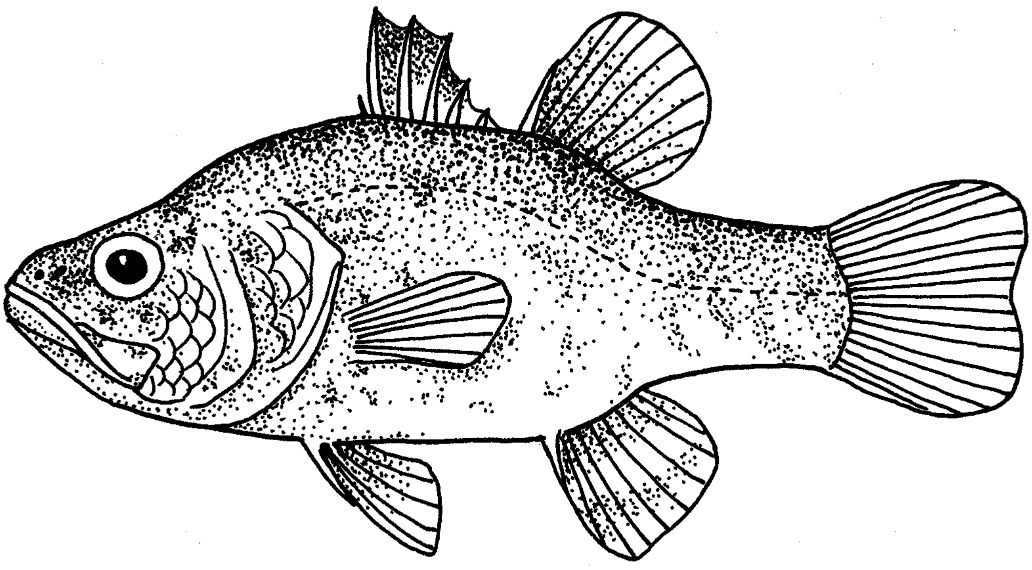
Family APOGONIDAE

3.29 *Glossamia aprion* (Richardson)

Glossamia aprion is commonly known as the mouth almighty or Queensland mouthbrooder. It is found in the drainage systems of the north-east coast, Gulf of Carpentaria and Timor Sea (see map 3). It also occurs in southern rivers of Papua New Guinea. Pollard (1974) found this species to be common in lowland backflow billabongs and sandy creekbeds. Miller (in Taylor 1964) found it to be abundant in large billabongs in the Oenpelli area.



Glossamia aprion

Glossamia aprion is a strictly freshwater species, in a predominantly marine family. It is reputedly a good eating fish, though generally small.

Detailed information on catches by site and season is given in volume 2. In summary, *G. aprion* was moderately abundant in all floodplain, corridor and lowland backflow billabongs, less abundant in lowland sandy creekbeds (mainly downstream of the RUPA) and rare in escarpment perennial streams and mainchannel waterbodies. In the 1978 Late-dry season it was found at 15 sites (mainly lowland backflow and floodplain billabongs); during the Mid-wet season it was found in only 10 sites (mainly lowland channel backflow billabongs). By the Late-wet–Early-dry season it was found in 19 sites (mainly lowland backflow and floodplain billabongs but also sandy creekbeds downstream of RUPA), presumably becoming more catchable as Wet season waters subsided.

Size composition

The lengths and weights of 1020 specimens were recorded. The smallest juveniles were captured with seine (10 mm mesh) nets and the very smallest specimens were captured when hydrophytes clogged the net and effectively reduced the mesh size. The smallest specimen captured by gillnets was 60 mm LCF. The slight peaks in the overall distribution of larger fish may be the result of mesh selectivity.

Length–weight relationship

The length–weight relationship was described by the following expression:[184]

$W = 1.09 \times 10^{-2} L^{3.17}$ r = 1.00 (length in cm, weight in g)

Seasonal mean lengths, weights and condition factors are shown in table 113. The seasonal condition factor was fairly stable throughout most of the study;[185] however, a slight peak was apparent in the Late-wet–Early-dry season and troughs were apparent in the Early-wet season, especially in the 1979–80 season after the extreme Dry season.

Table 113 Mean length, mean weight and condition factor of *G. aprion*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition (K)
Late-dry (1978)	250	43.2	1.12	0.99
Early-wet (1978–79)	58	42.0	1.00	0.97
Mid-wet	53	49.0	1.66	0.99
Late-wet–Early-dry (1979)	221	47.2	1.53	1.02
Mid-dry	263	65.1	4.13	1.00
Late-dry	72	63.1	3.75	1.00
Early-wet (1979–80)	19	67.3	4.29	0.93
Overall	936	51.7	1.99	1.00

Length composition

Range

The specimens ranged in length from 11 mm to 175 mm LCF (fig 132). Lake (1971) reported that this species grows to 200 mm.

Most of the smallest specimens were captured in the Late-wet–Early-dry season and some in the Mid-wet and Mid-dry seasons (fig 133). The largest specimens were captured in the 1979 Mid-dry season and also in the Late-wet–Early-dry season. Large adults were frequently observed in escarpment perennial streams of the Nourlangie catchment during the 1979 Mid-dry season.

Length-frequency distribution

The mean and modal lengths of all specimens captured were 52 mm and 30–35 mm LCF, respectively. The length composition of the populations had a negatively skewed distribution, which reflected the decreasing survival rate of larger specimens. Very small specimens were not abundant in the samples, due partly to gear selectivity and partly to this species being a mouth brooder. The length at first sexual maturity (LFM on fig 132) was approximately 60 to 70 mm LCF, indicating that most of the specimens captured were juveniles.

The seasonal length-frequency distributions of all *G. aprion* captured during the study are shown in figure 133.

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184 van Zweiten (1995) gave the following length-weight relationship for *G. gjellerupi* from the Sepik-Ramu basin in PNG:

$W = 8.21 \times 10^{-6} L^{3.14}$ (r=0.97, p=0.001) (L is standard length in mm, W is total weight in g)

The relationship did not vary significantly between males and females.

185 van Zweiten (1995) found the body condition of *G. gjellerupi* from the Sepik-Ramu basin in PNG to be generally stable and showing no particular seasonality. Condition was negatively correlated to current speeds, with populations from floodplain margin streams having the highest averages.

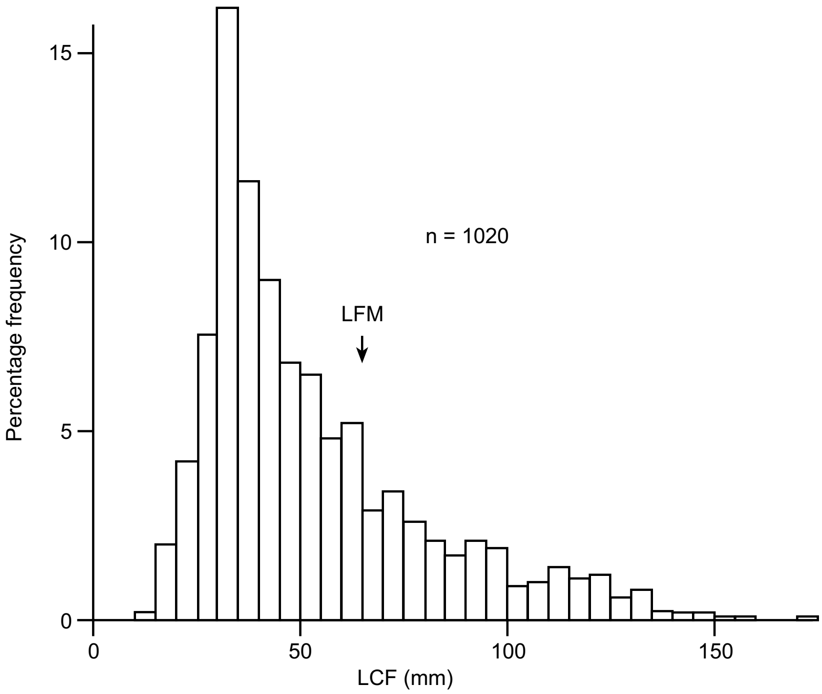


Figure 132 Length-frequency distribution of all *G. aprion* captured

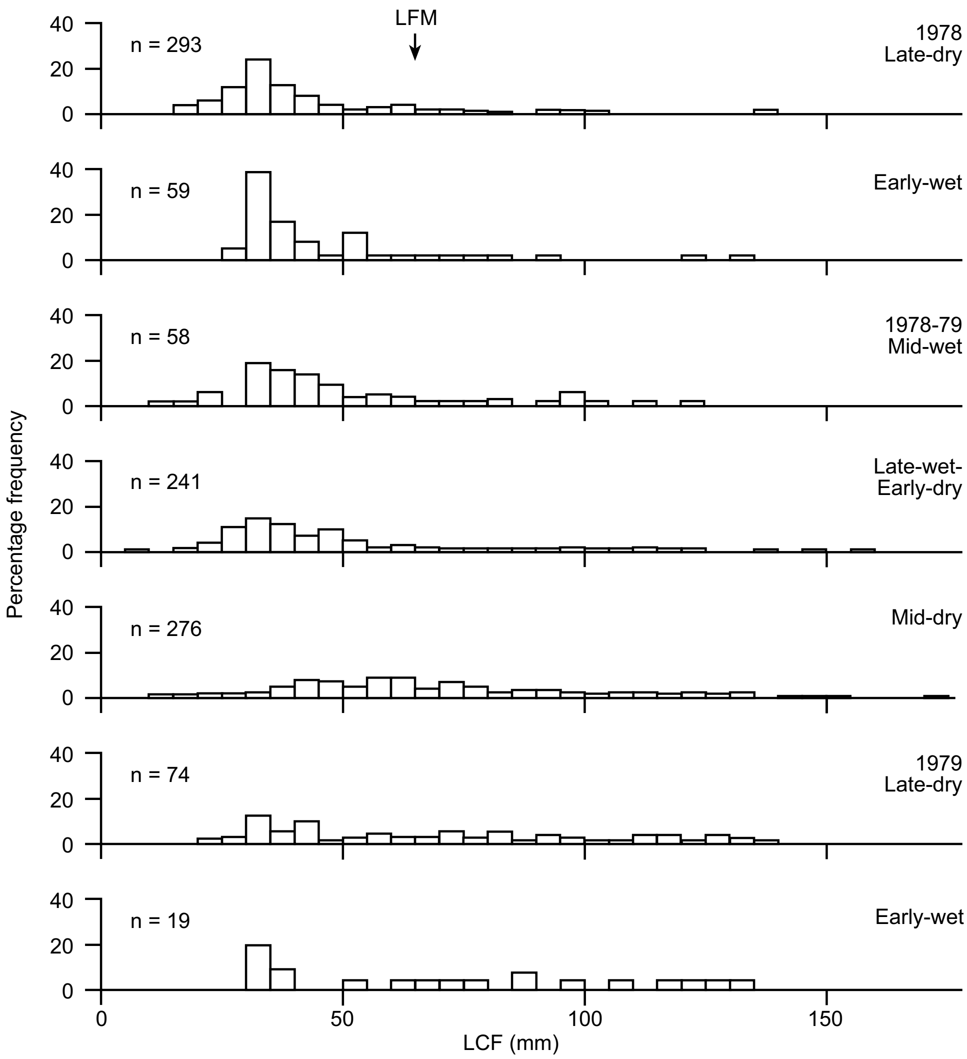


Figure 133 Seasonal length-frequency distribution of all *G. aprion* captured

The mean seasonal lengths are shown in table 113. They were shortest during the 1978 Late-dry and 1978–79 Early-wet seasons and then increased slightly during the Mid-wet and Late-wet–Early-dry seasons. By the Mid-dry season the mean lengths had increased dramatically but remained at much the same level to the end of the study.

The initial low mean lengths were primarily due to the many juveniles in the samples; in the following seasons the juvenile component remained strong, though more adults were found. By the 1979 Mid-dry season there were fewer small juveniles and more larger juveniles and adults (fig 133). This did not change in the 1979 Late-dry and 1979–80 Early-wet seasons, unlike the previous year. The environmental conditions in the 1979 Dry season were apparently less favourable for producing large numbers of juveniles than the 1978 season. The presence of juveniles in all sampling seasons indicates that the fish bred in the billabongs during these times; however, the length-frequency distributions indicate that this activity was greatest between the 1978 Late-dry season and the Late-wet–Early-dry season.

Growth rate

Estimation of the growth rate of *G. aprion* from the seasonal length-frequency distributions was difficult because of mesh selectivity, the range of habitats sampled, and especially the nearly continuous recruitment of juveniles.

Habitat differences in distribution

The habitats in which *G. aprion* was captured in regular sampling sites in the Magela and Nourlangie Creek catchments are shown in figure 134.

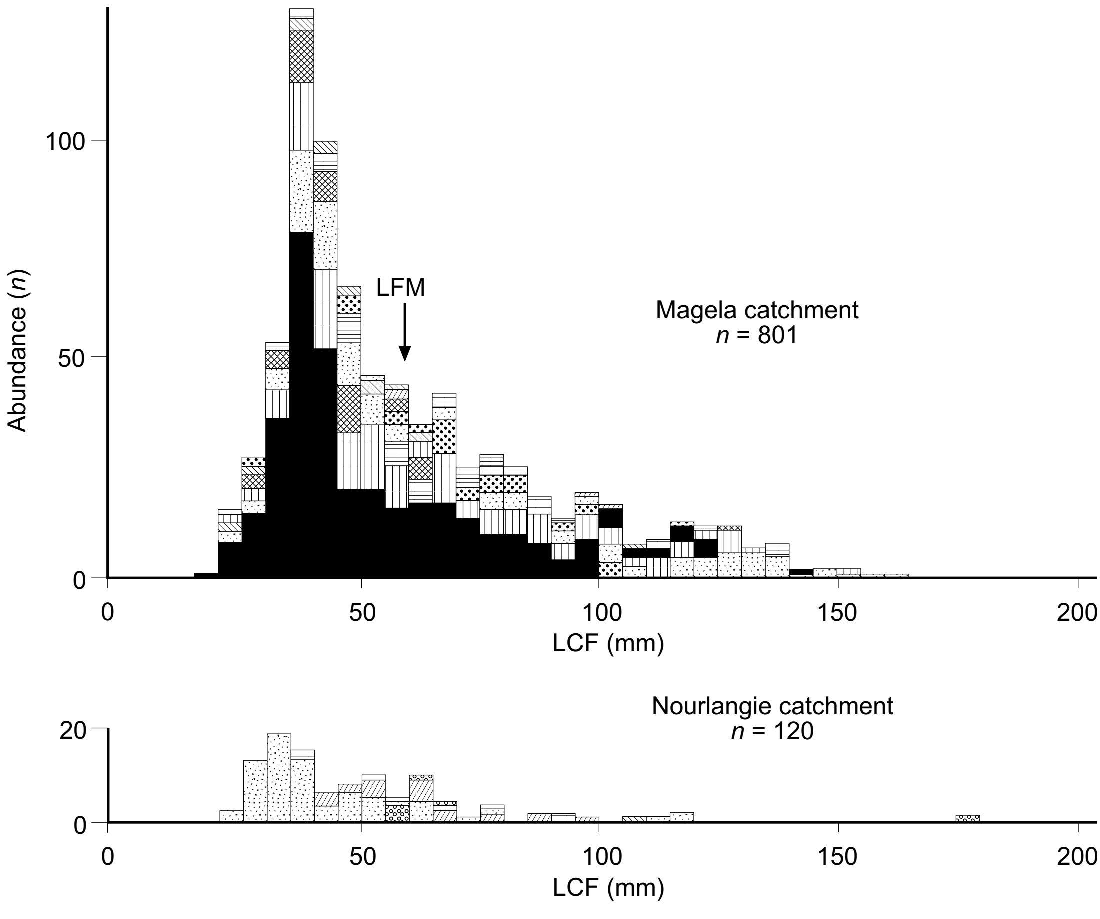


Figure 134 Length-frequency distribution and habitat preferences of *G. aprion* captured at regular sampling sites (see appendix 5 for key to the habitats)

Magela catchment
Most juveniles were captured in floodplain billabongs and secondarily in lowland backflow billabongs, and to a lesser extent in corridor waterbodies. Very few juveniles were found in sandy creekbeds. Juveniles were frequently captured upstream of RUPA in escarpment mainchannel waterbodies (though not in perennial streams) and backflow billabongs.

Smaller adults were found in a variety of habitats, but most frequently in floodplain billabongs and to a lesser extent in backflow billabongs. Considerable numbers of these small adults were also found in corridor waterbodies and lowland sandy creekbeds (unlike the juveniles) as well as in habitats upstream of RUPA. The presence of small adults in lowland sandy creekbeds may indicate dispersion of this size group to spawning or feeding areas or both.

The large adults were mainly found in backflow billabongs, and infrequently in floodplain billabongs, lowland sandy creekbeds, corridor waterbodies and habitats upstream of RUPA.

Nourlangie catchment
Both small and larger juveniles were mainly captured in channel backflow billabongs. The larger juveniles were also captured in lowland sandy creekbeds and shallow backflow billabongs. No juveniles were observed in escarpment habitats.

A large proportion of small adults captured in the Nourlangie catchment were found in lowland sandy creekbeds (as was the case in the Magela catchment) and to a lesser extent in backflow billabongs. The largest adult was captured in a shallow backflow billabong. Large adults were also frequently observed in escarpment perennial streams and in mainchannel waterbodies.

Environmental associations

Rank numbers for *G. aprion* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature
The water temperatures of sites where *G. aprion* was found ranged from 25 to 38°C (mean = 30.6°C) on the surface and from 23 to 35°C (mean = 29.0°C) on the bottom. Both means ranked high in the lower-middle quarter (see fig 170). The larvae of this species died when kept in water at 22 to 24°C (over five days). Although some specimens of *G. aprion* were found in cooler escarpment streams, it was more commonly captured in warmer lowland waterbodies.

Dissolved oxygen
Dissolved oxygen concentrations in waters inhabited by *G. aprion* ranged from 1.3 to 9.7 mg/L (mean = 6.2 mg/L) on the surface, and from 0.2 to 9.5 mg/L (mean 4.8 mg/L) on the bottom. Both means were ranked in the upper-middle quarter (see fig 171). *Glossamia aprion* thus apparently tolerates very low DO concentrations; however, a specimen of *G. aprion* was found in the Leichhardt Billabong fish kill (Bishop 1980) in which surface DO levels fell to 0.1 mg/L.[186]

Visibility
Secchi depth readings in waters in which *G. aprion* was caught ranged from 1 to 200 cm (mean = 41 cm). This mean ranked at the top of the lower quarter, indicating this species' association with moderately turbid waters (see fig 172).

186 van Zweiten (1995) suggested that mouth-brooding in *G. gjellerupi* from the Sepik-Ramu basin in PNG may restrict the species to well-oxygenated waters.

pH
The pH values of waters in which *G. aprion* was caught ranged from 4.9 to 8.1 (mean = 6.3) on the surface, and from 4.5 to 7.3 (mean = 5.9) on the bottom. These means were ranked in the upper-middle and lower-middle quarters, respectively (see fig 173).

Conductivity
Conductivity readings for waters in which *G. aprion* were captured ranged widely from 2 to 620 µS/cm on the surface, and from 2 to 110 µS/cm on the bottom. The closely related *G. wichmonni* is found in brackish to freshwaters in Papua New Guinea (Roberts 1978); however, Pollard (1974) stated that *G. aprion* is a purely freshwater species.

Habitat–structural variables[187]

Substrate
Glossamia aprion was most commonly found over muddy substrates (upper-middle quarter) followed by clay (upper-middle quarter), then sand, leaves, gravel, rocks and boulders (see fig 174). Such a wide range of types of substrate is in accord with the species' wide distribution.

Hydrophytes
This species was typically captured in heavily vegetated waters (vegetation-occurrence index 86.8%): the order of dominance was submergent followed by emergent and then floating-attached hydrophytes).

Reproduction

A total of 559 *G. aprion* was examined for reproductive condition: 255 were sexually indistinguishable (length range 11–115 mm TL); 146 were females (33–157 mm TL) and 158 were males (33–140 mm TL). Only males were observed incubating eggs in their mouths.

Length at first maturity

The LFM, determined by 10-mm-length groups, was found to be 63 mm for males and 67 mm for females (fig 135). The smallest maturing fish were 61 mm LCF (males) and 70 mm LCF (females).[188]

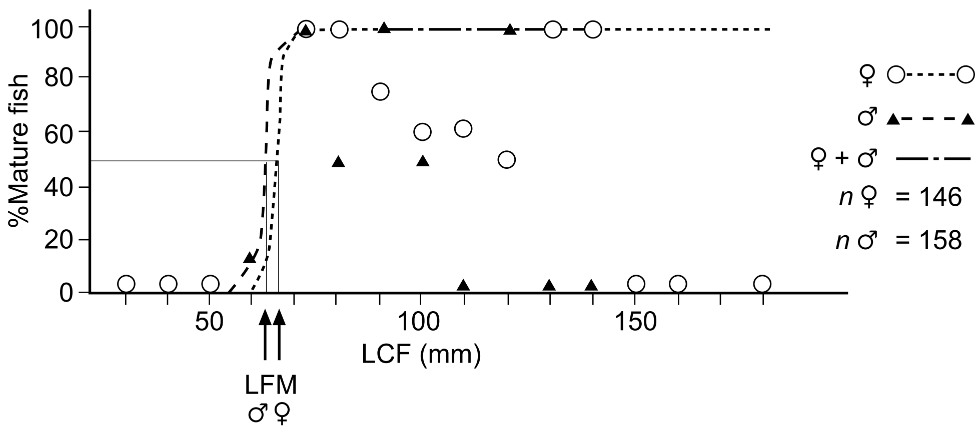


Figure 135 Estimated length at first maturity of *G. aprion*

187 van Zweiten (1995) found *G. gjellerupi* from the Sepik-Ramu basin in PNG to prefer slow flow rates: pools, alongside banks, under cover of vegetation, etc. Biomass and density decreased with increasing current speeds. Fluctuations in population size appeared to be related to the irregular occurrence of spates.

188 Data presented by van Zweiten (1995) indicated that LFM for *G. gjellerupi* from the Sepik-Ramu basin in PNG was 70–80 mm SL for females and 60 mm for males.

Sex ratio

A chi-squared test on adult fish only indicated no significant difference from a 1:1 sex ratio for each season; however, significantly more males were identified in the entire sample during the 1978 Late-dry ($0.01 < P < 0.05$), 1978–79 Early-wet ($0.001 < P < 0.01$) and the following Mid-wet ($0.01 < P < 0.05$) seasons (table 114).

Thus more juvenile males than females were identified (possibly some immature females were misidentified as males).

Breeding season

The breeding season was not well defined.[189] Roberts (1978) found that in Papua New Guinea, *G. aprion* reproduced aseasonally, while Lake (1978) found it spawned when water temperatures reached about 22°C. The information from figure 136 and table 114 indicates *G. aprion* may have bred over a range of seasons.

Table 114 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *G. aprion* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979-80
Sex ratio									
Juveniles	F	*n*	16	4	4	28	66	22	6
+ adults	M	*n*	34	18	14	21	48	18	5
		χ^2	6.5	8.9	5.6	1.0	2.8	0.4	0.09
		P	*	**	*	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	13	1	3	18	47	16	6
	M	*n*	19	6	8	14	42	16	4
		χ^2	1.1	3.6	2.3	0.5	0.3	0	0.4
		P	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
GSI									
Adults only	F	mean	7.6	1.8	3.9	1.1	1.9	1.4	1.4
		s.d.	7.3	–	5.8	1.0	1.0	0.5	1.3
	M	mean	0.3	0.2	0.2	0.1	0.1	0.1	0.1
		s.d.	0.3	0.2	0.1	0.1	0.1	0.1	0.1
	F+M	mean	3.5	0.5	1.6	0.7	1.1	0.8	0.9
		s.d.	5.9	0.7	3.7	0.9	1.2	0.8	1.2
GMSI									
Adults only	F	mean	4.1	4.0	3.0	2.3	2.9	2.3	2.2
		s.d.	0.7	–	2.0	0.9	0.8	0.4	1.0
	M	mean	2.8	2.9	2.3	1.8	2.1	2.1	2.0
		s.d.	0.4	1.0	0.9	0.6	0.6	0.7	0.8
	F+M	mean	3.8	3.1	2.5	2.1	2.5	2.2	2.1
		s.d	0.8	1.0	1.3	0.8	0.8	0.6	0.9

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant ($P > 0.05$); * = $0.01 < P < 0.05$; ** = $0.001 < P < 0.01$; s.d. = standard deviation.

189 van Zweiten (1995) found that *G. gjellerupi* from the Sepik-Ramu basin in PNG had no seasonality in its reproduction, although peaks occurred due to local conditions. Reproductive activity and/or survival was considered to be directly related to floods: prolonged periods of environmental stability, such as those occurring during periods with less rainfall, seemed to be conditional for the survival of juveniles.

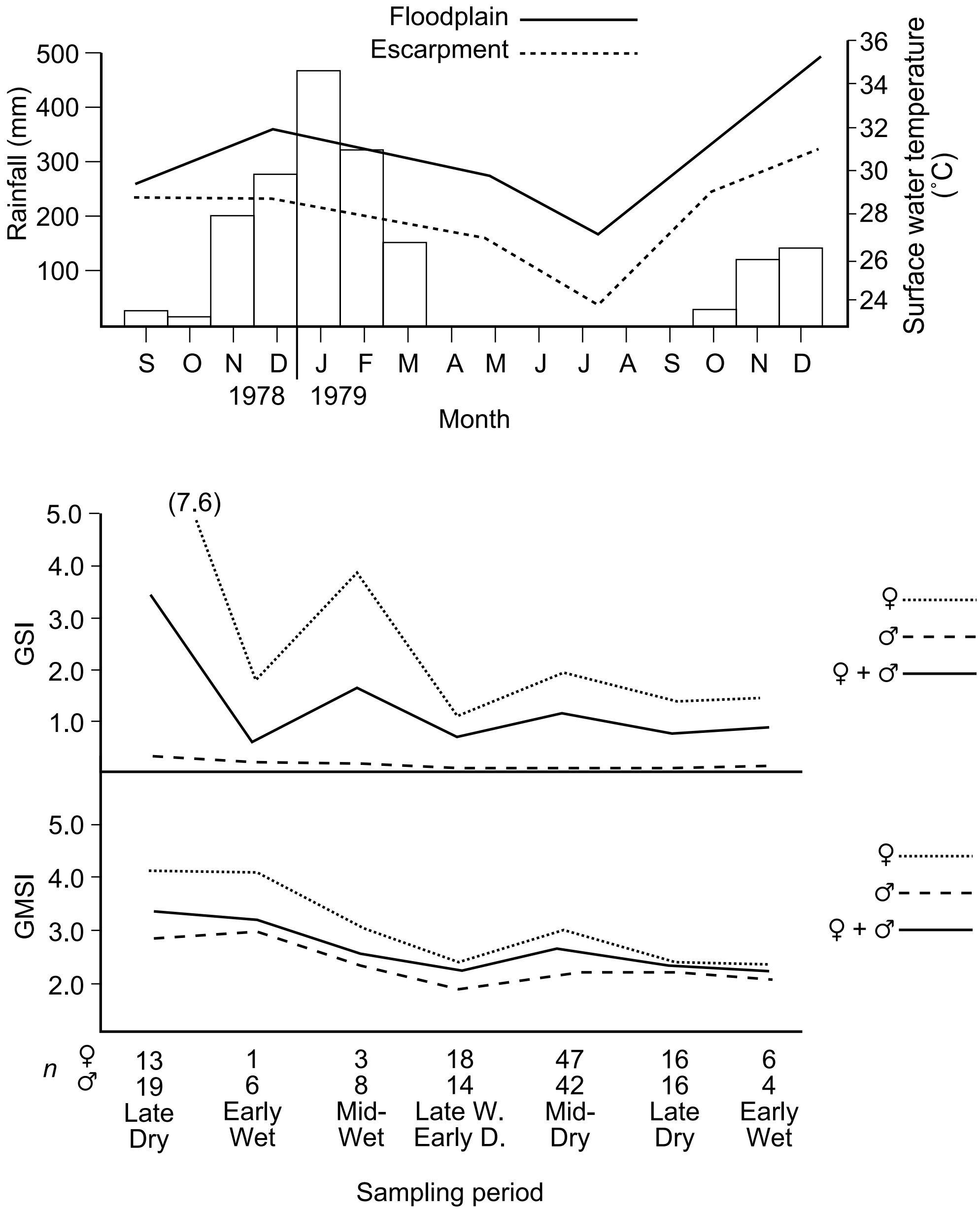


Figure 136 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *G. aprion*

GSI peaked in the 1978 Late-dry and 1978–79 Mid-wet seasons, while the GMSI was slightly high from the 1978 Late-dry season through to the 1978–79 Mid-wet season with a very small peak during the 1979 Mid-dry season. Incubating eggs and spent fish were found during the 1978–79 Early-wet and 1979 Mid-dry seasons. Mature fish were found in four seasons from the 1978 Late-dry to the 1979 Mid-dry seasons, excluding the 1978–79 Early-wet season. Juvenile fish, 11–15 mm LCF, were captured during the 1978–79 Mid-wet and 1979 Mid-dry seasons. The minimum temperature of 22°C described by Lake (1978) would not affect spawning activity in the Alligator Rivers Region, as surface water temperatures did not fall below 23°C during the study.

Site of spawning

Male *G. aprion* incubating eggs were found in two lowland backflow billabongs (Coonjimba Billabong and Baroalba Crossing) and in a floodplain billabong (Island Billabong); however, mature and juvenile fish were found over a far wider range of habitats, from escarpment mainchannel waterbodies (Bowerbird Billabong) down to the East Alligator floodplain billabongs (Cannon Hill Billabong). The evidence suggests *G. aprion* may breed throughout its entire preferred range (table 115). One environmental requirement may be lentic conditions where the females can spawn and the males can gather the eggs into its mouth.

Table 115 Possible sites of spawning of *G. aprion* as indicated by the abundance (*n*) of mature, ripe, spent fish, of males buccally incubating eggs, and of small (11–25 mm) juvenile fish

	Gonad stage							
	Mature (V)		Ripe (VI)		Spent (VII)		Males with eggs	Juveniles
Habitat	F	M	F	M	F	M		
Escarpment								
Mainchannel waterbody	–	–	–	–	–	–	–	4
Lowlands								
Backflow billabong	4	–	–	–	–	–	2	33
Corridor	4	–	–	–	–	–	4	24
Floodplain billabong								
Upper	2	1	–	–	1	1	–	–
Lower	1	–	–	–	–	–	–	2

Fecundity

The ovaries of *G. aprion* were bilobed and contained eggs in many stages of development (Plate 3). The ovary was long, and rounded and broader at the anterior end (ie pear-shaped). The most mature eggs were at the anterior end, grading down to tiny undeveloped eggs at the posterior end.

Only the largest size-class of eggs from 6 ovaries were counted. They averaged 250 eggs (range: 136–430; s.d. 98).[190] The number of eggs incubating in the mouths of male fish were 378 (fish length 123 mm LCF, weight 39.3 g) and 188 (108 mm LCF, 20 g) and 416 (no size available);[191] these numbers were not included in the determination of average fecundity as eggs may have been lost into the water upon capture, and males possibly collect eggs from more than one female, as recorded for a marine Apogonid by Ebine (1932, cited in Breder & Rosen 1966).

The diameters of the largest size-class of eggs ranged between 0.8 and 1.78 mm, with most being around 1.5 mm.[192] The diameter range of a less-developed stage of eggs was 0.16–0.25 mm. Eggs are laid in a bundle that appears to be enveloped in a very fine membrane; the eggshell is transparent (Lake 1978). Lake recorded that the eggs have a diameter of about 3 mm, and that they are incubated in the buccal cavity of the male for around two weeks, depending on temperature. Rudel (1934, cited by Breder & Rosen 1966) observed the spawning of *Glossamia gilli* (Steindachner), possibly a subspecies of *G. aprion* (Pollard

190 van Zweiten (1995) found the fecundity (F) of *G. gjellerupi* from the Sepik-Ramu basin in PNG to be correlated with fish size:

$F = -220.0 + 4.59*SL$ ($r=0.95$, $p<0.001$) (SL is standard length in mm)

191 van Zweiten (1995) found the number of eggs in broods held by male *G. gjellerupi* from the Sepik-Ramu basin in PNG varied from 62 to 94 (mean 85.3, n = 8) for fish ranging in length from 72 to 87 mm. Brood size appeared to be related fish size.

192 van Zweiten (1995) found *G. gjellerupi* from the Sepik-Ramu basin in PNG to have ripe eggs with a mean size 3.33 ± 0.54 mm. Eggs in a ripe ovary were all at the same stage of development.

1974), which he collected from a river near Brisbane and kept in a freshwater aquarium. At the time of spawning the male became a light golden colour on the body except below, where it was purple. The first dorsal and pectoral fins were intense black, and the operculum had a black edging. The eye bar was prominent. The female was golden, with dark spots on the body and dusky white fins. The male danced around the female, trembling with head inclined downwards, and finally the female deposited her eggs in one effort. The eggs were in a thin sac-like membrane about 20 mm x 10 mm. The male tore the egg sac apart and took each egg into his mouth separately. Young fishes were seen in the aquarium five weeks later. The male paid no attention to them.

During underwater observations in escarpment perennial streams, fish were seen with very different colouration from that normally seen in netted fish. Distinct orange and black stripes extended from the top of the head anteriorly to the snout, and there were other differences in colour. No ripe fish were captured to verify this as a breeding colouration.

A breeding study of *G. aprion* eggs was attempted; 416 eggs were removed from the mouth of a male fish and placed in a small aquarium in the open air. No heat or air was provided in the tank. The eggs (plate 4a) hatched after a day in the tank (the previous incubation period in the buccal cavity was not known). After an initially high mortality (30% died), to which an early morning temperature of 23°C was most likely a contributing factor, the prolarvae survived and grew from 7 mm when first hatched to over 10 mm in 8 days. The remaining larvae all died during one particularly cold night (the temperature at 7.30 a.m. the next morning was 22°C). Island Billabong, where the eggs were collected, had surface and bottom temperatures of 28 and 27°C, respectively, and thus the eggs had experienced quite a reduction in temperature when initially placed in the tank. The prolarvae were well developed at hatching, with well-formed fins and mouth structure. Vertical bands of pigmentation were visible along the body wall and around the head (plate 4b). The newly hatched fish were quite efficient swimmers and would often swim to the surface of the tank.

Summary

Glossamia aprion exhibits aseasonal reproduction. It may spawn throughout the year, and probably throughout all its preferred habitats. Areas of lentic water for the transfer of eggs from the female to the buccal cavity of the male is most likely an important environmental requirement.

Approximately 250 eggs (diameter around 1.5 mm) are spawned at a time (Breder & Rosen 1966). However, Lake (1978) cites a diameter of 3 mm. Recorded incubation times vary from two weeks (Lake 1978) to five weeks (Breder & Rosen 1966). The prolarvae are well developed at hatching, are about 7 mm long, and do not appear to be guarded by the male (Breder & Rosen 1966). Growth is rapid and the yolk sac is almost completely absorbed after a few days.

The bilobed ovaries of *G. aprion* contained eggs grouped into different stages of development. Those most developed were at the anterior end of the ovary. This characteristic may enable each female to spawn more than once a year. Colour differences in the sexes were observed in this species.

Feeding habits

Overall diet

The stomachs of 557 specimens were examined; 425 contained food. The diet of *G. aprion* is summarised in figure 137; the components are listed in table 116. The main components were aquatic insects (36%), macrocrustaceans (23%) and teleosts (17%). The aquatic insects were mainly baetid mayfly larvae, chironomid larvae and pupae, and chaoborinid larvae. The macrocrustaceans were mainly *Macrobrachium* and some *Caridina*.

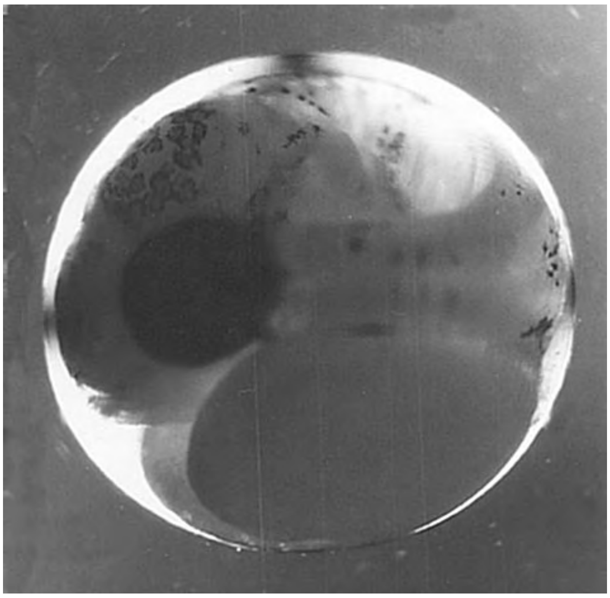
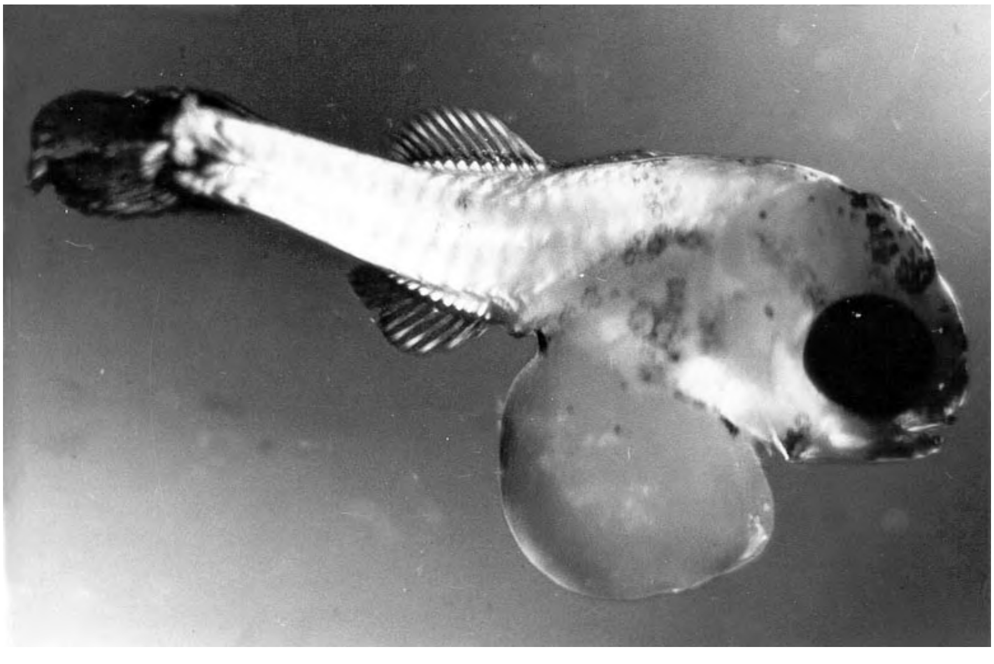


Plate 3 (above) Mature (stage v) ovary from *G. aprion* showing sequential stages of oocyte maturation. Diameter of largest oocytes 1.5 mm; of smallest oocytes 0.2 mm.

a

Plate 4 Stages in the embryonic and larval development of *G. aprion*: (a) fertilised egg x 25, diameter 3.5 mm; (b) newly hatched larva x 25, TL 6.5 mm



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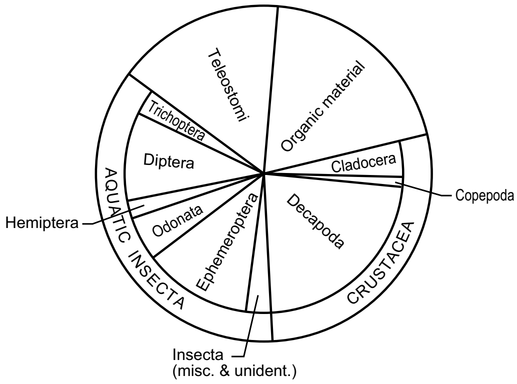

Figure 137 The main component of the diet of *G. aprion*

The three main teleosts of the seven identifiable species were *Ambassis* spp., *M. splendida inornata* and *Craterocephalus* spp. Microcrustaceans (mainly *Diaphanosoma*) were also eaten, as well as traces of algae, hydrophytes, terrestrial plants and animals. Large volumes of unidentifiable organic material, which may have been partly digested fish flesh, were frequently found in the stomachs.[193, 194]

Glossamia aprion can therefore be classified as a macrophagic carnivore feeding opportunistically on benthos and in the midwaters of the waterbodies. Pollard (1974) also noted that it was carnivorous, probably feeding upon small fish, crustaceans and aquatic insects. Lake (1978) commented that this species is carnivorous, and in an aquarium will eat all other fish smaller than itself and any other small moving animals.

Habitat differences [195]

A total of 443 stomachs of *G. aprion* were analysed (all seasons combined) from the Magela Creek catchment: 20 (5% empty) from escarpment mainchannel waterbodies, 10 (40% empty) from lowland sandy creekbeds, 235 (25% empty) from shallow backflow billabongs, 115 (25% empty) from corridor billabongs, and 63 (27% empty) from floodplain billabongs. The highest proportion of fish with empty stomachs were from lowland sandy creekbeds and the lowest proportion from escarpment waterbodies.

Glossamia aprion in the escarpment waterbodies were feeding mainly on aquatic insects (mainly baetids, libellulids and chlorolestids) and small portions of teleosts, microcrustaceans (cladocerans and ostracods) and terrestrial insects. In lowland sandy creekbeds they were also eating mainly aquatic insects (the same odonatans as above plus the mayfly larvae *Atalophlebia* and chironomid pupae), but more teleosts; *M. splendida inornata* was the main identifiable species.

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193 Barlow et al. (1987) indicated that the piscivorous feeding habits of *G. aprion*, which had been translocated to Lake Eacham in north-eastern Queensland, are likely to be responsible for the local extinction of the Lake Eacham rainbowfish *Melanotaenia eachamensis* (*G. aprion* did not occur in the lake beforehand).

194 van Zweiten (1995) found the diet of the closely related *G. gjellerupi* from the Sepik-Ramu basin in PNG to vary in relation to the size of individuals. Fish up to 30 mm fed predominantly on small benthic insect larvae. Fish larger than 60 mm were carnivorous top predators, feeding predominantly on crabs, bottom dwelling fish and large terrestrial insects. Fish of all sizes, except the largest, fed on caridinid prawns.

195 van Zweiten (1995) found the diet of *G. gjellerupi* from the Sepik-Ramu basin in PNG to vary between habitats depending on the local conditions. The most obvious differences occurred between large rocky streams with high flow rates and small muddy streams with lower flow rates. In this habitat order, the proportions of food from terrestrial sources decreased and caridinid prawns increased.

Table 116 Dietary composition of *G. aprion*

	Habitat							Season							Overall	
	Magela system					Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Em	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants																
Algae																0.1
Conjugatophyta																
Mougeotia	–	–	–	–	1.3	–	–	–	–	–	–	0.6	–	–	0.1	
Hydrophytes																+
Najas	–	–	–	–	–	–	0.3	–	–	–	–	0.1	–	–	+	
Aquatic animals																
Microcrustacea																4.4
Conchostraca																
Cyzicus	–	–	–	–	–	–	2.6	–	–	–	–	–	2.3	–	0.2	
Cladocera																
Miscellaneous	–	–	0.2	2.8	–	–	–	0.5	6.0	–	–	–	–	–	0.7	
Diaphanosoma	2.1	–	1.9	7.8	0.3	–	–	–	16.8	0.8	0.5	2.8	–	–	2.5	
Ostracoda	2.1	–	–	–	–	–	–	–	–	1.3	–	–	–	–	0.1	
Copepoda	0.3	–	0.6	0.8	–	–	5.3	–	1.8	2.2	2.3	–	–	–	0.9	
Macrocrustacea																22.8
Phreatoicidea	–	–	–	–	–	5.7	–	–	–	–	–	0.8	–	–	0.2	
Macrobrachium (juv)	–	–	9.9	41.6	34.8	14.3	21.1	2.4	1.0	6.3	–	–	–	–	1. 3	
Macrobrachium (adults)	–	–	2.3	0.4	2.2	–	–	45.9	22.5	10.2	9.2	17.9	21.9	6.3	21.3	
Insecta																36.1
Fragmented	7.9	–	3.0	1.2	3.7	–	–	4.5	2.5	3.1	3.5	0.9	4.0	–	2.8	
Ephemeroptera																
Baetidae	17.6	–	16.7	6.2	0.1	20.0	17.4	6.8	2.3	18.4	16.2	19.7	–	5.6	12.1	
Atalophlebia	4.7	16.7	–	–	–	–	–	–	2.5	–	–	–	–	5.6	0.5	
Tasmanocoenis	–	–	–	–	–	4.3	–	–	–	–	–	0.6	–	–	0.1	
Odonata																
Chlorolestidae	9.0	–	–	–	–	–	–	–	–	3.5	–	–	–	–	0.4	
Coenagrionidae	–	16.7	–	1.2	–	–	–	–	5.0	–	–	–	–	–	0.5	
I. heterosticta	4.7	–	3.3	–	2.5	–	–	–	–	8.1	3.6	–	–	5.6	1.9	
Libellulidae	10.5	16.7	1.4	0.5	–	8.6	–	–	2.5	7.1	3.5	0.6	–	–	1.9	

Table 116 continued

	Habitat							Season							Overall	
	Magela system					Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Em	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Hemiptera																
Naucoridae	–	–	0.6	–	–	–	0.3	–	–	–	–	1.0	–	–	0.3	
Corixidae	6.8	–	2.5	0.5	5.0	2.1	–	0.7	0.3	6.9	4.0	1.2	–	6.3	2.3	
Coleoptera																
Miscellaneous (adults)	–	–	0.7	–	–	–	–	–	–	–	0.2	–	2.3	–	0.3	
Miscellaneous (larvae)	4.5	–	0.2	–	–	–	–	–	1.0	1.8	–	–	–	–	0.3	
Diptera																
Tipulidae	0.3	–	–	–	–	–	–	–	–	–	–	–	–	0.3	+	
Culicidae	–	–	0.6	–	–	–	–	–	–	2.1	–	–	–	–	0.2	
Chaoborinae	–	–	1.3	–	–	–	–	–	5.0	1.7	0.3	–	–	50.0	2.6	
Chironomidae (larvae)	4.7	–	1.6	7.4	4.5	2.9	7.9	8.9	2.3	3.3	4.7	1.3	6.3	1.9	4.4	
Chironomidae (pupae)	5.3	16.7	1.7	4.2	1.9	8.6	7.9	3.1	–	–	2.1	6.8	4.7	–	3.2	
Ceratopogonidae	–	–	0.3	–	–	–	–	0.2	–	–	–	–	0.7	–	0.1	
Trichoptera																
Leptoceridae	–	–	3.2	1.2	–	–	3.7	–	3.3	1.9	0.8	3.2	4.7	–	3.2	
Teleostomi																16.9
Fragmented	9.0	16.7	12.6	6.5	10.8	14.3	10.5	5.9	12.5	9.4	10.4	12.3	14.0	–	10.0	
Scale	–	–	0.1	–	–	–	–	–	–	–	–	1.0	0.5	–	0.1	
Miscellaneous (larvae)	5.0	–	0.6	1.2	–	–	–	–	–	–	1.2	1.0	–	5.9	0.7	
N. erebi	–	–	0.5	–	–	–	–	–	2.0	–	–	–	–	–	0.2	
M. splendida inornata	–	16.7	0.6	1.2	–	–	2.6	–	5.0	–	1.2	0.9	–	–	0.9	
Craterocephalus spp.	–	–	0.6	0.5	4.4	–	–	3.5	1.0	–	–	–	–	–	0.8	
C. marianae	–	–	–	–	–	–	–	1.2	–	–	–	–	–	–	0.2	
P. tenellus	–	–	–	–	1.7	–	2.4	–	–	1.9	0.9	–	–	–	0.4	
Ambassis spp.	–	–	5.1	1.2	–	–	2.4	4.7	–	–	3.5	4.6	–	–	2.8	
A. agrammus	–	–	0.6	–	–	–	–	1.2	–	–	–	–	–	–	0.2	
Glossogobius spp.	–	–	0.6	–	–	–	–	–	–	–	–	–	–	6.3	0.2	
Egg material	–	–	–	1.1	–	–	–	–	–	–	–	–	2.1	–	0.2	
Glossamia spp. eggs	–	–	0.6	–	–	–	–	–	2.5	–	–	–	–	–	0.2	

Table 116 continued

	Habitat							Season							Overall	
	Magela system					Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Em	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Terrestrial plants																
Angiospermae																0.3
Miscellaneous	–	0.5	–	–	–	–	–	0.6	–	–	–	–	1.9	–	0.3	
Terrestrial animals																
Insecta																0.4
Fragmented	5.3	–	–	–	–	–	–	–	–	–	–	–	–	6.3	0.2	
Trichoptera	–	–	–	–	–	5.0	–	–	–	–	–	0.7	–	–	0.2	
Parasites																0.5
Cestoda	–	–	0.5	–	–	–	–	–	–	1.7	–	–	–	–	0.2	
Nematoda	–	–	–	–	–	–	–	1.3	–	–	–	–	–	–	0.3	
Inorganic material	0.3	–	0.6	–	–	–	–	1.2	–	0.1	–	–	–	–	0.2	0.2
Organic material	–	–	25.1	12.8	27.0	14.3	15.8	7.5	2.5	8.3	32.2	22.9	34.9		18.5	18.5
Number of empty fish	1	4	58	29	17	3	12	18	7	10	26	49	19	3	132	132
Number of fish with food	19	6	177	86	46	14	38	85	40	48	87	106	43	16	425	425

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creek bed; Bb = lowland backflow billabongs; Cb = corridor billabongs; Fb = floodplain billabongs

In the lowland backflow billabongs the diet was more varied (possibly due to the larger sampling effort), with mainly equal proportions of aquatic insects (mainly baetids) and teleosts (mainly *Ambassis* spp., but also *N. erebi, M. splendida inornata, Craterocephalus* spp.and *Glossogobius* spp.), and some macrocrustaceans (*Macrobrachium* and *Caridina*) and microcrustaceans. Partly digested *Glossamia* eggs, which had been buccally incubating, were also found in the stomachs along with large volumes of unidentified organic matter. In the corridor waterbodies the diet was based mainly on macrocrustaceans (mainly *Caridina* and *Macrobrachium*) and fairly equal proportions of aquatic insects (mainly chironomid larvae and pupae), microcrustaceans (mainly the cladoceran *Diaphanosoma*) and teleosts (*Ambassis* spp., *M. splendida inornata* and *Craterocephalus* spp. were identifiable). In the floodplain billabongs the diet was similar, with the main differences being the larger proportions of unidentified organic matter, and the lack of microcrustaceans. *Craterocephalus* spp. and *Pseudomugil* spp. were the main identifiable teleosts eaten.

Catchment differences

The stomach contents of 67 specimens were analysed (all seasons combined) from Nourlangie Creek catchment: 17 (18% empty) from lowland sandy creekbeds and 50 (24% empty) from shallow backflow billabongs. These levels of emptiness were similar to those of fish in the Magela system.

In the lowland sandy creekbeds the diet was based primarily on aquatic insects (mainly baetids, libellulids and chirinomid larvae and pupae) and significant portions of macrocrustaceans (mainly *Caridina* and phreatoicids), teleosts and terrestrial insects. This diet is most similar to that in the backflow billabongs in the Magela catchment. In the backflow billabongs of the Nourlangie catchment the diet was also similar to that in the Magela catchment, but was more varied. It included aquatic insects (mainly baetids and chironomids), macrocrustaceans (*Caridina*), teleosts (*M. splendida inornata, P. tenellus* and *Ambassis* spp.), microcrustaceans, and traces of incidentally ingested hydrophytes (*Najas*).

Seasonal changes

In sampling periods 1 to 7, respectively, 103 (17% empty), 47 (15% empty), 58 (17% empty), 113 (23% empty), 155 (32% empty), 62 (31% empty) and 18 (17% empty) stomachs were analysed (all habitats combined). The highest proportion of fish with empty stomachs were found in the 1979 Mid- and Late-dry seasons, while all other seasons had fairly equal proportions of fish with empty stomachs.

In the 1978 Late-dry season the diet was based mainly on macrocrustaceans (*Macrobrachium* and *Caridina*), with aquatic insects (mainly chironomids and baetids), teleosts (mainly *Ambassis* spp. and *Craterocephalus* spp.) and traces of microcrustaceans and terrestrial plant material. During the 1978–79 Early-wet season *G. aprion* ate fewer macrocrustaceans but ate microcrustaceans (mainly *Diaphanosoma*) and more teleosts (mainly *N. erebi, M. splendida inornata* and *Craterocephalus* spp.). In the Mid-wet season the microcrustacean component was smaller, as were the macrocrustacean and teleost components; the aquatic insects therefore dominated the diet in this season, with baetids, *Ischnura heterosticta* larvae, libellulid larvae and corixids being most commonly found in the stomachs.

By the Late-wet–Early-dry season a large unidentified organic material component — possibly partly digested fresh fish — was present in the diet. It persisted to the 1979 Late-dry season and then disappeared.

The diet at the end of the Wet season consisted mainly of aquatic insects (mainly baetids), teleosts (*M. splendida inornata, Ambassis* spp. and *P. tenellus*), macrocrustaceans

(*Macrobrachium*) and traces of microcrustaceans. In the Mid-dry season the diet became more varied, though baetids were still the main food items; however, there were more *Macrobrachium* and teleosts (*Ambassis* spp. and *M. splendida inornata*) and traces of microcrustaceans, algae, hydrophytes and terrestrial plants. In the 1979 Late-dry season *G. aprion* ate mainly macrocrustaceans, as in the 1978 Late-dry season; teleosts and aquatic insects (mainly chironomids) were also present in the stomachs, together with traces of microcrustaceans and terrestrial plant material. In the 1979–80 Early-wet season they ate mainly aquatic insects (mainly chaoborinids), unlike in 1978–79 when microcrustaceans became important in the diet, and also teleosts, *Macrobrachium* and terrestrial insects.

Fullness

A summary of mean fullness indices of *G. aprion* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 117. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 117 Mean fullness indices for *G. aprion* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments

	Sampling period							
Habitat	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	Habitat mean
Magela Creek catchment (regular sites)								
Upstream of RUPA:								
Escarpment main-channel waterbody	n/s	n/s	2.2 (14)	n/s	0 (1)	n/s	3.2 (5)	2.3 (20)
Lowland shallow backflow billabong	3.4 (11)	n/s	3.4 (8)	n/s	0.9 (7)	1.4 (10)	n/s	2.4 (36)
Downstream of RUPA:								
Lowland sandy creekbed	n/s	4.0 (5)	n/s	0 (2)	0.3 (3)	n/s	n/s	2.0 (10)
Lowland channel backflow billabong	0 (1)	4.0 (3)	2.3 (12)	1.6 (24)	1.1 (27)	0.5 (14)	0.7 (3)	1.8 (84)
Lowland shallow backflow billabong	2.3 (6)	2.5 (6)	1.2 (6)	1.8 (37)	1.5 (47)	0.9 (12)	0 (1)	1.6 (115)
Corridor sandy billabong	3.0 (10)	2.5 (2)	0 (1)	n/s	1.0 (10)	0 (1)	n/s	1.9 (24)
Corridor anabranch billabong	1.7 (3)	n/s	n/s	0.7 (3)	2.3 (10)	2.0 (4)	n/s	1.9 (20)
Floodplain billabong	2.4 (36)	3.0 (25)	1.5 (2)	1.4 (34)	1.5 (24)	1.0 (14)	n/s	1.9 (135)
Nourlangie Creek catchment (regular sites)								
Lowland channel backflow billabong	2.8 (5)	0 (1)	1.8 (4)	0.8 (10)	2.0 (10)	1.7 (7)	n/s	1.7 (37)
Lowland shallow backflow billabong	2.0 (5)	0 (1)	0 (1)	n/s	2.2 (6)	n/s	n/s	1.8 (13)
Lowland sandy creekbed	n/s	1.7 (3)	n/s	2.3 (4)	1.9 (10)	n/s	n/s	2.0 (17)
Seasonal mean (all sites)	2.6	3.0	2.1	1.5	1.5	1.1	2.3	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Habitat differences

In the Magela catchment upstream of RUPA, the mean fullness indices were slightly higher than in downstream habitats. Escarpment mainchannel waterbody and shallow backflow billabong indices were very similar.

Downstream of RUPA, the mean fullness indices were much the same across most habitats examined, though slightly lower in the shallow backflow billabongs.

In the Nourlangie catchment, the mean fullness indices were close to those recorded in comparable habitats in the Magela Creek catchment.

Seasonal changes

The mean fullness index (all habitats combined) increased from the 1978 Late-dry season to peak in the 1978–79 Early-wet season. It then fell through the Mid-wet season to stabilise at a lower level during the Late-wet–Early-dry and 1979 Mid-dry seasons. In the 1979 Late-dry season it fell to a much lower level than in the 1978 Late-dry season, but then rose in the 1979–80 Early-wet.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- lowland sandy creekbed; 1978–79 Early-wet season
- lowland channel backflow billabongs; 1978–79 Early-wet season
- lowland shallow backflow billabong (upstream of RUPA); 1978 Late-dry season
- lowland shallow backflow billabong (upstream of RUPA); 1978–79 Mid-wet season

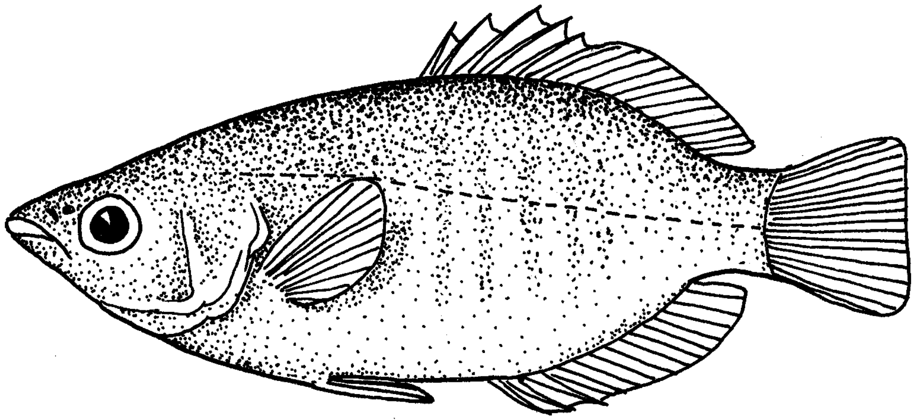
Nourlangie catchment

- lowland channel backflow billabongs; 1978 Late-dry season
- lowland sandy creekbeds; 1979 Late-wet–Early-dry season.

Family TOXOTIDAE

3.30 *Toxotes lorentzi* (Weber)

Toxotes lorentzi is commonly known as the primitive archer fish. It has been reported in the Northern Territory only in the Timor Sea drainage (map 3) at Yam Creek (Daly River system) by Whitley (1959), the Finniss River (below Rum Jungle) by Jeffree and Williams (1975), and at Sawcut, Deaf Adder and Baroalba Creeks (South Alligator River system) by Midgley (1973). W Rooney (pers comm) collected one specimen from Nourlangie Rock Billabong (NR) during the 1979–80 Wet season. *Toxotes lorentzi* is known from the Merauke River and the vicinity of Balimo in the central portion of southern New Guinea (Allen 1978b).[196]



Toxotes lorentzi

Information on catches at each site and in each season is given in volume 2. Only two specimens were captured: one from an escarpment mainchannel waterbody (Camp 1, Deaf Adder Creek) and another from a lowland channel backflow billabong (Baroalba Crossing) of the Nourlangie Creek systems; many specimens were observed in an escarpment perennial stream (Baroalba Springs) in this catchment.

Size composition

The length and weights of two specimens were determined. The smallest specimen (110 mm LCF) was captured in the Mid-wet season in a channel backflow billabong (Baroalba Crossing), and the largest (230 mm LCF) in the 1978 Late-dry season in an escarpment mainchannel waterbody (Deaf Adder). Smaller specimens (80–90 mm LCF) were observed in an escarpment perennial stream during the Mid-wet and Late-wet–Early-dry seasons.

Allen (1978b) examined specimens ranging from 69–150 mm TL in a recent taxonomic revision of the Toxotidae, and Lake (1971) recorded that *T. lorentzi* grew to only 140 mm. The largest specimen captured during the present study is thus the largest *T. lorentzi* recorded.

196 Allen (1991) noted that *T. lorentzi* is widespread in the Fly River delta area. In PNG it inhabits swamps and well-vegetated margins of streams.

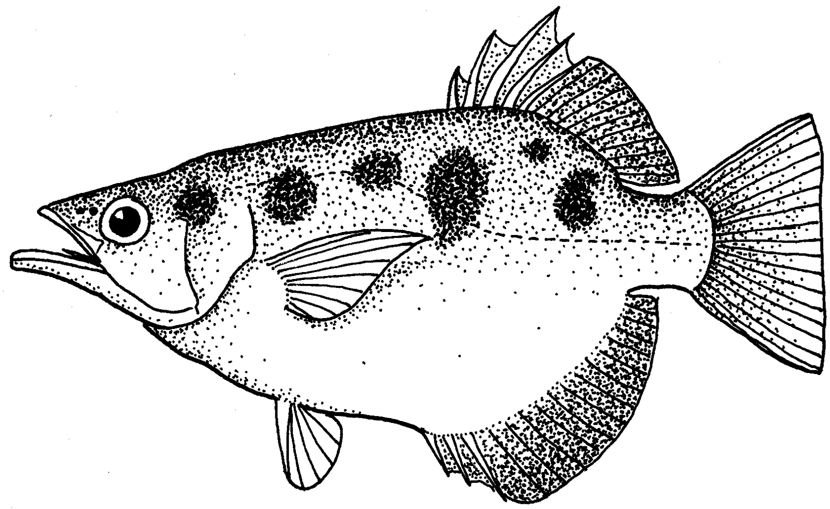
Feeding habits

No stomachs of *T. lorentzi* were examined in the present study. No literature on its feeding habits was found. However, *T. lorentzi* was observed to eject an aqueous bullet when preying upon small insects on overhanging terrestrial vegetation (W. Rooney, pers comm). This species is generally observed in surface waters, and probably has large terrestrial insect component in its diet, as does *T. chatareus*.

Family TOXOTIDAE

3.31 *Toxotes chatareus* (Hamilton-Buchanan)

Toxotes chatareus, commonly called archer fish or riflefish or seven spot[197] archerfish, has a relatively widespread distribution. The coastal populations in northern Australia extend approximately between Derby in WA and Townsville on the Pacific coast of Queensland. Freshwater populations are distributed in river systems flowing into the Timor and Arafura seas and the Gulf of Carpentaria (Allen 1978b). *Toxotes chatareus* is capable of penetrating far inland: Lake (1971) reported finding it 200 km up the Gregory River in northern Queensland; Pollard (1974) noted that it appeared to be common in all permanent freshwaters in the Region; Miller (in Taylor 1964) found many specimens in large billabongs in the Oenpelli area. It is also recorded from India, Sri Lanka, Malay Peninsula, Thailand, Vietnam, Singapore, Sumatra, Borneo and Papua New Guinea.[198]



Toxotes chatareus

Detailed information on catches at each site and in each season are given in volume 2. In summary, this species was found commonly in corridor and escarpment mainchannel waterbodies, and in most floodplain and backflow billabongs and sandy creekbed habitats. Specimens were found in escarpment perennial streams only in the Nourlangie Creek system; they were found in lower riverine floodplain billabongs and tidal and estuarine middle/lower reach habitats of the East Alligator River. In the 1978 Late-Dry season it was captured in only 6 sites (mainly escarpment mainchannel and corridor waterbodies); during the Mid-wet it had dispersed to 13 sites (with notable colonisation of backflow billabongs and floodplain billabongs); and by the Late-wet–Early-dry season it was found in 14 sites (sandy creekbed habitats, lowland backflow billabongs, and corridor and escarpment mainchannel waterbodies).

197 Archerfish have a series of six to seven alternating large and small black blotches along the sides of the body (Herbert & Peeters 1995).

198 Allen (1991) indicated that in PNG *T. chatareus* has only been recorded from southern drainages at numerous localities between the Purari River area and Bintuni Bay, including Lake Jamur. It inhabits brackish mangrove estuaries and freshwater streams. It is frequently found well inland, for example as far as 800 km upstream in the Fly River.

Size composition

The lengths and weights of 290 specimens were determined. *Toxotes chatareus* was captured by seine nets (10 mm mesh), gillnets and dipnet; underwater observations indicated that for a given clear water sampling site, the specimens captured by the various netting methods reflected those observed in the waters. In the 1978–79 Early-wet season large numbers of juveniles were observed in surface waters; these were captured in dipnet trawls.

Length–weight relationship

The length–weight relationship for the sexes combined was described by the following expression:

$$W = 2.1 \times 10^{-2} L^{2.97} \qquad r = 0.99 \text{ (length in cm, weight in g)}$$

Haines (1979) gave the following length–weight expression (using the same units) for *T. chatareus* captured in the Purari River, Papua New Guinea.

$$W = 1.1 \times 10^{-2} L^{3.14}$$

Seasonal mean lengths, weights and condition factors are shown in table 118. The seasonal condition factor was very high during the 1978 Late-dry season and then fell to unity (probably due to spawning activity) by the 1978–79 Early-wet season. Condition remained stable through the Mid-wet and Late-wet–Early-dry seasons and then fell dramatically during the 1979 Mid-dry season, when mostly juveniles were captured. It improved into the 1979 Late-dry (probably because more adults were captured from escarpment mainchannel waterbodies) but did not reach the level recorded in the 1978 Late-dry season. Environmental conditions in the 1978 Dry season were more favourable to condition than in the 1979 season.

Table 118 Mean length, mean weight and condition factor for *T. chatareus*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	37	171.6	101.03	1.05
Early-wet (1978–79)	60	149.3	65.26	1.00
Mid-wet	61	82.5	10.89	1.00
Late-wet–Early-dry (1979)	38	79.2	10.02	1.00
Mid-dry	18	105.0	22.38	0.76
Late-dry	15	174.2	96.88	0.95
Overall	229	115.5	30.14	1.00

Length-frequency distribution

Specimens ranged in length from 4 mm LCF to 307 mm LCF (fig 138). The largest specimen known (400 mm TL) was captured by Roberts (1978) from the Fly River catchment, Papua New Guinea; the smallest specimen recorded by Roberts was 8 mm TL. Haines (1979) captured *T. chatareus* ranging in lengths from 80 to 330 mm TL in the Purari River, Papua New Guinea.

The mean length of all specimens captured was 115 mm LCF. The length at first sexual maturity was found to be 180–190 mm LCF, indicating that most of the fish captured were small juveniles. There are three major peaks in the length-frequency distribution, with modes at 20, 90 and 222 mm LCF. Few specimens between 110 and 200 mm LCF were captured.

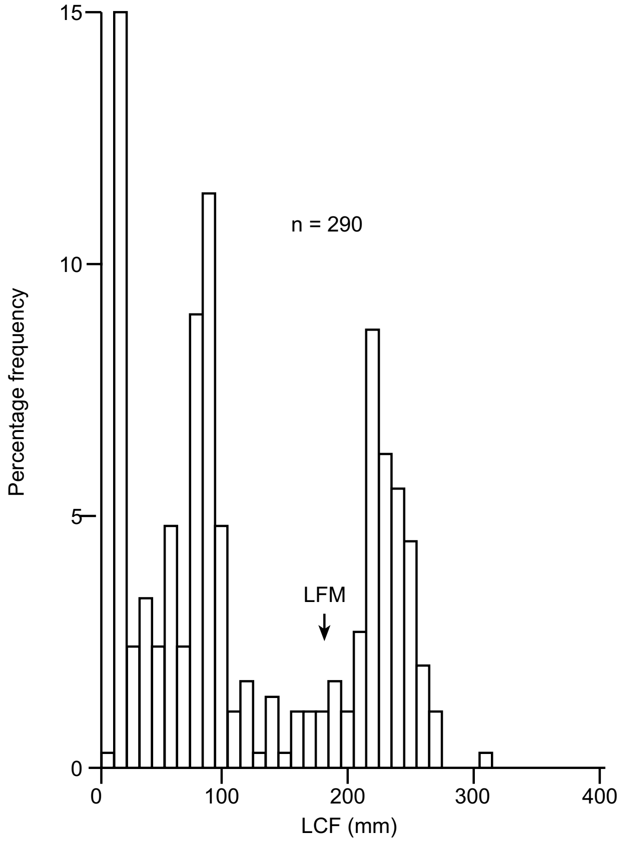


Figure 138 Length-frequency distribution of all *T. chatareus* captured

Seasonal changes in distribution

Seasonal length-frequency distributions of all *T. chatareus* captured are given in figure 139.

Most of the smallest juveniles were captured during the 1978–79 Early-wet season; a few were also caught during the Late-dry seasons (especially in 1978). The juveniles therefore appear to recruit to the populations mainly during the Early-wet season, though small numbers may be recruited in the Late-dry season (juveniles were observed even during the 1979 Mid-dry season).

The largest adult specimen was captured in the 1979 Late-dry season, but all other seasons except the Late-wet–Early-dry season had similar-sized specimens. During the Late-wet–Early-dry season no adults were sampled (so they were presumably in an unsampled habitat) and the largest specimen captured was 160 mm LCF.

The mean seasonal lengths of all specimens captured are shown in table 118. The mean lengths decreased slightly during the 1978–79 Early-wet season and reduced even further in the ensuing two seasons to reach a low by the Late-wet–Early-dry season when the juvenile recruits became more common in the populations. The mean lengths then increased through the following 1979 Mid-dry season, and by the 1979 Late-dry season they were similar to those recorded in the Late-dry 1978. The increase in mean lengths may have been caused by the growth of the juveniles and the increased catchability of adult specimens.

Growth rate

No published information on growth studies of *T. chatareus* could be found. Growth rates can be estimated for the juveniles spawned in the 1978–79 Early-wet season by following the progression of their size class (A on fig 139) throughout the remainder of the study. Growth appears to be fastest during the Wet season, with specimens attaining 70–90 mm LCF by the

Late-wet–Early-dry season (period of about 6 months). For the remainder of the Dry season, growth appears to be very slow, with only a further 10–20 mm being attained by the 1979 Late-dry season. The growth and survival of juveniles in the 1979 Dry season appears to be less than that recorded for juveniles spawned in the 1977–78 Early-wet season (B on fig 139).

Juveniles therefore do not appear to attain the LFM by the end of their first year; they probably spawn by the end of their second year.

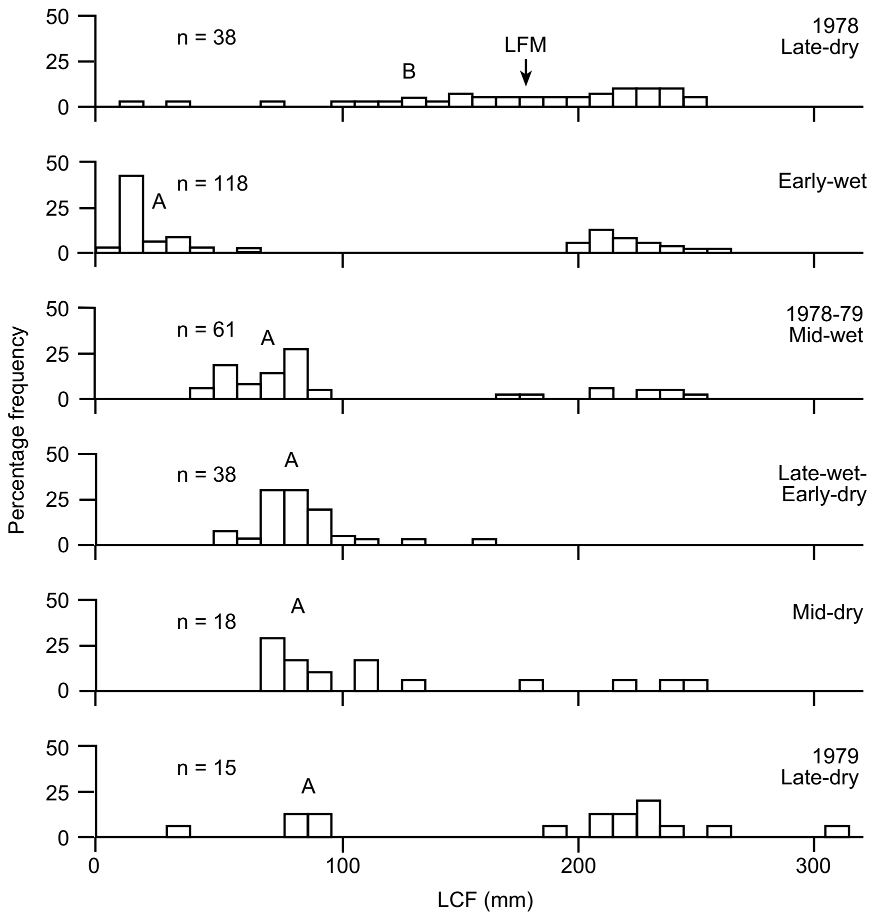


Figure 139 Seasonal length-frequency distribution of all *T. chatareus* captured

Habitat differences in distribution

The habitat preferences of all *T. chatareus* captured in regular sampling sites in the Magela and Nourlangie Creek catchments are shown in figure 140.

Magela catchment

The smallest juveniles were found mainly in lowland shallow backflow billabongs, although a few were found in escarpment mainchannel waterbodies. The few large juveniles that were collected were found in lowland channel backflow billabongs and, to a lesser extent, in corridor anabranch billabongs. Medium-sized juveniles were found mainly in channel backflow and shallow backflow billabongs, and to a lesser extent in floodplain billabongs (these may have been swept downstream by the Wet season flow) and sandy creekbeds upstream and downstream of RUPA.

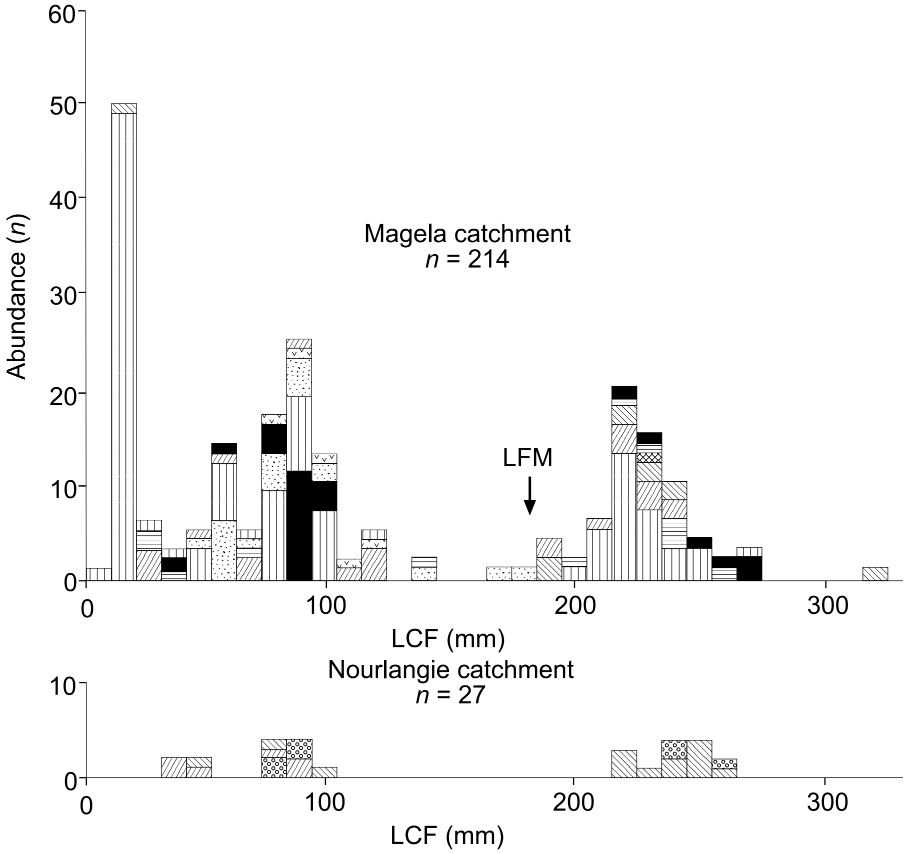


Figure 140 Length-frequency distribution and habitat preferences of all *T. chatareus* captured at regular sampling sites (see appendix 5 for key to the habitats)

The largest adult was found in an escarpment mainchannel waterbody. Most of the small adults were found in lowland shallow backflow billabongs, and a few in lowland sandy creekbeds and escarpment mainchannel waterbodies. Some small adults were also found in floodplain and corridor waterbodies.

Nourlangie catchment

Small- to medium-sized juveniles were found in sandy creekbeds, shallow backflow billabongs and in escarpment mainchannel waterbodies. Juveniles also appeared in escarpment perennial streams during the Wet season.

Adults were found mainly in escarpment mainchannel waterbodies and, to a lesser extent, in lowland shallow backflow billabongs. Some adults were observed in the lower reaches of an escarpment perennial stream during the 1979 Mid-dry season.

Environmental associations

Rank numbers for *T. chatareus* for the physico−chemical and habitat−structural parameters are shown in table 155.

Physico–chemical variables

Temperature

Toxotes chatareus was found in waters with surface temperatures ranging from 26 to 36°C (mean = 30.8°C), and with bottom temperatures ranging from 24[199] to 34°C (mean 29.5°C).

199 Merrick and Schmida (1984) indicate that *T. chatareus* can withstand temperatures down to 17°C.

These mean temperatures were close to the median values for all species studied, and both ranked at the base of the upper-middle quarter (see fig 170). Tolerance to this range of water temperature is indicative of the wide distribution of the species, from brackish-estuarine waters and river mouths to escarpment streams (Pollard 1974).

Dissolved oxygen

Dissolved oxygen concentrations in waters from which *T. chatareus* was captured ranged from 4.3 to 9.7 mg/L (mean = 6.3 mg/L) on the surface and from 0.2 to 7.4 mg/L (mean = 4.0 mg/L) on the bottom. These means ranked in the upper-middle and lower-middle quarters respectively (see fig 171).

Visibility

Secchi depths recorded in waters from which *T. chatareus* were captured ranged widely from 1 to 360 cm, with a mean of 83 cm (see fig 172). This mean was ranked at the base of the upper-middle quarter. This species was very pale in colouration when taken from highly turbid waters.

pH

Toxotes chatareus was found in waters with pH values ranging from 4.6 to 7.2 (mean = 6.1) on the surface, and from 4.8 to 7.3 (mean = 5.8) on the bottom (see fig 173). These means were both ranked at the base of the lower-middle quarter, indicating a slight tendency to be found in more acidic waters.

Conductivity

Conductivity values for waters in which *T. chatareus* were found ranged from 2 to 420 µS/cm in surface waters, and from 2 to 440 µS/cm in bottom waters. This species' tolerance of wide salinities has been reported by Pollard (1974) and Mees and Kailola (1977), who found it in waters ranging from brackish coastal to fresh inland. In the present study, specimens of *T. chatareus* were found in the East Alligator River in waters with salinity levels of up to 18 ppt.[200]

Habitat–structural variables

Substrate

In accordance with its wide distribution, *T. chatareus* was found in association with the entire range of substrate types defined in this study. Sand was the most dominant (upper-middle quarter), followed by mud (lower-middle quarter), then clay, leaves, gravel, rocks and boulders (see fig 174).

Hydrophytes

This species was found in waters with moderate vegetation content (vegetation-occurrence index 67.8%). Submergent vegetation was dominant, followed by emergent then floating hydrophytes. This species usually feeds by dislodging insects from overhanging vegetation (Lake 1971, Pollard 1974), so the presence of bank vegetation may influence the distribution of the species.

Reproduction

A total of 290 *T. chatareus* were captured; the reproductive condition of 284 was examined. A total of 162 were sexually indistinguishable (length range 4–112 mm LCF), 40 were female (82–260 mm LCF) and 82 were male (80–307 mm LCF).

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200 Allen (1991) noted that in PNG breeding populations of *T. chatareus* are known from both fresh and brackish water.

Length at first maturity

The smallest maturing fish found were a 156 mm female and a 120 mm LCF male. As only a small number of medium-sized fish (100–190 mm LCF) were captured, the LFM could not be accurately estimated. High percentages of mature fish were consistently found above 180 mm for males and 190 mm for females, so the LFM was set at those lengths (fig 141).

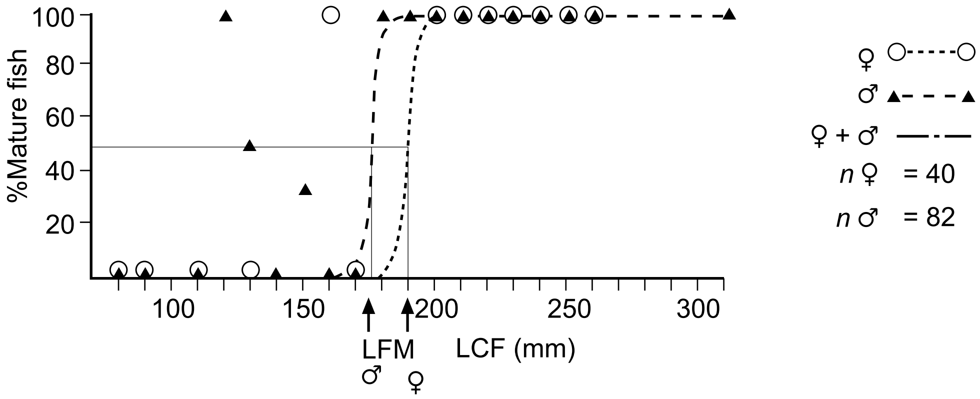

Figure 141 Estimated length at first maturity (LFM) of *T. chatareus*

Sex ratio

Over twice as many males as females were captured during the study. Chi-squared tests for each season on both all fish sampled and the adult fish only (table 119) indicated significantly more males in both samples during the 1978 Late-dry and 1978–79 Early-wet season. Over the entire length range, more males were identified during the 1978–79 Mid-wet season and 1979 Mid-dry season. In all other seasons the sex ratio was not significantly different from 1:1.

Haines (1979) found significantly more males than females in the total sample from the Purari River system; however, when divided into estuarine and riverine samples the deviation from 1:1 in the estuaries was not significant though there was a significant preponderance of males over females in the rivers. Haines suggested that either more males than females move up the rivers or that riverine populations are under some stress that reduces the proportion of females.

Sex ratios (male:female) for other major habitat types in the Magela Creek system, all seasons combined, are as follows:

Escarpment mainchannel waterbodies	2:5
Lowland sandy creekbeds	11:3
Backflow billabongs	28:12
Corridor waterbodies	7:6

A chi-squared test on these ratios found significant differences from a 1:1 ratio in the sandy creek habitats (0.01 <P <0.05) and the backflow billabongs (0.01 <P <0.05) with more males than females in both cases. The ratio was not significantly different from 1:1 in the escarpment area of Magela Creek, but the sample size was small. If the fish captured from the escarpment mainchannel waterbodies in the South Alligator system were added to the data, the ratio becomes 15 males to 13 females.

Table 119 Seasonal changes in sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) for *T. chatareus* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles	F	*n*	8	11	3	3	6	8	1
+ adults	M	*n*	25	37	10	2	0	7	1
		χ^2	8.8	14.1	3.8	0.2	6.0	0.1	0.0
		P	**	***	*	n.s.	*	n.s.	n.s.
Adults only	F	*n*	6	11	3	0	3	5	1
	M	*n*	16	37	9	0	0	6	0
		χ^2	4.5	14.1	3.0	0	3.0	0.1	1.0
		P	**	***	n.s.	n.s.	n.s.	n.s.	n.s.
GSI	F	mean	1.02	5.3	0.5	–	0.4	1.5	4.9
Adults only		s.d.	0.4	2.4	0.1	–	0.1	0.5	–
	M	mean	1.9	1.9	0.5	–	–	1.0	–
		s.d.	3.3	1.4	0.7	–	–	0.3	–
	F+M	mean	1.5	3.6	0.5	–	–	1.2	–
		s.d.	2.6	2.7	0.6	–	–	0.4	–
GMSI									
Adults only	F	mean	3.7	5.0	2.0	–	2.3	4.3	4.0
		s.d.	0.7	0.6	0.	–	0.6	0.5	–
	M	mean	4.7	6.0	2.1	–	–	4.8	–
		s.d.	0.8	0.1	0.1	–	–	1.8	–
	F+M	mean	4.3	5.6	2.0	–	–	4.6	–
		s.d.	0.9	0.5	0.1	–	–	1.3	–

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant (P > 0.05); * = 0.01 < P < 0.05; ** = 0.001 < P < 0.01; *** = P < 0.001; s.d. = standard deviation

Breeding season

Toxotes chatareus appeared to have a well-defined breeding season around the 1978–79 Early-wet season. Gonads began to develop in the 1978 Late-dry season (fig 142). The female GSI had a higher peak during the breeding season than the male. Males showed very little change in GSI from the early development period of the 1978 Late-dry season to the actual spawning period in the Early-wet season. Males have been reported to ripen earlier in the season than females (Midgley 1980). The GSIs for both sexes had dropped to their lowest levels by the following 1978–79 Mid-wet season. Due to the small number of fish collected during the 1979–80 Early-wet season, it could not be determined whether *T. chatareus* was spawning before the onset of the Wet season proper (ie heavy and consistent rains and associated stream flow); however, some juveniles were observed in corridor waterbodies.

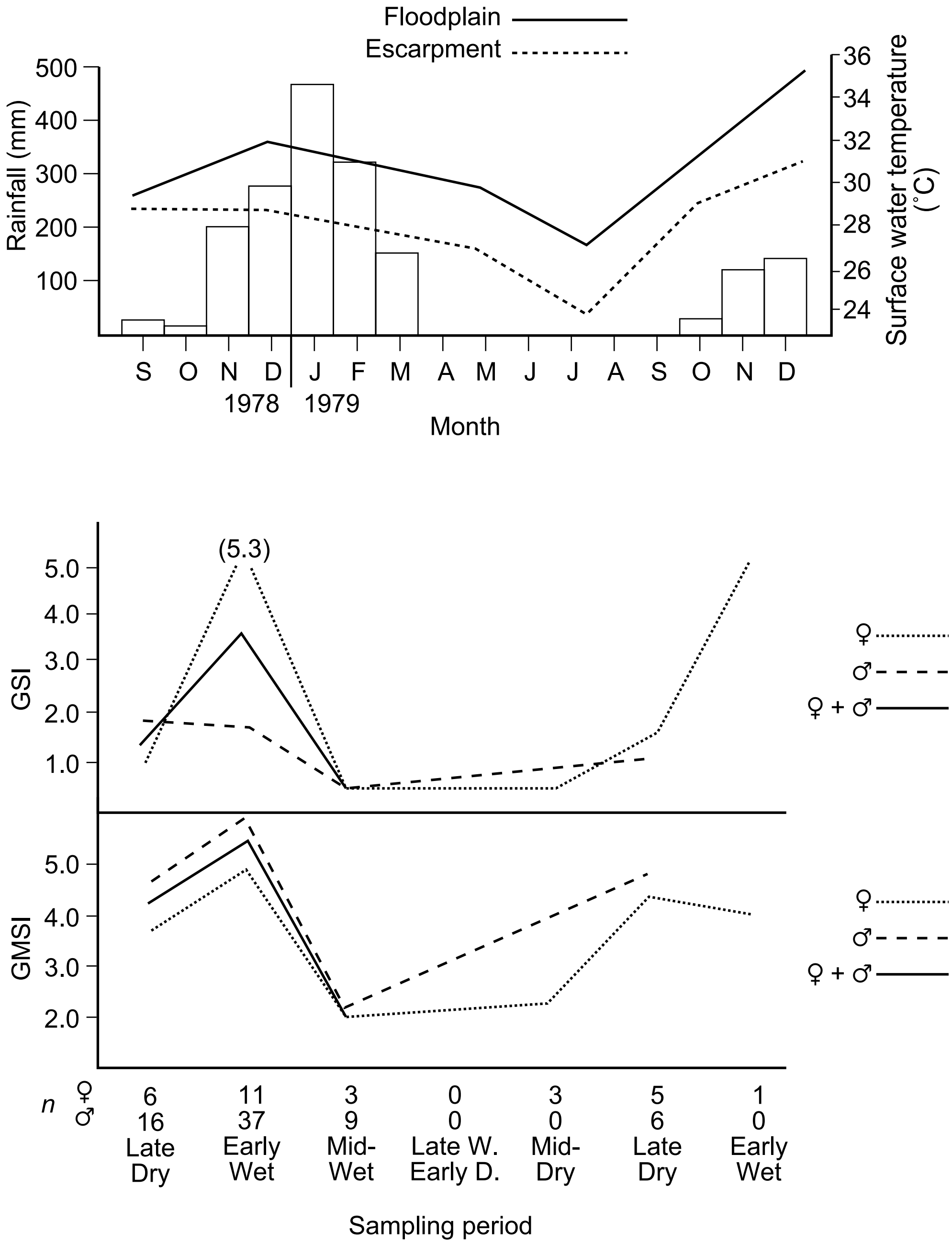

Figure 142 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *T. chatareus*

The occurrence of mature, ripe and spent fish (table 120) confirms an Early-wet season spawning period. Mature females were found during 1978 and 1979 Late-dry and 1978–79 Early-wet seasons, and mature males only during the 1978 Late-dry season. Ripe females were captured only during the 1978–79 Early-wet season and ripe males from 1978 and 1979 Late-dry and 1978–79 Early-wet seasons. Spent males and females were identified during the 1978–79 Mid-wet and one spent male was captured from the 1979 Late-dry; the latter suggests that some spawning may have occurred then. The range of gonad maturity stages is given in table 121.

Large numbers of postlarvae (4 to 7 mm LCF) were collected during the 1978–79 Early-wet season.

Table 120 Possible sites of spawning of *T. chatareus,* as indicated by the abundance (*n*) of mature, ripe, spent and juvenile fish

	Gonad stage						
	Mature (V)		Ripe (VI)		Spent (VII)		Juvenile
Habitat	F	M	F	M	F	M	
Escarpment							
Mainchannel waterbody	2	1	0	2	2	3	0
Lowlands							
Sandy creekbed	1	0	0	7	1	0	3
Backflow billabong	4	3	2	29	0	0	1
Corridor	1	2	0	5	0	1	1
Floodplain billabong							
Upper	1	0	0	0	0	0	0
Artificial	0	0	0	0	0	0	1

Table 121 Range of gonad maturity stages for each 1 cm length size class of *T. chatareus* for each season over all habitats

		Sampling season						
Sex	Length (cm)	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet-Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
F	8–1	–	–	–	i (1)	–	i, ii (2)	–
	9–1	–	–	–	i (1)	–	ii (1)	–
	11	–	–	–	–	i (1)	–	–
	13	–	–	–	i (1)	ii (1)	–	–
	16	iv (1)	–	–	–	–	–	–
	17	iii (1)	–	–	–	–	–	–
	18	–	–	–	–	ii (1)	–	–
	20	iii (1)	vi (1)	–	–	–	–	–
	21	iii (1)	iv, v (3)	vii (1)	–	–	iii, vi (2)	–
	22	iv (1)	v, vi (2)	–	–	ii (1)	iv (1)	iv (1)
	24	–	v (2)	vii (1)	–	iii (1)	–	–
	25	iv (1)	v (1)	–	–	ii (1)	–	–
	26	–	iv, v (2)	–	–	–	v (1)	–
M	8–1	–	–	–	–	–	–	ii (1)
	9–1	–	–	–	–	–	i (1)	–
	11	–	–	–	ii (1)	–	–	–
	12	v (1)	–	–	–	–	–	–
	13	iii, iv (2)	–	–	–	–	–	–
	14	iii (1)	–	–	–	–	–	–
	15	iii, iv (3)	–	–	–	–	–	–
	16	iii (1)	–	–	ii (1)	–	–	–
	17	iii (1)	–	ii (1)	–	–	–	–
	18	iv, v (2)	vi (1)	ii (1)	–	–	–	–
	19	v (1)	vi (1)	–	–	–	vi (1)	–
	20	v (1)	iv, vi (5)	–	–	–	–	–
	21	iii, iv (2)	vi (12)	ii, vii (3)	–	–	vi (1)	–
	22	iii, iv (3)	vi (9)	–	–	–	vi (2)	–
	23	iv, vi (2)	vi (6)	ii, vii (2)	–	–	iv (1)	–
	24	iv, vi (4)	vi, vii (2)	vii (1)	–	–	iv (1)	–
	25	vi (1)	vi (1)	ii (1)	–	–	–	–
	31	–	–	–	–	–	vii (1)	–

Numbers analysed are given in parentheses. F = female; M = male; – = no fish captured.

Midgley (1980) collected large numbers of juveniles (10–15 mm LCF) being carried downstream between mid- to late-January 1980; by early February the downstream drift of small fish had stopped, and fish 20–35 mm LCF were collected in quantity moving back upstream along the edges of the creek.

Gonad development was apparently well advanced by the 1978 Late-dry season, with running ripe males being collected before the ripe females were collected. Spawning generally occurred during the 1978–79 Early-wet season and most likely after the water flow began during late December to January in the 1979–80 Wet season. Stream flow, increase in water level, or changes in environmental conditions (such as food availability), are likely stimuli for final maturation of females and spawning. The males possibly respond to different stimuli than females, such as increased temperature, and therefore having a longer period of gonad maturation. This species has also been reported to exhibit aseasonal reproduction in Papua New Guinea (Roberts 1978).

Site of spawning

Ripe males were collected from a wide range of habitats, from escarpment mainchannel waterbodies through lowland sandy creekbed habitats and shallow backflow billabongs to corridor and floodplain billabongs (table 120). Ripe females, however, were only collected from two backflow billabongs, although spent females were collected from escarpment mainchannel waterbodies and lowland sandy creekbeds.

Large aggregations of adult *Toxotes* were observed at Camp 1 on Deaf Adder Creek, a large escarpment mainchannel waterbody, during the 1978 Late-dry season. No fish from the aggregation were captured and therefore the sex or reproductive condition of the individuals is unknown.

Newly hatched postlarvae (4–7 mm) were collected in large numbers from Gulungul Billabong, and 10–15 mm individuals were collected from shallow flooded grassy flats near the Mudginberri road crossing as they were carried downstream (Midgley 1980). The data suggest that *T. chatareus* was most likely spawning throughout its entire preferred range, particularly in lowland shallow backflow billabongs.

Fecundity

Three ovaries were examined for fecundity data. Egg diameters were relatively constant (0.35 ± 0.042 mm; 0.36 ± 0.052 mm; 0.43 ± 0.07 mm) with an average diameter of 0.4 mm. Egg numbers ranged from 20 000 to 150 000 (mean = 73 300). The eggs are reported to be pelagic (Midgley, pers. comm.). The development of the larvae at hatching is not known; however, larvae about 5 mm long have well-developed fins and mouth parts (Plate 5).

Summary

T. chatareus showed evidence of spawning over its entire distribution, which included most habitats of the Magela system, particularly lowland backflow billabongs, but only one of the four floodplain billabongs (Leichhardt Billabong). Males, possibly responding to a different stimulus (such as temperature) from females, were found running ripe before the females were ripe. Gonad maturation peaked during the 1978–79 Early-wet season, when spawning most likely occurred.

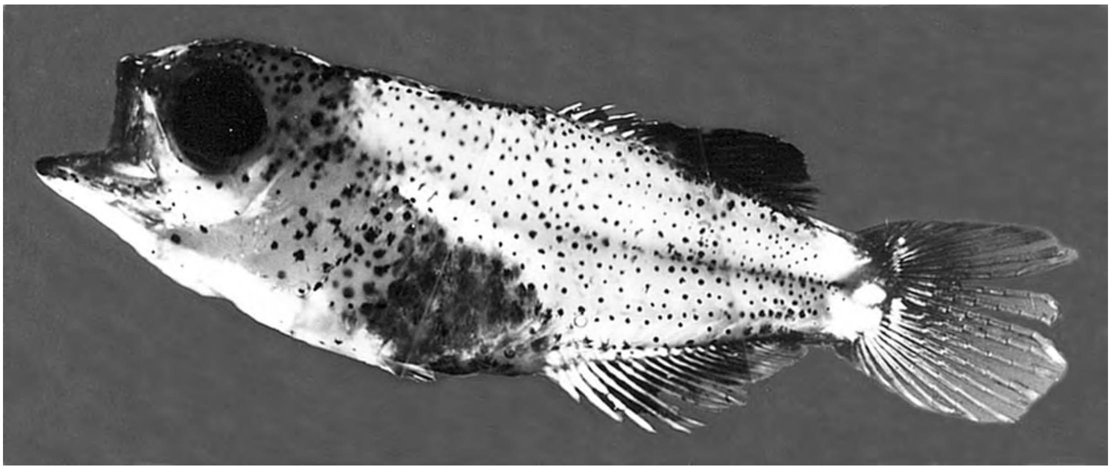

Plate 5 *T. chatareus* larva; TL 7.5 mm x 40

A large number (tens of thousands) of (0.4 mm diameter) eggs are spawned. The eggs are pelagic and tiny larvae less than 4 mm long are produced. The larvae are initially carried downstream with the floodwaters, but when they reach between 15 mm and 20 mm they are able to migrate back upstream.

Feeding habits

Overall diet

The stomachs of 236 specimens were examined; 225 contained food. The diet of *T. chatareus* is summarised in figure 143; the components are listed in table 122. The main components were terrestrial insects (53%) and aquatic insects (42%). The identifiable terrestrial insects were mainly zygopteran and orthopteran adults, ants (*Oecophylla*) and miscellaneous coleopterans. The identifiable aquatic insects were mainly gerrid bugs and miscellaneous coleopterans. Traces of gastropods, aquatic arachnids, micro- and macrocrustaceans, teleosts (*Ambassis* spp.), terrestrial plants and remains of reptiles and bird feathers were also found in the stomachs. *Toxotes chatareus* can therefore be classified as a meiophagic insectivore feeding opportunistically from overhanging terrestrial and aquatic emergent vegetation and the surface and midwaters of the waterbodies.

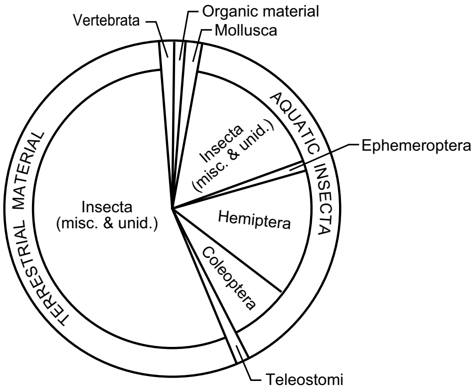

Figure 143 The components of the diet of *T. chatareus*

Table 122 Dietary composition of *T. chatareus*

	Habitat								Season								
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic plants																	
Algae																	+
Miscellaneous	–	–	0.1	–	–	–	–	–	–	–	–	0.1	–	–	–	+	
Aquatic animals																	
Gastropoda																	0.5
Amerianna	–	–	1.3	–	–	–	–	–	–	1.6	–	–	0.6	–	–	0.5	
Arachnida																	0.3
Miscellaneous	–	–	0.6	–	–	–	–	–	–	–	0.9	–	–	–	–	0.2	
Hydracharina	–	–	0.1	–	–	–	–	–	–	–	0.2	–	–	–	–	0.1	
Microcrustacea																	0.4
Conchostraca																	
Miscellaneous	–	–	0.6	–	–	–	–	–	–	0.7	–	–	–	–	–	0.2	
Cyzicus	–	–	–	–	–	–	–	–	–	–	0.7	–	–	–	–	0.2	
Macrocrustacea																	0.3
Macrobrachium	–	–	0.2	–	–	–	–	–	–	–	0.3	–	–	–	–	0.1	
Hymensomatidae																	
P. transversa	–	–	–	–	–	3.9	–	–	–	0.8	–	–	–	–	–	0.2	
Insecta																	42.4
Fragmented	8.3	5.7	13.8	29.5	6.2	10.8	26.7	20.0	43.6	12.2	11.5	13.2	10.6	17.7	–	17.4	
Ephemeroptera																	
Baetidae	–	–	–	2.9	–	–	–	–	–	1.0	1.0	–	–	–	–	0.5	
Odonata																	
I. heterosticta	–	–	0.7	–	–	–	–	–	–	–	–	1.6	–	–	–	0.3	
Libellulidae	–	–	1.2	–	–	–	–	–	–	1.6	–	–	–	–	–	0.4	
Hemiptera																	
Naucoridae	–	–	2.2	–	–	–	–	18.0	–	2.8	0.2	2.4	–	–	–	1.2	
Gerridae	15.0	15.7	4.5	6.7	–	10.0	3.3	20.0	6.0	7.1	8.5	3.2	18.8	5.4	–	7.4	
Veliidae	–	–	–	6.2	–	–	6.7	–	7.7	0.7	–	–	–	–	–	1.4	
Hydrometridae	–	3.3	–	–	–	–	–	–	4.6	–	–	–	5.9	–	–	1.2	
Notonectidae	–	–	–	–	–	–	16.7	–	–	1.6	–	–	–	–	–	0.4	
Anisops	–	1.0	5.7	1.9	–	–	–	–	3.1	1.6	4.5	–	3.5	10.8	–	3.0	
Corixidae	–	0.3	1.3	2.9	0.6	–	–	–	0.6	1.1	1.6	0.3	–	7.7	–	1.3	

Table 122 continued

Stomach contents	Habitat								Season							Overall	
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80		
	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Coleoptera																	
Miscellaneous (adults)	–	8.7	9.5	2.4	1.3	2.3	–	2.0	10.3	6.9	5.6	2.4	18.0	0.8	–	6.7	
Diptera																	
Miscellaneous (larv.)	5.0	–	–	–	–	3.9	–	–	–	–	0.9	–	–	2.3	–	0.3	
Chironomidae (larv.)	–	–	–	–	–	–	–	–	–	–	0.5	–	–	–	–	0.1	
Chironomidae (pup.)	–	–	0.1	–	–	–	–	–	–	–	0.2	–	–	–	–	0.1	
Trichoptera																	
Leptoceridae	–	–	1.1	–	–	–	–	–	–	1.5	–	–	–	–	–	0.4	
Lepidoptera																	
Pyralidae	–	–	–	–	–	–	10.0	–	–	1.0	–	–	–	–	–	0.3	
Teleostomi																	1.3
Scales	–	–	2.3	–	–	–	–	–		–	–	–	–	15.4	–	0.9	
Ambassis spp.	–	–	0.6	–	–	–	–	–	–	–	1.6	–	–	–	–	0.4	
Terrestrial plants																	
Angiospermae																	0.2
Seed material	–	–	0.1	1.4	–	–	–	–	–	–	–	0.3	1.8	–	–	0.2	
Terrestrial animals																	
Insecta																	
Fragmented	–	29.0	9.7	7.6	4.4	33.9	5.0	–	8.6	20.3	14.1	20.5	18.2	–	–	10.9	53.0
Odonata																	
Zygopteran adults	3.3	4.0	16.2	4.8	80.0	13.1	13.3	20.0	5.9	3.1	29.8	34.7	–	–	10.0	15.4	
I. heterosticta	–	–	–	16.7	–	–	–	–	–	–	–	–	–	26.9	–	1.6	
Anisopteran (adults)	–	–	1.5	–	–	–	–	–	–	–	–	3.3	–	–	–	0.6	
Orthoptera	3.3	8.7	10.3	0.5	1.3	–	8.3	–	1.7	15.9	2.1	4.0	–	–	–	9.8	
Hemiptera	–	0.7	–	–	–	7.7	–	–	–	–	1.7	0.5	–	–	–	0.5	
Coleoptera																	
Miscellaneous	1.7	6.0	7.0	4.8	–	7.7	–	–	–	9.4	1.9	5.3	1.8	7.7	–	4.6	
Fragmented	–	–	0.7	–	–	–	–	–	–	–	–	–	–	–	30.0	0.3	
Diptera	28.3	–	0.4	–	–	–	–	–	2.9	–	0.5	–	–	5.4	–	0.9	
Trichoptera	–	–	0.1	–	–	–	–	–	–	–	0.1	–	–	–	–	+	

Table 122 continued

Stomach contents	Habitat								Season							Overall	
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	1979–80		
	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Hymenoptera																	
Miscellaneous	–	–	1.4	–	–	–	–	–	–	–	–	3.2	–	–	–	0.5	
Formicidae	–	1.3	3.0	6.7	–	–	–	–	–	2.1	5.2	2.6	1.8	–	–	2.5	
Oecophylla	35.0	12.7	2.4	2.4	6.3	6.9	10.0	–	0.9	4.0	6.5	2.6	19.4	–	60.0	5.4	
Reptilia																	0.4
Egg material	–	1.0	–	–	–	–	–	–	–	0.5	–	–	–	–	–	0.1	
Scincidae	–	2.0	–	–	–	–	–	–	–	1.0	–	–	–	–	–	0.3	
Aves																	0.2
Feathers	–	–	–	–	–	–	–	–	1.1	–	–	–	–	–	–	0.2	
Parasites																	
Nematoda	–	–	–	–	–		–	–	+	–	–	–	–	–	+	+	+
Organic material	–	–	0.8	2.9	–	–	–	20.0	3.7	1.6	–	–	–	–	–	1.0	1.0
Number of empty fish	1	–	2	1	3	1	–	2	1	4	3	–	1	2	–	11	11
Number of fish with food	6	30	86	21	16	13	6	5	35	62	58	38	17	13	2	225	225

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creek bed; Fb = Floodplain billabongs; Cb = corridor billabongs; Bb = Lowland backflow billabong; + = present (<0.1%)

The ability of this species, and other members of the Toxotidae, to utilise terrestrial food resources that are not in contact with the aquatic environment, has been the subject of papers by Zolotnisky (1902), Gill (1909), Smith (1936; 1945), and Allen (1973). Allen (1978b) noted that when the fish sights suitable prey, usually a small insect, it rises to the surface and ejects an aqueous ‘bullet’ from its mouth by forcefully compressing its gill covers. Specimens as small as 20 mm LCF have been observed feeding in this manner in Magela Creek. Their aim is uncannily accurate to a distance of 0.5 m for 30 mm LCF specimens and to 3 m for 250 mm LCF specimens (pers. obs.); in most cases the victim is knocked into the water, where it is usually tasted before being eaten (pers. obs.).[201]

Pollard (1974) noted that the diet of this species included insects and also reputedly shrimps, small fish, and occasionally berries falling into the water from terrestrial vegetation; however, the last three items were rare in the present study. Haines (1979) classified *T. chatareus* as a frugivore (fruit eater)/omnivore in the Purari River, Papua New Guinea, and noted that distributional differences occur in the diet (with crabs and fruit predominating in estuarine populations and insects and fruit in freshwater populations).[202]

Seasonal changes

In sampling periods 1 to 7 respectively, totals of 36 (3% empty), 66 (6% empty), 61 (5% empty), 38 (0% empty), 18 (6% empty), 15 (13% empty), and 2 (0% empty) stomachs of *T. chatareus* were examined (all habitats combined). The highest proportion of specimens with empty stomachs occurred during the 1979 Late-dry season and the lowest proportion in the Mid-wet season (the sample size for 1979–80 Early-wet season was small).

The diet in the 1978 Late-dry season was based primarily on aquatic insects (mainly coleopterans and surface-dwelling hemipterans). During the 1978–79 Early-wet season the terrestrial insect component (mainly orthopteran and coleopteran adults and ants) increased to become larger than the aquatic insect component (mainly on hemipterans and coleopterans). The diet in the 1978–79 Early-wet season became more varied and included gastropods, micro- and macro-crustaceans, small skinks and reptile eggs. The proportion of terrestrial insects (mainly zygopterans and ants) increased relative to the aquatic component during the 1978–79 Mid-wet season. Teleosts (*Ambassis* spp.) were eaten in small quantities during the Mid-wet season. By the Late-wet–Early-dry season the terrestrial component (again mainly zygopterans and ants) of the diet peaked and then fell dramatically into the 1979 Mid-dry season when gerrids and coleopterans were the main aquatic insect components. Traces of terrestrial plant material were found in the stomachs during the Mid-dry season.

The diet in the 1979 Late-dry season was based primarily on aquatic insects (mainly surface-dwelling hemipterans); however, the terrestrial insect component was slightly higher than in the 1978 Late-dry season. The few specimens examined in the 1979–80 Early-wet season were eating terrestrial insects only, with green tree ants (*Oecophylla*) and coleopterans being the main items.

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201 Smith (1998) has observed *T. chatareus* from the Fly River in PNG using a less precise but equally effective feeding technique of squirting large quantities of water into clumps of grass and then consuming the numerous insects dislodged by the spray.

202 Smith (1998) considered that *T. chatareus* from the Fly River in PNG was a surface feeder. Terrestrial insects scored most highly in dietary analyses, with aquatic insects and aquatic plants being scored around one third the level of terrestrial insects. Hymenoptera and Hemiptera were the main orders of terrestrial insects consumed. However, Smith noted that he had collected specimens from north Queensland that had fed almost exclusively on Atyidae shrimps, despite living in waters with abundant overhanging vegetation and an abundance of terrestrial insects.

Habitat differences

Magela catchment

A total of 166 stomachs of *T. chatareus* were analysed (all seasons combined): 7 (14% empty) from the Magela Creek catchment escarpment mainchannel waterbodies; 30 (0% empty) from lowland sandy creekbeds; 88 (2% empty) from shallow backflow billabongs; 22 (5% empty) from corridor waterbodies and 19 (16% empty) from floodplain billabongs. The highest proportions of empty stomachs were found in floodplain billabongs and escarpment water bodies and the lowest proportions at almost equal levels, in the other habitats mentioned above.

In the escarpment waterbodies, the small number of *T. chatareus* examined were feeding mainly on terrestrial insects (mainly green tree ants [*Oecophylla*] and miscellaneous dipteran adults) and, to a lesser extent, on aquatic insects (mainly gerrid bugs). In the lowland sandy creekbeds the aquatic insect component of the diet (gerrids and coleopterans) was slightly greater than in the escarpment water bodies, with the main terrestrial items being green tree ants, orthopteran and coleopteran adults. Small skinks and reptile eggs were also present in the diet in this habitat.

In the lowland shallow backflow billabongs, the aquatic component of the diet was more varied and larger possibly because bank vegetation on which terrestrial prey live is scarce in the Dry seasons or terrestrial prey are hard to see in muddied waters. The aquatic organisms eaten include insects (mainly coleopterans, *Anisops* and gerrids), gastropods, conchostracans, hydracarinids, teleosts (*Ambassis* spp.) and traces of algae, terrestrial plants and macrocrustaceans.

In corridor waterbodies *T. chatareus* fed extensively on aquatic insects (the main identifiable insects were the surface-dwelling gerrids and veliids) and to a lesser extent on terrestrial insects (mainly the zygopteran *Ischnura heterosticta* and ants); traces of terrestrial plant material were also found in the stomachs. The diet in the floodplains was almost exclusively based on terrestrial insects (mainly zygopteran adults and green tree ants).

Nourlangie catchment

A total of 27 specimens were analysed: 14 (7% empty) from the Nourlangie Creek system escarpment mainchannel waterbodies; 6 (0% empty) from lowland sandy creekbeds; and 7 (28% empty) from shallow backflow billabongs. The large difference in proportions of empty stomachs may be attributable to the small sample sizes.

The diet in the escarpment waterbodies was based mainly on terrestrial insects, as in the Magela system, with aquatic insects (mainly gerrids) of secondary importance. In the lowland sandy creekbeds, the terrestrial and aquatic insect components of the diet were fairly equal. The terrestrial insects were mainly zygopteran adults and green tree ants. As in the Magela Creek system, terrestrial insects were eaten less often in the lowland backflow billabongs, with gerrid and notonectid bugs being the main items in the stomachs.

Fullness

Mean fullness indices of *T. chatareus* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments are shown in table 123. These data are presented on the assumption that feeding times within the day do not vary with habitat or season.

Seasonal changes

The mean fullness index (all habitats combined) remained at a fairly high, stable level between the 1978 Late-dry and the Late-wet–Early-dry seasons. The index fell gradually through the following Dry season to reach zero in the few fish examined in the 1979–80 Early-wet season.

Table 123 Mean fullness indices of *T. chatareus* in different sampling periods and habitat types

Habitat	Sampling period							Habitat mean
	Late-dry	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet 1979–80	
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	0 (1)	n/s	0 (1)	n/s	0 (1)	1.0 (3)	0 (1)	0.4 (7)
Lowland sandy creekbed	n/s	n/s	n/s	4.2 (6)	n/s	n/s	n/s	4.2 (6)
Downstream of RUPA:								
Lowland sandy creekbed	n/s	3.6 (12)	3.8 (6)	1.5 (2)	2.8 (4)	n/s	n/s	3.3 (24)
Lowland channel backflow billabong	n/s	0 (1)	4.7 (7)	3.4 (7)	3.6 (5)	n/s	n/s	3.7 (20)
Lowland shallow backflow billabong	0 (1)	3.4 (33)	4.4 (10)	3.3 (17)	4.0 (2)	1.3 (4)	0 (1)	3.3 (68)
Corridor sandy billabong	4.2 (5)	n/s	n/s	n/s	n/s	n/s	n/s	4.2 (5)
Corridor anabranch billabong	n/s	4.7 (3)	0 (1)	0 (1)	2.5 (2)	1.8 (5)	n/s	2.3 (12)
Floodplain billabong	0 (1)	2.7 (3)	2.8 (18)	n/s	n/s	2.3 (3)	n/s	2.6 (25)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	0 (1)	4.3 (3)	1.9 (8)	n/s	1.0 (2)	n/s	n/s	2.3 (14)
Lowland shallow backflow billabong	n/s	0.7 (3)	n/s	4.0 (2)	2.0 (2)	n/s	n/s	2.0 (7)
Lowland sandy creekbed	n/s	4.3 (3)	n/s	4.0 (3)	n/s	n/s	n/s	4.2 (6)
Seasonal mean (all sites)	3.6	3.4	3.3	3.5	2.8	1.6	0	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Habitat differences

In the Magela catchment, upstream of RUPA, mean fullness indices were highest in the lowland sandy creekbeds and lowest in escarpment mainchannel waterbodies; however, sample sizes were small.

Downstream of RUPA the fullness indices were high throughout most habitats. The mean fullness indices were highest in sandy corridor waterbodies and channel backflow billabongs and lowest in corridor anabranch and floodplain billabongs.

In the Nourlangie catchment, mean fullness indices were highest in lowland sandy creekbed pools and lower in lowland shallow backflow billabongs and escarpment mainchannel waterbodies. The indices in the lowland sandy and escarpment habitats were much higher than those recorded in the equivalent Magela Creek habitats.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- lowland channel backflow billabongs; 1978–79 Mid-wet season
- corridor anabranch billabong; 1978–79 Early-wet season
- lowland shallow backflow billabongs; 1978–79 Mid-wet season

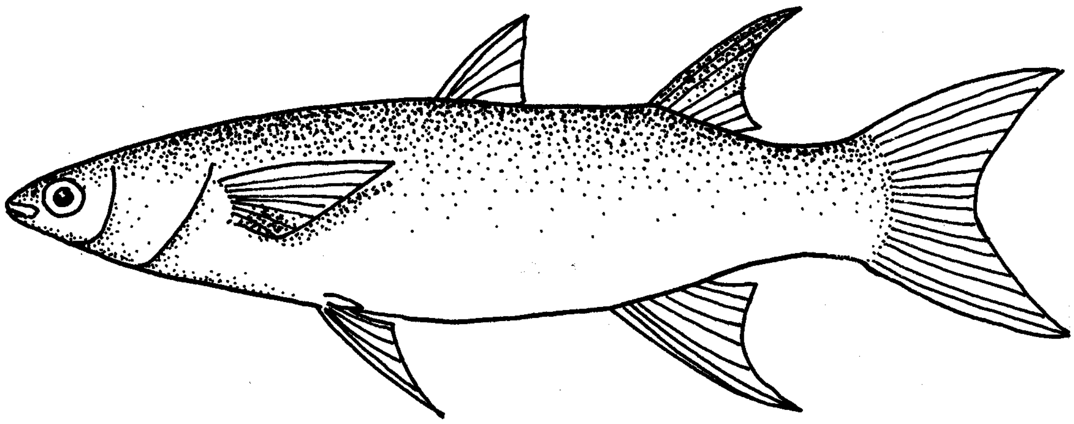
Nourlangie catchment

- escarpment mainchannel waterbody; 1978–79 Early-wet season
- lowland sandy creekbeds; 1978–79 Early-wet season

Family MUGILIDAE

3.32 *Liza alata* (Steindachner 1892)

This species is commonly known as the Ord River mullet. It is known from the Timor Sea drainage system of northern WA and the NT (see map 3).[203] Several other species of the family Mugilidae enter freshwater but most are essentially estuarine or marine. Pollard (1974) found this species to be abundant in tidal waterbodies of the East Alligator River. Miller (cited in Taylor 1964) found this species in billabongs in the Oenpelli area and in lower riverine floodplains of the East Alligator River. *Liza alata* is very similar morphologically to *Liza subviridis* (a species that Pollard and Miller also captured in the Region during their respective surveys), but the latter lacks both longitudinal dark lines and well-developed adipose eyelids.



Liza alata

Detailed information on catches on a site-by-site and season-by-season basis is given in volume 2. In summary, this species was found occasionally in all floodplain billabongs and in some corridor waterbodies; it was also found in lowland backflow billabongs in the Nourlangie Creek catchment. This species was found in 6 of 26 regularly sampled sites during the study.

The lengths and weights of 211 specimens were recorded. They placed this species at the base of the upper-middle quarter in the list of fish species ranked by the number of specimens examined (table 1).

Size composition

Length–weight relationship

The length–weight relationship was described by the following expression:

$W = 6.37 \times 10^{-2} L^{2.52}$ $r = 0.91$ (length in cm, weight in g)

203 Allen (1991) indicated that *L. alata* is widespread in the tropical Indo-West Pacific, from East Africa to Tonga. In PNG Allen noted that it had been reported from the Sepik River near Angoram. The habitat in the Sepik consisted mainly of coastal waters and estuaries, but it sometimes ascended rivers. Smith (1998) indicated that *L. alata* had also been recorded in the Fly River in PNG.

Seasonal mean lengths, weights and condition factors are shown in table 124. The seasonal condition factors were lowest in the 1978 Late-dry season and the 1979 Mid-dry season. The few specimens examined in the Mid-wet and Late-wet–Early-dry seasons had the highest condition factors.

Table 124 Mean length, mean weight and condition factor of *L. alata*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	5	261.2	210.02	0.89
Early-wet (1978–79)	33	355.5	500.18	0.97
Mid-wet	2	374.1	580.80	0.99
Late-wet–Early-dry (1979)	1	166.9	78.32	1.02
Mid-dry	5	190.1	91.64	0.86
Overall	46	316.6	384.68	1.00

Length composition

The smallest specimen captured in the study area was 128 mm LCF (fig 144). No smaller specimens were found in the catchments as this species does not breed in freshwaters (Roberts 1978). The largest specimen captured was 570 mm LCF. Lake (1971) indicated that this species grows to only 500 mm. Roberts (1978) found specimens up to only 410 mm in the Fly River, Papua New Guinea.

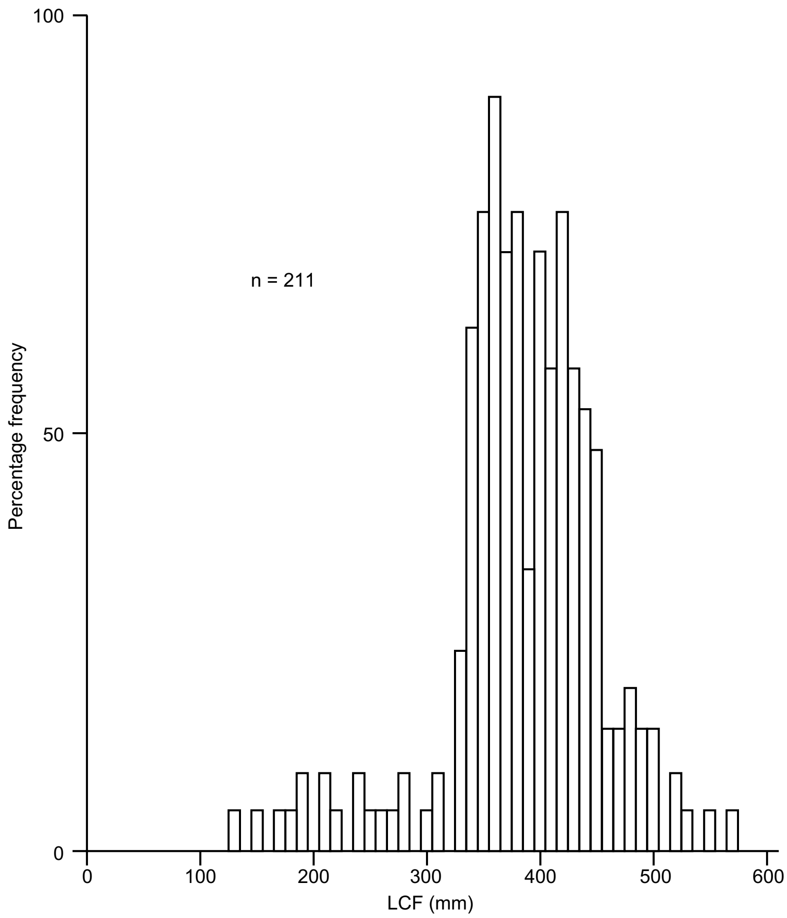


Figure 144 Length-frequency distribution of all *L. alata* captured

Length-frequency distribution

The mean length of all specimens captured was 370 mm and the modal length was 360 mm LCF. Only a few specimens were greater than 500 mm LCF; most ranged between 340 and 450 mm LCF.

The majority of specimens were collected during a fish kill in a floodplain billabong (Leichhardt Billabong) during the 1978–79 Early-wet season, but other specimens within the same length range were collected throughout the study. Small specimens were found in the 1978 Late-dry, 1978–79 Early-wet and Late-wet–Early-dry seasons; however, the smallest *L. alata* were captured in the 1979 Mid-dry season in the lower reach floodplain billabongs. The mean seasonal lengths (table 124) were lowest in the Late-wet–Early-dry and 1979 Mid-dry seasons. No small specimens were found in the Mid-wet season.

Habitat differences in distribution

Most specimens were captured in the Magela Creek catchment floodplain billabongs. The smaller specimens were mainly found in the lower reach floodplain billabongs; however, some small specimens, as well as a few large specimens, were found as far upstream as the corridor waterbodies. The largest specimen was also found in the floodplain billabongs.

Only a few small specimens were found in the Nourlangie Creek catchment. These were captured in shallow backflow billabongs in the 1978–79 Early-wet season. Larger specimens were frequently observed in the corridor waterbodies and there are unconfirmed reports that large schools may enter nearby escarpment mainchannel waterbodies.

Environmental associations

Rank numbers for *L. alata* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

L. alata was captured in waters with surface temperatures ranging from 27 to 35°C (mean = 30.7°C) and with bottom temperatures ranging from 26 to 34°C (mean = 29.7°C). These means were ranked into the lower-middle and upper-middle quarters, respectively (fig 170). Only small numbers of readings of environmental parameters were taken for this species; however, the close similarity of top and bottom water temperatures is notable.

Dissolved oxygen

Dissolved oxygen concentrations in waters in which *L. alata* was found were characteristically low, ranging from 0.1 to 8.0 mg/L (mean = 4.8 mg/L) on the surface and from 0.4 to 3.2 mg/L (mean = 2.4 mg/L) on the bottom. Both of these means were at the base of the lower quarters (see fig 171b). However, large numbers of this species were present in the Leichhardt Billabong fish kill (Bishop 1980), where surface DO concentrations fell to 0.1 mg/L.

Visibility

Secchi depth readings in waters from which *L. alata* was captured ranged from 1 to 150 cm, with a mean of 33 cm (see fig 172). This mean ranked in the lower quarter, indicating a preference for turbid waters. This species feeds in muddy benthic areas, so would be tolerant of highly turbid waters.

pH

pH values of waters from which *L. alata* were captured ranged from 5.1 to 7.4 (mean = 6.3) on the surface, and from 5.1 to 7.3 (mean = 5.9) on the bottom. These mean pH values ranked in the upper-middle and lower-middle quarters, respectively (see fig 173). These ranges of tolerance are relatively narrow.

Conductivity

Waters containing *L. alata* had surface conductivities ranging from 8 to 160 µS/cm, and bottom conductivities ranging from 8 to 230 µS/cm. Roberts (1978) found that *L. alata* was catadromous in the Fly River catchment, Papua New Guinea.

Habitat–structural variables

Substrate

The most dominant substrate type associated with *L. alata* was mud (upper quarter), followed by clay (lower-middle quarter), then sand, boulders and rocks (see fig 174). The marked dominance of mud substrate may be due to the feeding habits of the species, which browses for food in the benthic mud of lowland/floodplain waters.

Hydrophytes

Liza alata was found in waters with moderately high vegetation content (vegetation-occurrence index 94.7%). Emergent hydrophytes were dominant here (upper quarter) followed by submergent (lower-middle quarter) and floating hydrophytes. This species was often observed grazing on algae adhering to emergent vegetation.

Reproduction

A total of 27 *L. alata* were examined for reproductive condition: 12 females (length range 224–484 mm LCF), 5 males (167–405 mm LCF) and 10 sexually indistinguishable fish (128–327 mm LCF) (table 125).

Table 125 Number of sexually distinguishable *L. alata* captured showing gonad stage differences between habitats

	Gonad stage							
	Immature (I,II)		Developing (III)		Mature (V)		Spent (VII)	
Habitat	F	M	F	M	F	M	F	M
Corridor	0	0	0	1	0	0	2	0
Floodplain billabong								
Upper	4*	2	*6	0	0	1	0	0
Lower (riverine)	0	1	0	0	0	0	0	

* 2 immature and 6 developing females from fish kill (see Bishop 1980)

Length at first maturity

The LFM cannot be estimated due to the small number (3) of maturing fish captured. No maturing fish (ie greater than stage III) were found below 350 mm LCF.

Sex ratio

Of the 12 females and 5 males captured during the study (table 125) 9 females and 2 males were captured during the 1978–79 Early-wet season. When tested with a chi-squared test (Zar 1974) the sex ratio was found to be significantly ($0.01 < P < 0.05$) different from 1:1. The sample size was too small, however, to draw any general conclusions.

Breeding season

No information is available on the breeding season for this species. Plots of GSI and GMSI using all the male and female fish (as the LFM that distinguishes adults from juveniles was not determined) showed a minor peak during the 1978–79 Early-wet season (table 126). If a spawning migration to the estuaries takes place it must be during the Wet season, the only time that the Magela system is connected to the sea. *Liza argentia* has an extended period of reproductive development lasting from October to June in estuarine areas of southern NSW (SPCC 1981) and fish with ripe gonads were taken from December to June. Other mullet species, however, have winter breeding seasons. The SPCC (1981) recorded a spawning season of from March to July for *Mugil cephalus* in the estuary.

Table 126 Seasonal changes in gonadosomatic index (GSI) and gonad maturity stage index (GMSI) for *L. alata* over all habitats

Parameter	Sex	Statistic	Sampling period						
			Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
GSI									
Juveniles + adults	F	mean	0.2	0.3	0.3	–	–	–	–
		s.d.	–	0.1	0.04	–	–	–	–
	M	mean	0.01	0.2	–	0.2	0.01	–	–
		s.d.	–	0.1	–	–	–	–	–
	F+M	mean	0.1	0.3	–	–	–	–	–
		s.d.	0.1	0.1	–	–	–	–	–
GMSI									
Juveniles + adults	F	mean	2.0	2.7	2.0	–	–	–	–
		s.d.	–	0.5	0.0	–	–	–	–
	M	mean	2.0	3.5	–	3.0	1.0	–	–
		s.d.	–	2.1	–	–	–	–	–
	F+M	mean	2.0	2.8	–	–	–	–	–
		s.d.	0.0	0.9	–	–	–	–	–

Key: F = female; M = male; s.d. = standard deviation

Site of spawning

Most species of mullet are essentially marine or estuarine although nearly all will enter freshwater occasionally (Lake 1971). Breder and Rosen (1966) suggested the family Mugilidae can breed in both shallow seas or freshwater. However, Moore, cited by Haines (1978), reported spectacular migrations of *L. alata* into the lower reaches of the Fly River (near the mouth) during the breeding season. *Liza alata* was observed in large numbers in the East Alligator River near Cahills Crossing during the 1978–79 Early-wet season, although no evidence of spawning was observed and no fish were collected to assess reproductive condition.

Fecundity

The family Mugilidae generally exhibit distinct pairing but evidently with some polyandry. The males are generally smaller than the females. A spawning migration occurs and pelagic, non-adhesive eggs are produced (Breder & Rosen 1966).

No ovaries of *L. alata* were examined. The females of *Mugil cephalus,* a related species that spawns off the coast of southern and eastern Australia, are reported to carry more than 2 x 10^6 eggs within the ovary, which can weigh up to 20% of the total fish weight (Lake 1971).

Summary

Due to the small sample size, no conclusions could be made about the reproductive strategy of this species. However, the data did support the observations of other researchers on mullet reproduction. Large spawning migrations of *L. alata* down to the estuarine areas and the mouth of the river in the Fly River system were reported by Moore (Haines 1978). Large numbers of tiny, planktonic, non-adhesive eggs are laid (Breder & Rosen 1966, Lake 1971) and juveniles recruit to estuarine areas and may then move up river.

Feeding habits

Overall diet

The stomach contents of 18 specimens were analysed; 17 stomachs contained food. The diet of *L. alata* is summarised in figure 145; the components are listed in table 127. The main components were algae (48%) and detrital material (45%). The identifiable algae consisted mainly of conjugatophytes (*Mougeotia* and *Spirogyra*), dinoflagellates, desmids and diatoms. Traces of hydrophytes, aquatic arachnids and insects, and terrestrial plant material were also present in the diet. *Liza alata* may therefore be classified as a benthic herbivore (primarily algae)/detritivore. These data are generally in agreement with Lake (1971), who noted that the freshwater Mugilidae of Australia feed on algae from bottom mud, which they take into their gizzard-like stomachs. Haines (1979) noted that mullet of the genus *Liza* are detritophages in the Purari River, Papua New Guinea.

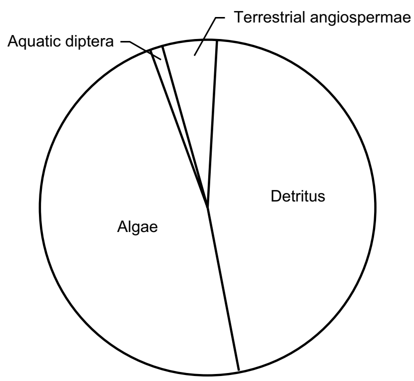


Figure 145 Dietary components of *L. alata*

Seasonal changes

Totals of 5, 5, 2, 1 and 5 stomachs of *L. alata* were analysed (all habitats combined) in sampling periods 1, 2, 3, 4 and 5, respectively. Only one fish during the whole study (in the 1978 Late-dry season) had no food in its stomach; the other specimens analysed in that season contained only detritus material. Specimens captured in the Early-wet season had eaten mainly detritus and algae, though large amounts of terrestrial plant material and traces of hydrophytes (*Hydrilla*), aquatic arachnids and chironomids were present in the stomachs.

During the Mid-wet season only algae (mainly *Spirogyra*) were found in the few stomachs examined. A specimen captured in Magela Creek channel (Magela Crossing) just downstream of a corridor waterbody (Mudginberri corridor) during the Mid-wet season contained the following algal genera (H Ling & D Thomas, pers comm): large numbers of dinoflagellates (*Peridium*); in smaller numbers, diatoms (*Eunotia, Gomphonema* and *Pinnularia*), conjugatophytes (*Oedogonium, Spirogyra* and *Mougeotia*), and desmids (*Pleurotaenium, Costerium, Desmidium* and *Cosmarium*).

The single specimen analysed in the Late-wet–Early-dry season had eaten only detritus. In the 1979 Mid-dry season the few specimens analysed were feeding only on algae (*Mougeotia* and desmids).

Table 127 Dietary composition of *L. alata*

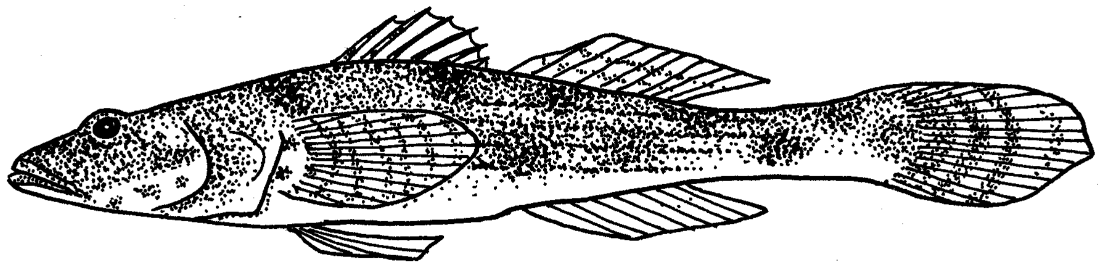
	Season					Overall	
	1978	1978–79	1978–79	1979	1979		
Stomach contents	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Sub-mean	Main-mean
Plant material							
Algae							48.0
Miscellaneous	–	37.0	5	–	–	11.1	
Desmidaceae	–	–	–	–	40.0	10.3	
Conjugatophyta							
Mougeotia	–	–	–	–	56.0	15.5	
Spirogyra	–	–	95	–	–	11.1	
Hydrophytes							0.3
Hydrilla	–	1.0	–	–	–	0.3	
Aquatic animals							
Arachnida							0.3
Hydracarina	–	1.0	–	–	–	0.3	
Insecta							0.6
Diptera							
Chironomidae	–	2.0	–	–	–	0.6	
Terrestrial plants							
Angiospermae							5.3
Fragmented	–	19.0	–	–	–	5.3	
Detrital material	100	40.0	–	100	4.0	45.3	45.3
Number of empty fish	1	–	–	–	–	1	1
Number of fish with food	4	5	2	1	5	17	17

Figures represent the mean percentage volume determined by the estimated volumetric method.

Family GOBIIDAE

3.33 *Glossogobius giuris* (Hamilton-Buchanan)

Glossogobius giuris is commonly known as the flathead goby or tank goby. It is probably one of the most widely distributed *Glossogobius* species, and is found from marine coastal waters to inland freshwaters (eg in mountain torrents in the Papua New Guinea highlands). It is found in the drainage systems of the north-east coast, Gulf of Carpentaria, Timor Sea, and Indian Ocean (see map 3) and also in Papua New Guinea and throughout the Indo-Pacific from East Africa to the Pacific islands. Pollard (1974) reported that this species was one of the less common fishes in the Magela Creek area, with only a few specimens collected from vegetation around the banks of waterholes. Although *G. giuris* attains a reasonably large size, no information is available on its eating qualities.



Glossogobius giuris

Detailed information on catches at each site and in each season is given in volume 2. This species appeared to be more common during the present study than during Pollard's 1974 study. In summary, it was found commonly in all escarpment mainchannel waterbodies (as well as terminal waterbodies in the Jim Jim Creek system) and corridor waterbodies (especially sandy types) and occasionally in lowland sandy creekbed habitats, lowland backflow and floodplain billabongs. In the 1978 Late-dry season it was found in six sites (mainly escarpment mainchannel waterbodies and corridor waterbodies); in the Mid-wet season in only two sites (one each of the above); and in the Late-wet–Early-dry season in two sites (corridor waterbodies).

Size composition

The lengths and weights of 278 specimens were recorded. This species was placed in the upper-middle quarter in the list of fish species ranked by the number of specimens examined (see table 1).

Method artefacts

All specimens were collected by seine net. The net was sometimes clogged by algae, which resulted in the capture of large numbers of very small juveniles (especially in the Mid-dry season).

Length–weight relationship

The length–weight relationship was described by the following expression:

$W = 1.03 \times 10^{-2} L^{2.78}$ $r = 0.98$ (length in cm, weight in g)

Seasonal mean lengths, weights and condition factors are shown in table 128. The seasonal condition factor was stable between the 1978 Late-dry and 1978–79 Early-wet seasons and then fell to a low during the Mid-wet and Late-wet–Early-dry seasons; however, this drop may have been an artefact of the small number of specimens examined. By the 1979 Mid-dry season the condition factor rose to reach a level in the 1979 Late-dry season similar to that attained in the same season in 1978. The condition factor increased further in the 1979–80 Early-wet season to a record level.[204]

Table 128 Mean length, mean weight and condition factor of *G. giuris*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	52	43.5	0.63	1.03
Early-wet (1978–79)	43	41.6	0.55	1.02
Mid-wet	5	46.1	0.63	0.88
Late-wet–Early-dry (1979)	6	51.9	0.88	0.88
Mid-dry	53	42.4	0.55	0.97
Late-dry	8	42.8	0.60	1.04
Early-wet (1979–80)	8	41.1	0.56	1.08
Overall	175	42.9	0.59	1.00

The changes in body condition of *G. giuris* indicate that the environmental conditions experienced in the Late-dry–Early-wet seasons were favourable to this species, and that the extreme 1979 Dry season was possibly more favourable than the 1978 season.

Length composition

Pollard (1974) stated that this species reputedly grows to 350 mm in Asia. In Papua New Guinea, *G. giuris* ranged in length from 50 to 200 mm in the Purari River (Haines 1979), and 13 to 171 mm in the Fly River (Roberts 1978).

Length-frequency distribution

The mean and modal lengths of all specimens captured were 40.6 and 33–34 mm TL, respectively. The LFM for females (fig 146) was approximately 35 mm TL, indicating that slightly more adults were captured than juveniles. The overall distribution displayed a negative skew, indicating lower survival for larger-sized fish. Most specimens were between 19–20 and 55–56 mm TL.

Seasonal mean lengths are shown in table 128. The mean seasonal length decreased slightly in the 1978–79 Early-wet season and then increased through the Mid-wet season to peak in the Late-wet–Early-dry season; this increase may have been an artefact, as few specimens were collected. The mean seasonal length then dropped in the 1979 Mid-dry season when large numbers of juvenile recruits entered the populations, and remained low for the remainder of the study.

Growth rate

Estimation of the growth rate of *G. giuris* from seasonal length-frequency distributions is difficult due to the frequency with which juveniles appeared to recruit.

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204 Jadhav and Patil (1984) examined the condition of *G. giuris* from the Godavari River in India and recorded condition factors (K) ranging from 0.75 to 0.92. The condition factor was found to vary between size groups and through time as related to cycles in gonadal maturity, spawning season, feeding habit, growth and environment.

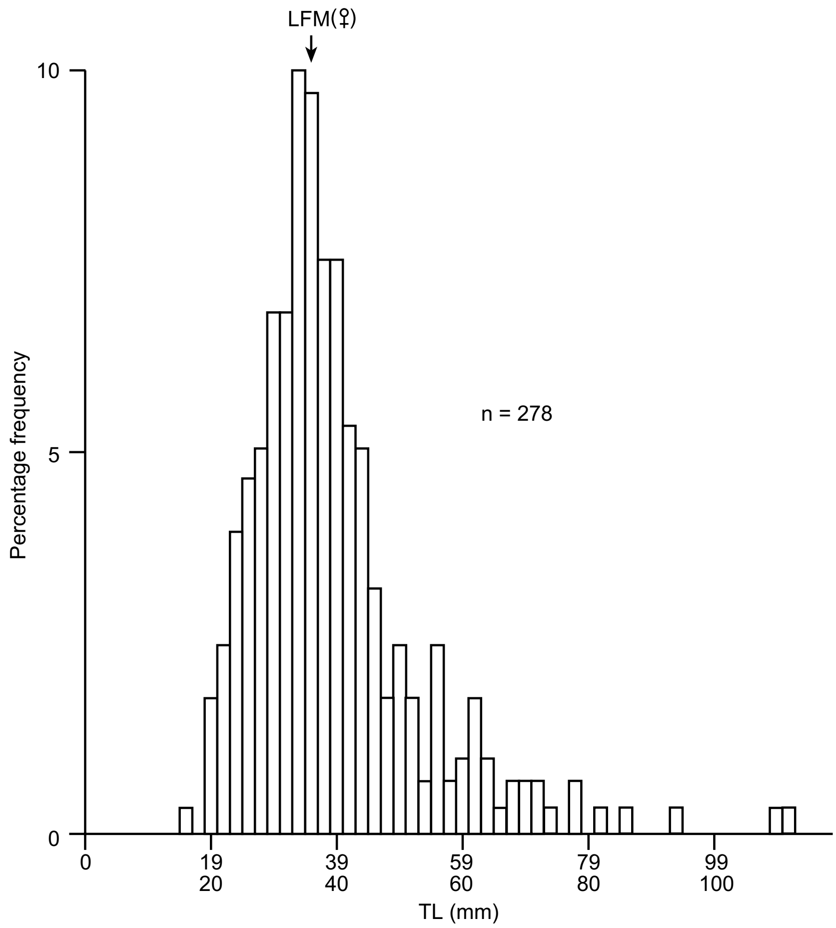

Figure 146 Length-frequency distribution of *G. giuris* (all sites)

The growth of juveniles (modal length 29–32 mm TL) present in the 1979 Late-dry season can possibly be followed (A on fig 147) until the 1979 Mid-dry season about ten months later, when a mean length of 64–65 mm was attained. This rate of growth suggests *G. giuris* may attain the LFM within its first year of life.

Habitat differences in distribution

The habitat preferences of all *G. giuris* captured in regular sampling sites in the Magela catchment are shown in figure 148.

Most of the juveniles, including the smallest, were found in sandy corridor waterbodies. A few were found in lowland sandy creekbeds, escarpment mainchannel waterbodies and corridor anabranch billabongs. Juveniles were also found in escarpment mainchannel billabongs of the Nourlangie system.

The smallest juveniles were captured during the 1979 Mid-dry season in a sandy corridor waterbody (Mudginberri Corridor). Juveniles were also collected frequently in the 1978 Late-dry and 1978–79 Early-wet seasons (fig 149). Comparatively few specimens were captured in the Mid-wet and Late-wet–Early-dry seasons (mainly due to sampling difficulties caused by the high flow) and the 1979 Late-dry and 1979–80 Early-wet seasons, resulting in a small range of specimens captured.

The largest adults were captured in the 1978 Late-dry season and the 1979 Mid-dry season.

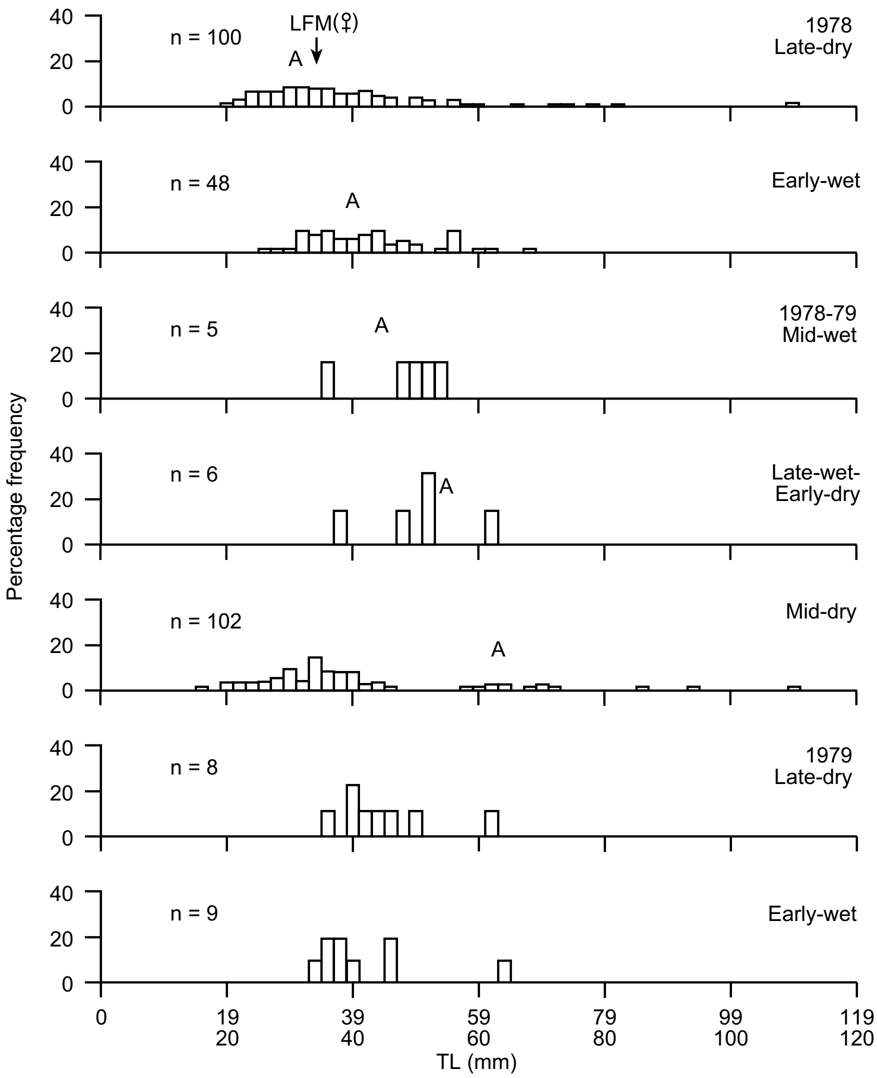

Figure 147 Seasonal length-frequency distribution of all *G. giuris* captured

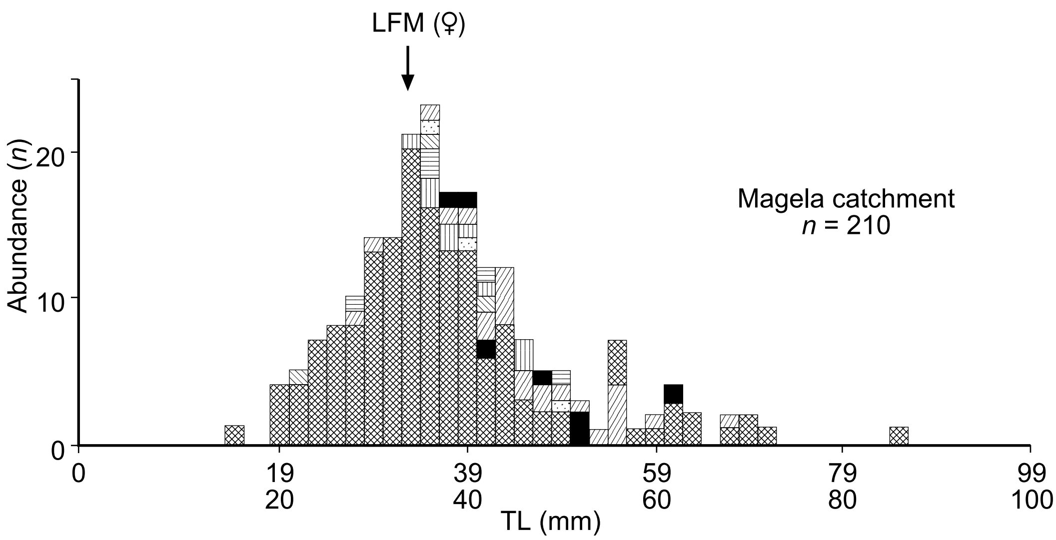

Figure 148 Length-frequency distribution and habitat preferences of *G. giuris* captured at regular sampling sites (see appendix 5 for key to the habitats)

The largest adults were found in sandy corridor waterbodies, as were most of the smaller adults; however, juveniles apparently dispersed to a wider variety of habitats upon attaining the LFM, as larger proportions of these small adults were found in lowland sandy creekbeds, lowland backflow billabongs, floodplain billabongs and escarpment mainchannel waterbodies. Few adults were found in lowland habitats upstream of the RUPA.

Of the few adults captured in the Nourlangie Creek system, the smallest and largest were found in lowland sandy creekbeds and the intermediate sizes were found in escarpment mainchannel waterbodies. No adults were ever observed in perennial or seasonal escarpment streams. Large numbers of adults and juveniles were observed in the littoral zone of occasionally sampled sandy corridor waterbodies in the Nourlangie system.

Environmental associations

Rank numbers for *G. giuris* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

At sites where *G. giuris* were captured, temperatures ranged from 23 to 38°C (mean = 30.7°C) on the surface, and from 23 to 35°C (mean = 29.7°C) on the bottom. Both means were ranked in the upper-middle quarter (see fig 170).[205]

Dissolved oxygen

Concentrations in waters in which *G. giuris* was found ranged from 5.4 to 7.4 mg/L (mean = 6.4 mg/L) at the surface, and from 5.2 to 6.8 mg/L (mean = 6.3 mg/L) on the bottom. Both means were ranked in the upper quarter (see fig 171). *Glossogobius giuris* appears to prefer a narrow range of moderately high DO concentrations, but the number of readings of DO concentrations was too small to be certain.

Visibility

Glossogobius giuris was captured in waters ranging from very clear to very turbid, as evidenced by the range of Secchi depths at sites where it was found (1–360 cm, mean depth = 76 cm). The mean depth was ranked in the upper quarter (see fig 172).

pH

The pH values of waters inhabited by *G. giuris* ranged from 5.6 to 8.3 (mean = 6.5) on the surface, and from 5.1 to 6.7 (mean = 6.2) on the bottom. These means were ranked in their respective upper quarters (see fig 173). This range of pH values is less acidic than the waters in which most other species in this study were found.

Conductivity

Readings in waters at sites where this species was captured ranged from 4 to 56 µS/cm on the surface, and from 6 to 36 µS/cm on the bottom. *Glossogobius giuris* is euryhaline, being found in coastal marine to inland freshwater habitats (Pollard 1974, Roberts 1978).[206]

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205 Geevarghese and John (1984) showed that the relationship of oxygen consumption to body weight in *G. giuris* was negative. Oxygen consumption also showed a positive exponential relationship with temperature and the partial pressure of the medium, while it was negatively exponentially related to salinity. Consumption of oxygen was higher in females than males.

206 Geevarghese and John (1984) showed that there was a negative exponential relationship between salinity and the oxygen consumption of *G. giuris*. The fish examined had been acclimated to 13.4 ppt salinity for 14 days before the experimentation.

Habitat–structural variables

Substrate

Glossogobius giuris was captured over a wide variety of substrates. Sandy substrates were clearly the most common (upper quarter), followed by leaf litter (upper quarter) then, in order, mud, rocks and clay (see fig 174). As with the physico–chemical parameters (above), the species' distribution is reflected in the variety of substrates over which it was found.

Hydrophytes

Glossogobius giuris was commonly found in moderately vegetated waters (vegetation-occurrence index 66%). Submergent and emergent hydrophytes were equally abundant in all sites sampled, and their percentage dominance values were both ranked into the upper quarter. Pollard (1974) found all of his specimens of *G. giuris* living amongst vegetation at the banks of waterholes.

Reproduction

A total of 118 *G. giuris* were examined for reproductive condition: 22 females (length range 35–110 mm TL), 25 males (32–108 mm TL) and 71 sexually indistinguishable fish (19–77 mm TL) (fig 149).

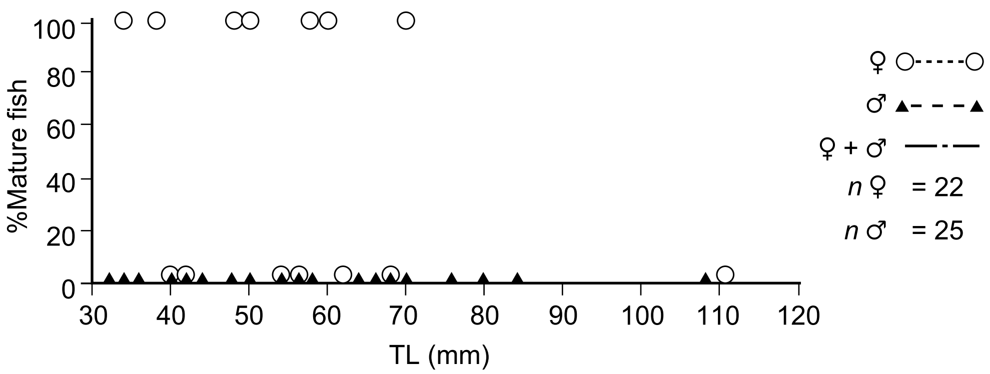

Figure 149 Estimated length at first maturity (LFM) of *G. giuris*

Length at first maturity

As no males with gonad stages greater than III (developing) were collected, neither a minimum length of maturation nor LFM could be estimated.

Maturing females were identified at even the smallest size of sexually distinguishable fish. The LFM was most likely around 35 mm TL, as gonads from fish captured below this length were indistinguishable (table 129).

Sex ratio

Glossogobius giuris was captured infrequently throughout the study, with no males or females being identified in the 1979 Late-wet–Early-dry or 1979–80 Early-wet seasons, and only one male in the 1978–79 Mid-wet season. Sex ratios were not significantly different from 1:1 in the remaining seasons (table 130).

Breeding season

The breeding season of this species cannot be determined from the data available (tables 129 & 130; fig 150). The GSI and GMSI fell between the 1978 Late-dry and 1978–79 Early-wet seasons, but rose again during the 1979 Mid-dry and 1979 Late-dry seasons, especially the females'. Too few fish were captured between the 1978–79 Early-wet and the 1979 Mid-dry seasons to determine the stages of reproductive development during that time.

Table 129 The range in gonad stages of each 10-mm-length size class of *G. giuris*

Sex	Length (mm)	Range of gonad stages						
		Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
F	30–39	iii,iv	–	–	–	–	ii,v	–
	40–49	iv,v	–	–	–	–	ii,iii	–
	50–59	iii,v	–	–	–	ii	–	–
	60–69	–	i	–	–	i,v	v	–
	70–79	iv	–	–	–	–	–	–
	110	–	–	–	–	iii	–	–
M	30–39	ii	ii	–	–	–	–	–
	40–49	ii	–	–	–	–	i	–
	50–59	ii	i,ii	i	–	–	–	–
	60–69	iii	i	–	–	ii	–	–
	70–79	ii	–	–	–	iii	–	–
	80–89	iii	–	–	–	iii	–	–
	108	ii	–	–	–	–	–	–

Table 130 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *G. giuris* over all habitats.

Parameter	Sex	Statistic	Sampling period						
			Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles +	F	*n*	8	1	–	–	7	6	–
Adults	M	*n*	13	6	1	–	4	1	–
		χ^2	1.2	3.6	1.0	–	0.8	3.6	–
		P	n.s.	n.s.	n.s.	–	n.s.	n.s.	–
GSI									
Adults only	F	mean	3.4	0.1	–	–	1.4	2.6	–
		s.d.	1.8	–	–	–	2.1	2.2	–
	M	mean	0.7	0.2	0.1	–	0.2	0.1	–
		s.d.	0.5	0.1	–	–	0.1	–	–
	F+M	mean	1.5	0.1	–	–	0.8	2.5	–
		s.d.	1.4	0.1	–	–	0.9	2.4	–
GMSI									
Adults only	F	mean	4.1	1.0	–	–	2.7	3.3	–
		s.d.	0.6	–	–	–	1.3	1.4	–
	M	mean	2.2	1.7	1.0	–	2.5	1.0	–
		s.d.	0.4	0.5	–	–	0.6	–	–
	F+M	mean	2.8	1.5	–	–	2.7	3.1	–
		s.d	1.1	0.5	–	–	0.4	1.6	–

n = number identified; χ^2 = Chi-squared value; P = probability; n.s. = not significant (P > 0.05); $\bar{x}$ = mean; s.d. = standard deviation.

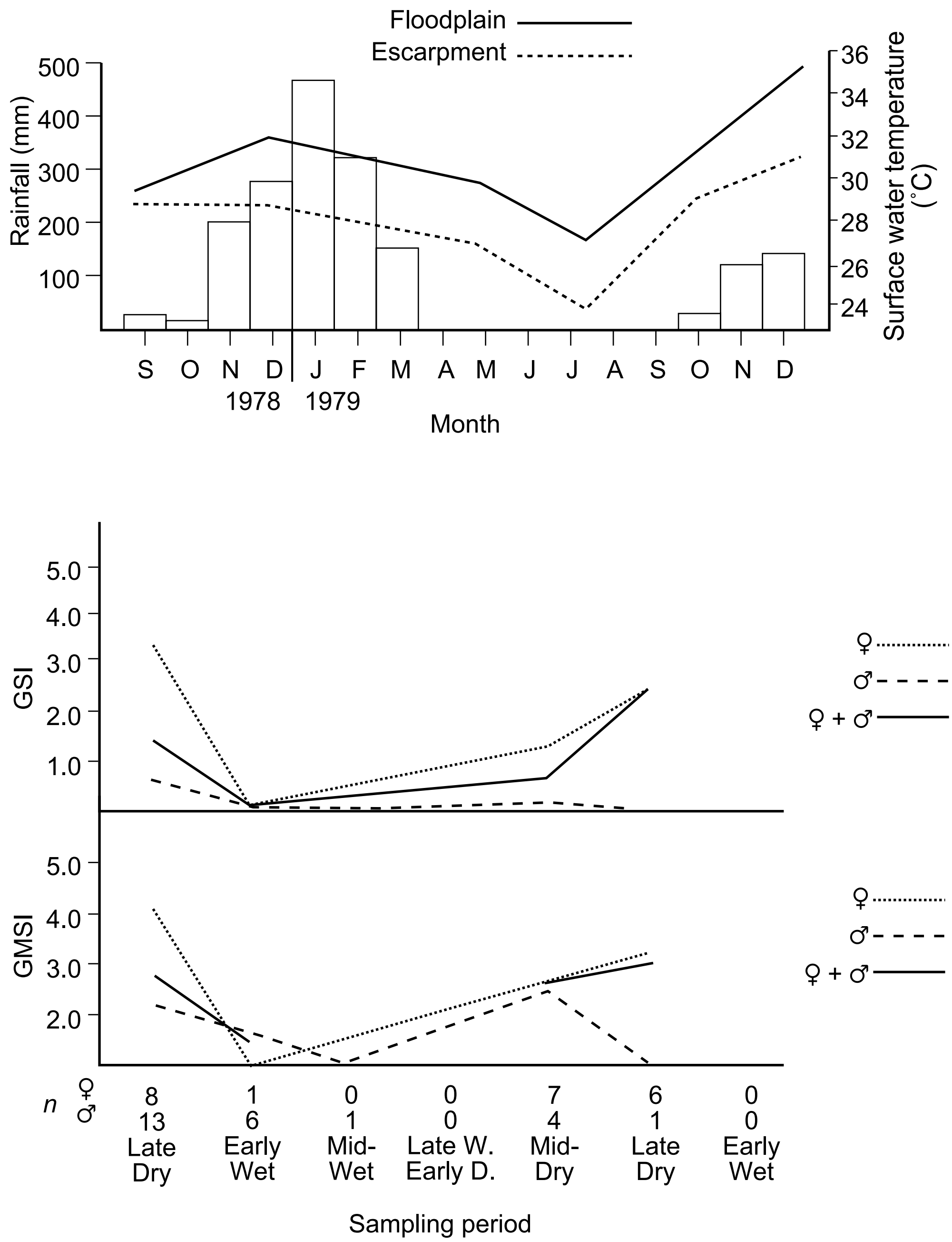

Figure 150 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad stage maturity index (GSMI) of *G. giuris*

Maturing females were identified in the 1978 Late-dry season and mature females in the 1978 Late-dry, 1979 Mid-dry and 1979 Late-dry seasons. Juvenile fish were collected mainly in the 1978 Late-dry and 1979 Mid-dry seasons (three juveniles were also collected in the 1978–79 Early-wet season).

The evidence suggests this species may breed during the Dry season, but no definite conclusions can be drawn. *Arenigobius bifrenatus*, a goby found in freshwater in southern Australia, spawns in spring and early summer (Hoese & Larson 1980) and *G. giuris brunneus* (=*olivaceus*) spawns in mid-summer in southern Japan (Ishikawa & Nakamura; in Breder & Rosen 1966). *Glossogobius* sp. bred aseasonally in Papua New Guinea (Roberts 1978).

Site of spawning

Mature fish were collected from a backflow billabong (Deaf Adder) in the South Alligator system, and two corridor waterbodies (Mudginberri Corridor and Buffalo Billabong) in the Magela Creek system. Juvenile fish were caught in a range of habitats from escarpment mainchannel waterbodies (Bowerbird Billabong) through lowland sandy creekbeds (Magela bed) to corridor waterbodies (Mudginberri Corridor). No ripe or spent fish or fish smaller than 15 mm were captured.

Hora (in Breder & Rosen 1966) suggested that *G. giuris* migrates to the sea to reproduce. As very few fish were captured during the Wet season in the present study, it is possible that there was a migration out to sea, but the drop in GSI at the start of the Wet season suggests that reproductive development was not increasing, as would be expected before a spawning migration. Juvenile fish (20–24 mm TL) were found in the escarpment area of Magela Creek in the 1978 Late-dry, and 15–19 mm TL fish were found in lowland sandy creekbeds near Gulungul Billabong in the same season. As there had been no flow, and the pools had been isolated from each other (and the sea) for at least four months, breeding was likely occurring at these and the other sites where small juveniles were found (table 131).

Table 131 Possible sites of spawning of *G. giuris,* as indicated by the abundance (*n*) of maturing, mature, ripe and juvenile fish

	Gonad stage						
	Maturing (IV)		Mature (V)		Ripe (VI)		Juvenile
Habitat	F	M	F	M	F	M	
Escarpment							
Mainchannel waterbody	0	0	0	0	0	0	3
Lowlands							
Sandy creekbed	0	0	0	0	0	0	16
Backflow billabong	4	0	5	0	0	0	0
Corridor	1	0	3	0	0	0	49

Fecundity

Three ovaries were examined. Egg numbers were approximately 1000 (length of fish 35 mm TL; GSI 6.25), 5000 (61 mm TL, GSI 4.53) and 16 000 (60 mm TL, GSI 6.20).[207] The eggs were pyriform in shape (approximately 0.3 mm long and 0.1 mm wide) and uniformly packed together. Each egg contained thousands of spherical granules.

Many records of breeding in the family Gobiidae (eg Breder & Rosen 1966) cite relatively small fecundities (eg 150–250 eggs per *Chlamydogobius eremius* female, Lake Eyre drainage, Central Australia) and egg sizes around 3 mm long by 1 mm diameter (eg 3.5 mm long for *G. giuris brunneus* from southern Japan). However, larger fecundities, of the order found in this study, have been reported: *Bathygobius soporator* from Florida, United States of America, spawns 15 000 to 18 000 eggs (Tavolga, in Breder & Rosen 1966) and *Favonigobius reichei* from India, which spawns before the monsoon season (October/ November), has eggs only 0.4 mm long. Aiyar (in Breder & Rosen 1966) attributed their

207 Gosh and Konar (1992) examined various aspects of the biology of *G. giuris* in the organically polluted Mathabhanga-Churni River in India. Oxygen depletion was the primary impact mechanism. In the most polluted zone the fecundity ranged from 200–300 eggs per female. Eighty kilometres further downstream the fecundity ranged from 400–500 eggs per female.

hatching more rapidly (in three days) than the European forms to the extremely small eggs and the higher temperatures of the habitats.

As both small eggs and relatively high temperatures occur in the Alligator Rivers area, a similar incubation period is suggested.

Summary

No definite breeding season or site of spawning could be determined, due to the small sample size captured. Reproductive development appeared to fall after the end of the 1978 Dry season and rose again at the 1979 Mid-dry season; however, very few maturing fish were captured during the study. Juvenile fish were found over a range of sites at the end of the 1978 Dry season, when the pools had been isolated for many months. This suggests *G. giuris* bred at those sites during the Dry season. A large number of very small eggs are spawned. The incubation period is probably short, due to the size of the eggs and the high water temperatures.

The family Gobiidae generally exhibit secondary sexual dimorphism. The males are often larger and with longer fins and brighter colours. Their urinogenital papilla is often longer and pointed, while females have a flatter, more rounded papilla. Males may pair with successive females. Demersal eggs with either threads or an adhesive pedestal are attached to the bottom or to objects on the bottom. The male builds a nest or selects a nesting site and guards, and usually aerates, the eggs (Breder & Rosen 1966), which hatch in a few days into planktonic larvae (Hoese & Larson 1980).

Feeding habits

Overall diet

The stomachs of 117 specimens were examined; 93 contained food. The diet of *G. giuris* is summarised in figure151: the components are listed in table 132. The main components were aquatic insects (68%) and microcrustaceans (13%). The aquatic insects were mainly chironomid larvae and then corixid bugs. Cladocerans (*Diaphanosoma*) were the main microcrustaceans. Oligochaetes and teleosts, as well as traces of nematomorphs and aquatic arachnids, were also eaten. *Glossogobius giuris* can therefore be classified as a meiophagic carnivore feeding opportunistically in the benthic and midwater zones of the waterbodies.[208]

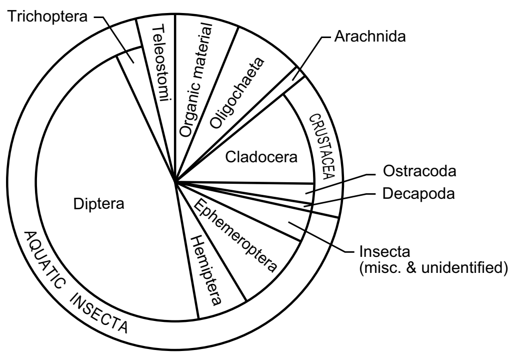

Figure 151 Dietary components of *G. giuris*

208 Mehta et al. (1990) indicated that *G. giuris* has a supraterminal mouth capable of straining food particles and preventing the prey from escaping. It was also noted that the cavity of the mouth cannot be enlarged much.

Table 132 Dietary composition of *G. giuris*

	Habitat					Season							Overall	
	Magela system				Nourlangie system	1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Em	Ls	Bb	Cb	Em	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic animals														
Nematomorpha	–	–	–	–	–	–	3.9	–	–	–	–	–	1.1	1.1
Oligochaeta	–	–	–	5.4	–	13.9	–	–	–	–	–	–	5.4	5.4
Arachnida														1.1
Hydracarina	–	–	–	2.7	–	2.8	–	–	–	–	–	–	1.1	
Microcrustacea														12.7
Conchostracea														
Cyzicus	–	–	–	0.5	–	–	0.8	–	–	–	–	–	0.2	
Cladocera														
Miscellaneous	–	–	–	5.4	–	3.9	3.9	–	–	–	–	–	2.6	
Diaphanosoma	–	2.0	61.8	–	–	–	1.2	–	–	–	–	97.1	7.6	
Ostracoda	–	6.7	6.4	–	–	2.2	3.9	–	–	–	1.9	2.9	2.3	
Macrocrustacea														1.1
Macrobrachium	–	6.7	–	–	–	2.8	–	–	–	–	–	–	1.1	
Insecta														68.0
Fragmented	33.3	–	–	3.0	–	5.6	0.4	20.0	–	11.1	–	–	4.4	
Ephemeroptera														
Baetidae	–	21.3	–	2.8	–	–	16.4	–	–	–	–	–	4.6	
Atalophlebia	–	22.7	–	–	–	–	13.1	–	–	–	–	–	3.7	

Table 132 continued

	Habitat					Season							Overall	
	Magela system				Nourlangie system	1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Em	Ls	Bb	Cb	Em	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Hemiptera														
Corixidae	–	–	–	13.0	20.0	–	–	20.0	–	–	60.0	–	6.2	
Diptera														
Chironomidae (larvae)	33.3	22.7	13.2	52.4	74.0	36.7	46.2	60.0	50.0	60.6	25.0	–	39.4	
Chironomidae (pupae)	–	–	–	5.4	–	9.4	–	–	–	–	–	–	3.7	
Ceratopogonidae	–	6.7	–	1.9	6.0	0.8	7.7	–	–	–	10.0	–	3.3	
Trichoptera														
Hydroptilidae	–	–	–	2.7	–	–	–	–	–	11.1	–	–	1.1	
Leptoceridae	–	–	9.1	1.4	–	–	–	–	–	16.7	–	–	1.6	
Teleostomi														4.4
Fragmented	–	–	–	–	–	2.8	–	–	–	–	–	–	1.1	
Craterocephalus spp.	–	–	–	–	–	2.8	–	–	–	–	–	–	1.1	
Ambassis spp.	33.3	–	–	–	–	2.8	–	–	–	–	–	–	1.1	
G. giurus	–	–	–	–	–	2.8	–	–	–	–	–	–	1.1	
Parasites														
Nematoda	–	–	–	0.5	–	1.7	–	–	–	–	3.1	–	0.9	0.9
Inorganic material	–	–	0.5	0.1	–	–	0.2	–	–	0.6	–	–	0.1	0.1
Organic material	–	11.3	9.1	2.7	–	9.2	2.7	–	50.0	–	–	–	5.4	5.4
Number of empty fish	–	5	2	6	–	15	2	–	4	2	–	1	24	24
Number of fish with food	3	15	11	37	5	36	26	5	2	9	8	7	93	93

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creek bed; Bb = lowland backflow billabongs; Cb = corridor billabongs

Pollard (1974) postulated that this species was probably an opportunistic carnivore. Haines (1979) noted that it was a 'prawn eater' in the Purari River, Papua New Guinea, while Roberts (1978) noted that it feeds on insects and prawns in the Fly River, Papua New Guinea.[209]

Habitat differences

A total of 79 stomachs of *G. giuris* were analysed (all seasons combined) from the Magela Creek catchment: 3 (0% empty) from escarpment mainchannel water-bodies, 20 (75% empty) from lowland sandy creekbeds, 13 (15% empty) from shallow backflow billabongs, and 43 (14% empty) from corridor waterbodies. The highest proportion of empty stomachs was thus found in fish from sandy creekbeds and the lowest proportion in the few fish from escarpment mainchannel waterbodies (table 132).

The small number of *G. giuris* examined from the escarpment zone were feeding only on aquatic insects (chironomids and unidentified fragments) and fish (*Ambassis* spp.). In the sandy creekbed lowland pools the diet consisted mainly of aquatic insects (baetids and chironomid larvae) and some macrocrustaceans (*Macrobrachium*) and microcrustaceans (mainly ostracods).

In the lowland shallow backflow billabongs, *G. giuris* had eaten mainly cladocerans (*Diaphanosoma*) with some aquatic insects (chironomid larvae and leptocerid larvae). In the corridor waterbodies, the diet was more varied (possibly due to the small sample size): mainly aquatic insects (mainly chironomid larvae and corixid bugs) with some oligochaetes, hydracarinids, cladocerans and traces of conchostracans.

Catchment differences

Five stomachs of *G. giuris* from an escarpment mainchannel waterbody in the Nourlangie Creek system were analysed; all contained food. The fish had eaten only aquatic insects (chironomid larvae, corixid bugs and ceratopognid larvae) and no teleosts, unlike the fish in the equivalent Magela Creek system habitat.

Seasonal changes

In sampling periods 1–7, respectively, 51 (29% empty), 28 (7% empty), 5 (0% empty), 8 (67% empty), 11 (18% empty), 8 (0% empty) and 8 (13% empty) stomachs of *G. giuris* were analysed (all habitats combined). The highest proportions of empty stomachs were thus found in the Late-wet–Early-dry season and the lowest proportions in the 1978–79 Mid-wet and 1979 Late-dry seasons.

The diet in the 1978 Late-dry season was based primarily on aquatic insects (as in all other seasons except the 1979–80 Early-wet season), with chironomid larvae as the main component. Oligochaetes, micro- and macrocrustaceans and teleosts (this was the only season when teleosts, namely *Craterocephalus* spp., *Ambassis* spp. and *Glossogobius* spp., appeared in the diet) were also found in the stomachs. The aquatic insects remained important in the diet during the 1978–79 Early-wet season, with an increase in baetid and chironomid larvae. Microcrustaceans became a more important component in the 1978–79 Early-wet season;

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209 Singh and Datta Munshi (1985) concluded that *G. giuris* from the River Ganga in India was a voracious carnivore. The gut contents comprised fishes, crustaceans, insect larvae and molluscs. It was also observed that the fish was a bottom dweller but a mid-water feeder. A cannibalistic food habit was also apparent, confirming findings by Bhiuyan and Haque (1984) who examined *G. giuris* from the River Padma. The latter authors noted that adults were highly cannibalistic, particularly the males. Note that in the present study in the Alligator Rivers Region *G. giuris* occurred in the stomach contents of the same species during the 1978 Late-dry season.

similarly, cladocerans (*Diaphanosoma*) and ostracods were the sole food in the stomachs in the 1979–80 Early-wet season.

During the Mid-wet season the few specimens examined had eaten only aquatic insects, with a larger component of chironomid larvae than at any other season. During the Late-wet–Early-dry season they appeared to eat mainly chironomid larvae, but large volumes of unidentified organic material were also present. In the 1979 Mid-dry season they again ate only aquatic insects (mainly chironomid, hydroptilid and leptocerid larvae). By the 1979 Late-dry season the aquatic insects were still most important, but there were more corixid bugs in the stomachs; microcrustaceans (ostracods) appeared for the first time since the previous Early-wet season.

Fullness

A summary of mean fullness indices of *G. giuris* for different periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 133. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 133 Mean fullness indices of *G. giuris* in different sampling periods and habitats

Habitat	Sampling period							Habitat mean
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Escarpment main-channel waterbody	3.5 (2)	n/s	0 (1)	n/s	n/s	n/s	0 (1)	1.8 (4)
Downstream of RUPA:								
Lowland sandy creekbed	1.2 (5)	2.4 (15)	n/s	n/s	n/s	n/s	n/s	2.1 (20)
Lowland channel backflow billabong	0.7 (3)	n/s	n/s	n/s	0 (1)	n/s	n/s	0.5 (4)
Lowland shallow backflow billabong	n/s	0 (1)	n/s	n/s	n/s	n/s	1.4 (8)	1.2 (9)
Corridor sandy billabong	3.2 (5)	3.8 (1)	1.0 (2)	n/s	2.5 (10)	3.8 (5)	n.s.	3.1 (23)
Corridor anabranch billabong	2.0 (4)	n/s	n/s	n/s	n/s	1.5 (2)	n/s	1.8 (6)
Floodplain billabong	n/s	n/s	n/s	0.4 (5)	n/s	0 (1)	n/s	0.3 (6)
Nourlangie Creek catchment (regular sites only)								
Escarpment main-channel waterbody	3.5 (2)	0 (1)	1.5 (2)	n/s	n/s	n/s	n/s	2.0 (5)
Lowland sandy creekbed	n/s	0 (1)	n/s	0 (1)	n/s	n/s	n/s	0 (2)
Seasonal mean (all sites)	1.8	3.0	1.4	0	1.6	3.0	1.7	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Habitat differences

In the Magela catchment upstream of RUPA, the mean fullness indices in escarpment waterbodies were similar to some other downstream habitats.

Downstream from RUPA, the mean fullness indices were highest in corridor sandy billabongs and lowest in floodplain and channel backflow billabongs.

Few specimens were captured in the Nourlangie catchment; however, in the escarpment waterbodies their mean fullness indices were slightly higher than in the equivalent Magela catchment. The few specimens captured in the lowland sandy creeks had not been feeding.

Seasonal changes

The mean fullness index (all habitats combined) peaked in the 1978–79 Early-wet season then gradually fell to a low in the Late-wet–Early-dry season. It rose again to peak in the 1979 Late-dry season, and then fell in the following Early-wet season.

Summary[210]

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- corridor sandy billabong; 1978–79 Early-wet season, 1978 and 1979 Late-dry seasons
- escarpment mainchannel waterbody; 1978 Late-dry season

Nourlangie catchment

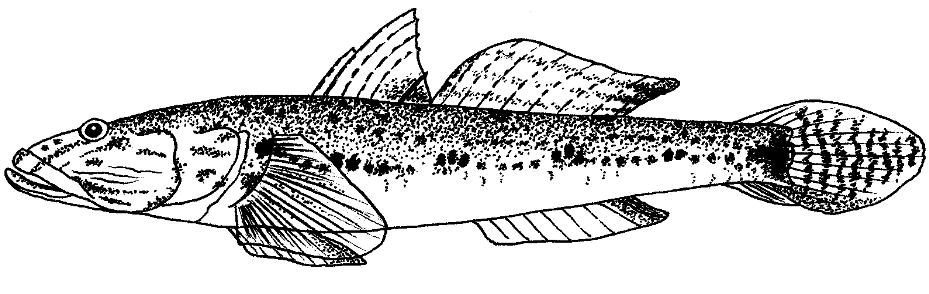
- escarpment mainchannel waterbody; 1978 Late-dry season.

210 Singh and Datta Munshi (1985) showed that *G. giuris* from the River Ganga in India fed throughout the year. Feeding activity peaked on three occasions: January, March to May, and October/November. It was apparent that less food was consumed during the monsoon (June to August) and winter (December) periods.

Family GOBIIDAE

3.34 *Glossogobius aureus* (Akihito and Meguro)

Glossogobius aureus (identified by Dr D Hoese of the Australian Museum) is commonly known as the golden goby. It is found in tropical freshwaters within the western Pacific and Eastern Indian ocean regions; the northern limit is Japan (Lat. 24°20'), the western limit is West Penang (Malaysia) and the southern limit is the Laura and Normandy Rivers (Lat. 15°50') of north Queensland, Australia.[211] In Australia it has been collected in the north-east coastal and Gulf of Carpentaria drainages (map 3); there is one previous record (unspecified site) for the Northern Territory.[212] A number of species of *Glossogobius* are found in the Indo-Pacific region, some in marine waters, some in brackish estuaries, and some in freshwaters. There appear to be no previous reports on the biology of this or other species of *Glossogobius*.[213] *Glossogobius aureus* differs marginally from *G. giuris* in having a slightly more rounded head, having an elongate black spot near the base of the sixth dorsal spine of the first dorsal fin, and having single (uniserial) rather than double or triple papillae in the five papillae rows across its cheek.



Glossogobius aureus

Information on catches for each site and each season is given in volume 2. It was only found in occasionally sampled lower riverine floodplain billabongs.

Size composition

The lengths and weights of 53 specimens were recorded.

Length composition

The specimens ranged in length from 20 mm to 125 mm TL.[214] The mean length was 53.3 mm TL and the modal lengths were 50–51 mm and 36–37mm. The smallest specimen was captured in the 1978 Late-dry season and the largest in the Mid-wet season. All specimens were either found in a riverine floodplain billabong (Cannon Hill Billabong) or tidal billabong (Rock Hole).

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211 Note footnotes in the *G. giuris* section that arise from recent publications on that species.

212 Larson and Martin (1989) indicated that in the Northern Territory this species is widely distributed and found in the Timor and Gulf drainages, from Victoria River across eastern Arnhem Land to the Nicholson River.

213 Allen (1991) indicated that *G. aureus* has only been collected from a single creek system near Wewak in northern Papua New Guinea. It inhabits clear to turbid water over sand or gravel.

214 Herbert and Peeters (1995) indicated that *G. aureus* grows to 200 mm TL.

Length–weight relationship

The length–weight relationship is described by the following expression:

$$W = 5.47 \times 10^{-3} L^{3.19} \qquad r = 1.00 \text{ (length in cm, weight in g)}$$

Seasonal mean lengths, weights and condition factors are shown in table 134. The condition factor was highest in the 1978 Late-dry season and lowest in the Mid-wet season, as was the case for *G. giuris*.

Table 134 Mean length, mean weight and condition factor of *G. aureus*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry	47	52.3	1.09	1.01
Mid-wet 1978–79	6	61.8	1.68	0.91
All seasons combined	53	53.3	1.14	1.00

Reproduction

Of 50 *G. aureus* examined, 30 were sexually indistinguishable (length range 20–74 mm TL), 8 were females (41–125 mm TL) and 12 were males (48–100 mm TL).

Except for one male captured in a tidal billabong (Rock Hole) during the 1978–79 Mid-wet season, all specimens were collected in the 1978 Late-dry and 1978–79 Mid-wet seasons from a riverine floodplain billabong (Cannon Hill Billabong).

Length at first maturity

No LFM was determined for this species, as few fish were collected. The smallest maturing fish were an 82 mm TL male and a 48 mm TL female.

Sex ratio

Most of the fish were collected from Cannon Hill Billabong in the 1978 Late-dry season. Ten were males and five were females, which is not significantly different (χ^2 test) from a 1:1 ratio.

Breeding season

Three of the five females in the 1978 Late-dry were mature, and two of the ten males were either maturing or mature. No ripe or spent fish were captured. One maturing female was caught in the 1978–79 Mid-wet season; the remainder were immature. Breeding may have taken place soon after the 1978 Late-dry season.

Site of spawning

Since fish were captured from only two sites in the study area, the range of possible spawning habitats could not be determined; however, as maturing fish and small juveniles (20 mm TL) were found in a riverine floodplain billabong (Cannon Hill Billabong), spawning most likely occurs at this site.[215]

Summary

The small range in sites and seasons of capture for this species resulted in limited information being available for analysis. Fish were maturing during the 1978 Late-dry season and probably spawning in the 1978–79 Early-wet season in the riverine floodplain billabong.

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215 Herbert and Peeters (1995) indicated that *G. aureus* probably has a marine larval stage.

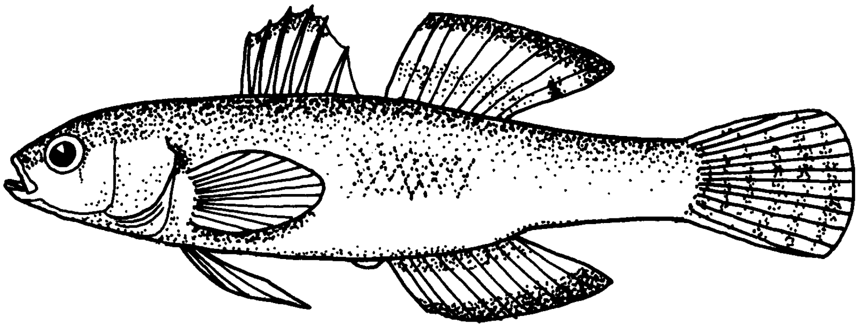
Feeding habits

The stomachs of 26 specimens were examined; 24 contained food. The main components of the diet were aquatic insects (49%), teleosts (17%) and macrocrustaceans (*Macrobrachium*). The aquatic insects were mainly chironomid larvae and pupae, chaorborinids and *Anisops*. The teleosts were *M. splendida inornata, Ambassis* spp. and *Glossogobius* spp. Oligochaetes, microcrustaceans (cladocerans), terrestrial zygopterans and traces of filamentous green algae also appeared in the diet. *Glossogobius aureus* could be classified as a meiophagic carnivore, opportunistically capturing organisms from the benthic, mid-water, and sometimes surface waters. This species appears to have similar feeding habits to *G. giuris,* but with the difference that it eats larger-sized and surface-dwelling organisms.

Family ELEOTRIDIDAE

3.35 *Hypseleotris compressa* (Krefft)

Hypseleotris compressa is commonly known as the empire fish or northern carp gudgeon. It is relatively common at low altitudes in coastal streams of Victoria, New South Wales, Queensland, the Northern Territory, and northern Western Australia, and also occurs in the coastal streams of Papua New Guinea.[216] All other species in this genus appear to be restricted to freshwaters; however, *H. compressa* can tolerate brackish water (Larson & Martin 1989), and has been collected from seawater creeks (Northern Territory Museum records) from brackish waters in the Hunter River catchment, New South Wales.[217] Midgley (1973) reported that *H. simplex* (which is now considered synonymous with *H. compressa*) was commonly captured in floodplain billabongs of the Alligator Rivers Region. This and the other related species in the genus make excellent aquarium fishes.



Hypseleotris compressa

Detailed information on catches at each site and each season is given in volume 2. In summary, this species was found occasionally in all floodplain billabongs and corridor anabranch billabongs. In the Nourlangie Creek catchment it was captured only in lowland shallow backflow billabongs. This species was also captured in lower riverine floodplain billabongs of the East Alligator Rivers. In the 1978 Late-dry it was captured in six sites; in the Mid-wet season it was found only in one floodplain billabong; in the Late-wet–Early-dry season no specimens were captured in the study area.

Size composition

The lengths and weights of 70 specimens were recorded.

Method artefacts

All specimens were collected by seine net. Clogging of the meshes by algae and hydrophytes sometimes resulted in the capture of considerable numbers of small juveniles.

Length–weight relationship

The length–weight relationship was described by the following expression:

$$W = 5.53 \times 10^{-3} L^{3.41} \qquad r = 0.94 \text{ (length in cm, weight in g)}$$

216 Allen (1991) noted that unlike in Australia where *H. compressa* is common, there are few reports of this species in PNG. Most reports are from the Fly River delta region including the Bensbach River.

217 Herbert and Peeters (1995) indicated that *H. compressa* is common to abundant in all coastal streams of Cape York Peninsula to within about 30 km of tidal influence.

Seasonal condition factors, mean lengths and mean weights are shown in table 135.

Table 135 Mean length, mean weight and condition factor of *H. compressa*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	41	47.6	1.04	0.92
Early-wet (1978–79)	4	39.8	0.70	1.14
Mid-wet	18	51.2	1.71	1.18
Late-wet–Early-dry (1979)	1	62.0	2.00	0.80
Mid-dry	5	37.9	0.55	0.93
Late-dry	1	27.0	0.30	0.99
Overall	70	48.5	1.21	1.00

The seasonal condition factor was highest in the 1978–79 Early-wet and Mid-wet seasons and lowest in the Late-wet–Early-dry season. The condition in the Late-dry seasons was slightly better in the 1979 season; however, few specimens were examined in this period. The high level recorded in the Mid-wet season was most likely a result of the large proportion of sexually ripe fish found during the season; the drop in condition thereafter would have been a result of spawning activity, as juvenile fish were recorded by the 1979 Mid-dry season.

Length composition

The range in length was 22 mm to 69 mm TL (fig 152) Auty (1978) reported that this species grows to 100 mm. Bishop (1979) found *H. compressa* from 26 to 44 mm TL in a temperate coastal Australian drainage — the Shoalhaven River, New South Wales.

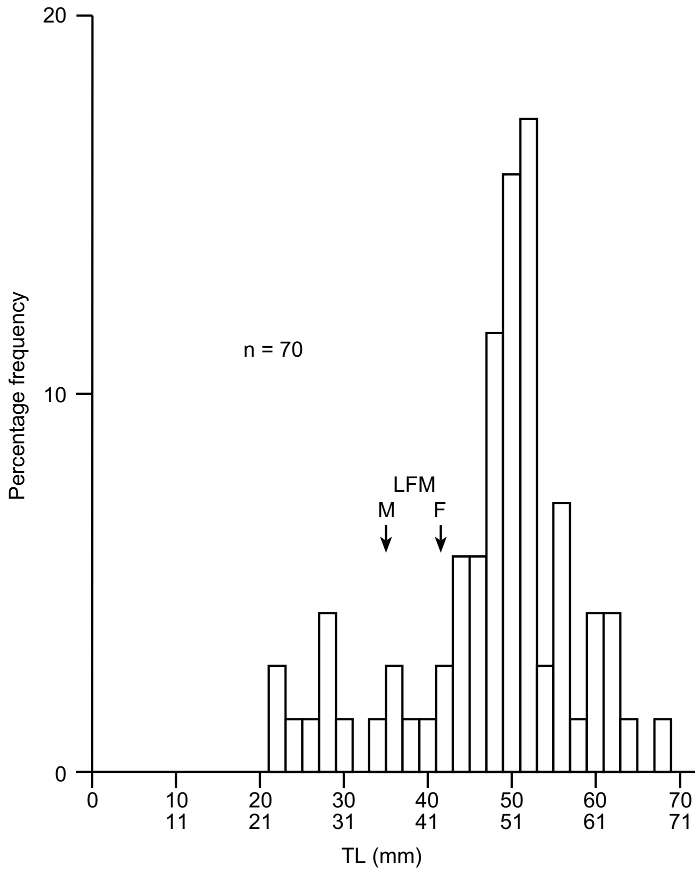


Figure 152 Length-frequency distribution of all *H. compressa* captured (all sites)

The smallest specimens were found in the Mid-dry season, followed closely by the 1978 and 1979 Late-dry seasons (fig 153) so juveniles probably recruit in those seasons. The largest specimen was captured in the Mid-dry season.

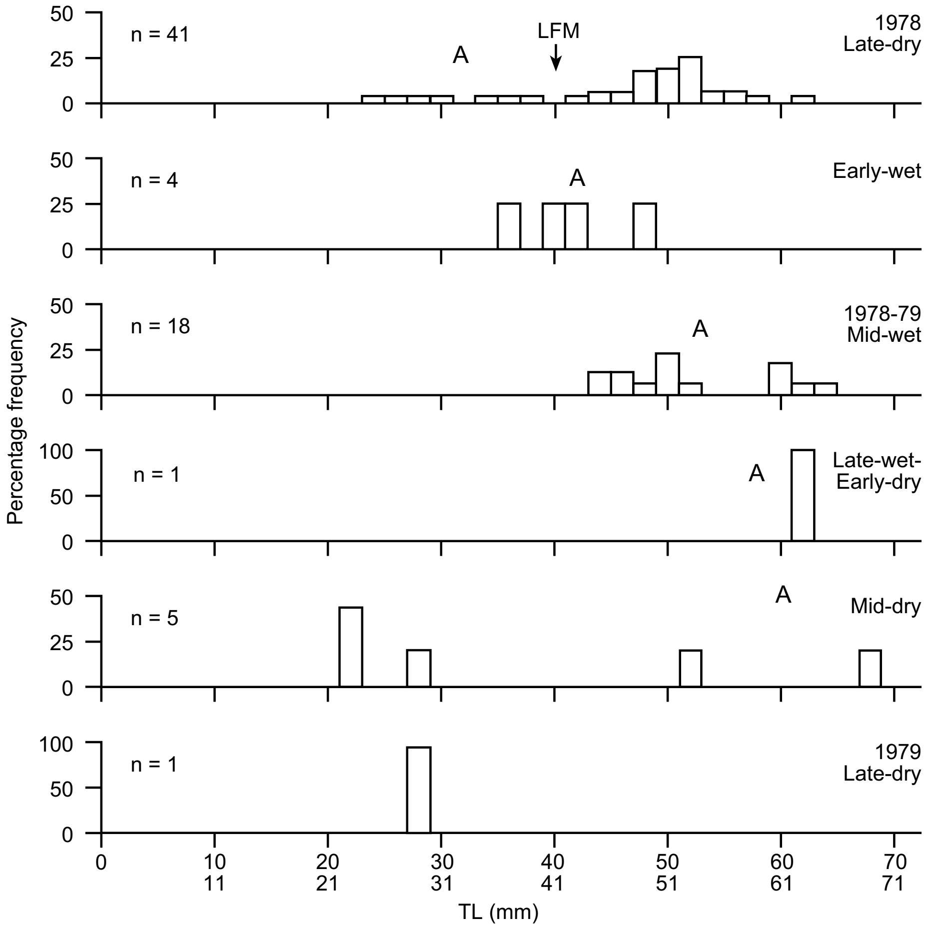


Figure 153 Seasonal length-frequency distribution of all *H. compressa* captured

Length-frequency distribution

The mean and modal lengths of all specimens captured were 48.5 and 52–53 mm TL, respectively. The length at first sexual maturity for males was 37 mm TL, and for females 43 mm TL, indicating that most specimens were adults. A mean LFM of 40 mm TL will be used in the following sections. Most specimens were between 44 and 56 mm. The overall distribution displayed a positive skew. (Very small specimens were frequently captured with aquatic plants that had clogged the 10 mm mesh.)

Seasonal mean lengths are shown in table 135. These were greatest in the Mid-wet and Late-wet–Early-dry seasons and lowest in the 1979 Late-dry season, followed by the Mid-dry and 1978–79 Early-wet seasons.

During the 1978 Late-dry season, there were strong adult and weak juvenile components in the samples (fig 153). By the 1978–79 Early-wet season only large juveniles and small adults were caught; these groups were dominated by adults in the Mid-wet and Late-wet–Early-dry seasons that followed. The small sample sizes make it difficult to interpret the length-frequency distributions for the remainder of the study. Juvenile peaks did, however, reappear during the 1979 Mid-dry season (with a diminishing adult component) and a juvenile was also found in the 1978 Late-dry season.

Growth rate

Estimation of growth rates from seasonal length-frequency distributions is complicated by the apparent frequency with which juveniles were recruited.

The growth of juveniles (median length 31–32 mm TL) in the 1978 Late-dry season may possibly be followed (A on fig 153) until the 1979 Mid-dry season 10 months later, when a median length of 60–61 mm was attained. This implies they grew about 30 mm, so this species may attain its LFM by the end of the first year of life.

Habitat differences in distribution

Most of the juveniles were found in floodplain billabongs and only large juveniles and small adults were found in corridor anabranch billabongs. No juveniles were found upstream from the corridor zone of the Magela Creek catchment. One large juvenile was found in a lowland shallow backflow billabong adjacent to a corridor waterbody in the Nourlangie Creek system.

Most adults were found in floodplain billabongs, with a few small adults being found in corridor anabranch billabongs. No adults were found upstream of the corridor waterbodies in the Magela Creek catchment.

Environmental associations

Rank numbers for *H. compressa* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Hypseleotris compressa was caught in waters with temperatures ranging from 28 to 36°C (mean = 30.8°C) on the surface, and from 27 to 33°C (mean = 29.9°C) on the bottom. These means were both placed in the upper quarter (see fig 170). Most specimens were found in the warmer floodplain billabongs. Bishop (1979) recorded specimens in the Shoalhaven River, New South Wales, at water temperatures down to 12°C, indicating this species can tolerate a wider range of temperatures than those recorded in the present study.

Dissolved oxygen

Concentrations in waters in which *H. compressa* was captured ranged from 3.7 to 7.8 mg/L (mean = 6.1 mg/L) at the surface. However, the narrow range may be because only six recordings were taken. The mean ranked in the lower-middle quarter (see fig 171). No bottom-water DO readings were obtained.[218]

Visibility

Secchi depths recorded in waters in which *H. compressa* was found ranged from 3 to 110 cm (mean = 25 cm) (see fig 172). This mean ranked at the base of the lower quarter, indicating a tendency for this species to be found in more turbid waters.

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218 Gee and Gee (1991) found that 10, 50 and 90% of an experimental population of *H. compressa* commenced aquatic surface respiration (ASR) when dissolved oxygen levels fell below 1.0, 0.6 and 0.3 mg/L respectively. To perform ASR fish move to the surface and ventilate their gills with surface water (a few mm deep) which has a high oxygen content. Buoyancy control is critical for midwater fish like *H. compressa* during ASR because they must be at or near neutral levels and must position the body at an appropriate angle so that their mouth is within the upper few mm of the water column. *Hypseleotris compressa* maintained their buoyancy by swimming slowly at the surface, and not ingesting a buccal bubble as in other gobioid fish.

pH

Hypseleotris compressa were found at sites with surface water pH values ranging from 5.0 to 9.1 (mean = 6.9). This mean was ranked in the upper quarter (see fig 173). No bottom-water pH readings were taken.

Conductivity

Surface-water conductivities for waters associated with this species ranged from 4 to 160 µS/cm. Only ten readings of surface-water and one (18 µS/cm) of bottom-water conductivity were taken. Pollard (1974) stated that this species is generally found in fresh water. However, Bishop (pers. obs.) observed this species using a fish ladder at Seaham Weir, Hunter River, New South Wales, in waters of 10 ppt salinity.[219]

Habitat–structural variables

Substrate

Hypseleotris compressa was usually found in waters with muddy substrates (upper quarter), followed by clay (lower-middle quarter), then sand, rocks, gravel and leaves. This is in accord with this species' apparent preference for turbid waters (see fig 174). Lake (1971) and Pollard (1974) observed that this species attaches its eggs to firm submerged objects, such as rocks and plants; Hoese et al (1980) state that all species of Eleotridae attach their eggs to bottom substrates or to vegetation (see also Auty 1978). Thus, the type of substrate may be important to this species in its breeding seasons.

Hydrophytes

Hypseleotris compressa was found in the most heavily vegetated waters encountered in this study (vegetation-occurrence index 100%).[220] Submergent hydrophytes (upper quarter) were the most common, followed by emergent (upper-middle quarter) then floating-attached hydrophytes.

Reproduction

A total of 57 *H. compressa* were examined for reproductive condition; 13 were found to be female (length range 43–67 mm TL), 20 were male (35–62 mm TL), and 24 were sexually indistinguishable (20–54 mm TL).

Length at first maturity

The smallest maturing male and female were 38 and 43 mm TL, respectively. No females smaller than 43 mm were identified and all but one fish above this length were mature, so the LFM for females is taken to be 43 mm TL. The LFM for male fish is taken to be 37 mm TL (fig 154), as the males at 41 mm that were not maturing were sampled outside the breeding season, when they would not be expected to be mature, whereas the 38 mm male was sampled during the breeding season.

Sex ratio

All the adult fish (except one juvenile male) could be sexed. Significantly more males were identified ($0.01 < P < 0.05$) during the 1978 Late-dry season (table 136). Only one female

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219 Data arising from Pollard and Hannan's (1994) study on fish communities in the lower Clarence River estuary in NSW indicated that 50% of the *H. compressa* captured came from waters with salinity > 7 ppt. The reducing proportions in relation to increasing salinity was as follows: 40% @ 11 ppt, 30% @ 12 ppt, 20% @ 13 ppt, and 10% @ 16 ppt (based on graphical data presented by Bishop [1999]). Williams and Williams (1991) investigated the salinity tolerance of the closely related *H. klunzingeri* from the Murray-Darling River system. They found that median lethal salinity (LD50) was 38.0 ± 1.1 ppt. The corresponding conductivities are far higher than any recorded in the Alligator Rivers Region.

220 Allen (1991) indicated that in PNG *H. compressa* is usually found in flowing streams amongst vegetation or submerged tree branches. Herbert and Peeters (1995) indicated that *H. compressa* in Cape York Peninsula prefer slow-moving or still water with abundant cover from aquatic plants, twigs or branches.

was identified in that season, which may be due to undeveloped females being classified as sexually indistinguishable (the GSI was very low).

The sex ratio was not significantly different from 1:1 at any other season.

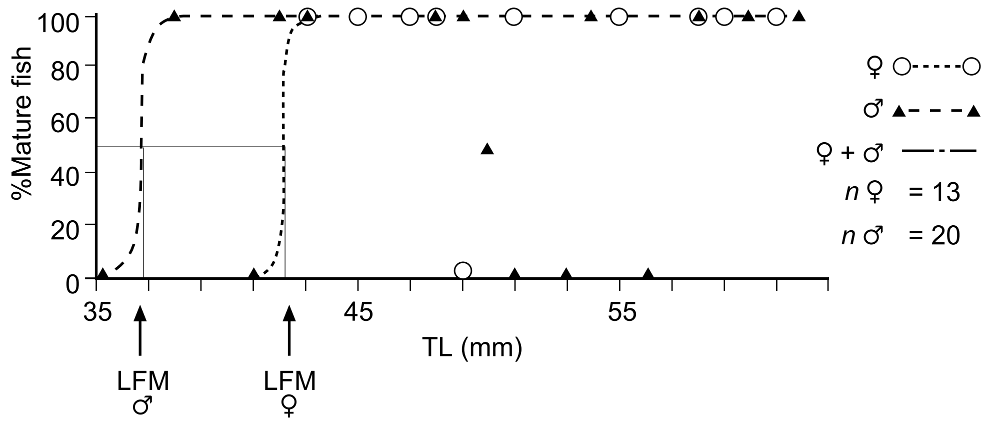


Figure 154 Estimated length at first maturity of male and female *H. compressa*

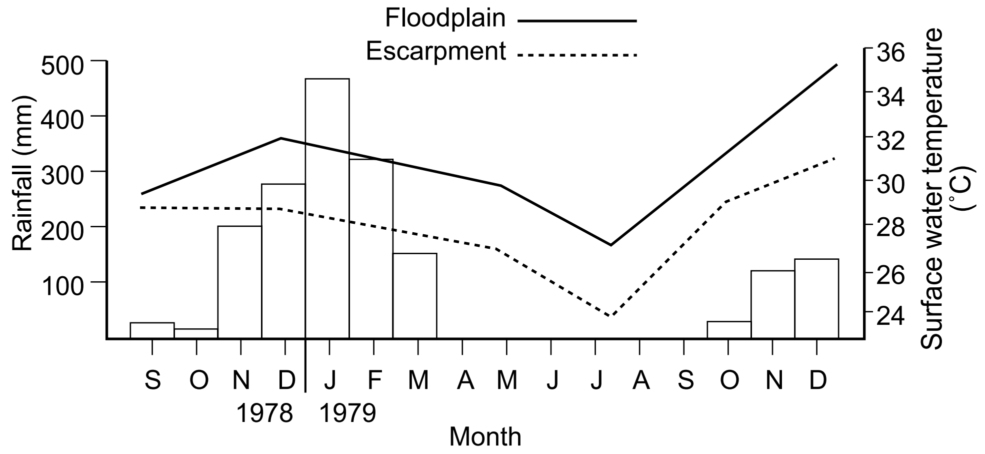
Table 136 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *H. compressa* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles	F	*n*	1	0	11	0	1	0	0
+ adults	M	*n*	8	3	7	1	1	0	0
		χ^2	5.4	3.0	0.9	1.0	0.0	–	–
		P	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	1	0	11	0	1	0	0
	M	*n*	8	2	7	1	1	0	0
		χ^2	5.4	2.0	0.9	1.0	0.0	–	–
		P	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s
GSI									
Adults only	F	mean	0.4	–	14.4	–	0.8	–	–
		s.d.	–	–	10.1	–	–	–	–
	M	mean	0.2	0.6	8.7	1.4	0.3	–	–
		s.d.	0.2	0.2	3.0	–	–	–	–
	F+M	mean	0.3	–	12.1	–	0.6	–	–
		s.d.	0.2	–	8.4	–	0.4	–	–
GMSI									
Adults only	F	mean	3.0	–	4.6	–	4.0	–	–
		s.d.	–	–	0.7	–	–	–	–
	M	mean	3.0	3.5	5.0	4.0	2.0	–	–
		s.d.	0.5	0.7	0.0	–	–	–	–
	F+M	mean	2.9	–	4.8	–	3.0	–	–
		s.d	0.5	–	0.3	–	1.4	–	–

n = number identified; χ^2 = Chi-squared value; P = probability; n.s. = not significant (P > 0.05); * = 0.01 < P < 0.05; s.d. = standard deviation.

Breeding season

The catches of *H. compressa* were small and were not evenly distributed over the seven sampling periods. It was therefore difficult to determine the breeding season for this species. The GSI (fig 155 and table 136) indicate a very large peak in reproductive development over the 1978–79 Mid-wet season.



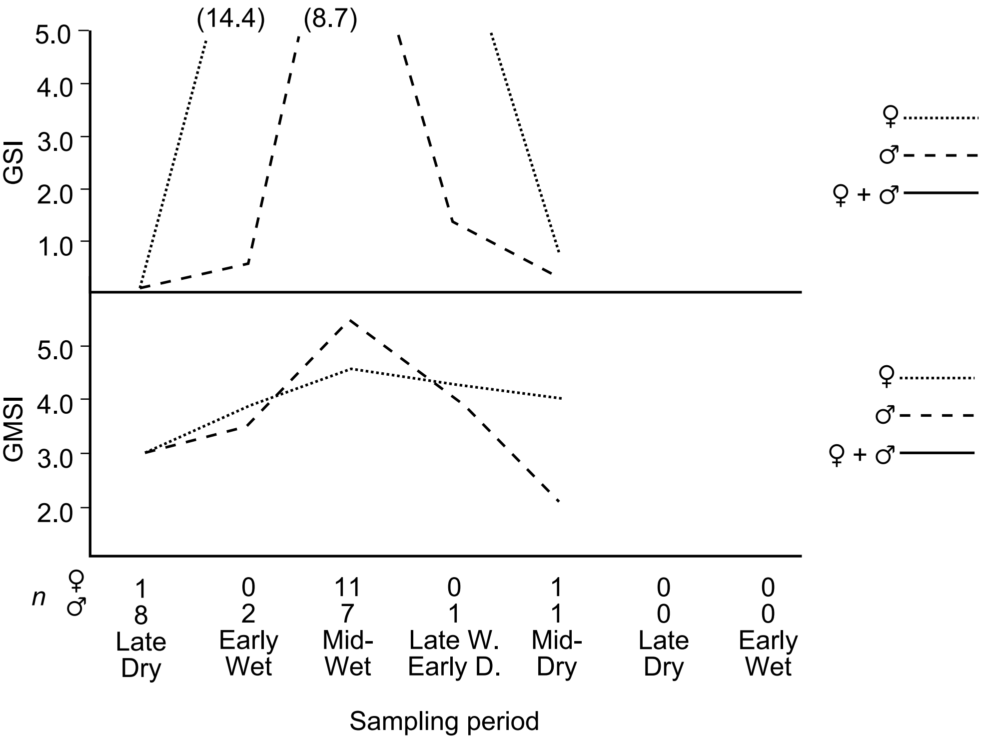


Figure 155 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad stage maturity index (GMSI) of male and female *H. compressa*

The GMSI also indicated a peak in development in that season, but this parameter remained high for longer: from the 1978 Late-dry season until the 1979 Late-wet–Early-dry season for males, or until the 1979 Mid-dry for females only.

Without samples from all seasons, it cannot be concluded that *H. compressa* breeds only in the Mid-wet season, although the evidence to date suggests this.

Mature fish were identified only in the 1978–79 Mid-wet, and juveniles (20–29 mm TL) were collected from the 1978 and 1979 Late-dry and the 1979 Mid-dry seasons. This information also supports a Mid-wet breeding season.

Site of spawning

Mature fish were captured from the upper Magela floodplain and on the East Alligator floodplain. None were ripe. Juveniles (20–29 mm TL) were captured in upper floodplain billabongs (table 137).

Table 137 Possible sites of spawning of *H. compressa* as indicated by the abundance (*n*) of mature and juvenile fish

	Gonad stage		
	Mature (V)		Juvenile
Habitat	F	M	
Floodplain billabongs			
Upper	1	0	0
Lower (riverine)	7	7	8

Fecundity

Egg numbers, from examination of seven ovaries, ranged from 4000 (45 mm TL; GSI 12.27) to 35 000 (48 mm TL; GSI 19.2) with a mean fecundity of 18 000 (standard deviation = 12 000). The eggs were, on average, 0.16 mm in diameter, ranging up to 0.32 mm in diameter.

In an aquarium, *H. compressa* spawned up to 20 times a season, with an average estimated egg count per laying of 2500 (ie up to 40 000 eggs per season; Auty 1978). Auty describes the eggs as demersal, very small and pear-shaped (0.26–0.28 x 0.30–0.32 mm), with an adhesive disc. They hatched in 10 to 10.5 hours at 30°C and in 12–12.5 hours at 26–28°C. The prolarvae were about 1 mm long and poorly developed, with no mouth or fins. Within 84 hours the eyes became pigmented, the jaw became functional and fins were developing.

The male guards the eggs, which are attached to firm objects, including plants (Lake 1978, Auty 1978, Hoese et al 1980).

Summary

Few *H. compressa* were captured during the study. Males were apparently smaller than females (this may be due to the small sample size). Males had an estimated LFM of 37 and females of 43 mm TL, and the sex ratio was 1:1 at all times except during the 1978 Late-dry season, when significantly more males were identified.

The peak in reproductive activity appeared to be during the 1978–79 Mid-wet, when many active specimens were collected from the lower riverine floodplain habitats. Juveniles are frequently found in estuaries (Hoese et al 1980). The male selects a territory and each female may mate with more than one male at a spawning session. A large number of tiny eggs are laid and attached to firm objects. The prolarvae are most likely washed down into the estuaries with the floods during the breeding season.

During breeding, the vertical fins of the male become more brightly coloured, and a bright orange colour develops under the head, belly and on the lower sides of the body (Hoese et al

1980, Auty 1978). The female develops a distinctive black spot at the base of the pectoral fins during spawning; the spot is normally present in mature males (Auty 1978).[221]

Feeding habits

Overall diet

The stomachs of 57 specimens were examined; 48 contained food. The diet of *H. compressa* is summarised in figure 156; the components are listed in table 138. The main components were microcrustaceans (mainly the cladoceran *Diaphanosoma* and copepods) and aquatic insects (mainly chironomid larvae). The large volume of unidentified organic material found in the stomachs was probably partly digested microcrustaceans. There were also algae (mainly phytoplankton) and traces of oligochaetes, detritus and inorganic material. *Hypseleotris compressa* can therefore be classified as a microphagic opportunistic carnivore (sometimes omnivorous) feeding on the benthos and from the mid-water zones of the waterbodies. These data agree with those of Lake (1978), who noted that this species ate small invertebrates, including mosquito larvae and cladocerans.

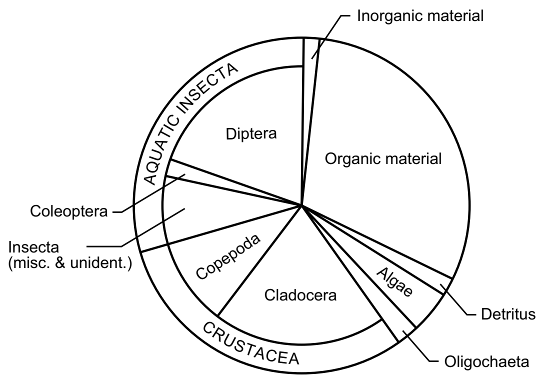


Figure 156 Dietary components of *H. compressa*

Habitat differences

Totals of 5 (20% empty) and 22 (18% empty) stomachs of *H. compressa* were analysed (all seasons combined) from the Magela Creek catchment corridor and floodplain billabongs, respectively. The largest volumes of organic, inorganic and detritus material, and some copepods and chironomid larvae were found in specimens from floodplain billabongs. Oligochaetes, cladocerans (*Diaphanosoma*) and chironomid larvae were mainly eaten by specimens in the corridor waterbodies.

Seasonal changes

In sampling periods 1, 2, 3 and 5, respectively, 28 (25% empty), 4 (0% empty), 18 (11% empty) and 5 (0% empty) stomachs of *H. compressa* were analysed (all habitats combined). The highest proportion of empty fish was in the 1978 Late-dry season.

Aquatic insects (mainly chironomid larvae) were most important in the diet in the 1978 Late-dry season; however, substantial quantities of unidentified organic material and small proportions of copepods and algae (mainly phytoplankton) were also eaten. During the Early-wet season aquatic insects were still important in the diet, but copepods and oligochaetes

221 Konagai and Rimmer (1985) described the larval ontogeny of the closely related fire-tailed gudgeon, *H. galii*.

became increasingly common. By the Mid-wet season *H. compressa* ate fewer aquatic insects and copepods, which were replaced by cladocerans (*Diaphanosoma*). Copepods (the large organic material component may have included digested copepods) were eaten most frequently during the Mid-dry season, when detritus and algae were also present in the stomachs.

Table 138 Dietary composition of *H. compressa*

	Habitat		Season					
	Magela system		1978	1978–79	1978–79	1979	Overall	
Stomach contents	Cb	Fb	Late-dry	Early-wet	Mid-wet	Mid-dry	Sub-mean	Main-mean
Aquatic plants								
Algae								4.3
Miscellaneous	–	1.1	8.6	–	–	4.0	4.2	
Conjugatophyta								
Mougeotia	–	–	–	–	0.3	–	0.1	
Aquatic animals								
Oligochaeta	25.0	–	–	25.0	–	–	2.1	2.1
Microcrustacea								30.3
Cladocera								
Miscellaneous	–	–	–	–	6.3	–	2.1	
Diaphanosoma	22.5	–	–	–	47.8	–	17.8	
Copepoda	–	22.2	9.5	22.5	6.3	40.0	10.4	
Insecta								30.4
Fragmented	–	11.1	6.2	25.0	4.4	–	6.3	
Coleoptera								
Miscellaneous (larvae)	–	5.6	4.8	–	–	–	2.1	
Diptera								
Chironomidae	12.5	11.1	31.9	12.5	10.0	–	20.4	
Ceratopogonidae	–	–	1.0	–	–	–	0.4	
Egg material	15.0	–	–	15.0	–	–	1.2	
Detrital material	–	4.4	–	–	–	16.0	1.7	1.7
Inorganic material	–	3.3	2.9	–	–	–	1.3	1.3
Organic material	25.0	41.1	35.2	–	25.0	40.0	30.0	30.0
Number of empty fish	1	4	7	–	2	–	9	9
Number of fish with food	4	18	21	4	16	5	48	48

Figures represent the mean percentage volume determined by the estimated volumetric method.

Cb = corridor billabong, Fb = floodplain billabong

Fullness

A summary of mean fullness indices of *H. compressa* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 139. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 139 Mean fullness indices of *H. compressa* in different sampling periods and habitats

Habitat	Sampling period						Habitat mean
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	
Magela Creek catchment (regular sites only)							
Downstream of RUPA:							
Corridor anabranch billabong	0 (1)	4.3 (3)	2.1 (15)	n/s	n/s	n/s	2.3 (19)
Floodplain billabong	1.4 (14)	0 (1)	0 (1)	0 (1)	1.6 (5)	0 (1)	1.2 (23)
Nourlangie Creek catchment (regular sites only)							
Lowland shallow backflow billabong	0 (1)	n/s	n/s	n/s	n/s	n/s	0 (1)
Seasonal mean (all sites)	1.8	3.8	1.9	0	1.7	0	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Habitat differences

In the Magela catchment *H. compressa* was found only downstream of the RUPA in corridor anabranch and floodplain billabongs. It fed most actively in the former habitat in the 1978–79 Early-wet and Mid-wet seasons. The only fish analysed in the Nourlangie Creek catchment had no food in its stomach.

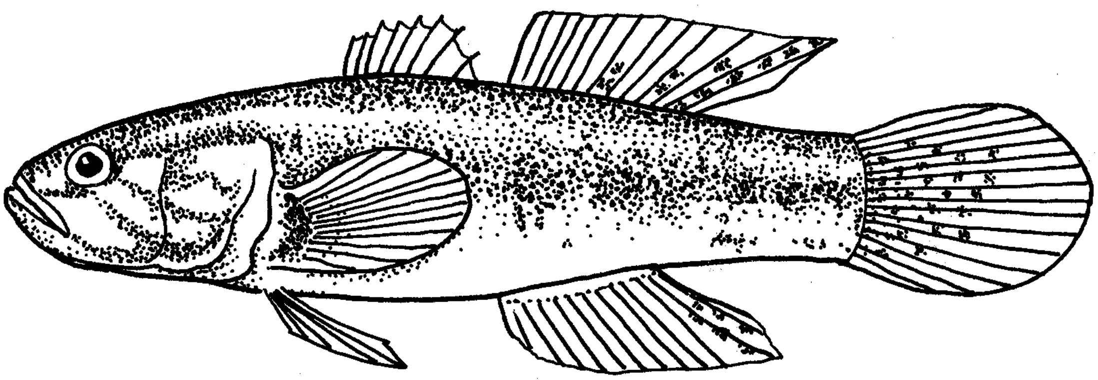
Seasonal changes

The stomachs of this species were most often full in the Early-wet season and least often in the Late-wet–Early-dry and 1979 Late-dry seasons; however, the sample sizes were very small.

Family ELEOTRIDIDAE

3.36 *Mogurnda mogurnda* (Richardson)

Mogurnda mogurnda is commonly known as the purple-spotted gudgeon, chequered gudgeon or trout gudgeon. It is found in the drainage systems of the north-east coast, Gulf of Carpentaria and Timor Sea (see map 3), and Papua New Guinea. Related species are relatively common in some localities in the central Australian Lake Eyre drainage system as far south as northern South Australia and north-western New South Wales. Pollard (1974) concluded that this species is a permanent inhabitant of freshwaters and probably occurs in most waterbodies in the Region. All species of this genus are restricted to freshwater; however, other members of the family are found in brackish estuarine waters and some in purely marine waters. It is an attractive species with considerable potential as an aquarium fish.



Mogurnda mogurnda

Detailed information on the catches at each site and in each season is given in volume 2. In summary, *M. mogurnda* was common in all floodplain, corridor and lowland backflow billabongs. It was found in most lowland sandy creekbed habitats up- and downstream of RUPA and in escarpment streams.[222] It was most abundant in the upper reaches of streams where other fish species could not penetrate.[223] In the 1978 Late-dry season it was found in only ten sites (mainly lowland backflow billabongs); by the Mid-wet season its distribution apparently decreased, as it was found in only four sites (mainly floodplain billabongs); but by the Late-wet–Early-dry season it was found in seven sites (mainly lowland backflow billabongs).[224]

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222 Robertson and Baidam (1983) found *M. mogurnda* to be very common in feeder streams of the Ok Tedi River in Papua New Guinea. They were particularly abundant in the lower reaches of these streams, but were also captured in the main river.

223 In 1984 *M. mogurnda* was observed (Bishop, pers obs) climbing vertical wet surfaces around waterfalls. This climbing ability explains its presence in escarpment stream reaches isolated from the lowlands by apparently insurmountable waterfalls or cascades. Herbert and Peeters (1995) indicated that in Cape York Peninsula *M. mogurnda* prefer the headwaters of streams where they are particularly abundant, but are usually found throughout river systems. They also indicated that *M. mogurnda* have remarkable powers of migration, being one of the few fish frequently found above large obstacles such as waterfalls.

224 Whitehead (1985) studied the closely related *M. adspersa* in a tropical upland stream in north-eastern Queensland and found patterns of habitat use and movement to be related to seasonal fluctuations in water levels. Fish moved to deep pools and aggregated around refuge sites during the dry season.

Size composition

The lengths and weights of 263 specimens were determined. Most of the specimens were caught by seine net, and therefore mesh selectivity influenced only the minimum size of specimens captured. Some of the smallest specimens were obtained by rotenone poisoning followed by collection with dipnets.

Length–weight relationship

The length–weight relationship was described by the following expression:

$$W = 8.84 \times 10^{-3} L^{3.19}$$ r = 0.99 (length in cm, weight in g)

Mean lengths, weights and seasonal condition factors are shown in table 140. The seasonal condition factor was lowest in the 1978–79 Early-wet season and highest in the Late-wet–Early-dry season. The condition factors in the two Late-dry seasons were similar. The drop in condition after the 1978 Late-dry season may have been caused by spawning activity.

Table 140 Mean length, mean weight and condition factor for *M. mogurnda*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	72	56.1	2.17	1.00
Early-wet (1978–79)	6	50.9	1.37	0.86
Mid-wet	49	39.8	0.72	0.99
Late-wet–Early-dry (1979)	8	37.1	0.73	1.25
Mid-dry	16	62.1	2.86	0.95
Late-dry	41	67.4	3.94	1.01
Early-wet (1979–80)	0	–	–	–
Overall	192	52.8	1.79	1.00

Length composition

The smallest specimen captured was 6 mm TL; the largest was 103 mm TL (fig 157). Specimens up to 180 mm in length were observed in escarpment habitats where no other fish species were seen. Pollard (1974) reported this species reputedly grows to 200 mm. Haines (1979) found specimens ranging in length from 10 to 110 mm in the Purari River, Papua New Guinea.[225]

The smallest specimen was found in the Mid-wet season. The largest specimens were found in the 1979 Mid-dry season followed closely by the 1978 Late-dry season (fig 158).

Length-frequency distribution

The mean length of specimens was 52.8 mm TL. The distribution peaked between 22 and 29 mm, and 49 and 63 mm (fig 157). The length at first sexual maturity (LFM on fig 157) was 51 mm for females and 55 mm for males, indicating that slightly more juveniles than adults were captured.

225 Using hook and line, Robertson and Baidam (1983) collected *M. mogurnda* ranging in size from 60–162 mm (3–59 g weight range) in feeder streams of the Ok Tedi River in Papua New Guinea. Kyle et al (1986) determined the concentrations of zinc, copper, lead and cadmium in whole specimens of *M. mogurnda* from the upper Ok Tedi River system in 1981. The specimens ranged in length from 75 to 162 mm and were collected before any mining activity.

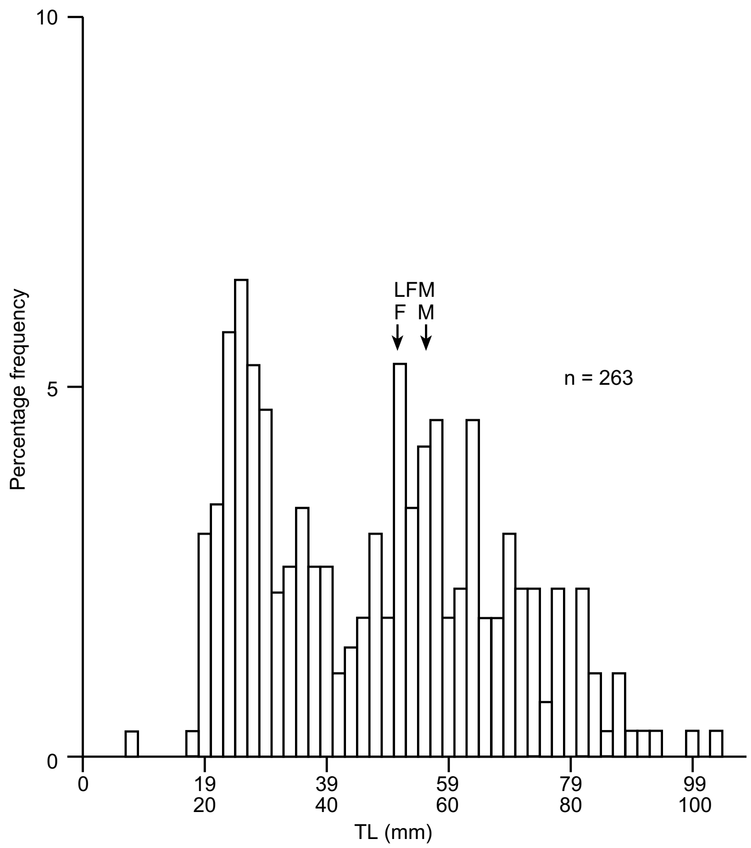


Figure 157 Length-frequency distribution of all *M. mogurnda* captured (all sites)

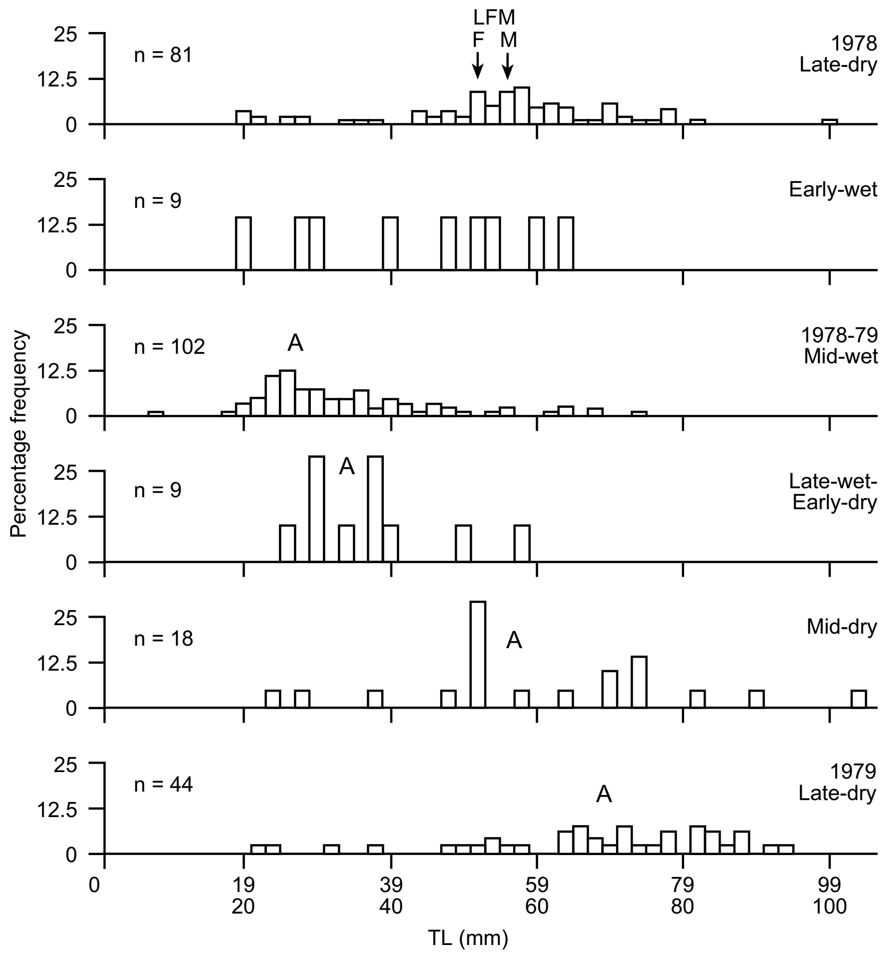


Figure 158 Seasonal length-frequency distribution of all *M. mogurnda* captured

Seasonal mean lengths are shown in table 140. The mean lengths were smallest during the Mid-wet and Late-wet–Early-dry seasons when most juvenile recruits appeared to enter the population (small numbers of juveniles were found throughout the study) and when the fewest adults were captured. The large adult and small juvenile components were strongest during the 1978 and 1979 Late-dry seasons. There was a strong adult component in the 1979 Late-dry season, but not in the same season in 1978.

Growth rate

Estimation of growth rates from the seasonal length-frequency distributions is difficult due to the frequency with which juveniles are recruited. The growth of juveniles present in the Mid-wet season (modal length 25–26 mm TL) may possibly be followed (A on fig 158) until the 1979 Late-dry season about 10 months later, when they appeared to attain lengths between 63 and 77 mm TL. The indications are therefore that this species may attain the LFM within its first year of life.

Habitat differences in distribution

The habitat preferences of *M. mogurnda* captured in regular sampling sites in the Magela and Nourlangie Creek catchments are shown in figure 159.

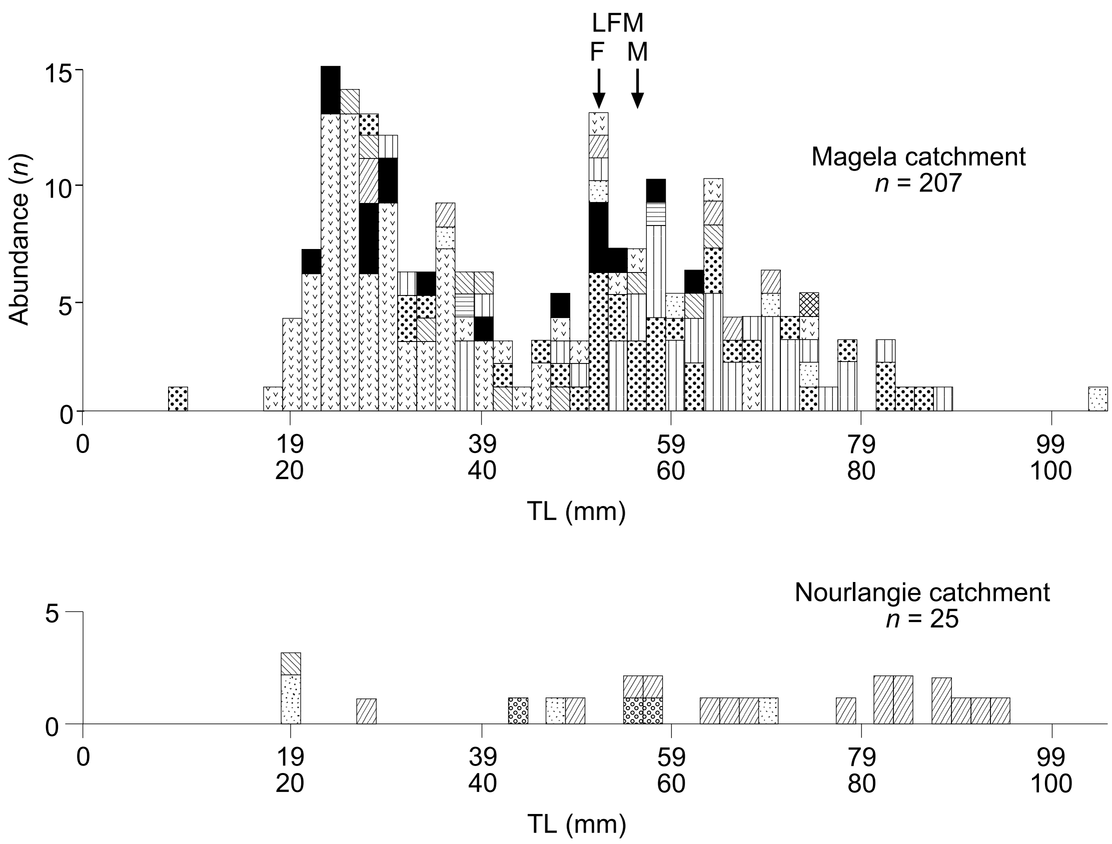


Figure 159 Length-frequency distribution and habitat preferences, *M. mogurnda* captured at regular sampling sites (see appendix 5 for key to the habitats)

Magela catchment

Juvenile *M. mogurnda* are defined as those fish less than the mean length (for males and females) at first sexual maturity (LFM 55–56 mm TL). The smallest juvenile was captured in a lowland shallow backflow billabong upstream of RUPA. Most of the smaller juveniles were captured in lowland sandy creekbeds upstream of RUPA, and secondarily in lowland shallow backflow billabongs (upstream and downstream of RUPA), floodplain billabongs and escarpment mainchannel waterbodies.

Smaller adults were captured in a range of habitats, though most frequently in lowland backflow billabongs up- and downstream of RUPA; sandy creekbed habitats did not appear important to these adults. Larger adults were found mainly in lowland shallow backflow billabongs up- and downstream of RUPA, with the largest specimen being captured from a channel backflow billabong.

Adults were frequently observed in an escarpment perennial stream, Radon Springs; very large adults were found in rock pools isolated from other fish species by insurmountable escarpment cascades.

Nourlangie catchment

The smallest juveniles were found in channel backflow billabongs and escarpment mainchannel waterbodies. The largest juveniles were found in backflow billabongs and in sandy creekbed lowland pools.

Adults were found mainly in lowland sandy creekbeds, with a few of the smaller specimens being found in backflow billabongs. Some small adults were found in plateau habitats.

Environmental associations [226]

Rank numbers for *M. mogurnda* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Water temperatures at sites where *M. mogurnda* was captured ranged from 25° to 36°C for surface waters (mean = 30.1°C), and from 24° to 35°C (mean = 28.9°C) for bottom waters. Both means were placed in the lower-middle quarters (see fig 170).

Dissolved oxygen

Mogurnda mogurnda was found in waters with dissolved oxygen concentrations ranging from 3.0 to 7.8 mg/L (mean = 5.6 mg/L) on the surface, and from 2.9 to 5.5 mg/L (mean = 4.8 mg/L) on the bottom. These mean DO concentrations ranked in the lower, and upper-middle quarters, respectively (see fig 171).

Visibility

This species was found in relatively turbid waters, with Secchi depths ranging from 1 to 190 cm (mean = 25 cm). This mean depth ranked at the base of the lower quarter (see fig 172). Pollard (1974) found large numbers of specimens of *M. mogurnda* in a turbid costean in RUPA.[227]

pH

The pH values of waters in which *M. mogurnda* was found ranged widely from 3.9 to 8.3 (mean = 5.9) on the surface, and from 3.9 to 6.7 (mean = 5.1) on the bottom (see fig 173).

226 *M. mogurnda* has subsequently been used in toxicity testing for predicting the potential for mining impacts in the Alligator Rivers Region (Holdway 1991). Sensitive tests have been developed for egg hatchability, embryo heart rate changes, larval survival, reproduction and growth. This species appears to be quite sensitive to metal toxicity in its early life history stages. Investigating the influence of one potential mining-related substance, Rippon et al (1992) exposed 4-day old larval *M. mogurnda* to a range of concentrations of sodium cyanide dissolved in Alligator Rivers Region water. Concentrations up to 200 ug/L were tested yet no affect was detected.

227 Herbert and Peeters (1995) indicated that *M. mogurnda* appear to prefer clear flowing water environments.

These means both ranked at the base of the lower quarter, indicating this species is generally found in more acidic waters (as in the escarpment zone), although some specimens were found in quite basic waters.

Conductivity

Conductivity values of waters in which this species was captured ranged from 6 to 202 µS/cm on the surface, and from 4 to 60 µS/cm on the bottom. This range reflects the wide distribution of *M. mogurnda* from escarpment to floodplain habitats.

Habitat–structural variables

Substrate

As might be expected from its wide distribution in the Alligator Rivers Region, *M. mogurnda* was captured over a range of substrates, chiefly mud, closely followed by sand and clay, then leaf litter, boulders, rocks and finally gravel. The percentage dominance values for mud and sand ranked in the upper-middle and lower-middle quarters, respectively. The predominance of muddy substrates accords with the low Secchi depths recorded for this species. The presence of boulders,[228] leaves and rocks is characteristic of the escarpment waters in which *M. mogurnda* was abundantly found.

Hydrophytes

This species was often found in waters with moderately thick vegetation (vegetation-occurrence index 75.4%), mainly submergent hydrophytes, followed by emergent hydrophytes then floating-attached hydrophytes.

Reproduction

A total of 178 *M. mogurnda* were examined for reproductive condition: 55 females (length range 27–88 mm TL), 53 males (34–103 mm TL) and 70 sexually indistinguishable fish (6–65 mm TL).

Length at first maturity

The smallest maturing male and female were 58 and 51 mm TL, respectively. The length at first maturity was calculated from 5-mm-length groups. The LFM was 55 mm TL for males, and 51 mm TL for females (fig 160).

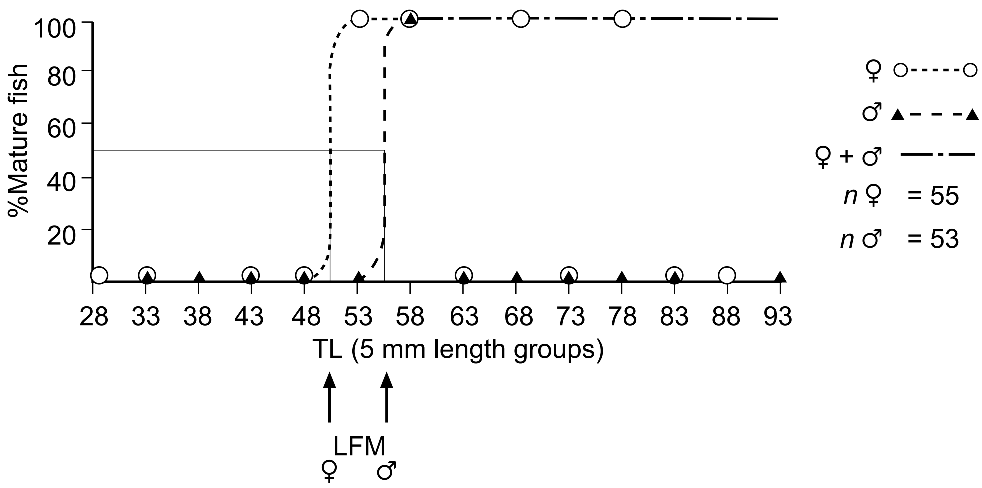


Figure 160 Estimated length at first maturity (LFM) of male and female *M. mogurnda*

228 Robertson and Baidam (1983) noted that *M. mogurnda* characteristically takes refuge amongst boulders in feeder streams of the Ok Tedi River in Papua New Guinea.

Sex ratio

Chi-squared tests were carried out on all male and female fish and on adult males and females only; these tests indicated a significantly greater proportion of males in both groups during the 1978 and 1979 Late-dry seasons (P < 0.005) (table 141). These are also the only two seasons during which more than 11 fish were captured. The unequal sex ratio may be due to misidentification of immature gonads, or a behavioural characteristic that may have resulted in the fishing methods selectively catching only one sex.

Breeding season

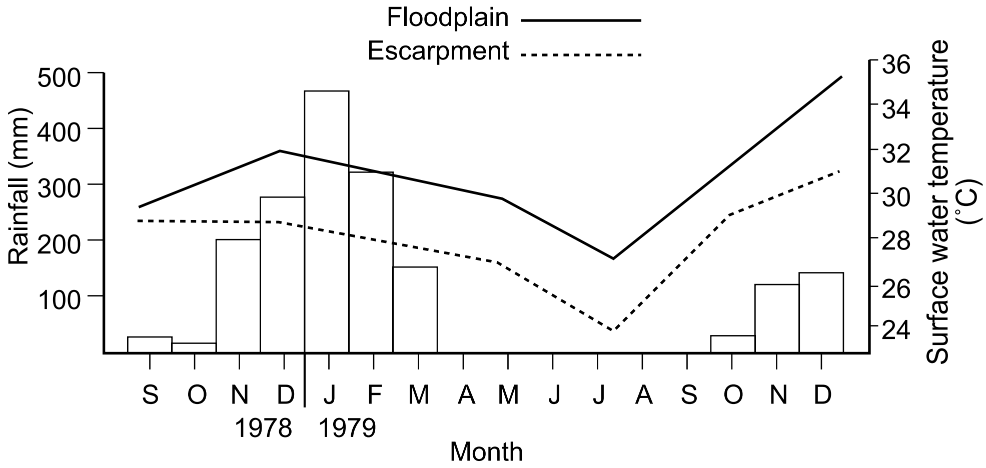
Very little change was observed in the reproductive state of *M. mogurnda* over the study period.[229] GSI and GMSI levels were slightly higher during the 1978–79 Early-wet season than in the 1979 Mid-dry and Late-dry seasons (table 141; fig 161). No mature or ripe fish were captured over the entire study period. Maturing fish were captured only in the 1978 Late-dry (10 fish), 1978–79 Early-wet (1 fish) and 1978–79 Mid-wet (1 fish) seasons. Juvenile fish were collected in all seasons, although the smallest (about 20 mm TL) were caught only in the 1978 Late-dry and 1978–79 Early-wet and 1978–79 Mid-wet seasons.

Table 141 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *M. mogurnda* over all habitats

			Sampling period						
Parameter	Sex	Statistic	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles +	F	*n*	12	2	3	1	6	31	0
adults	M	*n*	34	3	3	0	5	8	0
		χ^2	10.5	0.2	0	1.0	0.1	13.6	–
		P	**	n.s.	n.s.	n.s.	n.s.	***	n.s.
Adults only	F	*n*	9	2	3	1	2	27	0
	M	*n*	27	1	3	0	5	8	0
		χ^2	9.0	0.3	0	1.0	1.3	10.3	
		P	**	n.s.	n.s.	n.s.	n.s.	**	n.s
GSI									
(Adults only)	F	mean	1.4	2.6	1.7	0.3	0.7	0.7	–
		s.d.	1.9	1.0	2.1	–	0.4	0.2	–
	M	mean	0.2	0.5	0.3	–	0.2	0.2	–
		s.d.	0.1	–	0.2	–	0.2	0.1	–
	F+M	mean	0.7	1.9	1.1	–	0.4	0.6	–
		s.d.	1.3	1.4	1.7	–	0.4	0.3	–
GMSI									
(Adults only)	F	mean	3.4	3.5	3.0	2.0	2.5	–	–
		s.d.	0.9	0.7	1.0	–	0.7	0.3	–
	M	mean	2.8	3.0	2.0	–	2.0	2.1	–
		s.d.	0.6	–	1.4	–	0.8	0.4	–
	F+M	mean	3.1	3.3	2.6	–	2.2	2.4	–
		s.d	0.8	0.6	1.1	–	0.8	0.3	–

n = number; χ^2 = Chi-squared value; P = probability; n.s. = not significant (P > 0.05); ** = 0.001 < P < 0.01; *** = P < 0.001; s.d. = standard deviation.

229 Herbert and Peeters (1995) indicated that *M. mogurnda* appear to breed at the onset of the wet seasons and may breed continuously while temperatures are high.



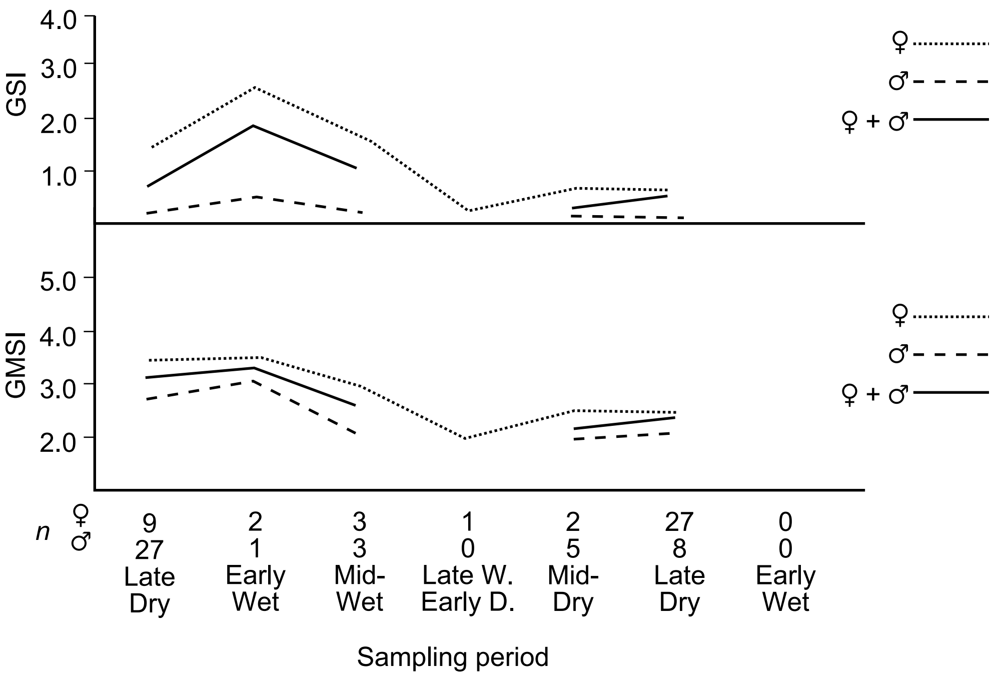


Figure 161 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad stage maturity index (GMSI) of male and female *M. mogurnda*

Mogurnda mogurnda is believed to have a similar spawning pattern to *M. adspersa* in eastern Australia: it breeds between December and February when temperatures vary from 26° to 34°C and food is abundant. Flooding was not essential for stimulating spawning in *M. adspersa* (Hoese et al 1980). *Mogurnda mogurnda* is believed to breed at the end of the year or any time of the year when conditions are suitable (Midgley, pers comm).

Site of spawning

Because no mature ripe fish were captured, the possible site of spawning could not be determined. Possibly this species moves into spawning areas that our methods or regular sampling sites did not cover. Both adults and small juveniles have been observed near waterfalls in escarpment perennial streams in habitats not regularly sampled in this study; breeding may occur at these sites. Juveniles were collected over a wide range of habitats, including escarpment area streams, sandy creekbed streams and shallow backflow billabongs (table 142).

Table 142 Possible sites of spawning of *M. mogurnda* as indicated by the abundance (*n*) of maturing and juvenile fish. No mature or ripe fish were captured.

	Gonad stage		
	Maturing (IV)		Juvenile
Habitat	F	M	
Escarpment			
Mainchannel waterbodies	1	0	3
Seasonal feeder streams	0	1	0
Perennial streams	0	0	2
Lowlands			
Sandy creekbed habitats	1	0	56
Backflow billabong	7	2	4
Corridor	0	0	4
Floodplain billabong			
Upper	0	0	5

Eggs are most likely laid in slow-flowing waters among aquatic weeds or attached to solid objects, often very close to the surface or on the underside of floating vegetation (see Llewellyn 1971 for *M. adspersa*).

Fecundity

The ovaries from the female with the highest GSI were examined to give some idea of relative fecundity and egg size. The fish was 73 mm TL long with a GSI of 4.73; the ovary contained 430 eggs of approximately 1 mm diameter. Female *M. adspersa,* which may spawn repeatedly, produce between 280 and 1300 ova at each spawning (Hoese et al 1980) or 500 to 800 ova (Llewellyn 1971).

The eggs of *M. adspersa* are adhesive, elongated and pointed at both ends, 2.6–3.8 mm long, and 1.1 to 1.3 mm wide. There are numerous small oil globules within the yolk. A sticky basal mass at one of the pointed ends allows attachment of a cluster of eggs to a solid object. The eggs are fanned and cared for by the male. Hatching takes from 3 to 8 days at temperatures around 29–30°C, and the prolarvae are about 3.5–4 mm long. The yolk is fully absorbed in about six days, when feeding on zooplankton begins (Llewellyn 1971, Hoese et al 1980). The sexes of *M. adspersa* are very similar, although the urino-genital papilla is pointed in males and broad with a fringed margin in females (Hoese et al 1980).

Summary

A breeding season and spawning site could not be determined because of the small number of maturing fish, and lack of mature and ripe fish.

A slight increase in reproductive development was observed during the 1978–79 Early-wet season. The breeding season may depend on food being abundant (L Llewellyn, pers comm).

The total absence of mature and ripe fish may be due to the fish breeding in a habitat we did not sample (such as heavily vegetated or rocky escarpment areas). *Mogurnda mogurnda* lays relatively few (around 500) of largish (1 mm diameter) eggs.

Feeding habits

Overall diet

The stomachs of 163 specimens were examined; 135 contained food. The diet is summarised in figure 162; the components are listed in table 143.

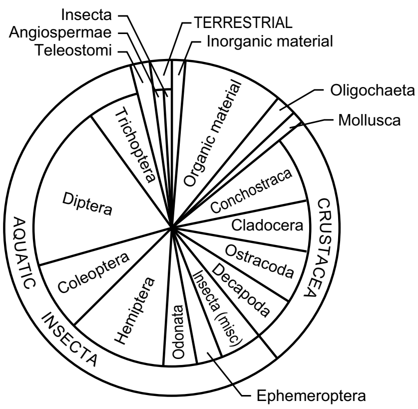


Figure 162 Dietary components of *M. mogurnda*

The main dietary items were aquatic insects (57%) and microcrustaceans (19%). A variety of aquatic insects were eaten, the most important being chironomid larvae and corixid bugs. The microcrustaceans were conchostracans, cladocerans and ostracods. *Macrobrachium* comprised less than 5% of the overall diet. Traces of oligochaetes, gastropods, teleosts, terrestrial plant material and terrestrial animals were also found in the stomachs. *Mogurnda mogurnda* can therefore be classified as a meiophagous carnivore feeding opportunistically in benthic and sometimes in the midwater zones of the waterbodies. Pollard (1974) suggested *M. mogurnda* was an opportunistic carnivore, eating insects, crustaceans and probably also small fish. Sanderson (1979) considered that *M. mogurnda* was an opportunistic carnivore, eating a variety of aquatic and terrestrial insects, helped by its cryptic occupation of pools and riffles in an intermittent stream running into the floodplain billabongs of the lower Magela Creek. Jeffree and Williams (1977) found that the diet of *M. mogurnda* in the Finniss River, Northern Territory, varied in unpolluted and polluted zones downstream from the mined area of Rum Jungle. However, Haines (1979), who studied this species in the Purari River, Papua New Guinea, classified it as an insectivore/detritophage. Fish do not appear to be important in its diet; however, large specimens could readily eat fish.[230]

Habitat differences

A total of 128 stomachs of *M. mogurnda* were examined (all seasons combined) in the Magela Creek catchment: 10 (10% empty) from escarpment mainchannel waterbodies, 28 (25% empty) from lowland sandy creekbeds, 72 (25% empty) from lowland backflow billabongs, 7 (43% empty) from corridor waterbodies and 11 (18% empty) from floodplain billabongs. The highest proportion of empty stomachs was thus found in corridor waterbodies and the lowest in escarpment mainchannel waterbodies.

230 Whitehead (1985) studied the diet of the closely related *M. adspersa* in a tropical upland stream in northeastern Queensland. Chironomids were of particular importance in the diet of small fish, while in large fish, ephemeropteran nymphs were of greatest importance. Both diel and seasonal variation in the composition of the diet were observed for small fish but not for large fish. Microcrustaceans were important in the diet of small fish during the day, but at night, chironomids were more important. Seasonally, microcrustaceans were more important for small fish towards the end of the Wet season, however, during the Dry season chironomids assumed dominance.

Table 143 Dietary composition of *M. mogurnda*

	Habitat								Season							
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979	Overall	
Stomach contents	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Sub-mean	Main-mean
Aquatic animals																
Oligochaeta	–	14.3	–	–	–	–	–	–	–	–	8.6	–	–	–	2.1	2.1
Gastropoda																1.2
Taxa1	–	–	1.3	–	–	–	–	20.0	3.3	–	–	–	–	–	1.2	
Microcrustacea																18.7
Conchostraca																
Miscellaneous	–	–	1.1	–	–	–	–	20.0	1.2	–	–	–	–	–	0.4	
Cyzicus	–	–	–	–	–	–	64.1	–	–	–	–	–	–	36.6	7.2	
Cladocera																
Miscellaneous	–	–	3.7	–	–	–	–	–	5.9	–	2.9	–	–	–	2.8	
Diaphanosoma	–	–	1.7	25.0	22.2	–	–	–	–	–	2.6	–	14.3	3.6	2.7	
Ostracoda	–	–	2.0	25.0	11.1	–	–	–	9.4	–	3.1	14.3	7.1	–	5.6	
Macrocrustacea																4.9
Macrobrachium	–	6.7	8.5	–	11.1	–	–	–	10.6	–	4.6	–	–	–	4.9	
Insecta																57.3
Fragmented	–	12.4	7.8	–	–	–	–	–	7.5	–	4.6	–	–	7.1	5.2	
Ephemeroptera																
Baetidae	–	1.0	2.8	–	–	20.0	–	–	1.2	28.6	0.6	7.1	–	3.6	3.0	
Odonata																
Lestidae	–	–	–	–	11.1	–	–	–	–	–	–	–	7.1	–	0.7	
I. heterosticta	–	–	3.0	–	–	–	–	–	–	–	4.6	–	–	–	1.1	
Gomphidae	–	4.8	1.8	–	–	–	–	–	3.9	–	–	–	–	–	1.4	
Libellulidae	–	–	3.5	–	–	–	–	–	3.7	–	–	–	–	–	1.3	
Hemiptera																
Corixidae	32.8	4.8	13.9	–	–	–	–	–	19.1	14.3	8.4	–	19.2	2.1	12.0	
Coleoptera																
Miscellaneous (adults)	18.9	4.8	2.9	–	–	20.0	–	40.0	5.1	14.3	4.9	–	14.3	–	5.1	
Miscellaneous (larvae)	11.1	–	1.7	–	–	–	–	–	1.8	–	2.9	–	–	–	1.3	

Table 143 continued

Stomach contents	Habitat								Season						Overall	
	Magela system					Nourlangie system			1978	1978–79	1978–79	1979	1979	1979		
	Em	Ls	Bb	Cb	Fb	Em	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Sub-mean	Main-mean
Rhantus	–	3.3	–	–	–	–	–	–	–	–	2.0	–	–	–	0.5	
Macrogyrus	–	–	1.8	–	–	–	6.3	–	–	–	–	–	7.1	3.6	1.4	
Hydrophilidae	–	–	0.7	–	–	–	–	–	–	–	1.1	–	–	–	0.3	
Diptera																
Miscellaneous (larvae)	–	–	–	–	–	–	4.4	–	–	–	–	–	5.0	–	0.5	
Chironomidae (larvae)	11.1	7.2	15.4	–	8.9	48.0	18.1	–	13.6	5.7	14.6	35.7	5.0	18.2	14.6	
Chironomidae (pupae)	–	2.9	–	–	–	–	2.5	–	0.8	–	1.7	–	–	1.4	1.0	
Ceratopogonidae	14.4	2.4	0.4	–	11.1	–	0.6	–	–	2.9	5.1	–	0.7	3.6	2.2	
Tabanidae	–	–	–	–	2.2	–	–	–	–	–	0.6	–	–	–	0.1	
Trichoptera																
Leptoceridae	–	7.1	10.4	–	–	12.0	4.1	–	2.7	20.0	5.4	–	14.3	5.9	5.9	
Teleostomi	–	–	4.8	–	–	–	–	–	1.6	–	–	14.3	5.7	–	1.8	1.8
Terrestrial plants																0.7
Angiospermae	–	–	1.9	–	–	–	–	–	–	–	–	–	–	3.6	0.7	
Terrestrial animals																
Insecta																1.4
Hymenoptera																
Formicidae	–	–	–	25.0	–	–	–	–	–	–	–	–	–	3.6	0.7	
Oecophylla	–	4.8	–	–	–	–	–	–	–	–	2.9	–	–	–	0.7	
Parasites																
Nematoda	–	4.8	–	–	–	–	–	–	0.1	–	2.9	–	–	–	0.7	0.7
Inorganic material	11.7	4.8	–	–	–	–	–	–	–	–	5.7	–	–	–	1.4	1.4
Organic material	–	14.3	8.9	25.0	22.2	–	–	20.0	8.6	14.3	10.3	28.6	–	7.14	9.2	9.2
Number of empty fish	1	7	18	3	2	2	1	–	7	2	6	–	4	16	35	35
Number of fish with food	9	21	54	4	9	5	16	5	51	7	35	7	14	28	128	128

Figures represent the mean percentage volume determined by the estimated volumetric method.

Em = escarpment mainchannel; Ls = lowland sandy creek bed; Bb = lowland backflow billabongs Cb = corridor billabongs; Fb = floodplain billabongs

Mogurnda mogurnda in the escarpment waterbodies were feeding entirely on insects (mainly corixids, miscellaneous beetles and ceratopogonids); the presence of sand in their stomachs indicates that it was benthic-dwelling when preying upon these insects. Aquatic insects were also important in the diet in sandy creekbeds; however, oligochaetes, *Macrobrachium* and terrestrial (green tree) ants were also eaten.

The diet in the lowland shallow backflow billabong was largely based on aquatic insects (corixids, chironomid larvae and leptocerid larvae); however *Macrobrachium,* microcrustaceans (conchostracans, cladocerans and ostracods), gastropods and traces of terrestrial plant material were also eaten. The few specimens examined from corridor waterbodies had eaten microcrustaceans and terrestrial ants that had fallen into the water. There were large quantities of unidentified organic material in the stomachs of specimens from corridor and floodplain billabongs. In floodplain billabongs *M. mogurnda* ate mostly microcrustaceans (cladocerans and ostracods) and *Macrobrachium,* and fewer aquatic insects.

Catchment differences

A total of 29 stomachs of *M. mogurnda* were analysed from Nourlangie Creek: 7 (28.6% empty) from escarpment mainchannel waterbodies, 17 (6% empty) from lowland sandy creekbeds and 5 (0% empty) from shallow backflow billabongs. The highest proportion of empty fish was found in the escarpment waterbodies and the lowest in the shallow backflow billabongs (in contrast to Magela Creek).

Mogurnda mogurnda ate only aquatic insects in the escarpment mainchannel waterbodies (with strong emphasis on chironomid larvae), as it did in the Magela catchment. In the lowland sandy creekbeds it ate mainly conchostracans (*Cyzicus*) and, to a lesser extent, aquatic insects (unlike the Magela catchment specimens). Coleopteran adults were eaten mainly in the shallow backflow billabongs, but *M. mogurnda* also ate gastropods and a quantity of conchostracan components.

Seasonal changes

In sampling periods 1 to 6, respectively, 58 (12% empty), 9 (22% empty), 41 (15% empty), 7 (0% empty), 18 (22% empty) and 44 (36% empty) stomachs of *M. mogurnda* were examined (all habitats combined). The highest proportion of empty fish was found in the 1979 Late-dry season and the lowest in the Late-wet–Early-dry season.

A variety of aquatic animals was found in the stomachs in the 1978 Late-dry season, the most important being aquatic insects (corixids and chironomid larvae), microcrustaceans (ostracods and cladocerans) and *Macrobrachium*, and traces of gastropods and teleosts. The diet was similar in the 1979 Late-dry season. In the 1978–79 Early-wet season the few specimens examined were eating exclusively aquatic insects (baetids and leptocerids).

The diet in the Mid-wet season appeared to became more varied than in the 1978–79 Early-wet, partly because more specimens were analysed. It included crustaceans, oligochaetes and terrestrial ants. In the Late-wet–Early-dry season, there was much unidentified organic material in the stomachs, as well as aquatic insects (mainly chironomid larvae), ostracods and teleosts. The diet in the 1979 Mid-dry season was similar to that in the Late-dry seasons, with microcrustaceans, aquatic insects (corixids, beetles and leptocerid larvae) and some teleosts being eaten.

Fullness

A summary of mean fullness indices of *M. mogurnda* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 144. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 144 Mean fullness indices of *M. mogurnda* in different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments

Habitat	Sampling period						
	Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Habitat mean
Magela Creek catchment (regular sites only)							
Upstream of RUPA:							
Escarpment main-channel waterbody	n/s	n/s	2.5 (10)	n/s	n/s	n/s	2.5 (10)
Lowland shallow backflow billabong	2.4 (10)	n/s	3.1 (8)	n/s	0 (1)	0.9 (7)	2.1 (26)
Lowland sandy creekbed	n/s	0 (1)	2.5 (20)	n/s	n/s	n/s	2.4 (21)
Downstream of RUPA:							
Lowland sandy creekbed	1.1 (7)	n/s	n/s	n/s	n/s	n/s	1.1 (7)
Lowland channel backflow billabong	n/s	0 (1)	0 (1)	n/s	1.2 (4)	n/s	0.8 (6)
Lowland shallow backflow billabong	2.9 (15)	1.5 (2)	n/s	2.0 (5)	3.0 (2)	0.4 (16)	1.7 (40)
Corridor sandy billabong	n/s	n/s	0 (1)	n/s	0 (1)	n/s	0 (2)
Corridor anabranch billabong	n/s	n/s	n/s	0 (1)	0 (1)	n/s	0 (2)
Floodplain billabong	0 (1)	0 (1)	3.5 (2)	0 (2)	2.0 (5)	1.2 (5)	1.3 16)
Nourlangie Creek catchment (regular sites only)							
Escarpment main-channel waterbody	n/s	0 (1)	n/s	n/s	n/s	n/s	0 (1)
Lowland channel backflow billabong	n/s	n/s	n/s	n/s	1.0 (2)	n/s	1.0 (2)
Lowland shallow backflow billabong	1.7 (3)	n/s	n/s	n/s	n/s	n/s	1.7 (3)
Lowland sandy creekbed	n/s	0 (1)	n/s	n/s	3.0 (2)	3.6 (14)	3.4 (17)
Seasonal mean (all sites)	2.3	2.1	2.5	1.4	1.7	1.7	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Habitat differences

In the Magela Catchment upstream from RUPA, mean fullness indices were higher than in similar downstream habitats, but were fairly equal between habitats.

Downstream from RUPA the mean fullness index was highest in shallow backflow billabongs and lowest in corridor waterbodies. Channel backflow billabongs also had a low mean fullness index.

In the Nourlangie Catchment, mean fullness indices were highest in the lowland sandy creekbed, and higher than in any habitat in the Magela catchment. The single specimen analysed in the escarpment mainchannel waterbody had an empty stomach.

Seasonal changes

The mean fullness index (all habitats combined) was fairly stable between the 1978 Late-dry and the 1978–79 Mid-wet seasons. The index then fell to a low after the Wet season (probably due to low dissolved oxygen levels in bottom-waters) and then increased slightly to reach a stable level between the Mid-dry and Late-dry season.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- floodplain billabongs; 1978–79 Mid-wet season
- lowland shallow backflow billabongs (upstream of RUPA); 1978–79 Mid-wet season
- lowland shallow backflow billabongs (downstream of RUPA); 1979 Mid-dry season

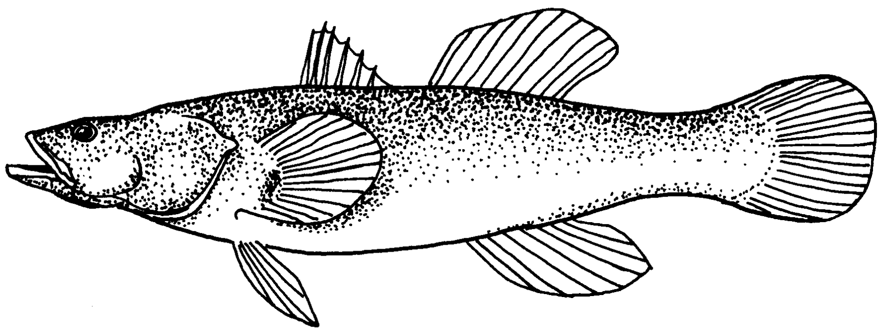
Nourlangie catchment

- lowland sandy creekbeds; 1979 Late-dry season, 1979 Mid-dry season.

Family ELEOTRIDIDAE

3.37 *Oxyeleotris lineolata* (Steindachner) vel assin[231]

Oxyeleotris lineolata is commonly known as the sleepy cod or sleeper. It is found in the drainage systems of the north-east coast, Gulf of Carpentaria and Timor Sea (see map 3), and also in Papua New Guinea. Pollard (1974) found large specimens in the lowland backflow billabongs (Georgetown Billabong and Indium Billabong) in the Magela Creek catchment and smaller specimens in fringing vegetation along the creek (Magela bed).



Oxyeleotris lineolata

Most members of the family Eleotrididae live in freshwater, but many are found in brackish and estuarine waters, and some in purely marine waters. *Oxyeleotris* appears to be a permanent inhabitant of freshwaters. It can be caught on hook and line and is excellent eating, though it is not a sport fish as it is extremely sluggish in relation to its size.

Detailed information on catches at each site and in each season is given in volume 2. In summary, this species was found commonly in all floodplain, corridor and lowland backflow billabongs and in lowland sandy creekbed habitats downstream of RUPA. It was observed only once in an escarpment mainchannel waterbody. In the 1978 Late-dry season it was found in only 5 sites (mainly lowland backflow billabongs); in the Mid-wet season, after some apparent recolonisation, it was found in 7 sites (backflow billabongs and floodplain billabongs); and in the Late-wet–Early-dry season it was found in 12 sites (lowland backflow billabongs, sandy creekbeds and floodplain billabongs).[232]

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231 The vel assin. specification (meaning 'or close relative') provides notice that *O. lineolata* samples analysed may have been contaminated by two closely related species, the dwarf (or poreless) gudgeon, *O. nullipora*, and/or the black-banded (or giant) gudgeon, *O. selheimi*. The dwarf gudgeon was recorded in the Alligator Rivers Region during 1984 (Bishop, pers obs). According to Larson and Martin (1989) this species has a discontinuous distribution across northern Australia, being found in the Northern Territory from the Reynolds to the Blyth Rivers. The black-banded gudgeon is widespread in the Timor Sea and Gulf drainages and Herbert et al (1995) recently recorded it in some north-east coast drainages (the Stewart and Annan Rivers of Cape York). In 1999 Helen Larson of the NT Museum advised that collections she has made from the Alligator Rivers Region contained more black-banded gudgeons than sleepy cod, *O. lineolata*. However, collections by Herbert et al (1995) from Cape York Peninsula indicated that *O. lineolata* was far more common than *O. selheimi*. Pollard (1974) considered small specimens with a colour pattern resembling *O. selheimi* (then known as *Bunaka herwerdenii*) to be but a juvenile colour phase of *O. lineolata*.

232 Coates (1992) found the closely related *O. heterodon* in the Sepik River of PNG to display greater catch rates on the floodplain compared with lakes during most of the flood season, confirming that this species prefers the floodplain habitats when it is flooded. Catches were probably greatly influenced by movements of the main stock onto and off the floodplain as river levels fluctuated.

Size composition

The lengths and weights of 134 specimens were determined. Most of the specimens were captured by seine net and therefore mesh selectivity influenced only the minimum size of specimens captured. Hydrophytes sometimes clogged the meshes, which resulted in the capture of some of the smallest juveniles. The few adult specimens that were captured by gill nets caused the minor peaks in the adult size range in figure 163.

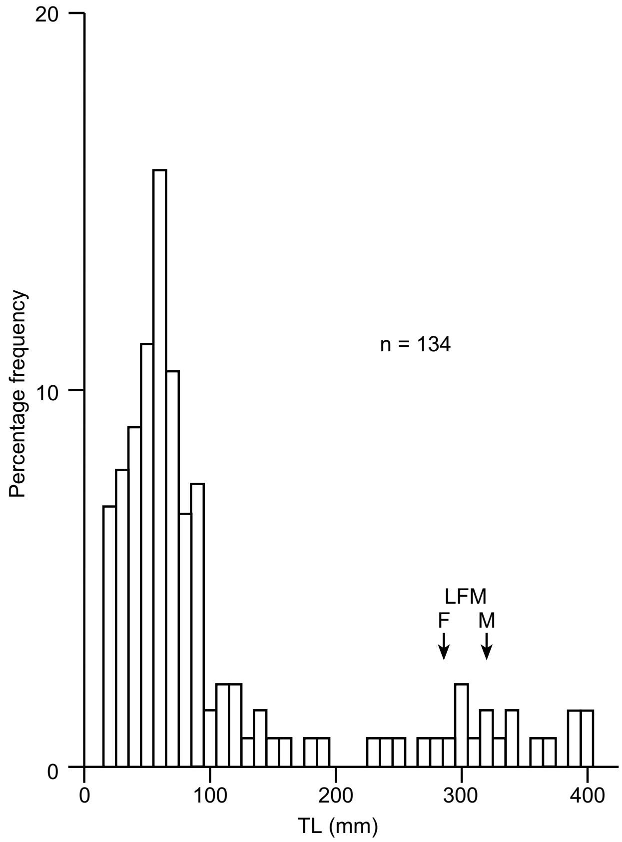

Figure 163 Length-frequency distribution of all *O. lineolata* captured (all sites)

Length–weight relationship

The length–weight relationship was described by the following expression:

$W = 7.68 \times 10^{-3} L^{3.14}$ r = 1.00 (length in cm, weight in g)

Seasonal mean lengths, weights and condition factors are shown in table 145. The seasonal condition factor was highest in the Late-dry seasons (especially in the 1978 season) and lowest from the 1978–79 Mid-wet to the 1979 Mid-dry season. The environmental conditions in the Late-dry seasons therefore appeared to be more favourable for good body condition in *O. lineolata*.[233]

233 Coates (1992) found that the closely related *O. heterodon* in the Sepik River of PNG to have a condition factor which exhibited little seasonality.

Table 145 Mean length, mean weight and condition factor of *O. lineolata*

Sampling period	*n*	Mean length (mm)	Mean weight (g)	Condition factor (K)
Late-dry (1978)	25	82.5	6.32	1.09
Early-wet (1978–79)	7	57.5	1.855	0.99
Mid-wet	9	84.3	5.97	0.96
Late-wet–Early-dry (1979)	20	75.6	4.22	0.96
Mid-dry	27	100.0	10.32	0.97
Late-dry (1979)	28	92.0	8.24	1.01
Early-wet (1979–80)	4	145.4	34.5	1.00
Overall	120	87.0	6.87	1.00

Length composition

Specimens ranged in size from 16 mm to 395 mm TL (fig 163). This species reputedly grows to 500 mm TL (Pollard 1974).[234]

Small juveniles were captured throughout all seasons of the study; however the smallest were captured in the 1978–79 Early-wet, 1979 Mid-dry and 1979 Late-dry seasons. The largest specimens were captured in the Mid-wet, 1979 Mid-dry and Late-dry seasons (fig 164).

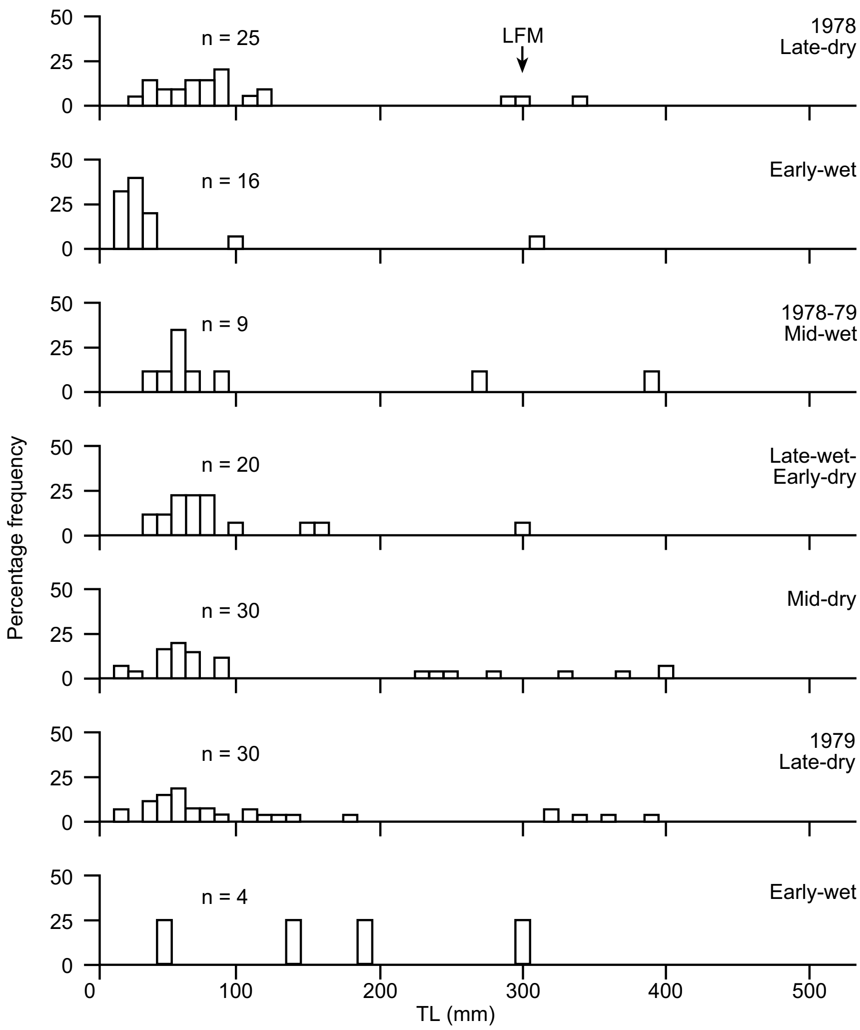

Figure 164 Seasonal length-frequency distribution of all *O. lineolata* captured

[234] Coates (1992) found the closely related *O. heterodon* in the Sepik River of PNG to attain 483 mm standard length (1.83 kg weight).

Length-frequency distribution

The mean and modal lengths of all specimens captured were 87 and 60 mm TL, respectively. The length at first sexual maturity (LFM on fig 163) ranged from 290 (females) to 320 mm TL (males), indicating that mostly juveniles were captured. Most specimens ranged in length from 20 to 90 mm TL. No specimens between 200 and 230 mm TL were captured. The overall distribution showed a strong negative skew, which illustrates the lower chances of juvenile specimens surviving to adulthood.

Seasonal mean lengths are shown in table 145. The shortest mean length was recorded in the 1978–79 Early-wet season, and the longest in the 1979–80 Early-wet. Evidently there is considerable yearly variation in juvenile recruitment in the study area, presumably due to differences in environmental conditions. Large juveniles and small adults appeared to be most common in the 1979 Mid-dry and Late-dry seasons (fig 164).

Growth rate

Estimation of the growth rate of *O. lineolata* from the seasonal length-frequency distributions is difficult due to the near-constant recruitment of juveniles.

Habitat differences in distribution

The habitats in which *O. lineolata* were captured in regular sampling sites in the Magela and Nourlangie catchments are shown in figure 165.

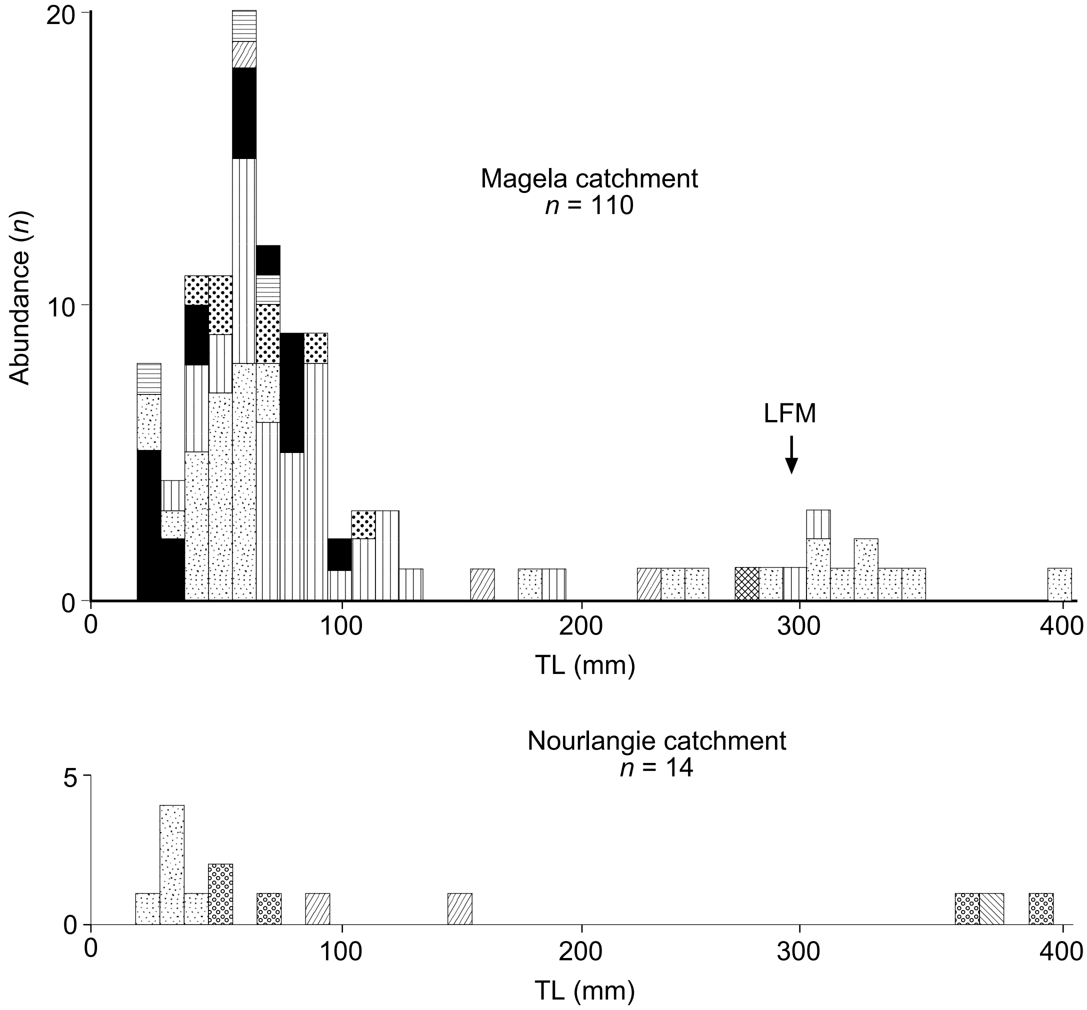

Figure 165 Length-frequency distribution and habitat preferences of *O. lineolata* captured at regular sampling sites (see appendix 5 for key to the habitats)

Magela catchment

The few large juveniles that were captured were found in lowland backflow billabongs, sandy corridor waterbodies and lowland sandy creekbeds (their presence in the last two may indicate dispersal before attaining the LFM). The smallest juveniles were mainly captured in backflow billabongs downstream and, to a lesser extent, upstream of RUPA in floodplain billabongs and corridor anabranch billabongs. No juveniles were found in escarpment habitats.

Most adults were found in backflow channel lowland billabongs downstream of RUPA. No adults were found in escarpment habitats.

Nourlangie catchment

No large juveniles were found in the Nourlangie system. The small juveniles were found mainly in lowland backflow billabongs, and the intermediate-sized specimens were found in sandy creekbeds. The few adults were captured in a lowland shallow backflow billabong and one specimen was found in an escarpment mainchannel waterbody. No juveniles were captured in the escarpment mainchannel waterbody. No juveniles or adults were found in escarpment perennial or seasonal streams.

Environmental associations

Rank numbers for *O. lineolata* for the physico–chemical and habitat–structural variables are shown in table 155.

Physico–chemical variables

Temperature

Water temperatures recorded at sites where *O. lineolata* was captured ranged from 26° to 38°C (mean = 31.1°C) on the surface, and from 23° to 35°C (mean = 29.3°C) on the bottom. Both means ranked in the upper-middle quarter (see fig 170). Specimens were often found lying in shallow waters at the edges of waterbodies, as reflected in its apparent preference for relatively high surface water temperatures.[235]

Dissolved oxygen

Dissolved oxygen concentrations in waters inhabited by *O. lineolata* ranged from 1.0 to 9.1 mg/L (mean = 5.8 mg/L) on the surface, and from 1.7 to 9.5 mg/L (mean = 4.6 mg/L) on the bottom. These means were ranked into their respective lower-middle and upper-middle quarters (see fig 171). The unexpectedly high extremes of both surface- and bottom-water ranges (*O. lineolata* is typically found in sluggish lowland waters) may be caused by photosynthetic production of oxygen by hydrophytes in the littoral waters (see below).

Visibility

Oxyeleotris lineolata was typically captured in very turbid waters, with Secchi depths ranging from 1 to 100 cm (mean = 26 cm) (see fig 172). This mean depth was ranked at the base of the lower quarter, indicating that this species was commonly found in some of the most turbid waters of the study area.

pH

The pH values of waters in which *O. lineolata* was captured ranged from 4.8 to 9.1 (mean = 6.4) on the surface, and from 4.5 to 7.1 (mean = 6.1) on the bottom. Both means were ranked in the upper-middle quarter (see fig 173). The range of pH values was broad.

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235 Merrick and Schmida (1984) indicated that *O. lineolata* spawned when water temperatures exceeded 24°C, which is virtually all year round in the Alligator Rivers Region.

Conductivity

Conductivity readings for waters in which this species was captured had a wide range, from 4 to 498 µS/cm on the surface, and from 2 to 478 µS/cm on the bottom.

Habitat–structural variables

Substrate

Oxyeleotris lineolata was most commonly found in waters with mud substrates (upper quarter), followed by clay (upper-middle quarter) then sand, gravel, leaf litter and rock substrates; this accords with the low visibility recorded.

Hydrophytes

Oxyeleotris lineolata was typically captured in heavily vegetated waterbodies (vegetation-occurrence index 80%): mainly submergent, followed by emergent then floating-attached hydrophytes. Pollard (1974) noted this species is found in heavily vegetated pools, often basking amongst vegetation at the shallow edges of waterholes.

Reproduction

A total of 133 *O. lineolata* were examined for reproductive condition; 94 were sexually indistinguishable (length range 16–164 mm TL), 17 were female (80–395 mm TL) and 22 were male (65–395 mm TL).

Length at first maturity

The smallest maturing male and female were 330 and 285 mm TL, respectively. The LFM, calculated with 10-mm-length groups, was 320 mm TL for males and 290 mm TL for females (fig 166).[236] No sexually indistinguishable fish were found above the LFM.

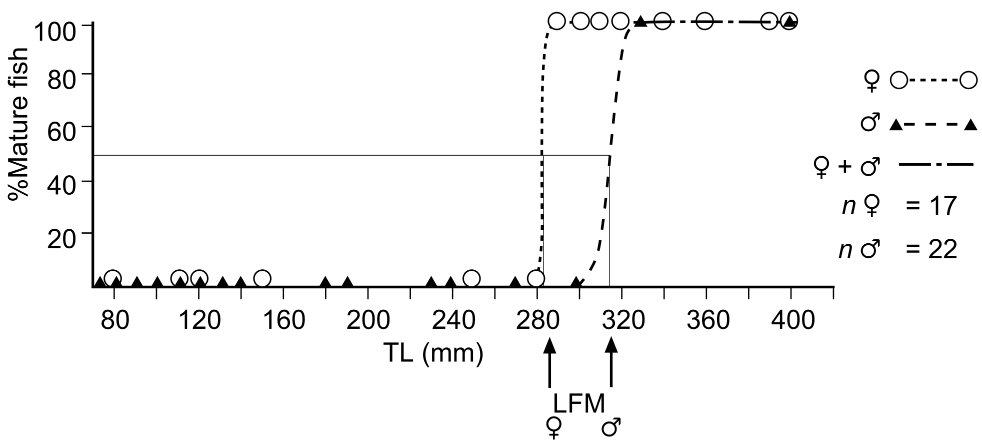

Figure 166 Estimated length at first maturity (LFM) of *O. lineolata*

Sex ratio

The ratio of males to females was not significantly different from 1:1 over the study period, both for the adult and juvenile fish combined and for the adult fish only (table 146).[237]

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236 Coates (1992) found the size at 50% maturity for the closely related *O. heterodon* in the Sepik River of PNG to be 210–230 mm for males, and 176–200 mm for females.

237 Merrick and Midgley (1982) indicated that adult *O. lineolata* were easily sexed by external examination using the dimorphic urogenital papillae, that of the female being longer and fatter than the males. Coates (1992) found the closely related *O. heterodon* in the Sepik River of PNG to have equal numbers of each sex all year round.

Breeding season

The samples of adult males and females were very small (one to five fish) in every season (table 146). No ripe fish, and only eight mature fish, were collected. Figure 167 indicates a high GSI and GMSI throughout the year, with a drop in reproductive development during the 1978–79 Mid-wet season. Juveniles were collected throughout the year, although the highest number were collected during the 1978–79 Early-wet season. Eggs were collected by Midgley (pers comm) from mid-November 1979 until the end of January 1980. Mature fish were captured only in the 1978 and 1979 Late-dry and 1979 Mid-dry seasons.

Table 146 Seasonal changes in the sex ratio, gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of *O. lineolata* over all habitats

Parameter	Sex	Statistic	Sampling period						
			Late-dry 1978	Early-wet 1978–79	Mid-wet	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80
Sex ratio									
Juveniles + adults	F	*n*	3	1	1	2	3	7	0
	M	*n*	4	1	1	1	6	6	3
		χ^2	0.1	0	0	0.3	1.0	0.1	3.0
		P	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Adults only	F	*n*	3	1	1	1	1	4	0
	M	*n*	0	0	0	0	2	1	0
		χ^2	3.0	1.0	1.0	1.0	0.3	1.8	–
		P	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
GSI									
Adults only	F	mean	1.9	1.9	0.0	1.2	1.4	1.7	–
		s.d.	0.8	–	–	–	–	0.6	–
	M	mean	–	–	–	–	0.2	0.3	–
		s.d.	–	–	–	–	0.3	–	–
	F+M	mean	–	–	–	–	0.3	1.4	–
		s.d.	–	–	–	–	0.2	0.8	–
GMSI									
Adults only	F	mean	4.7	4.0	2.0	4.0	5.0	4.7	–
		s.d.	0.6	–	–	–	–	0.6	–
	M	mean	–	–	–	–	4.5	5.0	–
		s.d.	–	–	–	–	0.7	–	–
	F+M	mean	–	–	–	–	4.7	4.8	–
		s.d	–	–	–	–	0.6	0.5	–

n = number identified; χ^2 = Chi-squared value; P = probability; n.s. = not significant (P > 0.05); s.d. = standard deviation.

The data, although sparse, suggest *O. lineolata* was spawning throughout the year, though possibly more were spawning around the Mid- to Late-dry seasons.[238] Other studies (Lake 1978; Midgley, pers comm) suggest that the breeding season extends from mid-October through to February, when temperatures reach 24°C. The virtually continuous breeding suggested by our data may be an artefact of the small samples of adult fish.

238 Coates (1992) found the closely related *O. heterodon* in the Sepik River of PNG to breed all year round. An examination of seasonal patterns in the gonadosomatic index indicated that breeding activity increased at the end of the flood season into the beginning of the dry season.

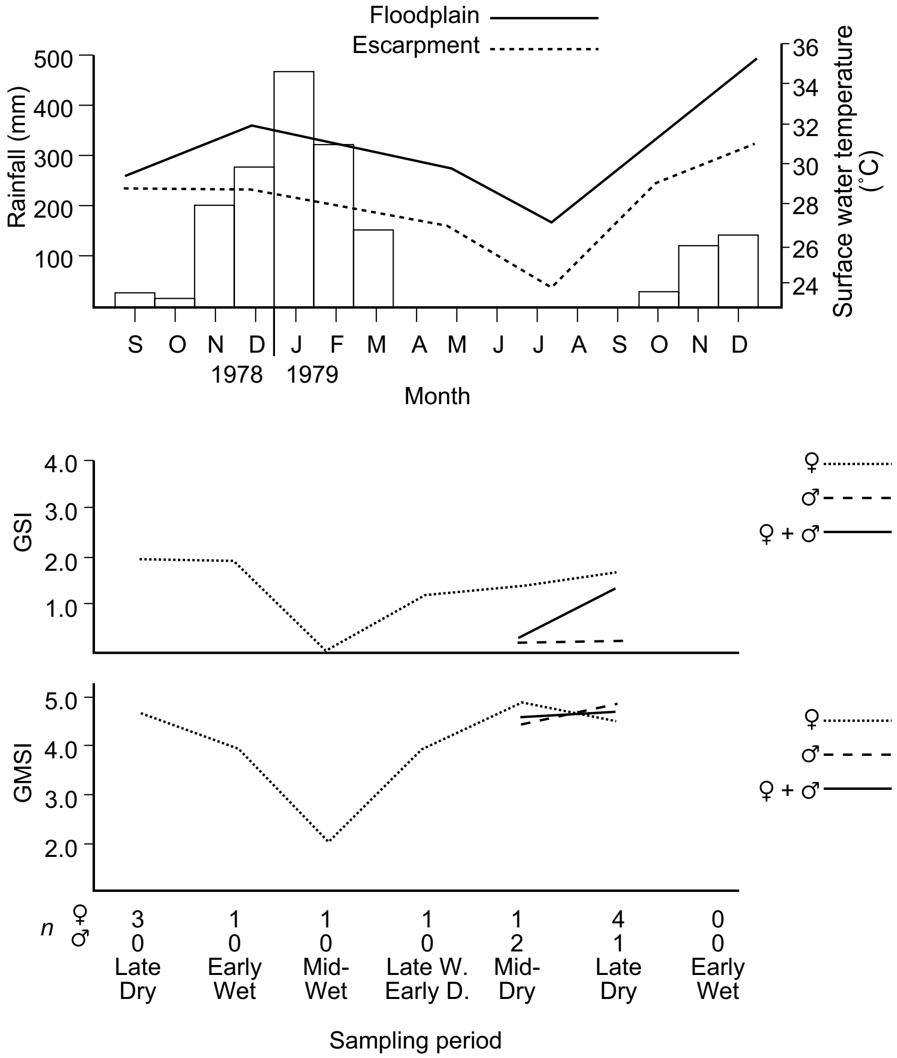

Figure 167 Seasonal fluctuations in the gonadosomatic index (GSI) and gonad maturity stage index (GMSI) of male and female *O. lineolata*

Site of spawning

No spawning was observed during our study, but Midgley collected about 700 000 eggs from four traps (five-gallon steel drums placed in billabongs) set in Georgetown Billabong and Indium Billabong, from mid-November 1979 to the end of January 1980 (Midgley 1980). The mature fish were collected from lowland backflow billabongs and from the East Alligator floodplain billabongs (table 147). Juveniles were generally collected from backflow billabongs and floodplain billabongs.

Table 147 Possible sites of spawning of *O. lineolata* as indicated by the abundance (*n*) of mature, ripe and juvenile fish

	Gonad stage				
	Mature (V)		Ripe (VI)		Juvenile
Habitat	F	M	F	M	
Lowlands					
Backflow billabong	5	2	0	0	23
Floodplain billabong					
Upper	0	0	0	0	10
Lower (riverine)	1	0	0	0	1

Fecundity
Six ovaries were examined. The number of eggs ranged from 35 000 (fish length 310 mm TL; GSI 1.88) to 170 000 (390 mm, 1.13), with an average of about 100 000. The diameters ranged between 0.3 and 0.5 mm (mean about 0.4 mm).[239] About 50 000 eggs are believed to be laid on patches generally ranging in area from 0.3 to 0.4 m^2 (Midgley, pers comm). The eggs are long and pear-shaped, with an adhesive disc that attaches the egg to objects in the water (plate 6).[240] The male guards the egg patch.

Summary
The data suggest that *O. lineolata* may breed throughout the year whenever conditions are suitable; however, very few adult fish were collected. Other reports indicate they breed from October until February, when water temperatures are above 24°C (Lake 1978; Midgley, pers comm).

Males are generally larger than females and have smaller urinogenital papilla (Midgley, pers. comm; Lake 1978). In the present study the males were smaller than the females.

Oxyeleotris lineolata most likely bred in the backflow billabongs and possibly in the floodplain billabongs. A large number (around 100 000) of tiny adhesive eggs (0.4 mm diameter) are laid in a patch, which is attached to an object in the water. The male guards this egg patch. The eggs incubate for about five to six days. The larvae are about 3 mm long with large pigmented eyes and a well-developed mouth.

Feeding habits

Overall diet
The stomachs of 133 specimens were examined; 106 contained food. The diet of *O. lineolata* is summarised in figure 168; the components are listed in table 148.

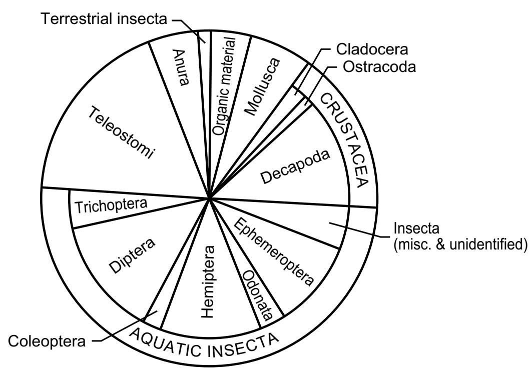

Figure 168 Dietary components of *O. lineolata*

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239 Coates (1992) found the closely related *O. heterodon* in the Sepik River of PNG to have a mean mature egg diameter of 0.46 (± 0.05) mm. The fecundity (F) versus standard length (SL) relationship for females with ripe gonads was:

F = 0.206 x SL2.25 (r = 0,55, p < 0.001).

The mean fecundity was approximately 160 eggs per gram of total body weight.

240 Merrick and Midgley (1982) described the eggs and early development of two species of *Oxyeleotris*, including *O. lineolata*. The development of drum traps used as a spawning substrate was detailed and the culture of harvested eggs to the feeding stage was described.

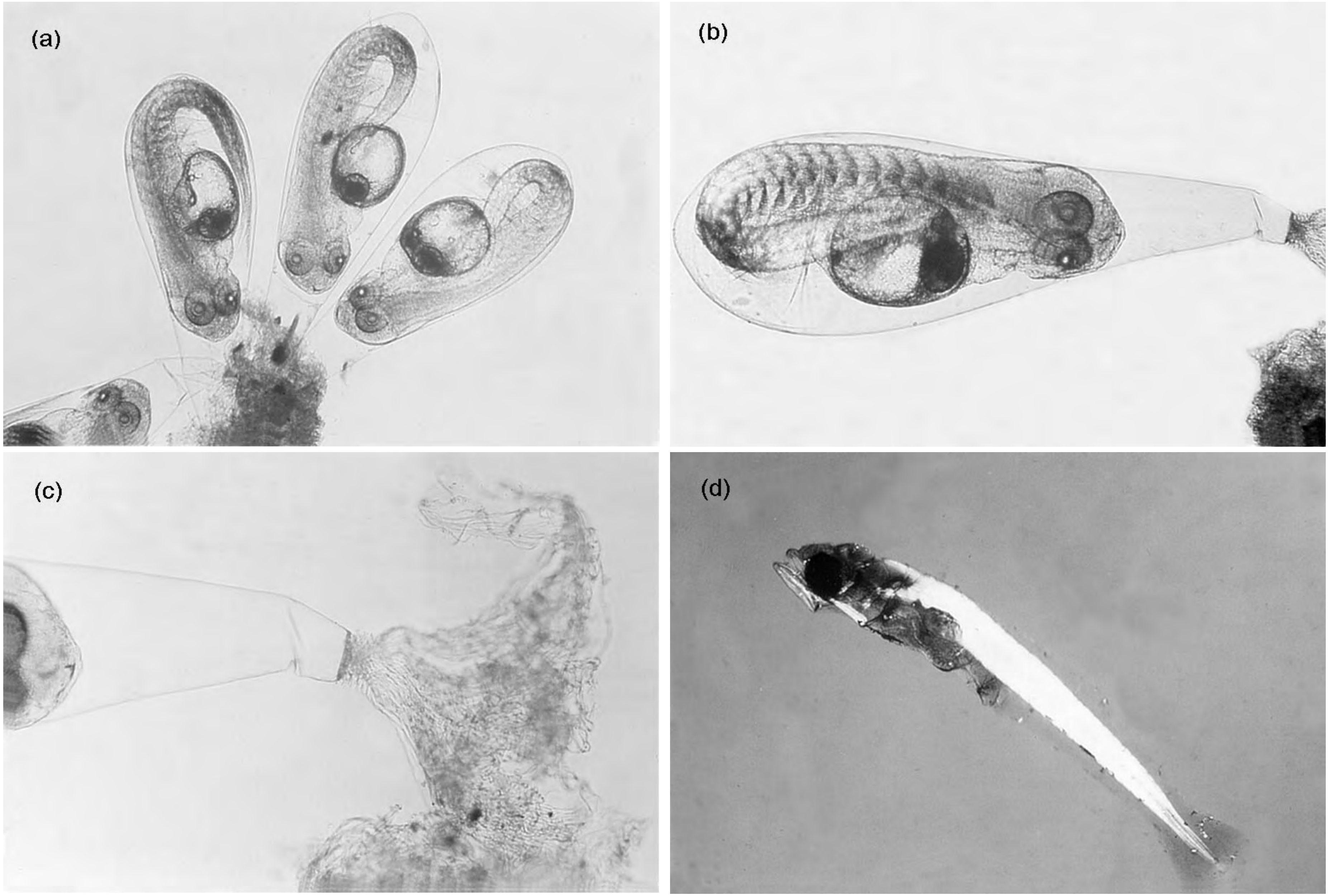

Plate 6 Stages in embryonic and larval development of *O. lineolata*: (a) eggs approximately 3 days after fertilisation x25; (b) x40; (c) adhesive basal disk of egg x100; (d) newly hatched larva, TL 3.1 mm, approx. 8 days after fertilisation.

Table 148 Dietary composition of *O. lineolata*

	Habitat						Season							Overall	
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Aquatic animals															
Gastropoda															6.4
Taxa 1	–	1.1	–	7.7	–	30.0	–	–	4.4	6.3	12.2	–	–	4.0	
Taxa 2	–	2.6	–	–	–	7.5	–	–	6.7	–	8.3	–	–	2.4	
Microcrustacea															2.9
Cladocera															
Diaphanosoma	–	–	25.0	7.7	–	–	–	–	–	–	–	4.6	–	1.9	
Ostracoda	–	–	–	0.4	–	–	5.3	7.1	0.6	–	–	–	–	1.0	
Macrocrustacea															12.5
Macrobrachium (juv)	–	5.1	–	–	–	–	19.5	–	–	–	–	–	–	3.5	
Macrobrachium (adults)	–	9.1	25.0	–	–	15.0	29.2	1.4	–	6.3	4.3	8.2	–	9.0	
Insecta															49.3
Fragmented	–	5.4	–	7.7	–	–	–	7.1	–	11.9	4.3	4.6	–	4.6	
Ephemeroptera															
Baetidae	–	11.5	–	7.7	50.0	–	–	7.1	11.1	16.3	24.8	–	–	9.7	
Odonata															
Libellulidae	–	2.4	–	7.7	–	–	8.9	–	11.1	6.3	–	–	–	3.5	
Hemiptera															
Gerridae	–	1.4	–	–	–	–	–	–	–	–	4.3	–	–	0.9	
Anisops	–	1.1	–	–	–	–	4.2	–	–	–	–	–	–	0.7	
Corixidae	–	13.6	–	7.7	–	–	7.4	7.1	–	6.3	14.8	18.2	–	10.2	
Coleoptera															
Miscellaneous	–	0.1	–	–	–	–	–	–	–	0.6	–	–	–	0.1	
Dytiscidae (larvae)	–	–	–	7.7	–	–	–	7.1	–	–	–	–	–	0.9	
Berosus	–	1.0	–	–	–	–	–	–	–	–	3.0	–	–	0.7	
Diptera															
Chaoborinae	–	6.9	–	–	–	–	–	–	–	–	–	22.7	–	4.7	
Chironomidae (larvae)	–	7.7	–	24.2	–	–	5.5	14.3	1.7	2.5	4.8	14.6	33.5	8.4	
Chironomidae (pupae)	–	0.1	–	–	–	–	–	–	–	–	0.4	–	–	0.1	
Ceratopogonidae	–	1.5	–	–	–	–	–	–	11.1	–	0.4	–	–	1.0	

Table 148 continued

	Habitat						Season							Overall	
	Magela system				Nourlangie system		1978	1978–79	1978–79	1979	1979	1979	1979–80		
Stomach contents	Ls	Bb	Cb	Fb	Ls	Bb	Late-dry	Early-wet	Mid-wet	Late-wet–Early-dry	Mid-dry	Late-dry	Early-wet	Sub-mean	Main-mean
Trichoptera															
Leptoceridae	50.0	4.2	–	–	–	–	–	–	11.1	6.2	4.3	4.6	–	3.8	
Teleostomi															16.2
Fragmented	–	4.2	–	–	50.0	–	–	–	–	18.8	–	–	33.5	3.8	
Miscellaneous (larvae)	–	1.4	–	–	–	–	–	–	–	6.2	–	–	–	0.9	
M. splendida inornata	–	3.9	–	–	–	–	14.7	–	–	–	–	–	–	2.6	
P. tenellus	–	–	25.0	13.1	–	–	–	–	18.9	–	4.3	–	–	2.5	
Ambassis spp.	–	1.4	–	–	–	–	–	–	–	6.2	–	–	–	0.9	
A. agrammus	–	–	25.0	–	–	–	5.3	–	11.1	–	–	–	–	1.9	
L. unicolor	50.0	–	–	–	–	–	–	–	–	6.2	–	–	–	0.9	
G. aprion	–	1.4	–	–	–	–	–	–	–	–	4.3	–	–	0.9	
Glossogobius spp.	–	1.4	–	–	–	–	–	–	–	–	–	–	33.5	0.9	
M. mogurnda	–	1.4	–	–	–	–	–	7.1	–	–	–	–	–	0.9	
Anura															5.4
Miscellaneous (larvae)	–	1.4	–	–	–	47.5	–	34.3	11.1	–	–	–	–	5.4	
Terrestrial plants															
Angiospermae															0.2
Fragmented	–	0.3	–	–	–	–	–	–	–	–	0.9	–	–	0.2	
Terrestrial animals															
Insecta															0.9
Coleoptera	–	1.4	–	–	–	–	–	–	–	–	–	4.5	–	0.9	
Parasites															
Nematoda	–	–	–	0.8	–	–	–	–	1.1	–	–	–	–	0.1	0.1
Organic material	–	6.9	–	7.7	–	–	–	7.1	–	–	4.3	18.2	–	5.7	5.7
Number of empty fish	1	17	3	2	–	3	6	2	–	4	6	8	–	27	27
Number of fish with food	2	72	4	13	2	8	19	14	9	16	23	22	3		

Figures represent the mean percentage volume determined by the estimated volumetric method.

Ls = lowland sandy creek bed; Bb = lowland backflow billabongs; Cb = corridor billabongs; Fb = floodplain billabongs

The main components were aquatic insects (49.3%), teleosts (16.2%) and macrocrustaceans (12.5%, *Macrobrachium* and probably some *Caridina*). The aquatic insects were mainly corixid bugs, baetid mayflies (mainly *Cloen*) and chironomid larvae. Nine species of teleosts were identified (mainly from the larger specimens); the most abundant were *M. splendida inornata, P. tenellus* and *Ambassis* spp. Gastropods, microcrustaceans (cladocerans and ostracods) and anuran larvae were also eaten, and there were traces of terrestrial plants and animals in the stomachs. *Oxyeleotris lineolata* can therefore be classified as a macrophagic carnivore opportunistically feeding in the benthic, midwater and littoral zones of waterbodies. These findings agree with Pollard's (1974) and Lake's (1978) that this species is an opportunistic carnivore, eating crustaceans, insects and small fishes. However, Haines (1979) reported that the closely related *O. fimbriatus* in the Purari River, Papua New Guinea, is a detritophage/insectivore.[241]

Habitat differences

A total of 114 stomachs of *O. lineolata* were examined (all seasons combined) from the Magela Creek catchment: 3 (33% with empty stomachs) from lowland sandy creekbeds, 89 (19% empty) from backflow billabongs, 7 (42.8% empty) from corridor waterbodies, and 15 (13% empty) from floodplain billabongs. The highest proportions of fish with empty stomachs were found in corridor waterbodies and the lowest proportions in floodplain and lowland shallow backflow billabongs.

The few stomachs of *O. lineolata* examined from the lowland sandy creekbeds contained only *L. unicolor* and leptocerid caddis fly larvae. The more numerous stomachs of *O. lineolata* from lowland backflow billabongs contained a greater variety, mainly corixid bugs, baetid mayfly larvae, chironomid and chaoborin larvae, *Macrobrachium* and *Caridina*; the identifiable fish were *M. splendida inornata, Ambassis* spp., *G. aprion, Glossogobius* spp. and *M. mogurnda*.

The few stomachs examined from corridor waterbodies contained only crustaceans and fish (*P. tenellus* and *Ambassis* spp.). The stomachs of *O. lineolata* from the floodplain billabongs mainly contained a wide range of aquatic insects, and to a lesser extent fish, crustaceans and gastropods. The most important food items in the floodplain billabongs were chironomid larvae and *P. tenellus*.

Catchment differences

A total of 13 stomachs of *O. lineolata* were examined (all seasons combined) from the Nourlangie Creek catchment: 2 (0% empty) from lowland sandy creekbeds and 11 (27% empty) from shallow backflow billabongs.

As in the Magela catchment, *O. lineolata* in the sandy creekbed pools, had eaten aquatic insects and fish. In the Nourlangie catchment the diet in the backflow billabongs was different from that in the Magela catchment: anuran larvae and gastropods were the main food items.

Seasonal changes

In sampling periods 1–7, respectively, 25 (24% empty), 16 (13% empty), 9 (0% empty), 20 (20% empty), 29 (21% empty), 30 (27% empty) and 4 (25% empty) stomachs of *O. lineolata* were examined (all habitats combined). The highest proportion of fish with empty stomachs was in the Late-dry seasons and the lowest proportion in the Mid-wet season.

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241 Coates (1992) found the closely related *O. heterodon* in the Sepik River of PNG to be primarily a piscivore, targeting almost exclusively *Ophieleotris aporos*. Large crustaceans (*Macrobrachium* and *Cardinia*) were also consumed.

The main food items in the diet of *O. lineolata* were different in the two Late-dry seasons: in 1978 they were the macrocrustaceans *Macrobrachium* and *Caridina*, the teleost *M. splendida inornata* and corixid bugs; in 1979 they were chaoborin and chironomid larvae and corixid bugs. In the 1978–79 Early-wet season anuran larvae became important in the diet and chironomid larvae were also eaten more often; *Macrobrachium* virtually disappeared and were replaced by aquatic insects such as baetid mayfly larvae and dytiscid beetle larvae; fish became less important and only *M. mogurnda* was found in the stomachs. The few fish examined in the 1979–80 Early-wet season had eaten mainly fish (*Glossogobius* spp.) and chironomid larvae.

During the Mid-wet season, the fish component (mainly *P. tenellus* and *Ambassis* spp.) of the diet increased, gastropods appeared and anuran larvae became less important. Ostracods, which were eaten in the previous seasons, had almost vanished, as had chironomid larvae. In the Late-wet–Early-dry season, the fish component of the diet became larger, corixid bugs reappeared, and baetid mayfly larvae were eaten more often. During the Mid-dry season, the fish component became smaller and more gastropods and aquatic insects (baetids and corixids) were eaten.

Fullness

A summary of mean fullness indices of *O. lineolata* for different sampling periods and habitat types in the Magela Creek and Nourlangie Creek catchments is shown in table 149. These data are presented on the assumption that feeding times do not vary with habitat or season.

Table 149 Mean fullness indices of *O. lineolata* in different sampling periods and habitats in the Magela Creek and Nourlangie Creek catchments

Habitat	Sampling period							Habitat mean
	Late-dry 1978	Early-wet	Mid-wet 1978–79	Late-wet–Early-dry 1979	Mid-dry	Late-dry	Early-wet 1979–80	
Magela Creek catchment (regular sites only)								
Upstream of RUPA:								
Lowland shallow backflow billabong	0 (1)	n/s	2.0 (2)	n/s	0 (1)	0.5 (2)	n/s	0.8 (6)
Downstream of RUPA:								
Lowland sandy creekbed	n/s	n/s	n/s	3.0 (2)	1.0 (7)	1.4 (5)	n/s	1.4 (14)
Lowland channel backflow billabong	n/s	0 (1)	0 (1)	0.7 (7)	2.5 (14)	1.5 (17)	3.0 (2)	1.7 (42)
Lowland shallow backflow billabong	2.7 (20)	0 (1)	0 (1)	2.0 (6)	1.0 (10)	0.6 (5)	2.5 (2)	1.9 (45)
Corridor sandy billabong	n/s	n/s	0 (1)	n/s	n/s	n/s	n/s	0 (1)
Corridor anabranch billabong	n/s	0 (1)	n/s	n/s	2.0 (2)	n/s	n/s	1.3 (3)
Floodplain billabong	n/s	1.6 (7)	5.0 (2)	0.4 (7)	n/s	2.5 (2)	n/s	1.6 (18)
Nourlangie Creek catchment (regular sites only)								
Lowland channel backflow billabong	n/s	2.5 (6)	n/s	n/s	n/s	0.5 (2)	n/s	2.0 (8)
Lowland shallow backflow billabong	n/s	n/s	0 (1)	n/s	4 (5)	n/s	n/s	3.3 (6)
Lowland sandy creekbed	n/s	n/s	n/s	0 (1)	0 (1)	n/s	n/s	0 (2)
Seasonal mean (all sites)	1.2	2.2	3.1	1.3	2.5	0.8	2.8	

Numbers analysed are given in parentheses; n/s = not sampled in the habitat.

Seasonal differences

The mean fullness index (all habitats combined) increased during the 1978–79 Early-wet season and then peaked in the 1978–79 Mid-wet season.[242] After the Wet season the index fell close to the level recorded in the previous Late-dry season. The low dissolved oxygen levels recorded in the bottom-water of most backflow billabongs during the Late-wet–Early-dry season may have reduced the feeding activity of this benthic-dwelling species. The fullness index increased in the Mid-dry season and then fell to a low in the 1979 Late-dry season. It increased in the 1979–80 Early-wet season, as it had the previous year.

Habitat differences

In the Magela catchment upstream from RUPA, the few specimens analysed were from a lowland shallow backflow billabong. They had very low mean fullness indices compared with specimens from similar downstream habitats.

Downstream from RUPA, the mean index was highest in shallow backflow and channel backflow billabongs and floodplain billabongs. The indices were lowest in corridor waterbodies.

In the Nourlangie catchment, the mean fullness indices were highest in shallow backflow and lowland channel backflow billabongs, and comparatively higher than in these habitats in the Magela catchment. The few specimens examined from the lowland sandy creekbeds had empty stomachs.

Summary

The habitats and periods of greatest apparent feeding activity were:

Magela catchment

- floodplain billabongs; 1978–79 Mid-wet season
- lowland channel backflow billabongs; 1979–80 Early-wet season
- lowland sandy creekbeds; 1979 Late-wet–Early-dry season
- lowland shallow backflow billabongs (downstream of RUPA); 1978 Late-dry season

Nourlangie catchment

- lowland shallow backflow billabongs; 1979 Mid-dry season
- lowland channel backflow billabongs; 1978–79 Early-wet season.

242 Coates (1992) found that the closely related *O. heterodon* in the Sepik River of PNG had a stomach fullness index which exhibited little seasonality. Variation in the index reflected the changing abundance of the fish species (*Ophieleotris aporos*) it almost exclusively consumed.