for 3-6 hours usually on the rising neap tide and removed from the water at slack tide. The gill nets were anchored with concrete blocks and buoyed with floats. Small specimens were immediately preserved in 10 % formalin. Larger fish were placed on ice and preserved in formalin in the laboratory a few hours after capture. All specimens were later transfered to 70 % ethanol. Museum specimens from all of the major Australian fish collections were examined, and all specimen localities were plotted on a map. Counts and measurements were made in the standard manner as described by Hubbs & Lagler (1958) with the following clarifications due to the unique anatomy of *Kurtus*. Standard length (SL) and head length were measured from the anterior knob projecting from the mandibular symphysis using a measuring

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Fig. 1. Map of Adelaide River, east of Darwin, Australia. Numbers are river kilometers from mouth. Most specimens for this study were taken from Marrakai Creek. Map modified from Messel et al. (1979) and Webb et al. (1983).

Fig. 2. Mouth of Marrakai Creek at low tide as seen from Adelaide River at river km 82.1. Note mud flats and mangroves.

board. Body depth was taken from the anus to the base of the first major dorsal fin spine. Dorsal fin length was measured from the base of the first major (as opposed to vestigial) dorsal fin spine to the posterior end of the fin. Fin ray counts were done under a dissecting microscope using light transmitted through the fin.

Description of habitat. The Adelaide River is a large, turbid, tidal, tropical river that empties into Adam Bay (an inlet of the Timor Sea on Clarence Strait, 51 km northeast of Darwin) and extends southward from its mouth at 12°13'S 131°13'E (Fig. 1). Its catchment area is 7600 km^2, and it has a surveyable length of 226.3 km (Messel et al., 1979). The river is highly convoluted and under tidal influence for its first 121 km (measured from aerial photographs with a geared-wheel map measurer). The straight-line distance is 77 km. Approximately 92 % of the 1400 mm annual average rainfall occurs between November and April (Webb et al., 1983). During the dry season (May to November) saline waters intrude steadily upstream. The river and its tributaries are flushed out in the annual wet season. Streams below river km 31.6 are considered ‘saltwater creeks’ and those upstream are ‘freshwater creeks’. Salinity during the study ranged from 28 ppt at ‘C’ Creek to 0 ppt in Marrakai Creek (Fig. 1). By November the salinity in Marrakai Creek had increased to 4 ppt. Most fish caught for this study came from Marrakai Creek (Fig. 2).

The river banks are mostly mud flats. Riverside vegetation consists of salt-tolerant mangroves *(Rhizophora stylosa, Camptostemon schultzii, Avicennia marina, A. officinalis)* and sedges in the tidal areas (Messel et al., 1979). Less salt-tolerant paperbark *Melaleuca* spp., *Pandanus* spp., and bamboo dominate the upstream banks above 121 km (Webb et al., 1983). There are two high and two low tides each day, and tidal range can be as large as 7 m at the mouth. A downstream constriction known as the ‘narrows’ (Fig. 1) reduces upstream tidal variation about 50 % as outgoing tides impede incoming tides. The substantial tidal variation makes setting gill nets difficult. Trial and error led to the conclusion that the best time to set gill nets for nurseryfish was on the incoming neap tide about 3-4 hours before high tide. The nets were removed from the water at slack tide or the beginning of the outgoing tide to prevent them from being swept away.

Another factor complicating field work is that the Adelaide River is prime habitat for the dan-

Fig. 3. *Kurtus gulliveri*, TMB01-16, male, 162 mm SL. Photographed immediately upon capture while fish was alive; 3 July 2001.

gerous saltwater crocodile, *Crocodylus porosus* (Webb et al., 1983). Crocodiles have been protected in the Northern Territory since 1971, and they have made a remarkable recovery. About 100 'problem' crocodiles are removed from Darwin Harbour each year (Webb & Manolis, 1998). Saltwater crocodiles have been responsible for eight human deaths in northern Australia over the last 20 years (Hancock, 2001). Above 121 km, upstream of tidal influence, the much less aggressive freshwater crocodile, *C. johnstoni*, is common (Webb et al., 1983). Making field work more

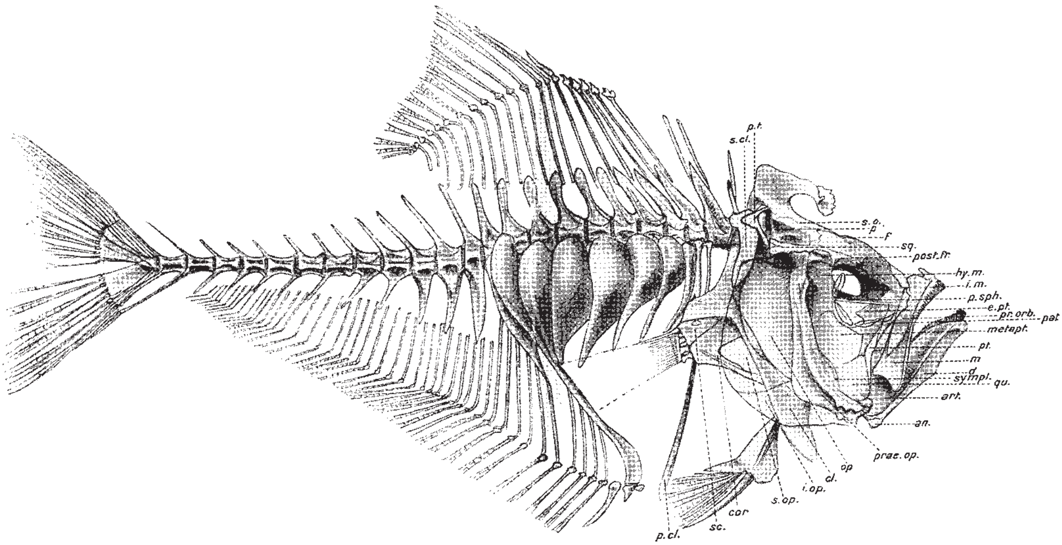

Fig. 4. *Kurtus gulliveri* skeleton from de Beaufort (1914). Abbreviations: **an.,** angular; **art.,** articular; **cl.,** cleithrum; **cor.,** coracoid; **d.,** dentary; **e.pt.,** endopterygoid; **f.,** frontal; **hy.m.,** hyomandibular; **i.m.,** premaxilla; **i.op.,** interopercle; **m.,** maxilla; **metapt.,** metapterygoid; **op.,** opercle; **p.,** parietal; **pat.,** palatine; **p.cl.,** postcleithrum; **post.fr.,** postfrontal; **p.sph.,** parasphenoid; **p.t.,** posttemporal; **prae.op.,** preopercle; **pr.orb.,** preorbital; **pt.**, ptergoid; **qu.**, quadrate; **sc.,** scapula; **s.cl.,** supracleithrum; **s.o.,** supraoccipital; **s.op.,** subopercule; **sq.,** squamosal; **sympl.,** symplectic.

Fig. 5. *Kurtus gulliveri*, female, 90 mm SL, South Alligator River; backlit to show 'rib windows'.

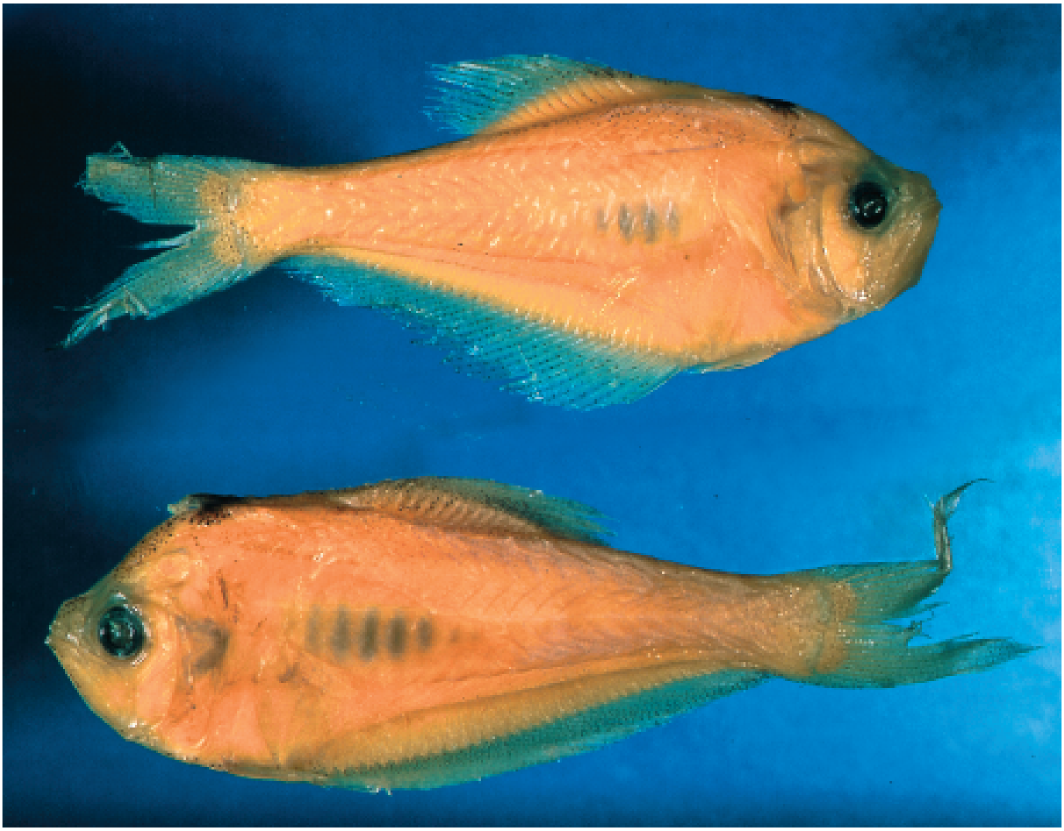

Fig. 6. *Kurtus indicus*, ZMA 120.688; Sumatra; female, 60 mm SL (top) and male, 65 mm SL (bottom).

interesting is the fact that tour operators have conditioned saltwater crocodiles near the Adelaide River / Arnhem Highway bridge (c. 80 km) (Fig. 1) to the sound of their boat engine (Grzelewski, 2001). Chunks of chickens are dangled from a rope on a long pole, and large crocodiles (3-5 m) leap 1-2 m into the air to grab a snack several times each day. It is an awe inspiring sight and gives one pause when leaning over the boat to check the nets.

Results and discussion

Redescription. Castelnau's (1878) description is very brief, based on only a few specimens whose maximum total length was 100 mm, and does not show how *K. gulliveri* is distinct from *K. indicus*. However, a minimal description for both species and a key for distinguishing them was given by de Beaufort & Chapman (1951). *Kurtus gulliveri* is shaped like a hatchet (Fig. 3). The anterior end is compressed and deep-bodied, and the tail is long and narrow. The forehead is humped. The protractile, terminal mouth is very large and obliquely angled. There is a bony knob at the mandibular symphysis. Very fine villiform bands of teeth can be seen and felt on the outside of the upper and lower jaws. Small teeth are also present on the basibranchials and palatines. Gill rakers are long and slender with fine teeth on a patch at the distal end (Berra & Wedd, 2001). The posterior edge of the maxillary is notched. The preopercle is spiny (Fig. 4), and the distal margins of the interopercle, subopercle, and opercle are very thin. The head is naked except for the preopercle and opercle which are covered with tiny, cycloid scales as is the rest of the body. A very short lateral line extends high on the body only to the level of the first supraneural spine. The body is covered with a slippery coating of mucus making the fish difficult to handle. Two nostrils are present. The eye makes up about 13 % of the head length (Table 1). Pectoral fins are long (25 % SL) usually with 18 (16-21) rays, and the pelvic fins are short (13 % SL) with one spine and 5 rays. The anus is located anteriorly, just behind the pelvic fins, far removed from the caudal fin. The anal fin is very long (II spines, 40-48 rays), and the dorsal fin is short (18 % SL) (II, 11-14) (Table 1). This latter count excluded the five vestigial dorsal spines.

No variation was found in the following counts in 159 *K. gulliveri* and 25 *K. indicus*. The number of supraneurals (predorsals) was always three. These were followed by five pterygiophores bearing vestigial spines that barely protrude through the skin and two major dorsal fin spines.

Table 1. Meristics and morphometrics for 159 *Kurtus gulliveri* from northern Australia and southern New Guinea and 25 *K. indicus* from Malaysia and Sumatra.

	K. gulliveri				*K. indicus*			
	min	max	mean	SD	min	max	mean	SD
SL (mm)	47	333	141.2	57.2	25	100	63.5	19.4
Dorsal rays	11	14	12.9	0.5	12	14	12.6	0.6
Anal rays	39	49	44.3	1.9	30	35	31.6	1.4
Pectoral rays	16	21	17.7	0.8	16	19	17.8	0.6
In percents of standard length								
Head length	26.8	35.6	31.6	1.3	25.7	36.4	33.1	2.1
Body depth	36.0	55.1	41.8	2.2	33.0	44.8	41.0	2.5
Pectoral fin length	17.7	32.0	25.4	2.2	14.0	27.7	23.5	3.1
Pelvic fin length	10.5	18.3	13.4	1.2	10.3	15.2	13.1	1.3
Dorsal fin length	11.9	21.0	17.8	1.4	17.6	25.1	21.2	2.1
Anal fin length	43.7	66.9	59.8	3.2	46.9	58.4	53.8	3.0
Depth of caudal peduncle	6.8	9.9	8.3	0.6	9.3	12.2	11.1	0.6
In percents of head length								
Snout length	16.5	29.6	21.6	2.4	17.5	28.2	22.0	2.5
Eye diameter	8.0	21.0	13.1	2.6	10.1	21.4	15.9	2.5
Postorbital length	49.3	70.8	61.6	2.8	51.7	66.1	61.1	3.2
Upper jaw length	41.7	63.3	47.7	3.4	40.7	55.2	46.3	4.2

The dorsal spine count could be listed as VII (V+II) if the vestigial spines are included as was done by de Beaufort & Chapman (1951) and Berra & Neira (2003). The anal fin always had two spines. The pelvic fin always consisted of one spine and five rays. The caudal fin was composed of 15 branched or 17 principal fin rays.

Males have a hook at the muscular forehead hump formed from the supraoccipital (Figs. 3-4). Ossification of the medium septum that separates the muscles of the nape results in the supraoccipital crest as an attachment point for the nape muscles (Rojo, 1991). This crest is elongated anteriorly in male nurseryfish. Serrations on the anterior end of the supraoccipital may help hold the egg mass in place. The hook may form a nearly complete eyelet when covered with thickened skin during egg carrying (Berra & Humphrey, 2002: fig. 4a). Three interneurals and five pterygiophores protrude through the skin and extend from the forehead hump posteriorly to the first major dorsal spine (Berra & Neria, 2002: fig. 1c). There is a gap between the 3rd supraneural and 1st pterygiophore (Fig. 4). The five pterygiophores are each capped with a tiny spine suggesting an ancestral spiny first dorsal fin that is now vestigial. The caudal fin is deeply forked with pointed lobes.

There are 24 vertebrae including the urostyle. The first vertebra lacks ribs, and only epipleural ribs are present on the second vertebra. The pleural ribs of the third and fourth vertebrae are slightly widened. Ribs of vertebrae 5-10 are expanded laterally and convex along their outer surface. The inner concavities of these ribs contain lobes of the swim bladder. The ribs, which taper ventrally, form a bony capsule around the dorsal part of the swim bladder (Fig. 4). The ventral part of the swim bladder is covered by the dorsal peritoneum. The last pair of ribs is flattened and joined with the wide 1st hemal spine and stout interhemal spine to form a bony backwall against the swim bladder. When backlit, four or five 'rib windows' midway between the dorsal and anal fin origin transmit light through the body (Fig. 5). This is apparent on both living and preserved specimens. Light passes through the thin skin, expanded ribs, swim bladder, and out the other side without the interference of a muscle wall or the internal organs, which are positioned anteriorly into a small triangular body cavity bounded by the pelvic fins, 1st interhamel spine, and head (Berra & Wedd, 2001). Anatomical studies are underway to determine if the bone-covered swim bladder could be involved in sound reception to locate conspecifics or prey in the noisy environment of a turbid, tidal river.

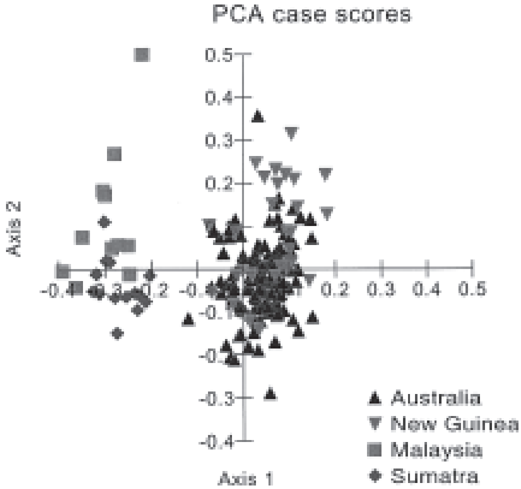

Fig. 7. Principal Components Analysis showing the cluster of Australia-New Guinea specimens *(Kurtus gulliveri)* separated from the cluster of Malaysia-Sumatra specimens *(K. indicus).*

The kidneys are located between the spinal column and the swim bladder along the median dorsal line. Muscle chevrons are clearly visible along the sides of the fish. Weber (1913) (repeated by de Beaufort and Chapman, 1951) reported a maximum size of 590 mm TL. Weber's specimens cannot be located and may not have been preserved. The largest specimen of hundreds examined for this study was 330 mm SL.

The south and south-east Asian *K. indicus* is much smaller, 126 mm TL (de Beaufort & Chapman, 1951) with a tiny hook on the male and a triangular blotch of dark pigment on the dorsal hump of males and females (Fig. 6). The male's hook is so small that it is unlikely to support an egg mass. Hardenberg (1936) examined thousands of *K. indicus* and never found males carrying eggs. Table 1 shows the meristics and morphometrics of *K. gulliveri* and *K. indicus*. There is no overlap in the number of anal fin rays and insignificant overlap in the depth of the caudal peduncle as a percent of SL between the two species. *Kurtus gulliveri* has 39-49 anal rays, *K. indicus* has 30-35. *Kurtus gulliveri* has a narrow caudal peduncle (6.8-9.9 % SL) while *K. indicus* has a broad caudal peduncle (9.3-12.2 % SL) (Table 1).

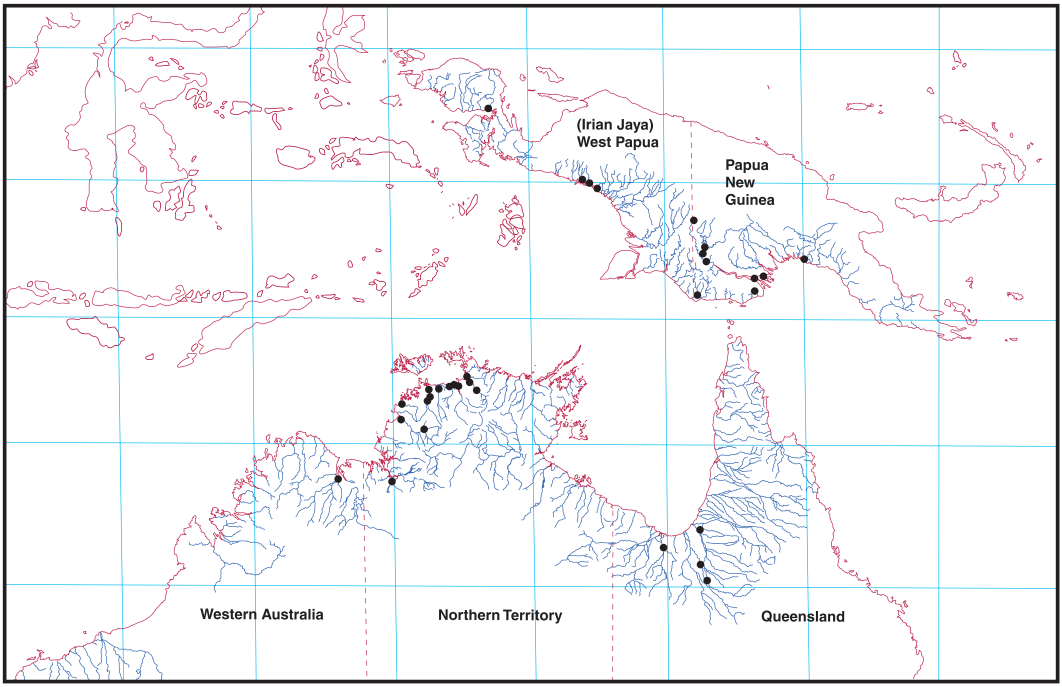

Fig. 8. Distribution map of *Kurtus gulliveri* based on museum specimens and literature records.

Fig. 9. *Kurtus gulliveri*, yolk-sac fry 5.5-5.8 mm body length that fell from the partial egg mass taken from a gill net on 20 June 2001.

One way analysis of variance showed that there were no significant sexually dimorphic differences for either species. A principal components analysis was performed with a multivariate statistical package (Kovach, 1999). Meristic and standardized morphometric data were transformed by natural logs ($\log_e$). Figure 7 shows that the two species are clearly separated and that New Guinea specimens of *K. gulliveri* (N = 30) are indistinguishable from Australian specimens (N = 129). The most variation occurs within the first two axes. Anal fin ray numbers and caudal peduncle depth as a per cent of SL provide the greatest variability of the 1st axis, and body depth as a per cent of SL and upper jaw length as a per cent of head length comprise the greatest sources of variability for the 2nd axis.

Coloration. Specimens of *K. gulliveri* were photographed immediately upon capture. This was important because their color fades within a few minutes after capture, and a detailed description of the living color has never been published, although photographs of pale, living specimens are provided by Merrick & Schmida (1984) and Allen (1989). An iridescent violet wash covers the

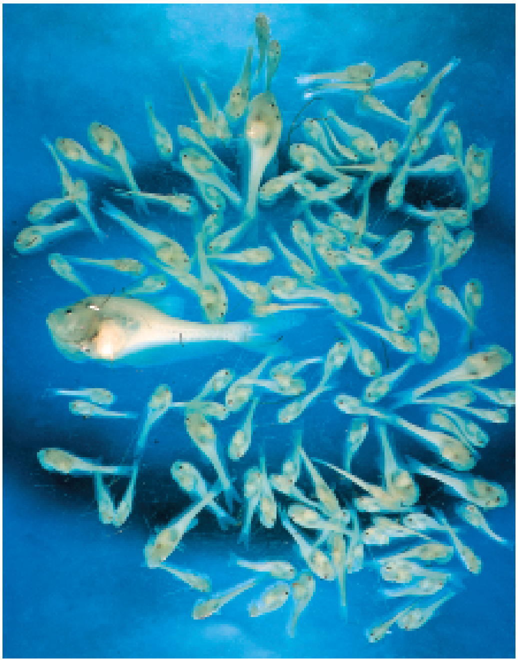

Fig. 10. *Kurtus gulliveri,* larvae from plankton sample (TMB01-24) taken on 17 August 2001. Size of the 129 specimens ranged from 6.5-26.4 mm SL.

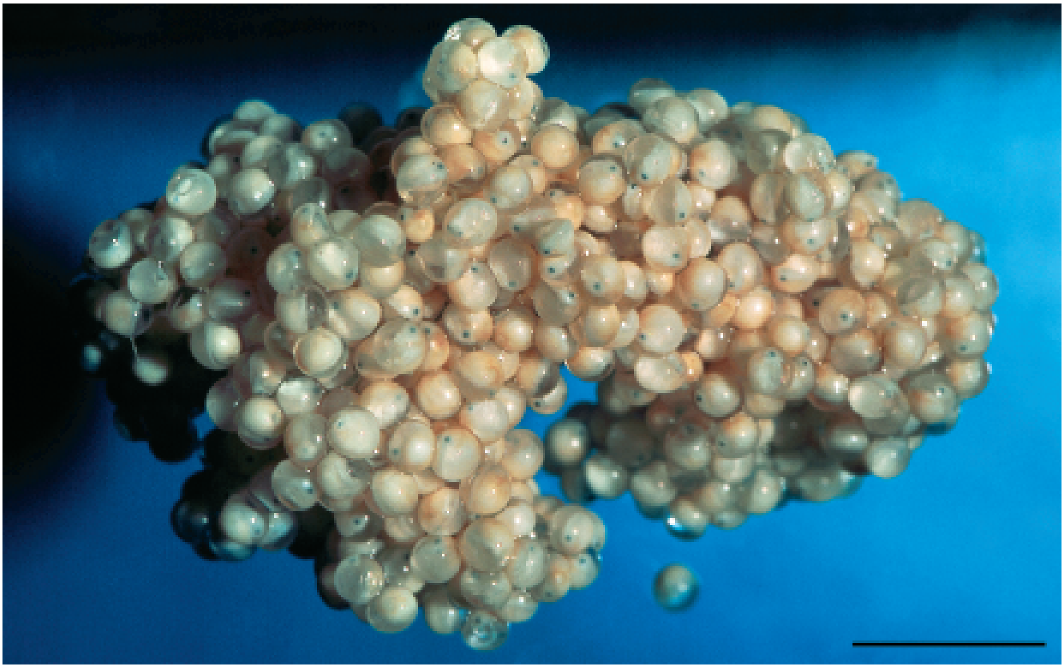

Fig. 11. *Kurtus gulliveri,* egg mass (TMB 01-27) removed from gill net on 21 September 2001 showing late-stage embryos with eye spots and tails folded over bodies. Note left and right half of egg mass.

dorsal and ventral surfaces, the anal and caudal fins, and the fleshy base of the dorsal fin (Fig. 3). This color has a 'neon glow' quality. The violet grades to rosy pink in the middle of the body and brassy yellow along the anterior half of the dorsal-lateral surface. The head, opercular region, and thorax are silvery with greenish blue highlights. The iris is black.

Blanched living specimens become a translucent silvery pink. In alcohol newly preserved specimens are silvery white while specimens preserved for several years become yellowish or pinkish. In life the fins are translucent. Some specimens have black pigment along the caudal and anal fin margins. After preservation melanophores are discernable in the fins, along the mid-dorsal line and sides of the body. The melanophores become apparent in living specimens kept in an aquarium for a week or more. This results in a darker, charcoal-colored specimen (Berra & Humphrey 2002: fig. 4d). This pigment remains in drops of alcohol or water and is apparent when preserved fish are removed from a white dissection tray.

Distribution. Figure 8 shows the distribution of *K. gulliveri* from Australia and New Guinea based upon museum and literature records. Nurseryfish have been taken in the following north Australian Rivers: Western Australia: West Arm of Pentecost; Northern Territory: East Baines; Daly; Finnis; Adelaide; Mary; Wildman; West, South, and East Alligator, Cooper Creek; Queensland: Leichhardt; Saxby; Norman. In southern New Guinea nurseryfish are recorded from the following rivers or localities: Papua Province (formerly Irian Jaya): Bintuni, Otokwa, Ajkwa, Timka; Papua New Guinea: Bensbach, Sambu, Fly, Strickland, Kikori, Oriomo, Panaroa.

Egg mass and larvae. A 224 mm SL male was caught in a gill net on 20 June 2001, and a partial egg mass was adjacent to it, presumably knocked from the male's hook by the gill net (Berra & Neira, 2003: fig. 1b). Six late-stage embryos were contained within the egg mass, one yolk-sac fry was trapped within the matrix holding the mass together, and two yolk-sac fry fell out of the mass (Fig. 9). A 269 mm SL squeeze-ripe female was removed from the gill net on 12 July. Larval nurseryfish (Fig. 10) were taken in the Adelaide River via plankton net from 7 August until 13 November. On 21 September, three complete egg masses without associated males were removed from the gill net in Marrakai Creek. These isolated egg masses were most likely dislodged from the male's hook by contact with the gill net. Two of the masses were pink and consisted of late-stage embryos (Fig. 11) while the third mass was white and contained either unfertilized eggs or eggs so recently fertilized as to show no gross changes. The egg masses consisted of a left and right half connected by an isthmus, presumably where the mass was attached under the male's hook. The number of eggs present was estimated by weighing a subsample of loose eggs and extrapolating to the weight of the egg mass. An estimate of 900, 1200 and 1300 eggs was obtained, but this is surely an overestimate since the weight of the gelatinous matrix was not taken into account. If the assumption that these egg masses were detached from the male's hook by contact with the gill net is correct, and if one of the egg masses was unfertilized, it is likely that the eggs are fertilized after they become attached to the male's hook. How the eggs become attached to the hook and the mechanics of courtship, spawning, and fertilization are unknown. Weber (1913; reproduced in Berra, 2002) provided a drawing of a male with an attached egg mass. Allen et al. (2002) included a photograph of a male carrying an egg mass. As far as I can determine, these are the only two known specimens of males with eggs and neither fish was preserved. On 18 November 2002, staff of the Tokyo Sea Life Park collected two males (c. 370 mm SL) with eggs in the Adelaide river 6.0-1.6 km downstream from the Arnhem Highway Bridge (D. Wedd, pers. comm.). One egg mass was pink, the other was white. The fate of these specimens is unknown to me.

Material examined. The following specimens were used for meristic and morphometric data. Museum abbreviations follow Leviton et al. (1985); TMB is Tim M. Berra collection. The number of specimens is in parentheses.

Kurtus gulliveri: AMS B9208, holotype; Queensland: Norman River. – AMS I40096001 (1); AMS I17998001 (5); NTM S14140-005 (1); CSIRO C4590 (1), CSIRO C4591(1); Queensland: Saxby River. – WAM P25630-001 (2); Queensland: Leichardt River. – TMB01-4 (9); TMB01-6 (1); TMB01-16 (4); TMB01-17 (1); TMB01-18 (7); TMB01-26 (9); TMB01-27 (11); Northern Territory: Adelaide River. – NTM S14676-001 (1); NTM S14435-001 (1); NTM S14634-003 (3); NTM S15095-002 (3); NTM S14675-003 (1); NTM S14474-001 (1); NTM S14633-005 (1); NTM S14475-008 (1); Northern Territory: West Alligator River. – NTM S15097-002 (4); Northern Territory: South Alligator River. – NTM S14466-001 (1); NTM S14462-001 (1); NTM S14465-001 (2); AMS I21817001 (1); Northern Territory: East Alligator River. – NTM S14473-003 (2); NTM S14503-001 (1); NTM S14502-001 (3); NTM S14436-004 (3); NTM S15287-001 (1); Northern Territory: Wildman River. – NTM S12251-001 (5); NTM S12252-001 (5); Northern Territory: Finniss River. – NTM S10827.001 (2); Northern Territory: Mary River. – NTM S11568-001 (1); NTM S12254-001 (29); Northern Territory: Daly River. – NTM S15358-001 (1); Northern Territory: East Baines River, Victoria River drainage. – WAM P4620 (1); Western Australia: "Wyndham" (probably West Arm of Pentecost River). – NTM S15063 (1); Papua New Guinea: Samu River. – NTM S15064-002 (2); Papua New Guinea: Fly River. – WAM P31212-001 (1); P30979-006 (3); Papua New Guinea: Kikori River. – WAM P27815-001 (1); Papua New Guinea: Orioma River. – CSIRO A3068 (1); CSIRO A3142 (1); CSIRO A3143 (1); Papua New Guinea: Panaroa River. – WAM P29978-002 (3); WAM P29959-008 (2); WAM P2997-006(1); Papua Province (Irian Jaya): Bintuni River. – CSIRO H4933-02(1); Papua Province (Irian Jaya): Otokwa River. – CSIRO H5248-01 (12); Papua Province (Irian Jaya): Ajkwa River.

Kurtus indicus: AMS I27630025 (1); AMS I27764024 (1); Malaysia: Perak. – WAM P30530-007 (2); WAM P30527-001 (5); Malaysia: Benkalis. – ZMA 120.688 (14); Sumatra: Bagan si Api Api. – ZRC 3410 (2); Malaysia: Malacca.

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