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Freshwater Sawfish *Pristis microdon* Latham, 1794 (Chondrichthyes : Pristidae) in the Kimberley region of Western Australia

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Abstract

The Freshwater Sawfish *Pristis microdon* was captured in marine waters of King Sound, and estuarine and fresh waters of the Fitzroy and Robinson rivers, in the Kimberley region of Western Australia. In light of the IUCN listing of the species as critically endangered, non-destructive means, including tagging-recapture data and information from specimens found dead on the banks, were utilised. Observations of sexual maturity, annuli present on vertebrae, recaptures of tagged individuals and length-frequency data suggested that the freshwaters of the Fitzroy River are a nursery for this species where immature individuals (up to 2800 mm total length) remain for a maximum of four or five years. Morphology and counts of the number of rostral teeth indicated that, in most cases, the rostral tooth morphology can be used to differentiate male and female *P. microdon* and also are useful in distinguishing this species from the congeneric and sympatric *Pristis clavata*. Furthermore, differences in the relationship between rostrum length and total length between the sexes may provide an effective diagnostic tool for the collation of historical distribution and sex ratio data from rostrums held in private collections. Rostral tooth counts and length at age data also suggest that the synonymisation of *P. microdon*, *Pristis zephyreus* and *Pristis perotteti* is not warranted.

Key words: sawfish, *Pristis microdon*, *Pristis clavata*, Western Australia, Kimberley, Fitzroy River, rostral teeth

Introduction

Of the four *Pristis* species recorded from Australian waters, the Freshwater Sawfish *Pristis microdon* Latham, 1794 is the species most commonly encountered in freshwaters (Last & Stevens 1994). It is also known to occur throughout the Indo-West Pacific including New Guinea, South-east Asia, India and eastern Africa. *Pristis microdon* can attain lengths of up to 7 m and is distinguished from other sawfishes by the combination of the following characteristics: first dorsal fin anterior to the pelvic fins; caudal fin bearing a conspicuous ventral lobe; 18–23 teeth on the rostrum (Last & Stevens 1994; Compagno & Last 1998). There is currently some argument as to whether *P. microdon* should be synonymised with *Pristis perotteti* Müller and Henle, 1839 and *Pristis zephyreus* Jordan and Starks, 1895 from the Atlantic and east Pacific. Similar to *P. microdon* these latter species are commonly encountered in fresh inland waters, possess a first dorsal fin anterior to pelvic fins and have a distinct lobe on the lower caudal fin (Thorson 1982; Last & Stevens 1994; Compagno & Cook 1995; Compagno & Last 1998). Ishihara *et al.* (1991) however, found that their rostral teeth counts varied significantly, i.e. 17–21 and 19–23 cf. 14–17 and 16–20 in female and male *P. microdon* and *P. perotteti*, respectively, and although they tentatively considered that these species were valid, they expressed the need for further investigation.

Sawfish populations throughout the world have been decimated by gill net and trawl fisheries due to their susceptibility to entanglement in nets by their rostrum (Simpfendorfer 2000). Although there are currently

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insufficient data to determine the status of Australian populations, the susceptibility of *Pristis* species to fishing and habitat loss has been observed elsewhere with numerous populations threatened or their distributional ranges contracting (Pogonoski *et al*. 2002). This decline has subsequently led to *P. microdon* being listed as critically endangered (IUCN Red List 2006) throughout the world and as vulnerable (*Environment Protection and Biodiversity Conservation Act* (EPBC) 1999) in Commonwealth waters of Australia. However, under the Offshore Constitutional Settlement (1987, 1988 & 1995) of Australia, Commonwealth waters begin three nautical miles from the low water mark. Each of the respective State Governments is subsequently responsible for the fish and fisheries occurring within this three nautical mile limit and the coast, including inland waters within their respective borders (see Boulter 2002). In 2005 *P. microdon* was listed under Schedule 2 (Protected Fish) of the Western Australian State Fish Resources Management Regulations 1995 and is now afforded protection in waters managed by the Western Australian State Government. *Pristis microdon* remains unprotected in other State waters which encompass the majority of this species known geographical range across the continent.

With the exception of differences in rostral teeth counts between sexes, and some age versus length data (collected from Papua New Guinean specimens) (Ishihara *et al*. 1991; Tanaka 1991) virtually nothing is known about the biology of this species in Australia. *Pristis microdon* is also an important cultural and spiritual icon for a number of indigenous groups throughout northern Australia, including those of the Fitzroy River such as the Bunuba, Gooniyandi, Nyikina and Walmajarri peoples (Morgan *et al*. 2004; Thorburn *et al*. 2004a). In the Fitzroy River, *P. microdon* is referred to as 'galwanyi' in Bunuba and Gooniyandi, 'wirridanyniny' or 'bial bial' (pial pial) in Nyikina, and 'wirrdani' in Walmajarri. This species is actively fished for and remains an important food for traditional owners of the west Kimberley.

In light of the decline of many sawfish populations throughout the world, the fact that the Fitzroy River was shown to contain a higher number of *P. microdon* than any of the other systems sampled throughout northern Australia (Thorburn *et al.* 2003), and the cultural significance of the species to traditional owners of the region, the current study focused on that system to: determine the distribution and any broad-scale habitat associations within the Fitzroy River and nearby marine waters; describe the biology of the species in those waters; determine if a relationship exists between size and sex of individuals, and the size and the number of teeth on their rostrum for use as a diagnostic tool in determining historical sex and size data from rostra that were collected as trophies from sawfish in freshwaters; determine if *P. microdon* can be distinguished from *Pristis clavata* Garman, 1906, which possess a similar number of rostral teeth to *P. microdon* and also occurs in the region, from the rostrum alone; implement a tagging program that in future will provide valuable data on the movements and growth of *P. microdon* within the river and nearby marine habitats; and test the hypothesis that *P. microdon* and *P. perotteti* are morphologically indistinguishable.

Materials and Methods

Study site. Located in the western Kimberley of northern Western Australia, the Fitzroy River drains almost 90 000 km^2 and is significantly larger than any other river in the region (Figure 1). The Fitzroy River enters King Sound south of Derby and continues upstream ~300 km (past the town of Fitzroy Crossing) before splitting into the Margaret and Fitzroy rivers. Sampling during this study was mainly focused on the river near to and downstream of this junction. This region experiences an arid to semi-arid monsoonal climate and receives the majority of its rain during the wet season, i.e. between November and March. During this time the river experiences peak flows and receives almost 90% of its mean annual streamflow of 6150 gigalitres per year (measured at Fitzroy Crossing), the highest of any river in Western Australia (Ruprecht & Rodgers 1998).

Environmental variables and habitat. Salinity (ppt), temperature (ºC), water clarity using a secchi disc (cm), depth (m), and tidal influence were recorded at each sampling site. In addition the immediate habitat was described, including predominant sediment type, density of aquatic vegetation types and detritus, riparian vegetation and snag density.

Sample sites and methods. *Pristis microdon* was captured in the Fitzroy River, King Sound and in the Robinson River during sampling in October and November 2002, June and November 2003, and March, April and July 2004. Sampling within the river was primarily conducted at sites accessible to the general public including the tidally affected Snag, Telegraph and Langi's Pools, and freshwaters below Camballin Barrage and in Geikie Gorge (Figure 1).

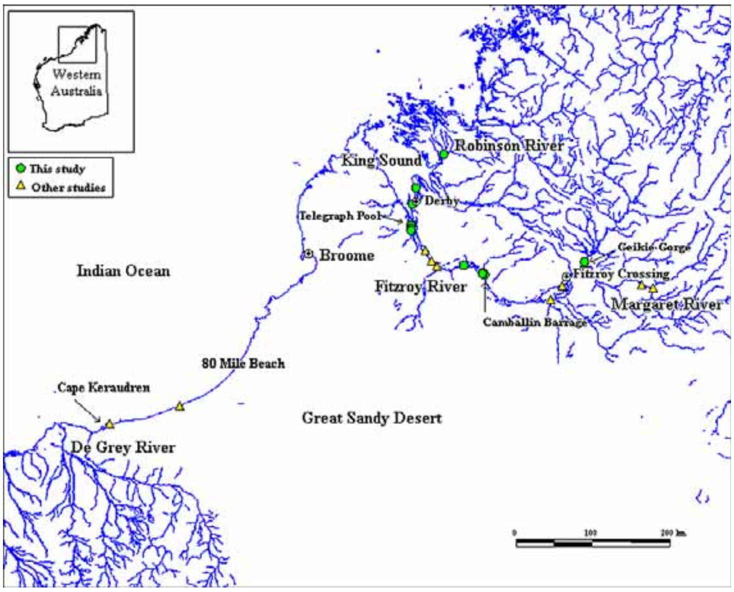


FIGURE 1. Sites at which *Pristis microdon* was captured during this study and other studies, in the western Kimberley region.

Sampling equipment included sinking monofilament gill nets (20 m panels of 5, 7.5, 10, 15 and 20 cm stretched mesh) that were set from to the bank. Nets were checked every hour to ensure that handling and release times were minimised. A priority of this study was to attain as much information as possible on this species without employing fatal techniques. All possible data that could be collected from dead individuals found on the river banks were recorded, including vertebrae and dietary samples. Several individuals captured by traditional owners using baited lines were also utilised. Records of *P. microdon* collected by colleagues undertaking studies in the Kimberley have been collated with data collected during the current study.

Measurements and tagging. The total length (TL) (mm), sex, clasper length and stage of calcification in males, rostrum length (RL) (mm) (measured from the tip to where the head begins to broaden, Figure 2), and number of teeth on each side of the rostrum were recorded for all individuals captured. A tag (Dalton Rototag) was also placed in the first or second dorsal fin of sawfish captured during 2003 and 2004 prior to release (Figure 3).

Age and length. At least six vertebrae were removed from beneath the first dorsal fin of 10 of the dead specimens encountered during this study. Vertebrae were cleaned and kept on ice in the field until they could be frozen. Once defrosted, excess tissue was removed and the centra separated before being placed in 5% sodium hypochlorite solution until the centra were free from tissue. The centra were then rinsed thoroughly in water and allowed to dry for several hours. A minimum of two centra from each specimen was then embedded in resin and a 0.3 mm longitudinal section cut with an Isomet low speed rotary saw. These sections were then mounted on a slide with DePex and observed under a dissecting microscope with reflected light. Counts of the number of growth rings or annuli (i.e. the narrow translucent bands representing reduced growth periods, as opposed to the adjacent wider opaque bands that represent faster growth) commencing after the birth mark (identified by a change of angle on the outer edge of the corpus calcerium) were then made for each individual (Goldman 2004). Although the small sample size precluded the use of marginal increment analysis to validate the annual deposition of growth rings, vertebral data closely corresponded to the length-frequency histograms (see Results).

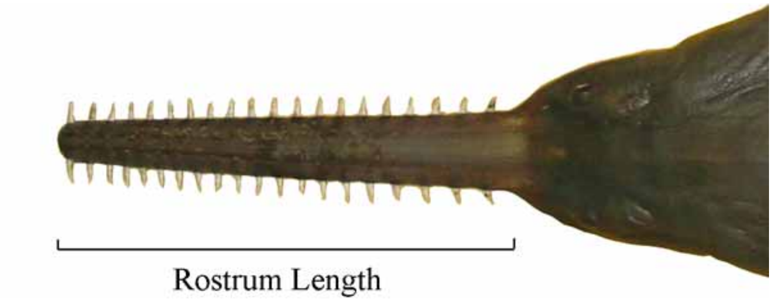


FIGURE 2. Measurement of the rostrum length (RL).

FIGURE 3. Location of tag in second dorsal fin of *Pristis microdon*.

Stage of maturity. The stage of maturity in male *P. microdon* was determined on the basis of clasper calcification. Individuals were considered immature when claspers were small and uncalcified, maturing if claspers were extending and becoming semi-calcified or mature when claspers were fully calcified. Recently dead females found on the banks were dissected and their ovaries and uteri examined. An individual possessing undeveloped ovaries and thin flaccid uteri was considered immature, maturing when the uterus begins to enlarge and ovary contains differentiated ova, and mature when the ovary contains yolked ova and the uterus is enlarged (Conrath 2004).

Stomach contents. Of the dead individuals encountered, the stomachs from nine were retrieved. Samples were frozen or preserved in 100% ethanol, and the contents viewed and identified under a dissecting microscope. Estimations of the stomach fullness on a scale of zero to 10 (zero representing an empty gut and 10 being fully distended) and the percentage contribution of each food category were made, from which the percentage frequency (%F) and mean percentage volumetric contribution (%V) of each food category were calculated (Hynes 1950; Ball 1961).

Relationship of rostrum length and total length. A likelihood ratio test (Cerrato 1990) was used to determine if the ratio of rostrum length (RL) to total length (TL) was significantly different between the sexes. As a significant difference was detected, the SPSS statistical package was used to describe the relationship of RL to TL for each sex independently.

Sexual dimorphism of rostral tooth number. To investigate if differences exist in the number of rostral teeth between sexes, the number of teeth on the left and right side was recorded for 43 female and 25 male *P. microdon*. As no significant differences were detected between the tooth number on either side of the rostrum in either males or females, analysis of variance (ANOVA) was used to investigate if there were differences in the number of left rostral teeth, and of the total number of rostral teeth between males and females.

Identification of rostral features for use in differentiating sawfish species. The rostra of at least 20 *P. microdon* (832 to 2130 mm TL) and 20 *P. clavata* (865 to 2130 mm TL), which also occur in the Fitzroy River (see Thorburn et al. 2003; Morgan et al. 2004), were examined to determine if there were any gross morphological difference in the structure that would allow the rostra of these species to be readily distinguished.

Results

Sex ratio, length ranges and capture locations. A total of 79 *P. microdon* were recorded from the Fitzroy River and other sites sampled throughout King Sound between 2002 and 2004 (Figure 1). Fifty seven of these were captured in the Fitzroy River, two were captured in the Robinson River and two were captured in the marine waters of King Sound. A further 15 individuals were found dead on the banks of the river (callously killed by fishers), one was observed free swimming at Camballin Barrage and two were obtained from fishers at Geikie Gorge. Of those individuals in which the sex could be determined, 43 were female and 30 were male (sex ratio was 1.43 females: 1 male). The females ranged in length from 832 to 2770 mm TL, while the males ranged from 815 to 2350 mm TL.

Two *P. microdon* were captured from a total of 26 sites sampled in King Sound, 18 were captured from 20 estuarine sites, and 34 and seven were captured from the middle (16 sites) and upper reaches (17 sites) of the river, respectively. *Pristis microdon* was captured from salinities of 21 and 31 ppt in King Sound and from 0 to 40 ppt in the estuarine reaches. Salinities in non-tidal reaches of the river were always 0 ppt.

At the sites of capture, water was generally shallow and warm with an average depth of 2.3 m and temperatures between 29 and 32 ºC. The capture of this species in both upper freshwater and macrotidal marine environments is reflected in the range of water clarity, with secchi disc readings ranging from greater than 170 cm at Geikie Gorge to as little as 5 cm in King Sound. In terms of the immediate habitat from which individuals were captured, sites generally had substrates of sand and to a lesser extent silt, and little algal, macrophyte, or detritus.

During independent studies undertaken by colleagues working in the region, one, 12 and two *P. microdon* were captured from estuarine (one site), and middle (10 sites) and upper (16 sites) riverine sampling sites in the Fitzroy River (Morgan *et al.* 2004). All of these were apparently immature. An additional two large individuals (one female ~3500 mm TL and one male ~3000 mm TL) were captured in the nearshore waters of 80 Mile Beach (Wallal) and Cape Keraudren, respectively (Dr Glen Young, Murdoch University, pers. comm.). The latter two individuals were the only animals over three metres recorded during these studies. A 635 mm rostrum was also collected from 80 Mile Beach (possessing 17 left and 18 right rostral teeth), and from which a TL of 2847 mm TL was extrapolated (see below). Although none of the small males captured in the Fitzroy

River was mature, the large male captured at Cape Keraudren possessed large calcified claspers indicating maturity.

Tagging. A total of 40 *P. microdon* (29 female and 11 male) were tagged during sampling in 2003 and 2004. One female (2150 mm TL) that was originally tagged in June 2003 approximately three kilometres below Camballin Barrage was recaptured near the point of first capture four months later (November 2003). In this time she had attained a length of 2180 mm TL. Five recaptures (of three individuals) were also recorded from this locality in 2004. Two of the tagged individuals, first captured below the Camballin Barrage in July 2004, were each recaptured twice, once in October and again in November. The fifth recapture also originally tagged at this location in July 2004, was also recaptured in November 2004. Although one of the individuals did not increase in length between captures, the remaining two grew 82 mm and 170 mm TL in their four months at liberty.

Age and length. The number of annuli present in the vertebrae, in conjunction with length-frequency data and the presence of umbilical scars, suggest that individuals between 800 and 900 mm TL were recently born. The number of annuli in conjunction with length-frequency data also suggest that individuals of 1000 mm TL were approximately one year old, those between 1400 and 1600 mm TL were approximately two years old, those between 1800 and 2200 mm TL were approximately three years old and that the largest animals between 2300 and 2800 mm TL were likely to be at least four years old (Figures 4–5, Table 1).

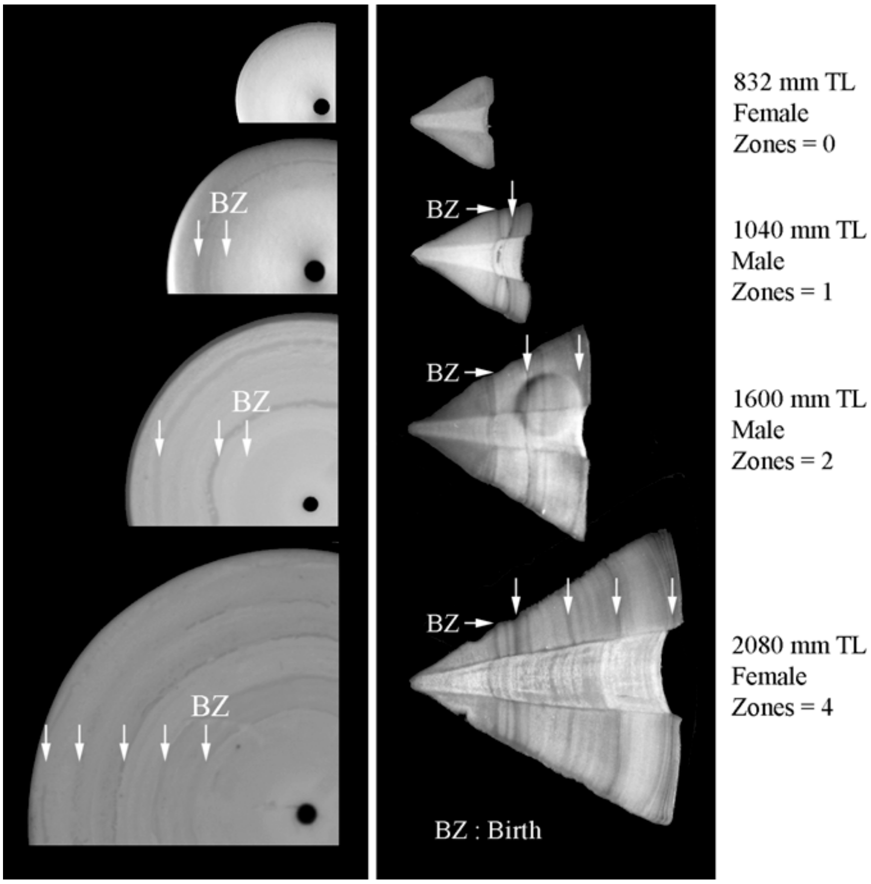


FIGURE 4. Whole and sectioned vertebrae of *Pristis microdon*, depicting main translucent zones, which are believed to be laid down annually (see text).

Stage of maturity. All 30 male *P. microdon* captured in the Fitzroy River and King Sound (ranging in length from 815 to 2350 mm TL) were immature, possessing small non-calcified claspers. Inner clasper length ranged from 25 to 92 mm, while the outer length ranged from 10 to 43 mm. A mature male (~ 3000 mm TL) possessing large calcified claspers was captured by Dr Glen Young (Murdoch University) near Cape Keraudren in 2003. Dissection of two large female *P. microdon*, 2500 mm TL and 2271 mm TL, found dead on the banks of the Fitzroy River, revealed undeveloped ovaries and thin, flaccid uteri, indicating immaturity.

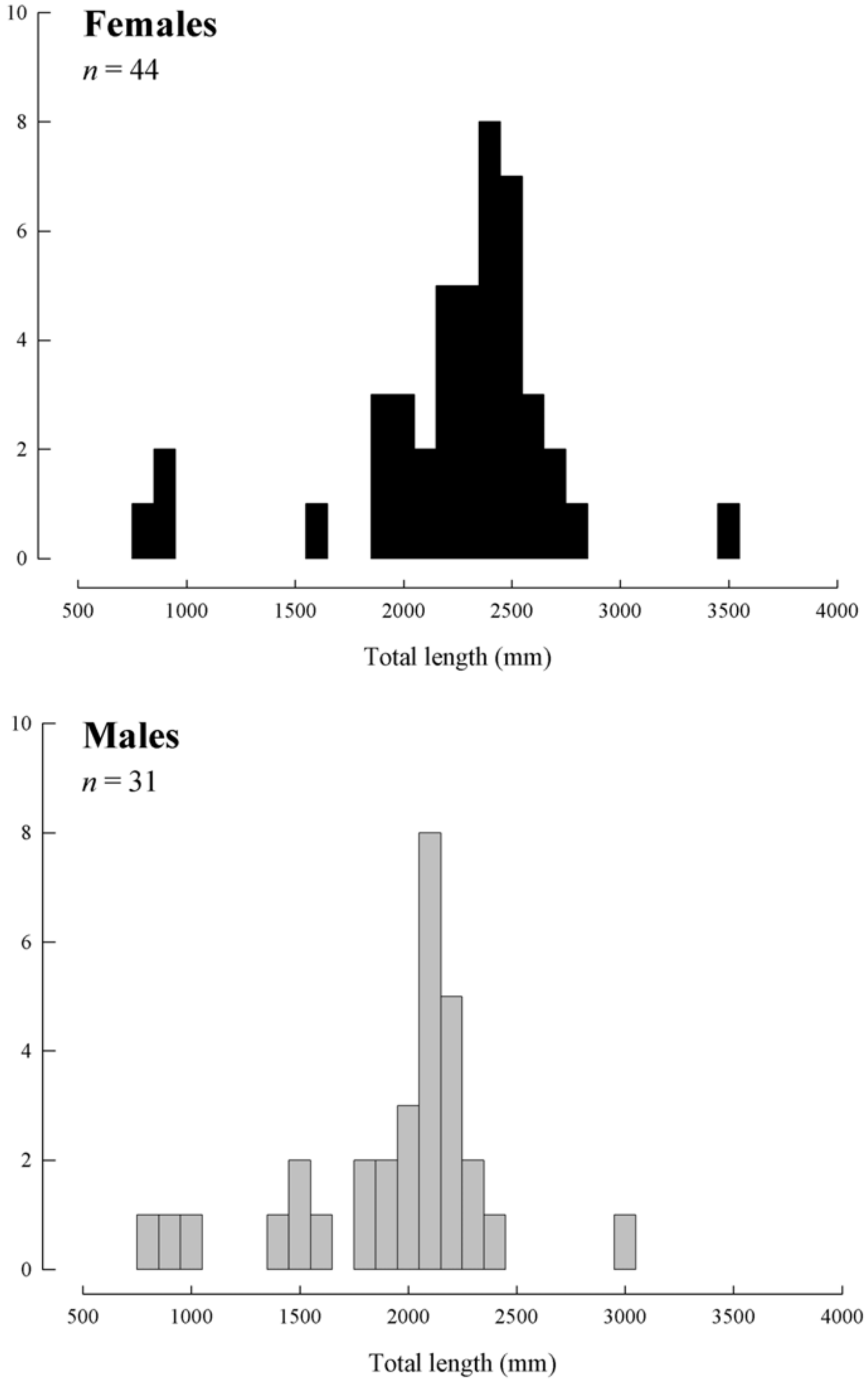
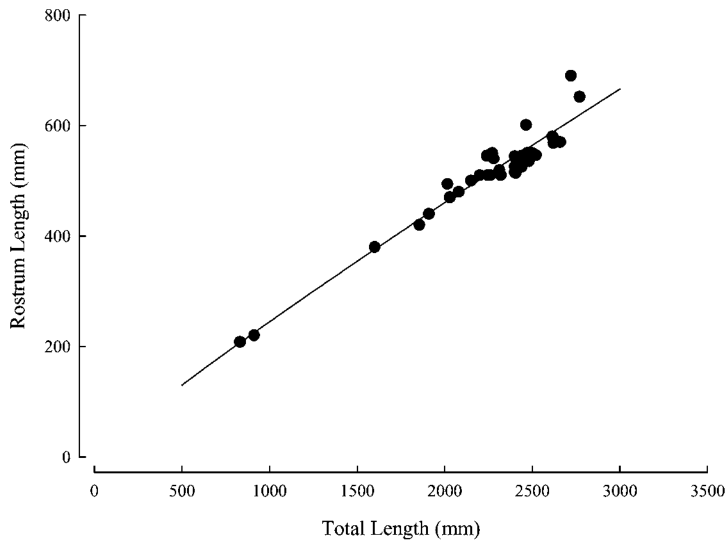


FIGURE 5. Length-frequency histograms for female and male *Pristis microdon* collected during the study.

Diet of *P. microdon*. All nine of the stomachs of *P. microdon* dissected contained the Lesser Salmon Catfish *Arius graeffei* Kner and Steindachner, 1867, which constituted almost 60% of their overall diet. The other major components of the diets were fine detrital matter (13%V, 55%F), cherabin *Macrobrachium rosenbergii* (De Man, 1879) (9%V, 67%F) and insect parts (6%V, 78%F). Filamentous algae, coarse detrital matter, unidentified fish, nematodes and molluscs were also present but minor components of the diet of *P. microdon*.

TABLE 1. Total length (mm) and respective number of growth rings on the vertebrae of four female and six male *Pristis microdon.*

Sex	Total Length (mm)	Number of Zones
Females	832	0
	912	0
	1600	2
	2271	4
Males	933	0
	1040	1
	1587	2
	2080	4
	2105	3
	2142	3



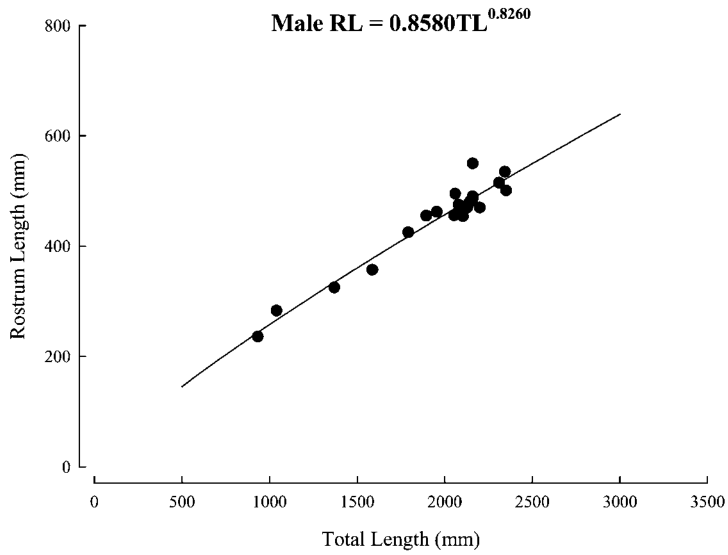


FIGURE 6. Relationship between total length (TL) and rostrum length (RL) in female (n=37) and male (n=22) *Pristis microdon.*

Rostrum length versus total length, and sexual dimorphism of rostrum tooth number. A likelihood ratio test (Cerrato 1990) revealed that the relationship between total length (TL) and rostrum length (RL) for female and male *P. microdon* was significantly different ($P < 0.001$, df = 2) therefore the sexes were not pooled. The relationship between TL and RL (mm) in female and male *P. microdon* is $RL = 0.4517.TL^{0.9113}$ and $RL = 0.8580.TL^{0.8260}$, respectively (Figure 6).

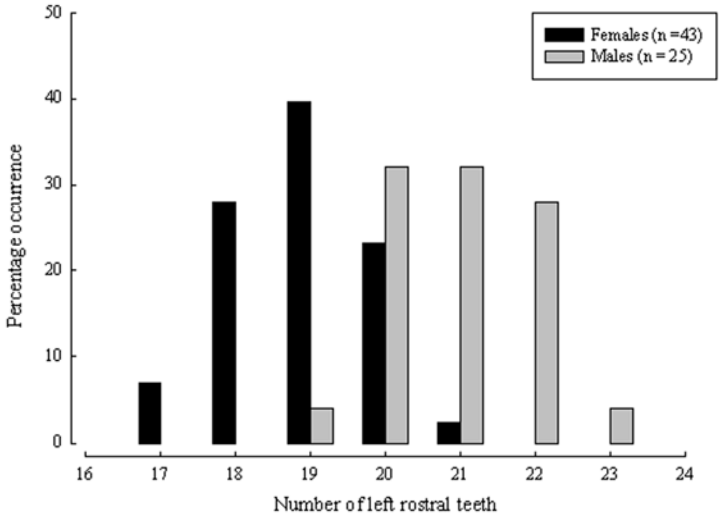


FIGURE 7. Percentage occurrence of the number of left rostral teeth in female and male *Pristis microdon*.

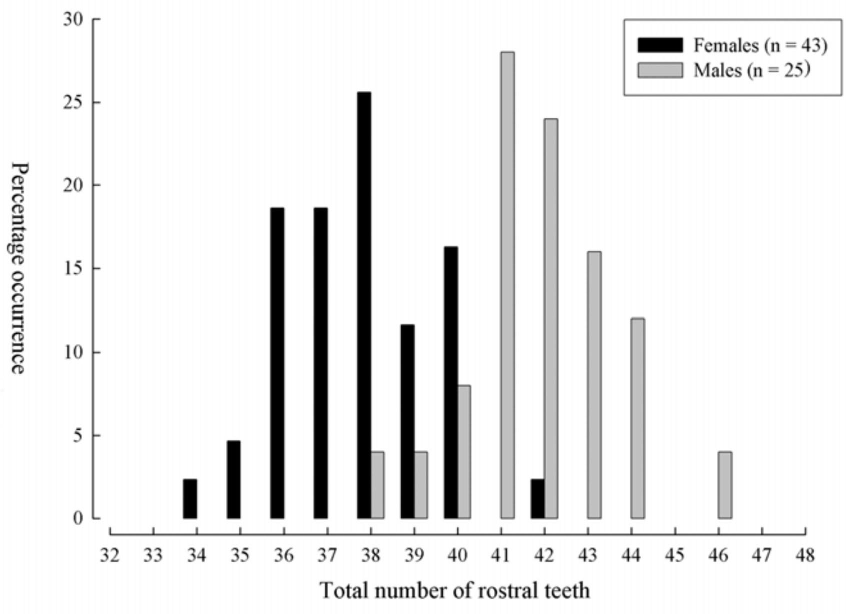


FIGURE 8. Percentage occurrence of the total number of rostral teeth in female and male *Pristis microdon*.

A Levenes test of homogeneity found that variances in the number of left rostral teeth or total number of teeth between females and males was not significant and thus the data were not transformed. ANOVA revealed that both the difference of the number of left rostral teeth ($P < 0.001$), and the total number of rostral teeth ($P < 0.001$) of males and females were significantly different. Females generally possessed fewer left rostral teeth (17 to 21 (mean of 19)) than males (19 to 23 (mean of 21)) (Figure 7). Although there is some overlap between females and males, 97% of individuals with $\leq$19 left rostral teeth were female, and 94% of individuals with $\geq$21 left rostral teeth were male. Overlap in the total number of rostral teeth also existed between the sexes, however 94% of individuals with $\leq$39 were female, and 95 % of individuals with $\geq$41 rostral teeth were male (Figure 8). In terms of rostrum symmetry, 63% of females and 44% of males had the same number of teeth on both the left and right side.

Differentiation of *P. microdon* and *P. clavata* rostrum teeth. The rostra of recently born and larger *P. microdon* could be easily differentiated from *P. clavata* by the possession of a highly defined groove on the posterior edge of the teeth that runs the entire length of the tooth into and beyond its confluence with the blade of the rostrum (Figure 9). In *P. clavata* the groove is absent in juveniles and whilst it develops in larger individuals it generally rarely runs along the entire posterior edge of the tooth, i.e. does not go beyond or even reach its confluence with the rostrum.

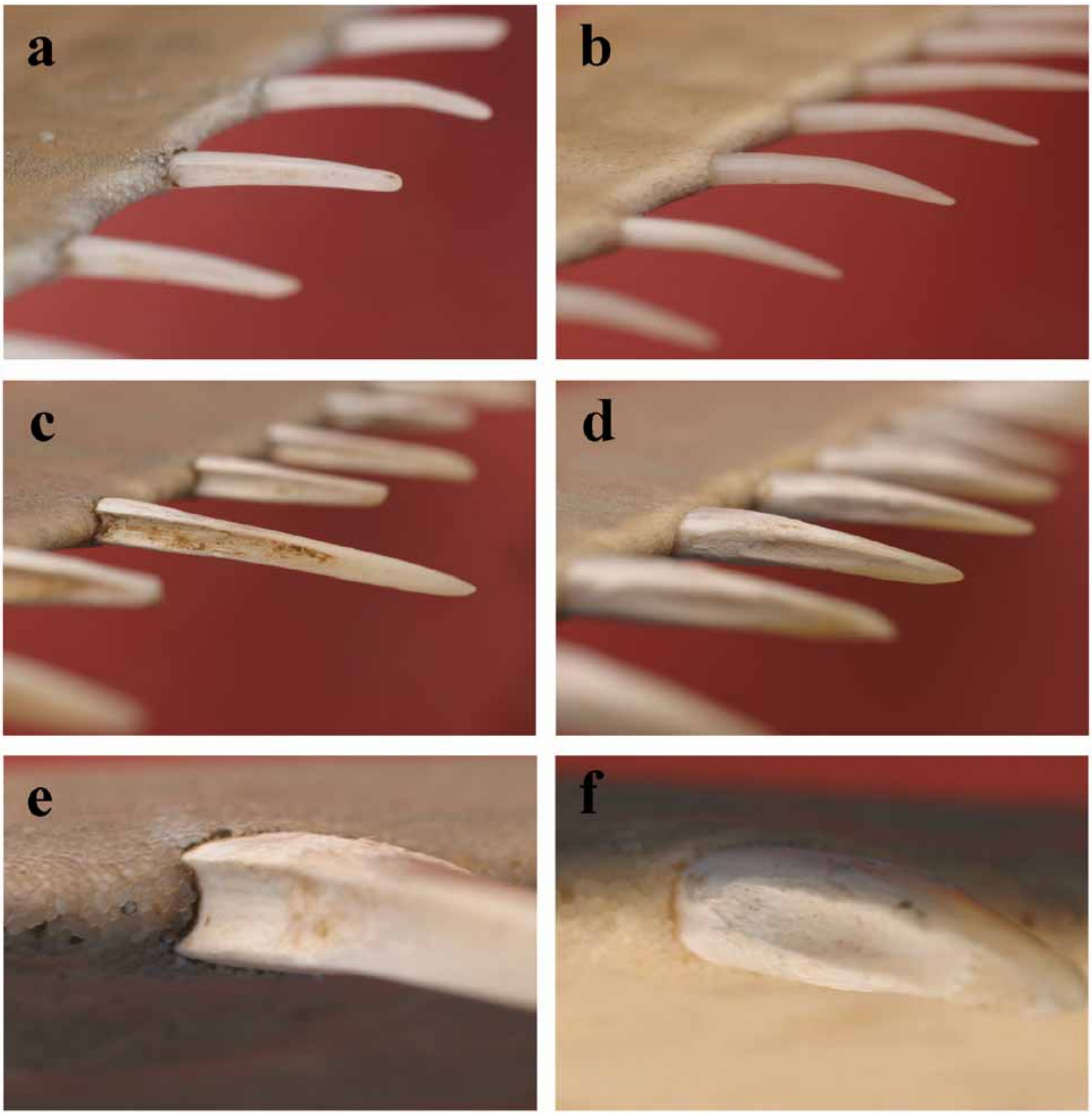


FIGURE 9. Comparison of the rostral tooth shape of *Pristis microdon* and *Pristis clavata* from the Fitzroy River, illustrating the strong groove present along the posterior edge of the rostral teeth of *P. microdon. T*his groove is present in (a) small juvenile (832 mm TL) and (c and e) larger juvenile (2271 mm TL) *P. microdon,* and runs the entire length of the tooth back into the rostrum itself. In comparison, the posterior edge of the rostral teeth of (b) small juvenile (865 mm TL) *P. clavata* is convex (lacking a groove), and although a groove may be present in (d and f) larger juveniles (2130 mm TL) it is rarely present along the entire length of the tooth.

Discussion

Habitat utilisation and growth. Many authors have considered *P. microdon* to be a 'true' freshwater species based on the observation that in Australia it appeared to be confined to freshwater drainages (or the upper reaches of estuaries), and probably bred in freshwater (Last & Stevens 1994; Compagno & Last 1998; Pogonoski *et al*. 2002). Tanaka (1991) also considered *P. microdon* to be a freshwater species, basing this contention on the facts that Taniuchi *et al*. (1991) reported that several specimens collected 80 kilometres from the mouth of the Sepik River possessed yolk (umbilical) scars and, secondly, that Thorson (1973) stated the related species *P. perotteti* bred in Lake Nicaragua. This was despite the fact that Taniuchi *et al*. (1991) considered that *P. microdon* bred in the estuary of the Sepik River or the sea, and that juveniles only remain in the river during their early stages.

The data collected during the current study strongly suggest that freshwater sawfish utilise freshwaters as a nursery ground but spend their adult life and breed in marine environments, thereby supporting the view of Taniuchi *et al*. (1991). For example, despite this species being reputed to reach 7000 mm TL (Last & Stevens 1994), only immature and small individuals (<2800 mm TL) were captured in the Fitzroy River, whereas colleagues captured a ~3500 mm TL female and a ~3000 mm TL mature male in nearshore marine waters a significant distance south of King Sound, i.e. at 80 Mile Beach (Wallal) and near Cape Keraudren (Figure 1). In addition, according to the sole professional fisherman working in King Sound, the capture of large sawfish (>3000 mm TL) during the netting of Barramundi *Lates calcarifer* (Bloch, 1790) is a relatively common occurrence. Further support that *P. microdon* utilises rivers as nursery areas before moving out either just prior to or upon maturation is provided by the capture of a pupping 3030 mm TL *P. microdon* from the mouth of the Mitchell River, Queensland (Peverell 2005); a size only slightly larger than the maximum size attained by females in the Fitzroy River. Such a strategy is also used by the Bull Shark *Carcharhinus leucas* (Valenciennes, 1839) (Thorson 1972, Snelson *et al*. 1984; Cliff & Dudley 1991). This latter species is also known to inhabit rivers throughout northern Australia, including the Fitzroy River (Thorburn *et al*. 2003), and while large mature individuals appear to remain offshore, juveniles often penetrate freshwater riverine reaches far inland (Merrick & Schmida 1984; Thorburn *et al*. 2003; Morgan *et al*. 2004).

Many fish have been reported to cover large distances over a relatively short time. For example, the tagging of Golden Perch *Macquaria ambigua* (Richarson, 1845) in South Australian rivers revealed that this species can travel at an average rate of 3.75 km day $^{-1}$ during their upstream spawning migration (Harris 1984). In elasmobranchs, Stevens *et al.* (2000) reports that during an extensive shark tagging project conducted in the waters of northern Australian, the five most commonly re-captured species recorded maximum daily rates of movement of between 6.8 (*Carcharhinus sorrah* (Müller & Henle, 1839)) and 24.7 (*Carcharhinus tilstoni* (Whitley, 1950)) km day $^{-1}$. Umbilical scars are visible until approximately three months of age in the Nervous Shark *Carcharhinus cautus* (Whitley, 1945) (Dr William White, Murdoch University, pers. comm). Thus, the capture of *P. microdon* (and *C. leucas*) possessing umbilical scars at Camballin Barrage more than 100 kilometres upstream of the mouth of the Fitzroy River, in no way precludes their birth in the marine waters of King Sound. Such a view is also consistent with that proposed by Taniuchi *et al*. (1991) for the Sepik River population, and it is suggested that, at least in the Fitzroy and Sepik rivers, this species is better described as a 'marine opportunist' and not as a 'freshwater' species. The argument against *P. microdon* being a truly 'freshwater' species in the rivers of northern Australia, is further strengthened by the fact that these rivers undergo massive seasonal fluctuations in water level, often becoming a series of small pools and billabongs for up to eight months of the year. Such small pools would be unlikely to provide enough food or space to maintain such a large predatory animal for such a lengthy period.

Ichthyological surveys of rivers to the north of King Sound, including the Isdell, Lawley, Mitchell, Prince Regent, King Edward and Drysdale rivers, (Rosen, Nelson and Butler cited in Vari 1978; Allen 1975; Hutchins 1977, 1981; Allen & Leggett 1990; Thorburn *et al*. 2003) did not discover *P. microdon*. Much of the terrain to the north of King Sound is high plateau, e.g. the Mitchell Plateau, and thus many rivers flow over elevated land before plunging many metres into small estuarine lagoons. These large vertical waterfalls and steep cascades present formidable barriers and preclude penetration of diadromous species. Between King Sound and the De Grey River some 600 km to the south-west there are no river systems, as in this area the Great Sandy Desert extends to the coast. Furthermore, *P. microdon* has never been recorded from any of the rivers in this region, i.e. the Pilbara (Morgan & Gill 2004). In addition to being one of the few rivers that is accessible to *P. microdon* in the Pilbara and west Kimberley, the Fitzroy River is the only river in this region that has a main channel that is accessible to the sea throughout the year. This accessibility is presumably due to the combination of the following: the Fitzroy River has the highest run-off of any river in Western Australia and the largest catchment (~90 000 km^2) of any river in the Kimberley; the topography of the land surrounding King Sound and the Fitzroy River is comparatively flat (especially below Fitzroy Crossing where the floodplain extends some 300 km to the coast); and King Sound experiences the second largest tides in the world (>10 m). Thus, the entrance to this river is accessible to *P. microdon* throughout the year, even during the dry season, and small individuals are able to move upstream into waters that are rich in food and contain few large predators (Morgan *et al*. 2004). The waters of King Sound, and permanence of the Fitzroy River, may therefore provide the most significant habitat for this species in at least the north of Western Australia if not all of northern Australia.

Considering the length-frequency data and growth ring patterns observed during this study, *P. microdon* may inhabit the river for a maximum of four or five years. Assuming a birth size of between 500 (Wilson 1999) and 760 mm TL (Compagno & Last 1998), and that *P. microdon* of 1000 mm TL appear to be approximately one year old, the first year growth rate observed during this study appears consistent with the study of Tanaka (1991), whereby first year growth was estimated to be 180 mm TL. After this period the estimated growth rates of each study vary greatly, with Tanaka (1991) reporting slow growth. For example, during that study a 2473 mm TL *P. microdon* was estimated to be 16 years old (having grown 100 mm in its tenth year), whereas an individual of a similar total length encountered during this study was estimated to be 4 years old. Further support of the growth rates of *P. microdon* estimated during this study is provided by the re-capture of a tagged individual that had grown 170 mm in its four months at liberty (this period coincided with the cooler waters of the dry season and was presumably a period of slower growth) and also by the work of Wilson (1999) who reported that a captive *P. microdon* grew from 600 to 2600 mm TL in 3 years.

The discrepancy in growth rates between studies is possibly due to the differences in the technique employed when reading and interpreting the annuli present on vertebrae. During this study, the distinction and the number of rings present on the vertebrae varied greatly depending on whether transmitted or reflected light was used. Under transmitted light several narrow and indistinct rings were often observable between the distinct broad annuli on vertebral sections. However, when both the facia of whole vertebrae and sections were viewed under a dissection microscope with reflected light, the distinct annuli became more pronounced. Thus, these broad distinct zones were considered to represent annual rings. Irrespective of the differences between the studies, the fact that all of the specimens captured within the rivers by Tanaka (1991) were immature, and that the only mature individual captured (3611 mm TL) was from the mouth of the Oriomo River, further indicates the use of rivers by juveniles.

Diet. *Pristis microdon* has been noted to use its rostrum to stun fishes (Merrick & Schmida 1984; Allen *et al.* 2002; Pogonoski *et al*. 2002). This action was reflected by the dominance of fish in its diet, in particular that of the ariid catfish *A. graeffei*. The presence of relatively large amounts of silt and detrital matter, benthic invertebrates and catfish in conjunction with dorso-ventral flattening and ventrally situated mouth strongly suggest that this species is a benthic opportunist.

Migration of *P. microdon* in the Fitzroy River. The average mean discharge of the Fitzroy River (measured at Willare Bridge) increases dramatically in January, peaks in February and March, and begins to rapidly decrease in April, with average monthly discharges of 846, 2582, 6265 and 985 GL, respectively

(Department of the Environment, Government of Western Australia, 2004). During these peak flows no barriers exist to impede the upstream migration of *P. microdon* within the Fitzroy River. Due to the erratic nature of this seasonal flooding, however, access throughout the catchment may be for as little as two weeks in years of low rainfall or more than four months in particularly wet years.

Sampling during this project emphasised the effect of both natural and artificial barriers on the upstream migration of *P. microdon* in the Fitzroy River. In the lower estuary for example, shallow sand banks form natural barriers to the upstream movement of sawfish at times of low flow, including neap tides. Alternatively large spring tides (up to 12 metres in King Sound) cover these shallow sand banks and thereby provide an opportunity for fish to move further upstream. There are several artificial barriers, the most significant of which is the barrage at Camballin, that are beyond the tidal limit and act as barriers to fishes for much of the year. Camballin Barrage is a remnant of failed irrigated agriculture and water abstraction trials during the 1960's and diverts water into Snake Creek and the surrounding flood plain. Although inundated during the peak floods of the wet season, for much of the year it is exposed and thus impedes the movement of all migratory species both up and downstream. The pools immediately below the barrage are therefore typified by high numbers of *P. microdon* and other migratory species, such as *C. leucas* and *L. calcarifer* (Thorburn *et al.* 2003, 2004b). A combination of a considerable number of *C. leucas*, a large aggressive predator, immediately below the barrage and the ease of access to the barrage for recreational fishers is likely to place significant pressure on *P. microdon* at this locality.

Utilising rostrums in distinguishing between sawfish species, sex, total length, and historical distribution. Whilst this study does not confirm or deny the validity of the synonymisation of *P. perotteti* and *P. zephyreus* with *P. microdon*, the average number of rostral teeth observed in *P. microdon* was generally greater than that of *P. perotteti*. Although Tanaka (1991) found the growth rate of *P. microdon* to differ from that of *P. perotteti* (Thorson 1982) growing 180 mm in the first year and 100 mm in the tenth cf. 300–400 mm in the first three years and 120 mm in the tenth, Tanaka (1991) does not appear to clarify if these species are different, but rather suggests that the differences may be due to the aging methodology used, rather than to their habitat. The length-frequency and vertebral aging data in this study, however, although being less comprehensive than that of Thorson (1982) and Tanaka (1991), indicate that *P. microdon* from King Sound may grow at a much faster rate than that of *P. perotteti*.

The use of rostrums held in private collections from sawfish captured from King Sound and the rivers entering it may provide valuable insight into the ecology of *P. microdon*, including for example historical distributions. The ability to distinguish *P. microdon* from other sawfish in the area on the basis of rostral tooth count or rostral morphology alone also increases the efficacy of determining other factors, including the sex ($\leq$19 in female *P. microdon* cf. $\geq$21 in males) and sex ratio. The difference in the relationship between rostrum length and total length in male and female *P. microdon* also increases the accuracy of length-frequency data that may be obtained from collected rostra.

Conservation recommendations. Although the recent listing of *P. microdon* as a 'totally protected fish' under Schedule 2 (Protected Fish) of the Fish Resources Management Regulations, affords the species complete protection in State waters of Western Australia, *P. microdon* remains threatened in nearshore waters throughout a majority of the species known geographical range in Australia. Indeed, the adoption of legislative protection for *P. microdon* in other States of Australia is essential for the longevity of this species in those waters. Furthermore, the recognition by the Commonwealth Government of the significance of Australian populations and the upgrading of this species current EPBC 1999 listing from vulnerable to endangered would further aid in the species persistence in the region. Penalties for the unlawful killing of this species would deter such acts as trophy collecting for the rostrum alone.

At this point in time the potential for intensive irrigated agriculture continues to be investigated in the Fitzroy River region. The effects of impassable barriers on migratory species may be observed at Camballin Barrage. While the diversion of water into Snake Creek is dependent upon the barrage remaining, the construction of a fish ladder or fish diversion channel would allow migratory species to continue upstream throughout the year. Large dams such as that proposed at Dimond Gorge or Margaret Gorge, however, which aimed to reduce the natural flooding regime during the wet season, and increase the flow during the dry season (Anon 1993), would invariably affect the seasonal distribution of fishes, and again deny migratory species access to the habitat upstream (*P. microdon* was recorded from Margaret Gorge by Morgan *et al.* (2004)). The exclusion of species above dams has been observed on the Ord River above the Diversion Dam in Lake Kununarra (Doupé *et al*. 2003).

Further studies of *P. microdon* throughout the Kimberley region (and northern Australia) are required to understand the true robustness of Australian populations. Education of local communities and others who utilise the Fitzroy River as to the vulnerability of this iconic species will aid in its protection.

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