

## Observation of egg carrying by male nurseryfish, *Kurtus gulliveri* (Perciformes: Kurtidae), and natural history notes from northern Australia

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### ABSTRACT

Egg carrying by male nurseryfish, *Kurtus gulliveri* Castelnau, 1878, is often cited in literature reviews of parental care, but rarely witnessed in nature. During 20 field trips in October and November 2003, and eight trips in July and August 2004, 988 nurseryfish (70% male, 30% female) were collected by gill netting in Marrakai Creek, a tributary of the Adelaide River 65 km east of Darwin, Northern Territory. Seven egg masses (six unfertilized and one containing eyed embryos) were caught during 2003 in the nets, stripped from the male's supraoccipital hook by the mesh. This demonstrates that eggs become attached to the male before fertilization. We observed males carrying eggs, and we witnessed the subsequent detachment of the egg mass. Two unfertilized and six fertilized egg masses were caught in gill nets in 2004. A table of 29 other species that were caught with *Kurtus* is provided. This includes 31 specimens of the undescribed speartooth shark, *Glyphus* sp. A. The polynemid, *Eleutheronema tetradactylum*, regurgitated a partially digested nurseryfish, and a barramundi, *Lates calcarifer*, had a nurseryfish in its stomach. These represent the first records of fish predation on *Kurtus gulliveri*. A nurseryfish specimen with a minute left pupil is illustrated for the first time – a teratological phenomenon known as a pin-hole camera eye. In July and August 2004 electrofishing in Marrakai Creek and Beatrice Creek was carried out in an attempt to collect males with intact egg masses. This technique was very effective for barramundi but not for nurseryfish. Water chemistry data are presented showing that this region of the Adelaide River is of low conductivity and high turbidity.

KEYWORDS: Adelaide River, Northern Territory, eggs, egg mass, electrofishing, embryos, forehead brooding, *Kurtus gulliveri*, nurseryfish, parental care, pin-hole camera eye.

### INTRODUCTION

*Kurtus gulliveri* Castelnau, 1878, is remarkable for its bizarre method of parental care. The male carries a fertilized egg mass on a supraoccipital hook (Berra and Humphrey 2002; Berra and Neira 2003). This has been termed 'forehead brooding' by Balon (1975) and has earned the common name of nurseryfish for this species. This unique phenomenon was first described by Weber (1910, 1913). No further illustration of egg-carrying males is found in the literature until Allen *et al.* (2002) (reproduced in Berra and Neira (2003)) published a photograph of a 'pregnant male' from New Guinea. As far as we can determine, neither Weber's specimen nor the one depicted by Allen *et al.* was preserved.

*Kurtus gulliveri* occurs in coastal rivers of northern Australia and southern New Guinea (Berra 2001). Its congener, *K. indicus*, which ranges from India to Borneo, is not known to carry eggs (Hardenberg 1936).

Fieldwork was commenced in 2001 on the Adelaide River east of Darwin, Northern Territory (NT) in order to understand aspects of the life history of nurseryfish. Their diet was shown to be composed of prawns, isopods, insect larvae, and small fishes (Berra and Wedd 2001). The anatomy and histology of the male's hook was studied and various adaptations for egg carrying were reported (Berra and Humphrey 2002). For example, the epidermis in the cleft of the hook is folded into crypts and is devoid of secretory and neurosensory cells. The dermis is highly vascularized and engorgement of this area with blood may help hold the egg mass in place. Berra and Neira (2003) described the eggs and larvae and suggested that the spawning season coincides with the Dry season (May–November) based upon length-frequency distribution of planktonic larvae. Berra (2003) compared *K. gulliveri* and *K. indicus*, and provided a redescription and distribution map of *K. gulliveri*, illustrated an egg mass

with eyed embryos and estimated that the cluster consisted of 900–1300 embryos. The unusual swim bladder and ribs of nurseryfish were studied with high resolution X-ray tomography and hypothesized to be an accessory hearing organ (Carpenter *et al.* 2004). Berra and Aday (2004) described the sagittal otolith of *Kurtus* and determined that most nurseryfish in the population were one or two years of age, but a few lived to age 4. After one year, females were usually larger than males. During the 2001 fieldwork, a partial egg mass immediately adjacent to a male (Berra and Neira 2003: fig. 1B) and three complete egg masses were taken from one gill net, presumably dislodged from the male's hook when the fish struck the net. The purposes of this paper are to report observations of egg-carrying by males and natural history notes.

## METHODS

As in 2001, the principal study site during October–November 2003 and July–August 2004 was Marrakai Creek (12°40.950'S, 131°20.030'E), a major freshwater tributary of the Adelaide River 2.5 river km upstream from the boat ramp at the Arnhem Highway bridge about 65 km east of Darwin. A map of the river system is given by Berra (2003). The Top End of the Northern Territory around Darwin belongs to the humid tropics with a monsoonal climate featuring a Wet and Dry season. Nearly 93% of the 1652 mm average rainfall occurs from late November to early April (Webb *et al.* 1983). Rainfall is minimal during the Dry. Daytime maximum temperatures throughout the year in Darwin are in the low 30s° C with minimum temperatures about 25° C in the Wet and 19° C in the Dry. Near the Adelaide River study area, minimum air temperatures can be considerably lower in the Dry.

A different technique was utilized for the 2003 fieldwork in an attempt to prevent the egg mass from being ripped from the male's hook. Instead of setting a gill net across the stream as in 2001, either a 2.5 cm or a 10.7 cm mesh net 30 m long and 5 m deep was tied between two boats. The net was bowed by the incoming or outgoing tide while the boats maintained position or drifted with the tide as much as 200 m during the 10-minute set period. The amount of drift was smaller during neap tides as opposed to spring tides. We tried to achieve a four hour working period, usually about two hours on the incoming and two hours on the outgoing tide. The tidal regime in the Adelaide River is dramatic. The difference between high and low tide can be nearly 8 m at the mouth of the river during some times of the lunar month. This massive variation is mitigated somewhat by a downstream constriction known as the "narrows" (Berra 2003: fig. 1) so that the tidal variation in Marrakai Creek is not as great as predicted in the tide tables, but it still poses a major

difficulty when setting and tending nets. After each 10-minute set the net was retrieved from one boat by hauling on the float and lead lines while keeping a bag between them. The float and lead lines at the other end of the net were tied together to create a purse that could retain fish as the net was checked and hauled into the boat.

Larval nurseryfish were sampled on 20 November 2003 by towing a plankton net (500 µm mesh, 50 cm<sup>2</sup> mouth) at a depth of approximately 1 m for 20 minutes from the boat ramp at the Arnhem Highway bridge to the mouth of Marrakai Creek as was done in 2001 (Berra and Neira 2003).

Electrofishing fieldwork commenced in July 2004 in a further effort to collect "pregnant males". A Smith-Root type VI-A boat shocker emitting pulsed direct current was used. Reynolds (1996) provided a primer on electrofishing and guidelines for its safe and efficient use. A Horiba U-10 meter was used to record various relevant water chemistry data during electrofishing trips. Both banks of a 2-km stretch of Marrakai Creek from 12°40.943'S 131°20.041'E to 12°40.928'S 131°19.848'E were repeatedly shocked on 26, 27, 28 July 2004 for about four hours each day.

A 10.2 cm mesh gill net 20 m long and 4 m deep was also set across the stream during electrofishing on 27 and 28 July to sample the fishes in mid-channel. Additional netting was carried out on 5, 6, 11 and 13 August 2004 with the net mentioned above and a 10.7 cm x 30 m x 5 m gill net. Beatrice Creek, 12.4 km upstream from Marrakai Creek, was shocked and gill netted on 9 August. A 2.5 cm mesh gill net was employed on 10 August in Marrakai Creek, and a 17.8 cm gill net was used in Marrakai Creek on 13 August.

## RESULTS

**Egg Carrying.** A total of 698 nurseryfish (72% male, 28% female) was caught in the sampling period from 3 October through 20 November 2003 on 20 field trips. During eight netting trips in late July–August 2004, 290 nurseryfish (64% male, 36% female) were captured. The total for the two years was 988 with 688 males (70%) and 300 females (30%). The 2.5 cm gill net captured an additional 137 nurseryfish, most of which were 85–150 mm SL. These specimens were not sexed. No fish of any species were caught in the 17.8 cm mesh net. The vast majority of all specimens were released alive. Seven egg masses were caught in the gill nets in 2003. One egg mass was pink and contained eyed embryos (Fig. 1), and six were white (Fig. 2) and presumably unfertilized. Unfortunately, all but one unfertilized egg mass were detached from the male's hook by the gill net mesh and could not be associated with any male. Figure 3 depicts the circumstances that



**Fig. 1.** Pink *Kurtus gulliveri* egg mass in gill net taken in Marrakai Creek on 22 October 2003. Egg mass contained embryos with eye spots and tails readily visible under microscope. Eggs about 2 mm in diameter.



**Fig. 2.** White *Kurtus gulliveri* egg mass in gill net taken in Marrakai Creek on 22 October 2003. Egg mass was unfertilized and revealed no embryonic structure when viewed under microscope. Eggs approximately 2 mm in diameter.



**Fig. 3.** Male nurseryfish enmeshed in gill net virtually guaranteeing dislodgement of egg mass.



result in detached egg masses (Figs 1, 2). The chances of a struggling male retaining an egg mass in the gill net are minimal. We observed males carrying egg masses in 2003 and watched with horror as the egg mass became detached in the net while the male slipped into the water. Figure 4 shows a male and its egg mass and illustrates the ease with which an egg mass can become detached from the male's hook. Six pink (fertilized) and two white (unfertilized) egg masses were caught in 2004. Four fertilized egg masses in the net had a male immediately adjacent to them.

**Predation.** A gill-netted polynemid, *Eleutheronema tetradactylum* (Shaw), known as the blue salmon or the fourfingered threadfin, regurgitated a semi-digested nurseryfish. The nurseryfish was apparently swallowed head first since its anterior end was partially digested, and the caudal peduncle and tail were intact. The identification was immediately obvious from the unusual ribs of *Kurtus*, which were exposed. A 70 mm SL partially digested nurseryfish was found in the stomach of a 410 mm SL gill-netted barramundi, *Lates calcarifer* (Bloch). These are the first reports of fish predation on *Kurtus gulliveri*.

During the 2003 fieldwork we caught 31 specimens of the undescribed spartooth shark, *Glyphis* sp. A (Last and Stevens 1994) under 1 m SL. Most were released immediately and a few were taken to the Territory Wildlife Park Aquarium. It is not unreasonable to suggest that this rather common shark could be a predator of nurseryfish, although no stomach contents were examined.

**Larvae.** Only eight larvae were taken in the plankton tow on 20 November. Their TL ranged from 12 mm to 26 mm and the average size was 19 mm.

**Teratology.** A 185 mm SL male with a malformed eye was captured on 7 October 2003. The right and left eye were both of normal size and shape, but the left eye had a tiny pupil that measured 25% of the corneal length (Fig. 5), while the normal right pupil



**Fig. 4.** One of two egg-carrying male nurseryfish (c. 370 mm SL) taken by gill netting from Adelaide River on 18 November 2002 by D. Wedd and staff of Tokyo Sea Life Park showing edematous hook from which an egg mass had just detached. Photograph by D. Wedd.



**Fig. 5.** Pinhole camera eye on left side of a 185 mm SL male nurseryfish, *Kurtus gulliveri*, from Adelaide River 4 km downstream from Arnhem Highway bridge. Specimen in collection of first author (TMB03-4).



**Fig. 6.** Normal right eye of nurseryfish specimen in Figure 5.

was 68% (Fig. 6). The lens was absent from the left eye. This defect is known as a pinhole camera eye (Moore and Curd 1966).

**Associated species.** Table 1 lists the fish species collected with *Kurtus* in the freshwater reaches of the Adelaide River about 82 river km from the mouth. Identifications were confirmed using Allen *et al.* (2002), Carpenter and Niem (1998), Kailola (2000), Larson and Martin (1990), and Last and Stevens (1994).

**Electrofishing.** Table 2 lists the water chemistry parameters important for electrofishing. Adelaide River water is of low conductivity and high turbidity. Hundreds of barramundi and dozens of archerfish and mullet were stunned, especially around woody debris and snags, on each 4-hr electrofishing trip. However, only five nurseryfish (100–200 mm SL) were recovered during three days of intensive shocking. Gill netting in the same area on two days produced 42 nurseryfish. No nurseryfish were stunned in Beatrice Creek, but 38 specimens were gill netted. Table 1 indicates the eight species collected by electrofishing, all of which were previously captured by gill netting. Stunned fish recovered and escaped or were released, and netted fish were set free.

## Egg carrying in nurseryfish

**Table 1.** Fish species associated with *Kurtus gulliveri* from freshwater reaches of Adelaide River and its tributary Marrakai Creek about 82 river km upstream from mouth.

Family	Species	Common name
Carcharhinidae	<i>Carcharhinus leucas</i> (Valenciennes)	Bull shark
Carcharhinidae	<i>Glyphis</i> sp. A	Speartooth shark
Pristidae	<i>Pristis microdon</i> Latham	Freshwater sawfish
Dasyatidae	<i>Himantura uarnak</i> (Forsskål)	Reticulate whipray
Engraulidae	<i>Thryssa brevicauda</i> Roberts	Short-tail thryssa
Engraulidae	<i>Thryssa marasriae</i> Wongratana	Marasri's thryssa
Clupeidae	<i>Herklotsichthys gotoi</i> Wongratana	Goto's herring
Clupeidae	<i>Nematalosa erebi</i> (Gunther)	Bony bream
Ariidae	<i>Arius armiger</i> De Vis	Copper catfish
Ariidae	<i>Arius dioctes</i> Kailola	Yellow catfish
Ariidae	<i>Arius hainesi</i> Kailola	Haines's catfish
Ariidae	<i>Cinetodus froggatti</i> Ramsay and Ogilby	Small-mouthed catfish
Mugilidae	* <i>Liza alata</i> (Steindachner)	Diamond mullet
Mugilidae	<i>Liza planiceps</i> (Valenciennes)	Tade mullet
Mugilidae	<i>Liza subviridis</i> (Valenciennes)	Greenback mullet
Mugilidae	<i>Rhinomugil nasutus</i> (De Vis)	Shark mullet
Belonidae	* <i>Strongylura krefftii</i> (Gunther)	Freshwater longtom
Hemiramphidae	<i>Zenarchopterus buffonis</i> (Valenciennes)	Buffon's garfish
Centropomidae	* <i>Lates calcarifer</i> (Bloch)	Barramundi
Ambassidae	* <i>Ambassis interruptus</i> Bleeker	Long-spined glassperch
Leiognathidae	<i>Leiognathus equulus</i> (Forsskål)	Common ponyfish
Polynemidae	<i>Eleutheronema tetradactylum</i> (Shaw)	Fourfingered threadfin
Polynemidae	<i>Polydactylus macrochir</i> (Gunther)	King threadfin
Sciaenidae	<i>Johnius novaeguineae</i> (Nichols)	Paperhead croaker
Sciaenidae	<i>Nibea microgenys</i> Sasaki	Smalljaw croaker
Sciaenidae	<i>Nibea squamosa</i> Sasaki	Scale croaker
Toxotidae	* <i>Toxotes chatareus</i> (Hamilton-Buchanan)	Seven-spot archerfish
Gobiidae	* <i>Glossogobius aureus</i> Akihito and Meguro	Golden goby
Kurtidae	* <i>Kurtus gulliveri</i> Castelnau	Nurseryfish
Soleidae	* <i>Aseraggodes klunzingeri</i> (Bleeker)	Tailed sole
Cynoglossidae	<i>Cynoglossus heterolepis</i> Weber	Freshwater tongue sole

\*also collected by electrofishing

**Table 2.** Water chemistry parameters relevant to electrofishing in Adelaide River at mouth of Marrakai Creek and Beatrice Creek. Darwin tap water is listed for comparison.

Tide	Date	Time	Conductivity	Turbidity	Temp.	D.O.	Salinity	pH
	2004		µS/cm	NTU	°C	mg/l	ppt	units
outgoing	26 July	08:45	0.616	155	23.1	8.1	0.2	8.4
incoming	26 July	13:45	0.667	482	24.1	8.3	0.2	8.4
outgoing	27 July	08:47	0.626	370	23.1	8.3	0.2	8.2
outgoing	28 July	09:00	0.694	329	23.6	8.1	0.3	8.4
outgoing	29 July	11:45	0.705	585	24.6	8.3	0.3	8.2
*incoming	9 Aug	11:30	0.416	276	26.2	8.2	0.1	8.1
Darwin tap water			0.089	0	26.3	9+	0.0	7.8

\*Beatrice Creek

## DISCUSSION

**Egg carrying.** Breder and Rosen (1966) listed 61 oviparous fish families (out of 246 discussed) with representatives that provided some form of care for eggs or larvae. Most of this care involves nest-guarding behavior. Balon (1975) defined 32 reproductive guilds of fishes. Egg and larval protection is part of the behavioral repertoire represented in 26 of the guilds.

Oral incubation is found in six families (Osteoglossidae, Ariidae, Apogonidae, Cichlidae, Opisthognathidae, Anabantidae). Brood chambers are utilized by three families: Solenostomidae and Syngnathidae (pouch brooders) and Amblyopsidae (gill-chamber brooders). Balon (1975) described three families of skin brooders who carry eggs attached to the skin surface (Aspredinidae, Loricariidae, Syngnathidae). To this group Pietsch and Grobecker (1980, 1987) and Pietsch (1981) have added two

species of the anglerfish families Antennariidae and Tetrabrachiidae that carry eggs on their skin. *Kurtus gulliveri* is the only known 'forehead brooding' species.

Egg carrying by nurseryfish is almost certainly an adaptation that protects the vulnerable egg and embryo stages from a hostile environment. The severe, twice-daily tidal flushing could play havoc with eggs deposited on vegetation or in a nest. The tremendous silt load in the turbid water could easily smother eggs in a nest. An egg mass carried on the male's hook can easily be placed in the optimum temperature and oxygen environment where it is protected from tidal changes, siltation and predation. Even in rivers less hostile than the Adelaide, parental care of an egg mass would be expected to confer an advantage.

We observed males carrying white (unfertilized) egg masses, and we caught both white and pink (fertilized) masses in the gill nets. This demonstrates that the eggs are deposited on the male's hook before fertilization. How the egg mass gets on the male's hook will only be known when courtship and spawning are observed in captivity. However it is possible to speculate on how fertilization takes place. We suggest that the male releases a cloud of sperm and swims through it after the egg mass becomes attached to his supraoccipital hook. If several males in the same area are doing this simultaneously, a given egg mass could have multiple fathers. Evolutionary theory predicts that males should adjust their level of paternal care to their degree of certainty of paternity (Neff 2003). DNA paternity analysis is necessary to determine if the male nurseryfish carrying the embryos is the genetic father or if multiple paternity is involved. These studies are underway.

The skewed sex ratio 70:30 in favor of males is puzzling. Does the male's hook make it easier to catch in gill nets than the female, or are the females in a different locality? Does the excess of males have something to do with egg-carrying? There are still many things we do not know about the life history of this unusual species, but spawning is clearly a Dry season, nearly freshwater phenomenon.

**Predation.** *Eleutheronema tetradactylum* and *Lates calcarifer* are the first reported fish predators of *Kurtus gulliveri*. Berra and Wedd (2001) found no nurseryfish remains in the stomach contents of 15 barramundi. Davis (1985) examined the diet of *L. calcarifer* based on 3684 specimens from northern Australia and found representatives of 14 fish families, but no *Kurtus* were recorded. When the biology of *Glyphis* sp. A is studied, we would not be surprised to find nurseryfish included in their diet.

**Larvae.** The small number of larvae (N=8) taken on 20 November 2003 continued the downward trend reported for 2001 by Berra and Neira (2003) for

4 November (N = 68) and 13 November (N = 29). This is interpreted to represent that the end of the spawning season coincides with the end of the Dry season in November.

**Teratology.** A pinhole camera eye was described for a white crappie, *Pomoxis annularis* Rafinesque, 1818 by Moore and Curd (1966). The pupil diameter of the left eye of the crappie was 13.3% of the corneal length, and the right eye was 54.5%. In the absence of a lens, which normally protrudes through the pupil, the iris grows unrestrictedly resulting in a very small pupil. It is possible that this tiny pupil could form a useful image on the retina as in a pinhole camera. The nurseryfish with this abnormality appeared in good condition and could apparently find food and avoid predation. We do not know if the lens failed to develop or was lost through an early injury, but there were no signs of trauma to the eye.

**Associated species.** A multi-year survey, using a variety of gear, during all months of the year in tributaries and the main channel is necessary for a comprehensive list of species. Likewise a thorough larval fish survey of the Adelaide River is likely to yield additional species.

**Electrofishing.** Very high turbidity combined with rapid water flow from tidal movement and current combined to reduce electrofishing efficiency. Fishes stunned in the Adelaide River are only visible for a few seconds and are often swept away or vanish below the surface before they can be dip netted. Large scaled fishes such as barramundi, mullet, and archerfish, are more vulnerable to electrofishing than fine scaled fishes like nurseryfish (Reynolds 1996). This technique was highly effective for sampling barramundi, but was not of much value for collecting nurseryfish which prefer the mid-water channel to the more easily electrofished banks.

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## REFERENCES

- Allen, G. R., Midgley, S. H. and Allen, M. 2002. *Field guide to the freshwater fishes of Australia*. Western Australian Museum: Perth, WA.
- Balon, E. K. 1975. Reproductive guilds of fishes: a proposal and definition. *Journal of the Fisheries Research Board of Canada* **32**: 821–864.
- Berra, T. M. 2001. *Freshwater fish distribution*. Academic Press: San Diego.
- Berra, T. M. 2003. Nurseryfish, *Kurtus gulliveri* (Perciformes: Kurtidae), from northern Australia: redescription, distribution, egg mass, and comparison with *K. indicus* from southeast Asia. *Ichthyological Explorations of Freshwater* **14**: 295–306.
- Berra, T. M. and Aday, D. D. 2004. Otolith description and age-and-growth of *Kurtus gulliveri* from northern Australia. *Journal of Fish Biology* **65**: 354–362.
- Berra T.M. and Humphrey, J. D. 2002. Gross anatomy and histology of the hook and skin of forehead brooding male nurseryfish, *Kurtus gulliveri*, from northern Australia. *Environmental Biology of Fishes* **65**: 263–270.
- Berra, T. M. and Neira, F. 2003. Early life history of the nurseryfish, *Kurtus gulliveri* (Perciformes: Kurtidae), from northern Australia. *Copeia* **2003**: 384–390.
- Berra, T. M. and Wedd, D. 2001. Alimentary canal anatomy and diet of the nurseryfish, *Kurtus gulliveri* (Perciformes: Kurtidae), from the Northern Territory of Australia. *The Beagle, Records of the Museums and Art Galleries of the Northern Territory* **17**: 21–25.
- Breder, C. M., Jr. and Rosen, D. E. 1966. *Modes of reproduction in fishes*. Natural History Press: New York.
- Carpenter, K. E., Berra, T. M. and Humphries, J. M. Jr. 2004. Swim bladder and posterior lateral line nerve of the nurseryfish, *Kurtus gulliveri* (Perciformes: Kurtidae). *Journal of Morphology* **260**: 193–200.
- Carpenter, K. E. and Niem, V. H. (eds). 1998. *FAO species identification guide for fishery purposes. The living marine resources of the Western Central Pacific*. Volumes 2–6. FAO, Rome.
- Castelnau, F. de. 1878. Australian fishes. New or little known species. *Proceedings of the Linnean Society of New South Wales*. **2**: 225–248.
- Davis, T.L.O. 1985. The food of barramundi, *Lates calcarifer* (Bloch), in coastal and inland waters of Van Diemen Gulf and the Gulf of Carpentaria, Australia. *Journal of Fish Biology* **26**: 669–682.
- Hardenberg, J.D.F. 1936. On a collection of fishes from the estuary of the lower and middle course of the river Kapuas (W. Borneo). *Treubia*. **15**: 225–254.
- Kailola, P. J. 2000. Six new species of fork-tailed catfish (Pisces, Teleostei, Ariidae) from Australia and New Guinea. *The Beagle, Records of the Museums and Art Galleries of the Northern Territory* **16**: 127–144.
- Larson, H. K. and Martin, K. C. 1990. *Freshwater fishes of the Northern Territory*. Northern Territory Museum of Arts and Sciences, Handbook Series Number 1: Darwin, NT.
- Last, P. R. and Stevens, J. D. 1994. *Sharks and rays of Australia*. CSIRO: Hobart.
- Moore, G. A. and Curd, M. R. 1966. A pinhole camera eye in the white crappie, *Pomoxis annularis*. *Copeia* **1966**: 359–360.
- Neff, B. D. 2003. Decisions about parental care in response to perceived paternity. *Nature* **422**: 716–719.
- Pietsch, T. D. 1981. The osteology and relationships of the anglerfish genus *Tetrabrachium* with comments on lophiiform classification. *Fishery Bulletin* **79**: 387–419.
- Pietsch, T. W. and Grobecker, D. B. 1980. Parental care as an alternative reproductive mode in an antennariid anglerfish. *Copeia* **1980**: 551–553.
- Pietsch, T. W. and Grobecker, D. B. 1987. *Frogfishes of the world*. Stanford University Press: Stanford, CA.
- Reynolds, J. B. 1996. Electrofishing. In: Murphy, B. R. and Willis, D. W. (eds) *Fisheries techniques*, 2<sup>nd</sup> edition. Pp 221–253. American Fisheries Society: Bethesda, Maryland.
- Webb, G. J. W., Manolis, S. C. and Sack, G. C. 1983. *Crocodylus johnstoni* and *C. porosus* coexisting in a tidal river. *Australian Journal of Wildlife Research* **10**: 639–650.
- Weber, M. 1910. A new case of parental care among fishes. *Koninklijke Akademie van Wetenschappen te Amsterdam* **13**: 583–587.
- Weber, M. 1913. Süßwasserfische aus Niederländisch süd-und nord-Neu-Guinea. In: *Nova Guinea. Résultats de L'Expédition Scientifique Néerlandaise à la Nouvelle-Guinée en 1907 et 1909*. *Zoologie, Leiden* **9**: 513–613, Pl. 12–14.

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