Notes on the diet of the Black-spotted Croaker (*Protonibea diacanthus*) across northern Australia

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Abstract

This study has provided some baseline data on the diet of the Black-spotted Croaker (*Protonibea diacanthus*) in coastal waters off northern Australia. Black-spotted Croakers were found to be opportunistic predators, feeding on a variety of fishes and crustaceans. Larger individuals contained more fish remains, with prawns dominating the diet of smaller individuals. Seasonality of diet is suggested by the results, however a wider range of samples across all months of the year would be required to confirm this.

Introduction

The Black-spotted Croaker (*Protonibea diacanthus*) (family Sciaenidae), known locally as the Black Jewfish, is a widespread species throughout tropical Indo-West Pacific marine waters and forms an important component of both commercial and recreational fisheries (Phelan *et al.* 2008a, 2008b; Froese & Pauly 2015; Saunders *et al.* 2016). Within Australia, it is found from Shark Bay in Western Australia, across northern Australia, to Hervey Bay on the central coast of Queensland (Phelan 2008; Froese & Pauly 2015; Saunders *et al.* 2016). Despite its importance in fisheries within these regions, and the suspected overfishing in many locations, especially within waters of the Northern Territory (Phelan 2008; Saunders *et al.* 2016), little is known of the biology of this species of fish, including its diet (Phelan *et al.* 2008a, 2008b).

Black-spotted Croakers caught in waters greater than 10 m are susceptible to barotrauma, a symptom of which is eversion of the stomach through the mouth, as they are brought to the surface, thus expelling the stomach's contents (Phelan *et al.* 2008a, 2008b; Saunders *et al.* 2016). This makes the collection of diet data difficult, with large percentages of fish previously studied having everted stomachs (Rao 1963; Thomas & Kunju 1981; Phelan *et al.* 2008b). Despite this, the Black-spotted Croaker has been reported to be an opportunistic predator, with crustaceans (crabs and prawns) and fishes being the primary prey items. In studies in Indian waters, Rao (1963) found prawns were the dominant prey item, but Thomas and Kunju (1981) found fishes to be the dominant prey item. Conversely, Phelan *et al.* (2008b) found that crabs were the dominant prey item in Black-spotted Croakers in waters off Cape York Peninsula in tropical northern Australia.

As part of a wider study on the parasites of the Black-spotted Croaker in northern Australian waters, data on diet from stomach content analysis were noted and will be presented here for increasing knowledge of aspects of the basic biology of this species of fish.

Materials and Methods

Protonibea diacanthus is a large species of fish, attaining over 1.5 m maximum length (Froese & Pauly 2015). It exhibits rapid growth, with females reaching sexual maturity at approximately 2 years of age and between 890 mm and 980 mm total length (TL) (Phelan & Errity 2008; Phelan *et al.* 2008b).

As part of a larger study, Black-spotted Croakers were collected from a number of locations across northern Australia (Figure 1; Table 1), primarily by line fishing by staff of both the Western Australian and Northern Territory Departments of Fisheries and Indigenous Marine Rangers, as well as by commercial fishers (collected under Northern Territory Fisheries Permit S17/2737). All the fishes were euthanased (Charles Darwin University Animal Ethics Approval A13014), placed on ice, and transported to the laboratory for processing; some were frozen whole prior to processing. Total length (in mm) and sex was recorded for most fish, with the exception of those from the Arafura Sea that were collected by a commercial trawler and were neither measured nor had their gonads collected, and fish collected from Peron Islands that were not measured. The internal organs were removed, and the stomach and intestinal tract was separated from the mesenteries and associated organs, and slit along its length for examination.

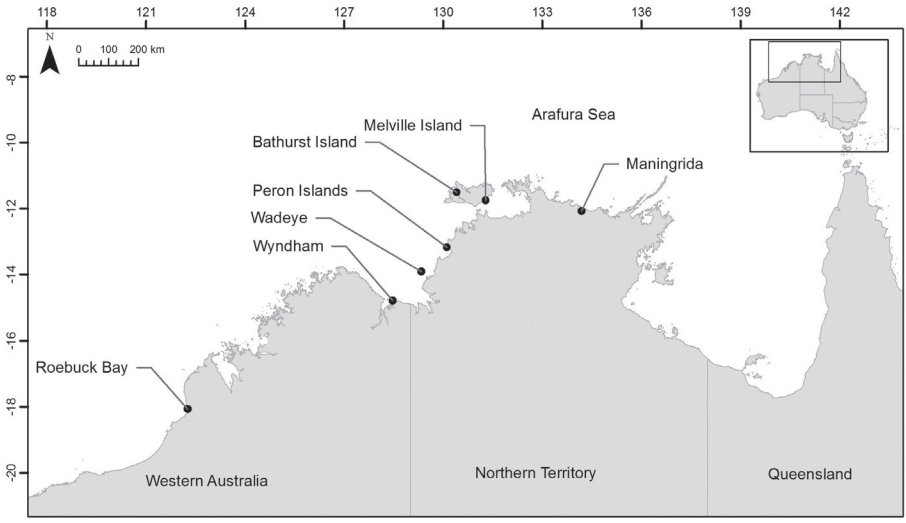

Figure 1. Map of collection localities for *Protonibea diacanthus* across northern Australia that were used in this study.

At the time of examination, it was noted whether the stomach was everted or not. For non-everted stomachs, whether the stomach was empty or contained food (that was not obviously bait items such as cut chunks of fish) was also noted. Stomach contents were classified broadly as crabs (whole crabs or segments of the carapace and/or claws), prawns (including stomatopods), or fishes (including whole fishes, skeletal remains, or flesh). As the main aim of the study was the collection of parasites and not a detailed examination of diet, weight and proportions of items were not recorded and identification of dietary item beyond the higher taxonomic levels was not usually attempted.

Results

A total of 223 *Protonibea diacanthus* had their stomach contents noted at the time of dissection (Table 1). A total of 60 (26.9%) stomachs were everted, either partially or completely. Of the remaining 163 stomachs, 74 (45.4%) contained food items.

The highest numbers of fish with everted stomachs were in the collections from Arafura Sea (17 of the 19 (90%) fish; no TL data), Wadeye (14 of 25 (56%); mean TL 699.5 (540–1090) mm) and Bathurst Island (12 of 28 (43%); mean TL (8 fish) 948.1 (510–1120) mm). Depth of collection for fish from these locations was generally over 20 m; fish collected from more shallow waters had higher numbers of non-everted stomachs (Table 1). There was no difference between male and female fish, with 21 males (773.5 (520–1120) mm) and 22 females (797.1 (405–1100) mm) having everted stomachs.

Table 1. Locations of fishes collected from along the coastlines of Western Australia (WA) and the Northern Territory (NT) examined in this study. Locations are listed in order from west to east. The number of fishes examined from each location is presented, with the mean Total Length (TL) in mm (range in parentheses), reported water depth at location of collection, and stomach contents (number of fish with relative percentage for each category in parentheses). N/A indicates fish where TL data was not obtained.

Location	No. fish	TL (mm)	Water depth (m)	Number everted	Number with food[a]	Crabs[b]	Prawns[b]	Fishes[b]
Western Australia								
Roebuck Bay	36	1018.5 (720–1199)	8–15	3 (8)	17 (47)	10 (18)	3 (18)	15 (88)
Wyndham	34	1067.1 (804–1300)	10–20	1 (3)	23 (68)	7 (4)	1 (4)	17 (74)
Northern Territory								
Wadeye	25	789.2 (540–1160)	20–25	14 (56)	1 (9)	0 (0)	0 (0)	1 (100)
Peron Islands	22	N/A	15	7 (32)	7 (47)	5 (71)	1 (14)	4 (57)
Bathurst Island	28	980.6 (387–1235)	8–35	12 (43)	2 (11)	1 (50)	0 (0)	2 (100)
Melville Island	30	646.3 (405–1170)	8–12	3 (10)	13 (48)	7 (54)	5 (39)	3 (23)
Maningrida	29	730.9 (420–1210)	3–5	3 (10)	11 (42)	5 (46)	5 (46)	3 (27)
Arafura Sea	19	N/A	60	17 (90)	0 (0)	0 (0)	0 (0)	0 (0)
TOTAL	223	879.1 (387–1300)		60 (27)	74 (45)	35 (47)	15 (20)	45 (61)

[a] Percent of fish calculated as percent of fish with food in stomach out of total number of fish with non-everted stomachs.

[b] Percent of fish calculated as percent of fish with that food type (alone or in combination) out of total number of fish with food in stomach.

Of the 74 stomachs with food items (Table 1), 35 (47.3%) contained crab remains (usually parts of the carapace or claws), 15 (20.3%) contained prawn (and/or stomatopod) remains, and 45 (60.8%) contained fish remains (usually skeletal remains). Of the stomachs with food items, 16 (21.6%) contained two types of food (usually crabs and fishes – 14 (87.5%)), and 2 (2.7%) contained elements of all three food types.

The mean TL of fish that contained only prawns was 734 (415–1171) mm, only crabs was 882 (420–1195) mm, and only fishes was 1067.1 (700–1300) mm (Figure 2). However, the distribution of fish with only crab remains was bimodal, with the smaller group 511.7 (420–610; 6 fish) and the larger 1128.9 (1010–1210; 9 fish); notes taken at the time of dissection did not indicate any difference in size of crabs ingested, with small crabs (<5 cm carapace width) dominating both groups. Fishes with two diet items had a mean TL of 940.7 (510–1162) mm; for the fish that contained a combination of prawns and fish TL was 520 mm, for the two fishes that contained prawns and crabs, mean TL was 525 (510–540) mm and for fishes containing crabs and fish (n = 14), mean TL was 1054.5 (984–1168) mm. For the fishes with three diet items, mean TL was 941 (870–1012) mm.

Of the total of 223 fishes, 115 were female (960.2 (405–1220) mm), 88 were male (770.8 (387–1300) mm), and 20 were undetermined (as explained in the Introduction, 19 of these were the Arafura Sea trawler samples from which gonads and TL were not collected; the other was a 1170 mm TL fish from Maningrida, Northern Territory, which contained only prawns in its stomach). Of the female fishes, 45 (13%) contained food,

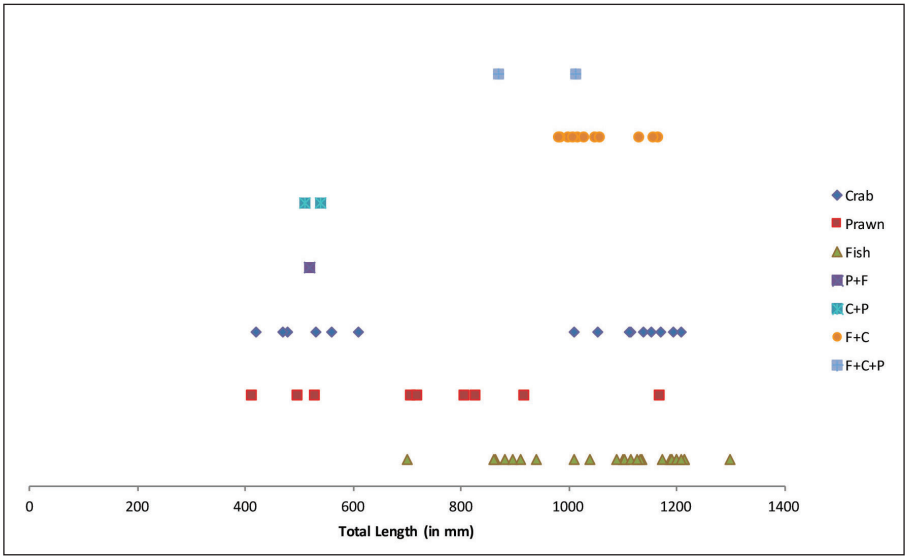

Figure 2. Stomach contents of *Protonibea diacanthus* related to Total Length of fish. C, Crabs; F, Fishes; P, Prawns.

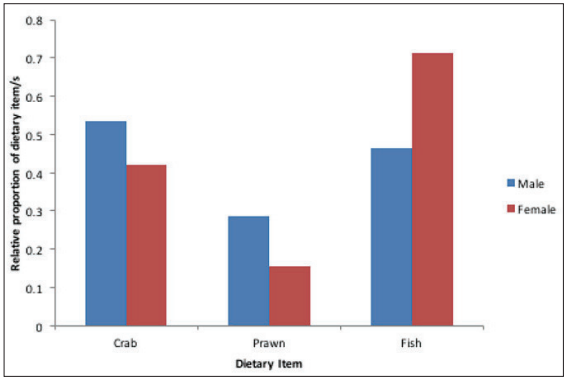

Figure 3. Relative proportions of male and female fishes with dietary items in their stomach contents. Relative proportion is the number of fishes of each sex that contained that food item, either alone or in combination.

of which 19 (42.2%) had crabs, 7 (15.6%) had prawns and 32 (71.1%) had fishes; 11 (24.4%) fish had two food items and 1 (2.2%) fish had three items; 22 (19.1%) fishes had everted stomachs (Figure 3). Of the male fishes, 28 (31.8%) contained food, of which 15 (53.6%) had crabs, 8 (28.6%) had prawns, 13 (46.4%) had fish; 6 (21.4%) fish had two food items and 1 (3.6%) fish had three; 21 (23.9%) had everted stomachs.

The month of collection may have an effect on dietary items found within the stomach contents (Figure 4; Table 2); however, not all months were sampled. Fish dominated the prey items for Black-spotted Croakers collected in May to July, whereas crabs were the dominant items in August (Figure 4; Table 2).

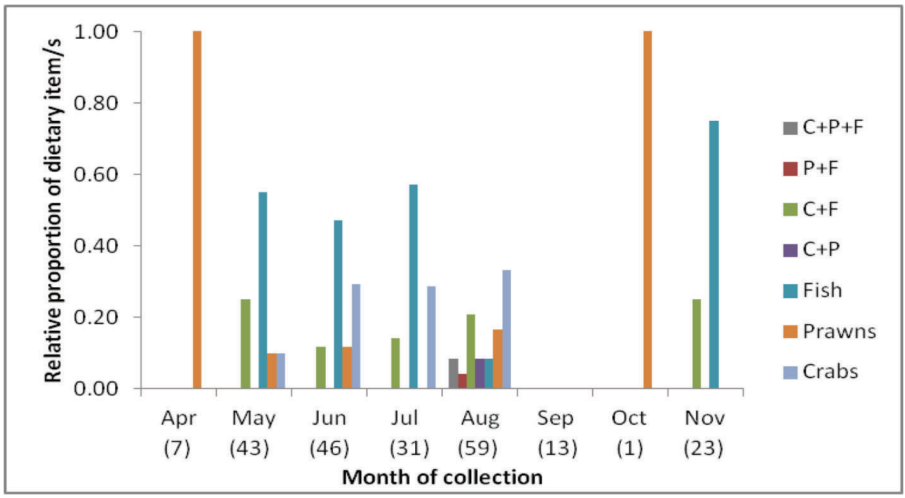

Figure 4. Stomach contents of *Protonibea diacanthus* by month of collection (relative proportion of fish collected for that month). Data combined for all fishes, independent of sex or location of collection. Sample size for each month of collection indicated by the number in parentheses under month of collection. C, Crabs; F, Fishes; P, Prawns.

Table 2. Months of collection for fishes caught from along the coastlines of Western Australia and the Northern Territory examined in this study. Numbers are combined across years of collection and across all sites of collection. Number of fishes examined per month (number of fishes with relative percentage for each category in parentheses; percentages calculated as per Table 1) is presented, with the mean Total Length (TL) in mm (range in parentheses).

Month	Number of fishes	TL (mm)	Number everted	Number with food	Crabs	Prawns	Fishes
April	7	708.6 (405–1170)	2 (29)	1 (20)	0 (0)	1 (100)	0 (0)
May	43	1042.1 (822–1215)	7 (16)	20 (56)	7 (35)	2 (10)	16 (80)
June	46	911.6 (540–1300)	14 (30)	17 (53)	7 (41)	2 (12)	10 (59)
July	31	1084.2 (899–1210)	19 (61)	7 (58)	3 (43)	0 (0)	5 (71)
August	59	723.9 (420–1199)	8 (14)	24 (69)	17 (71)	9 (38)	10 (42)
September	13	744.2 (540–1100)	6 (46)	0 (0)	0 (0)	0 (0)	0 (0)
October	1	720	0 (0)	1 (100)	0 (0)	1 (100)	0 (0)
November	23	1051.0 (387–1235)	4 (18)	4 (21)	1 (25)	0 (0)	4 (25)
TOTAL	223	879.1 (387–1300)	60 (27)	74 (45)	35 (47)	15 (20)	45 (61)

Discussion

Little is known of the biology of many of the commercial and recreationally important fish species of northern Australia. As the current status of the Black-spotted Croaker is overfished or undefined (Saunders *et al.* 2016), the requirement for more knowledge on its biology is paramount. Thus, aspects of the diet of the Black-spotted Croaker are presented here to provide baseline data on a previously unreported aspect of the biology of this species of fish in these waters. The only previous study to report on diet of the Black-spotted Croaker in Australian waters (Phelan *et al.* 2008b) was conducted off the northern tip of Cape York Peninsula, an area not included within this study. The data reported here were collected as an adjunct to a parasitological study primarily to assist with parasite life cycle determinations and, as such, were not recorded at a level required for in-depth dietary analysis. The results do show, however, that overall, the diet is similar to that recorded previously (Rao 1963; Thomas & Kunju 1981; Phelan *et al.* 2008b), with Black-spotted Croakers being opportunistic predators, feeding primarily on benthic organisms.

Everted stomachs affected a low number of Black-spotted Croakers in this study (27%) compared to previous studies. Rao (1963) found that 95% (of 679 fishes) collected from trawlers had everted stomachs. These fish were predominantly large (over 500 mm TL), whereas fish under 500 mm TL were usually caught by land-based nets and had a much lower frequency (<37%) of everted stomachs. Thomas & Kunju (1981) also recorded 95% (of 57 fishes) with everted stomachs; all of which were taken by trawlers. Phelan *et al.* (2008b) found 93% of the fish caught by handlines by indigenous subsistence and recreational fishers had everted stomachs; fish were caught in depths ranging from 10 to 25 m. High numbers of everted stomachs were found in this study into Black-spotted Croakers collected from Arafura Sea (trawler samples), and Wadeye and Bathurst Island (commercial fishermen) where collection occurred in water over 20 m in depth. This corresponded with the results of Phelan *et al.* (2008a), who found that 100% of fish

caught in waters over 15 m in depth had everted stomachs. Other collection localities still contained fish with everted stomachs, but at much lower levels which may be due to collection from shallower waters or slower ascent through the water column.

It is apparent that differently sized Black-spotted Croakers exhibit different diets. Rao (1963) divided his samples into big- and medium-sized fish (over 500 mm) and juveniles (below 500 mm). For the big Black-spotted Croakers, fishes and prawns were the major food items, but the percentage of prawns was not as high as in juveniles. Black-spotted Croakers reach sexual maturity at approximately 890–980 mm TL (Phelan *et al.* 2008a, 2008b), which corresponds with a shift in dietary items from prawns to fishes in this study (Figure 2). Similar results were found for *Argyrosomus japonicus*, a sciaenid found in waters off southern Australia, with a shift in diet from mysids, to prawns, to fishes corresponding with increasing size (Taylor *et al.* 2006). Crabs, however, had a split distribution with smaller and larger fish containing crabs in their diet. There were no apparent differences in the size of crabs targeted by these fishes, with notes taken at the time of dissection showing that small to medium crabs (less than 5 cm carapace width) were common across both groups of fish. Thus, the dominance of crabs in the diet of Black-spotted Croakers studied by Phelan *et al.* (2008b) could be due to a preference for crustaceans by smaller individuals. The size range of the fishes studied by Phelan *et al.* (2008b) was at the lower end of the size range (429–825 mm TL) compared to the fishes examined in this study (325–1300 mm TL).

Rao (1963) suggested that the Black-spotted Croaker can travel in separate sex-related shoals as there was a consistent difference in the number of female and male fishes collected in trawls across months. As in Rao's (1963) study, females dominated the samples overall, with 56.7% of fish (that were able to be determined) being female and 43.3% being male. Female Black-spotted Croakers in this study generally ate more fishes (70% of all females compared to 46% of males), whereas males ate more crabs and prawns (82% of all males compared to 58% of females). However, the size differences between males and females caught in this study (males mean TL 770.8 (387–1300) mm, females 960.2 (405–1235) mm) is likely to be a confounding factor. More research needs to be conducted on fishes across a wide size range, including juveniles, to determine if there is a relationship between the sex of the fish and dietary preferences.

Aggregations of Black-spotted Croakers are well known and are often targeted by fishermen, leading to overfishing of the species (Phelan *et al.* 2008a, 2008b; Saunders *et al.* 2016). The aggregations are suggested to be either breeding aggregations (Welch *et al.* 2014), or due to food availability (Thomas & Kunju 1981). Recent studies have shown, however, that Black-spotted Croakers show high levels of localised site fidelity (Semmens *et al.* 2010; Taillebois *et al.* 2017), with small scale seasonal migration from shallow to deeper waters, with individuals returning to the same location over time (Semmens *et al.* 2010). Although there is apparent seasonal variability in the diet of the Black-spotted Croakers examined in this study, the lack of samples over the spawning

season (peaking in December to January; Phelan & Errity 2008) prevents any conclusion regarding the relationship between aggregation and either diet or reproduction.

The majority of dietary items identified in this study were demersal in origin, indicating that the Black-spotted Croaker is a predominantly benthic feeder at all stages of its life cycle. The various crustaceans found are known to be associated with benthic structures, such as reefs; however a few portunid crabs were also found in stomachs, although, generally only in smaller Black-spotted Croakers. The fish that could be identified to either family (i.e. Ophichthidae) or genus (i.e. *Arius, Johnius, Ambassis*) were primarily associated with demersal habitats (Froese & Pauly 2015). The fish identified by Rao (1963) and the sole collected by Thomas and Kunju (1981) are also predominantly benthic.

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References

Froese R. and Pauly D. (2015) *FishBase*. http://www.fishbase.org (accessed 18 December 2015).

Phelan M., Campbell D. and Humphrey, J. (2008a) Implications of barotrauma and hook type on catching and releasing black-spotted croaker. In: *Assessment of the implications of target fishing on black-spotted croaker* (Protonibea diacanthus) *aggregations in the Northern Territory*. (ed. Phelan M.), pp. 63–92. Fishery Report No. 91, Fisheries Research and Development Corporation and Northern Territory Department of Primary Industry, Fisheries and Mines, Darwin.

Phelan M. and Errity C. (2008) Reproductive biology of black-spotted croaker from Northern Territory coastal waters. In: *Assessment of the implications of target fishing on black-spotted croaker* (Protonibea diacanthus) *aggregations in the Northern Territory*. (ed. Phelan M.), pp. 22–33. Fishery Report No. 91, Fisheries Research and Development Corporation and Northern Territory Department of Primary Industry, Fisheries and Mines, Darwin.

Phelan M.J., Gribble N.A. and Garrett R.N. (2008b) Fishery biology and management of *Protonibea diacanthus* (Sciaenidae) aggregations in far northern Cape York Peninsula waters. *Continental Shelf Research 28*, 2143–2151.

Rao K.Y. (1963) Some aspects of the biology of 'ghol', *Pseudosciaena diacanthus* (Lacépéde). *Indian Journal of Fisheries* 10, 413–459.

Saunders T., Roelofs A. and Newman S. (2016) Black-spotted croaker, *Protonibea diacanthus*. In: *Status of Australian fish stocks reports 2016* (eds Stewardson C., Andrews J., Ashby C., Haddon M., Hartmann K., Hone P., Horvat P., Mayfield S., Roelofs A., Sainsbury K., Saunders T., Stewart J., Stobutzki I. and Wise B.). Fisheries Research and Development Corporation, Canberra. http://fish.gov.au (accessed 15 June 2018).

Semmens J.M., Buxton C.D., Forbes E. and Phelan M.J. (2010) Spatial and temporal use of spawning aggregation sites by the tropical sciaenid *Protonibea diacanthus*. *Marine Ecology Progress Series* 403, 193–203.

Taillebois L., Barton D.P., Taylor J., Crook D.A., Saunders T., Grieg A., Hearnden M., Welch D.J., Newman S.J., Travers M.J., Saunders R.J., Dudgeon C., Maher S. and Ovenden J. (2018) Fine-scale population structure in *Protonibea diacanthus* suggests that fisheries will croak without appropriate spatial management. *Evolutionary Applications* 10, 978–993. doi: 10.1111/EVA.12499.

Taylor M.D., Fielder D.S. and Suthers I.M. (2006) Spatial and ontogenetic variation in the diet of wild and stocked mulloway (*Argyrosomus japonicus*, Sciaenidae) in Australian estuaries. *Estuaries and Coasts* 29, 785–793.

Thomas P.A. and Kunju M.M. (1981) On an unusual catch of Ghol *Pseudosciaena diacanthus* off Goa. *Indian Journal of Fisheries* 25, 266–268.