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Endangered Sawfishes and River Sharks in Western Australia

Report to

Woodside Energy Ltd.

DL Morgan, JM Whitty & NM Phillips

Centre for Fish & Fisheries Research

Murdoch University

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Woodside Energy Ltd.
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By

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Background

The coastal waters of the northern Pilbara and the western Kimberley are a global hotspot for sawfish (Pristidae) diversity, with four of the world's seven[1] species found there; these four species comprise all of the known Australian species. This unique group of rays is readily identified by the presence of a blade-like snout possessing enlarged tooth-like denticles known as rostral teeth (Last and Stevens 2009). Globally, almost all sawfishes have undergone major declines in both range and abundance, largely as a result of their vulnerability to entanglement in fishing nets, but also through loss of habitat. It is only recently that information on the distribution, ecology, biology, population demographics and genetics and habitat utilisation of the Australian sawfish fauna has started to become available, with much of this information restricted to grey literature or as unpublished work in progress. There is limited (or no) information on the size of the remaining populations, but many of the world's sawfish populations are thought to survive in small fragmented areas (e.g. Simpfendorfer 2000). The four Australian species are from two genera, and are typically found throughout northern Australia, but accurate distributional descriptions are hindered by a lack of targeted surveying and are based on: limited surveys, from anecdotal reports or from collections of dried rostra. However, the Pilbara coast and west Kimberley are known to represent an important area for the four species, namely Freshwater Sawfish (*Pristis microdon*), Dwarf Sawfish (*Pristis clavata*), Green Sawfish (*Pristis zijsron*) and the Narrow Sawfish (*Anoxypristis cuspidata*). The first three of these species are listed as *Vulnerable* under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and these form the basis of this review; although all are protected species within Western Australia under the *Fish Resource Management Act 1994* (FRMA Act). *Pristis zijsron* was also listed under *Schedule 1* of the *Wildlife Conservation Act 1950* in Western Australia in 2006. Woodside Energy Ltd contracted the Centre for Fish & Fisheries Research (Murdoch University) to provide an overview of the current knowledge of the three EPBC Act listed pristids (*P. microdon*, *P. clavata* and *P. zijsron*) and also the *Endangered* (EPBC Act) Northern River Shark (*Glyphis garricki*) in Western Australian waters. *Glyphis garricki* was discovered in Western Australia in 2002 (Thorburn and Morgan 2004) and its formal description is recent (Compagno *et al*. 2008). Collectively, these species represent 50% of Australia's elasmobranchs that are listed as *Vulnerable* or higher under the EPBC Act.

This report presents all known information with regard to their distribution in Western Australia, morphological characteristics, habitat utilisation and population structure and genetic diversity in relation to northern Australia populations. The relevance of these data are then discussed in relation to the James Price Point development.

[1]Believed to be up to seven species of Pristidae, however, this may be as low as five if some species are synonimised (see Last and Stevens 2009).

Contents

Introduction

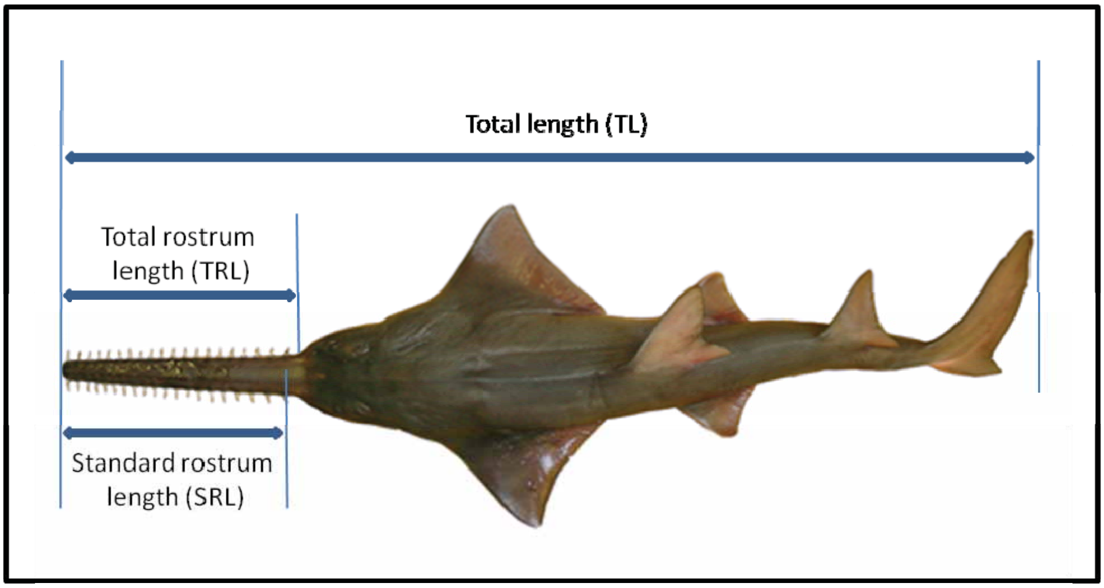
This report provides an overview on the current status of knowledge on three species of sawfish (Pristidae) within Western Australian waters that are listed under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), namely the Freshwater Sawfish (*Pristis microdon*), the Dwarf Sawfish (*Pristis clavata*) and the Green Sawfish (*Pristis zijsron*). Each of these species is listed as *Vulnerable* under the (EPBC Act), with *P. clavata* being listed only very recently (7th October 2009). An overview of current knowledge of the *Endangered* (EPBC Act) Northern River Shark (*Glyphis garricki*) is also provided; a species that was only discovered in Western Australia in 2002 (Thorburn and Morgan 2004). Collectively, these species represent 50% of all of Australia's elasmobranchs that are listed as *Vulnerable* or higher under the EPBC Act. Furthermore, they are all protected species within Western Australia under the *Fish Resource Management Act 1994* (FRMA Act), while *P. zijsron* was listed as *Schedule 1* under the *Wildlife Conservation Act 1950* in Western Australia in 2006 (Government Gazette, 2008). All pristids are listed under CITES (IUCN) as Appendix I, with the exception of *P. microdon* which is listed as Appendix II, which allows trade in aquarium industry for conservation purposes only.

It is only recently that research has been conducted into the distribution and ecology of these species in Western Australia, and much of the information is only found within grey literature or is unpublished data. However, recent research in the region includes ecological studies (habitat utilisation, population demographics, migrations and genetics) on *P. microdon* (Thorburn *et al*. 2003, 2004, 2007, Thorburn and Morgan 2005a, Phillips 2006, Phillips *et al.* 2008, 2009b, Whitty *et al*. 2008, 2009a, 2009b), *P. clavata* (Phillips *et al*. 2008, Stevens *et al*. 2008, Thorburn *et al*. 2008), *P. zijsron* (Stevens *et al*. 2008, Phillips *et al*. 2009b), and *G. garricki* (Thorburn and Morgan 2004, 2005b, Whitty *et al*. 2008, Wynen *et al*. 2009). It is from these publications and that of Peverell (2005, 2008) and Last and Stevens (2009) and from our unpublished collections that most of the information in this report is generated. In light of the potential development of the James Price Point LNG precinct, Woodside Energy Ltd contracted the Centre for Fish & Fisheries Research to collate existing information on these Federally (EPBC Act) listed species, which therefore excludes the remaining pristid known from Western Australia, i.e. the Narrow Sawfish (*Anoxypristis cuspidata*).

Materials and Methods

Data presented is focussed on Western Australian assemblages of the species listed above, but information from other regions is used to increase the power of results and/or for comparative purposes. Information on these species was compiled from a combination of literature reviews as well as from unpublished data. Reviewed literature included peer-reviewed journal articles, reports and web based material. Unless otherwise cited, unpublished data consisted of ongoing research in Western Australia by the Department of Fisheries, Government of Western Australia (Rory McAuley) and Murdoch University (Nicole Phillips, Jeff Whitty, David Morgan and Dean Thorburn).

The report includes information on aspects of the morphology of each species. Morphometric data presented include total length (TL), total rostrum length (TRL; alternatively labelled rostrum length (RL) in other literature (e.g. Thorburn *et al*. 2007, Whitty *et al*. 2008)), standard rostrum length (SRL), inter-tooth gap and weight (WT). TL is the distance from the tip of the rostrum to the tip of the caudal fin. TRL (pictured below) is the distance from the tip of the rostrum to its base, where the rostrum flares to join the head. SRL is the distance between the tip of the rostrum and the middle of the rostrum adjacent to the proximal left rostral tooth. As rostra are often cut short before the base, TRL may not be a reliable measurement when the whole animal is not present and so SRL is used. If sample sizes are low for SRL, TRL was used in its place. Inter-tooth gap is the distance from the anterior base of tooth n to the posterior base of tooth n+1. All linear and weight measurements are reported in cm and kg, respectively.



Species synopses

Freshwater Sawfish (*Pristis microdon* Latham, 1794)

Figure 1 *Pristis microdon* (Photograph: Dean Thorburn)

Other common names

Largetooth Sawfish, Smalltooth Sawfish, Leichhardt's Sawfish, Wide Sawfish

Description

General appearance and coloration: A shark-like ray (gills on ventral surface), with a relatively evenly-spaced, broad, stout and laterally toothed-lined rostrum or 'saw' protruding anteriorly from a flattened head (Figure 1) (Compagno and Last 1999). Most similar to *Pristis clavata*, but *P. microdon* can be distinguished from this species most easily by its first dorsal fin origin located anterior to the origin of its pelvic fins (*c.f.* inline with the pelvic fin origin in *P. clavata* (Compagno and Last 1999, Last and Stevens 2009)), an observable lower caudal lobe and the resulting fork in the caudal fin (*c.f*. negligible lower caudal lobe on *P. clavata* (Compagno and Last 1999, Last and Stevens 2009)), marginal grooves that go to the base of rostral teeth (*c.f.* grooves that generally don't reach the base in juveniles and some adults of *P. clavatat* (Thorburn *et al*. 2007, 2008)) and distal rostral tooth gaps are greater than the second most distal tooth gaps (relationship reversed in *P. clavata;* Whitty unpublished data). Outside of the genus, *P. microdon* is also superficially similar in appearance to sawsharks (Pristiophormes), but can be differentiated by a few characteristics including a lack of barbels on the rostrum, gill slits located on the ventral surface and a dorsally-flattened head (Compagno and Last 1999). Olive-brown dorsal coloration and white ventrally.

***Fin position/markings*:** No discernable markings on fins (Taniuchi *et al*. 1991b). Wide pectoral fins with wide base. Base of first dorsal fin greater than that of the second; height of second dorsal fin slightly higher than that of the first (Taniuchi *et al*. 1991b). Origin of first dorsal fin anterior with that of the pelvic fin (Taniuchi *et al*. 1991b, Compagno and Last 1999, Thorburn and Morgan 2005a, Last and Stevens 2009). Ventral lobe of caudal fin small but apparent; no terminal notch (Ishihara *et al*. 1991, Taniuchi *et al*. 1991a, Compagno and Last 1999). No anal fin.

Rostral teeth count and morphology: Proximal rostral teeth begin near the base of the rostrum (Compagno and Last 1999). 14-23 pairs of teeth, varying between regions and sexes (Ishihara *et al*. 1991b, Taniuchi *et al*. 1991a, Compagno and Last 1999, Thorburn *et al*. 2007, Whitty *et al*. 2008). In Western Australia, individuals of *P. microdon* have been observed with 17-24 pairs of rostral teeth (see Table 1, Figures 2-4) (Thorburn *et al*. 2004, 2007, Whitty *et al*. 2008, 2009a). Differences between left and right rostral tooth counts ranged between 0-2 (Figure 5). This was also observed by Ishihara *et al.* (1991) in *P. microdon* collected in other regions of northern Australia and Papua New Guinea. TRL between 17.8 and 27.5% of TL, gradually decreasing with size ($TRL = -0.3753 + 0.4331(TL^{0.8813})$) (Figure 6). Taniuchi *et al*. (1991b) documented this range to be ~25% for *P. microdon* (99.2-108.4 cm TL) outside of Western Australia. Relatively minor difference in the ratio of the distal: proximal tooth gap ratio with the distal tooth gap on average being 76.5% (± 0.01 SE; range = 52.5-109%) that of the proximal tooth gap (Figure 7, Whitty unpublished data). Groove on posterior margin of tooth extends to tooth base (Thorburn *et al*. 2007). Second most distal tooth gap smaller than most distal tooth gap (Figure 7, Whitty unpublished data).

Table 1 Range and average of left, right and total tooth counts for male and female *Pristis microdon*. 1 = inclusion of unsexed rostra increased the number of left teeth to 24. See Figures 2 and 3 for numbers of fish used.

Tooth count	Female	Male
Left teeth [1]	17-23 (avg = 18.9 ± 0.1 SE)	19-23 (avg = 20.7 ± 0.1 SE)
Right teeth	17-24 (avg = 18.8 ± 0.1 SE)	17-24 (avg = 20.7 ± 0.1 SE)
Total teeth	34-47 (avg = 37.7 ± 0.2 SE)	36-47 (avg = 41.4 ± 0.2 SE)

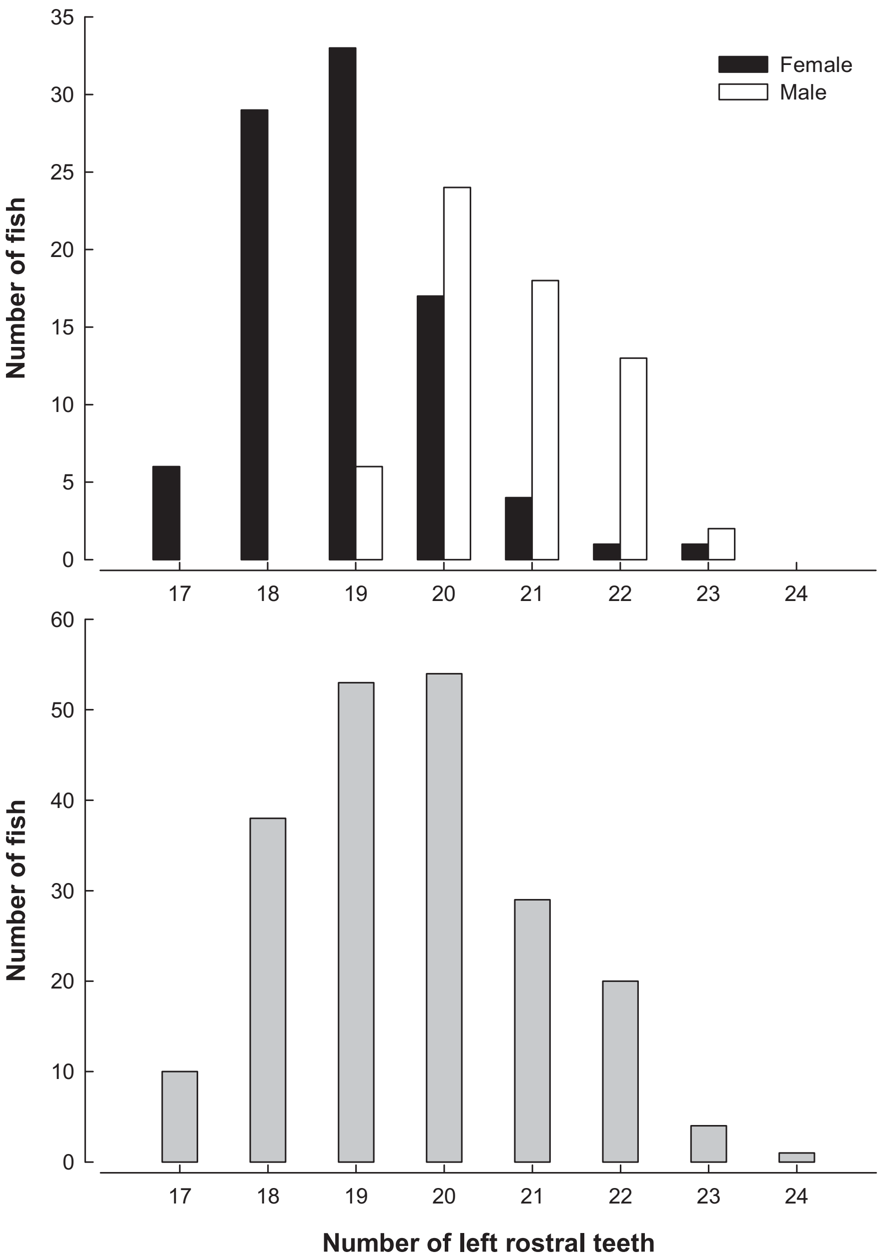


Figure 2 Left rostral teeth count of sexed (top) and pooled (sexed and unsexed) *Pristis microdon* captured in Western Australia.

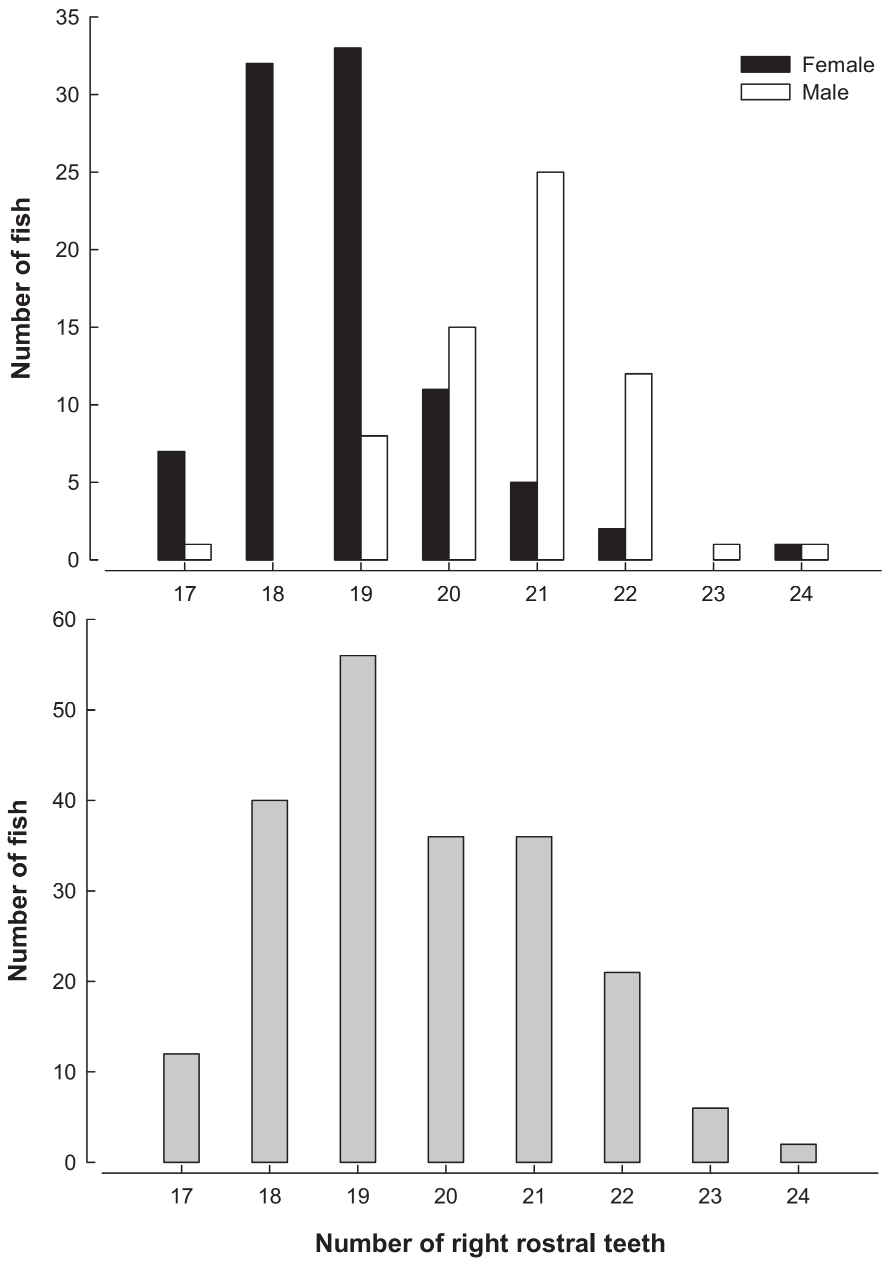


Figure 3 Right rostral teeth count of sexed (top) and pooled (sexed and unsexed) *Pristis microdon* captured in Western Australia.

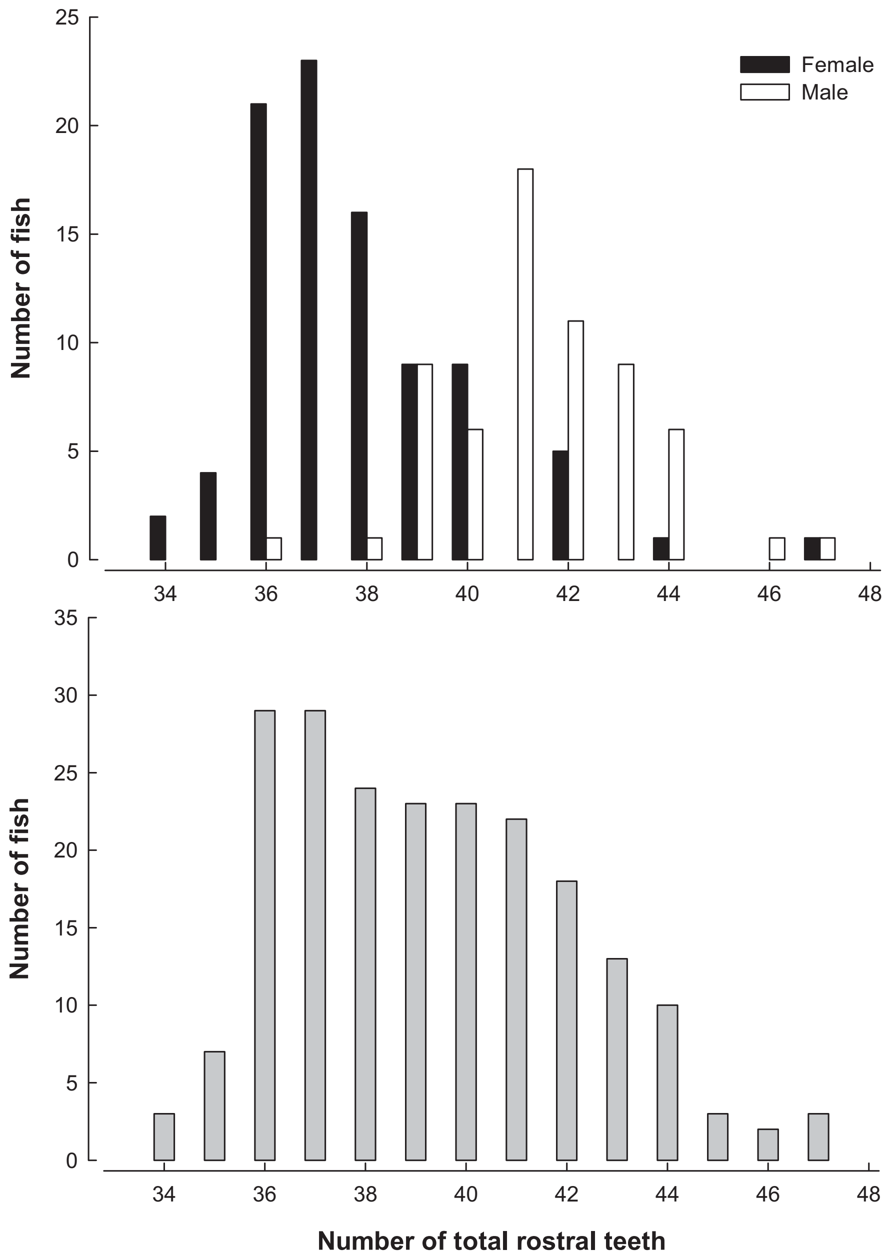


Figure 4 Total number of rostral teeth for sexed (top) and pooled (sexed and unsexed) (bottom) *Pristis microdon* captured in Western Australia.

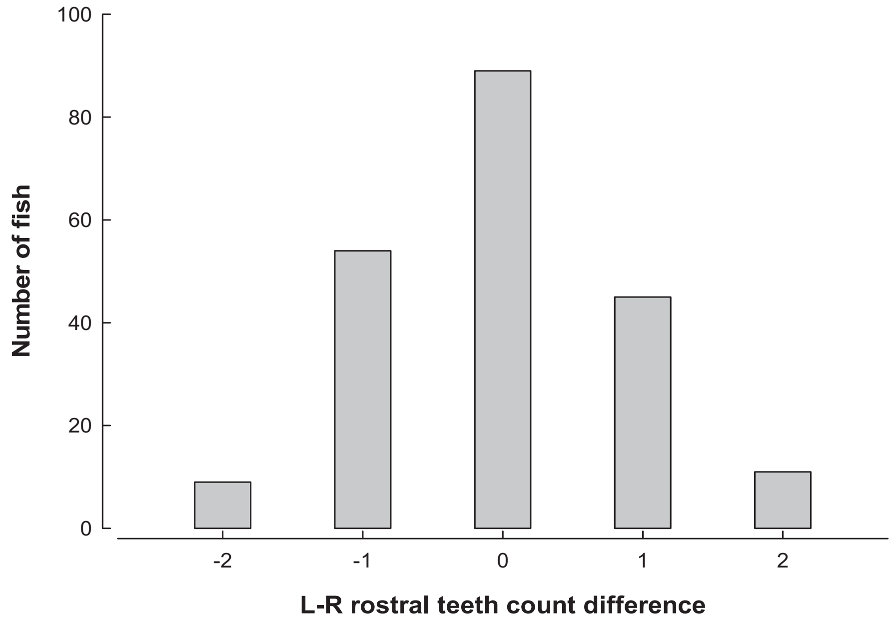


Figure 5 Difference between left and right rostral tooth counts for *Pristis microdon* captured in Western Australia.

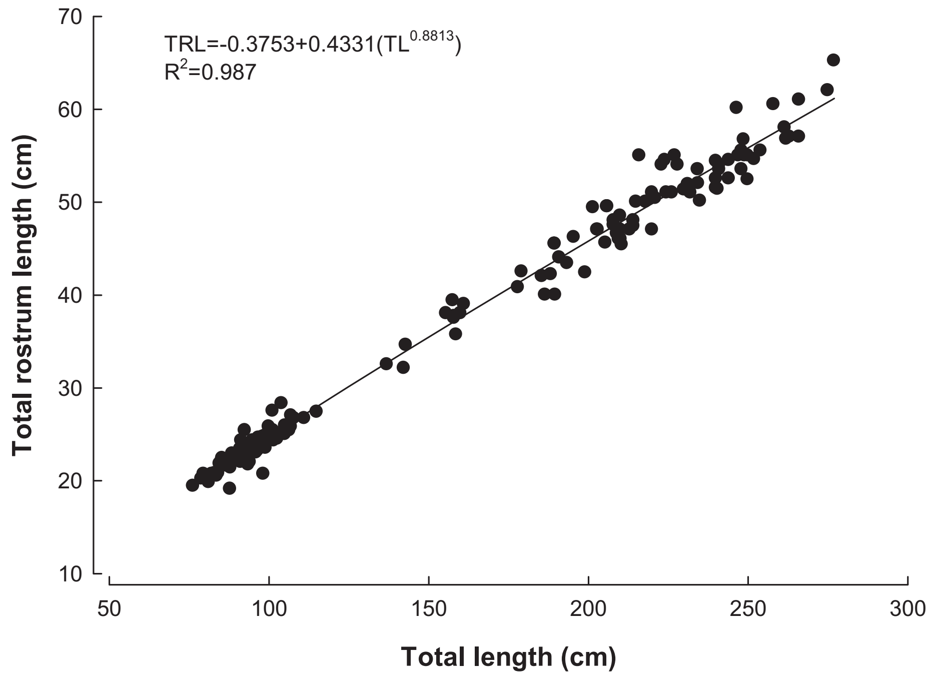


Figure 6 Relationship of total length (TL) to total rostrum length (TRL) of *Pristis microdon* (captured in Western Australia).

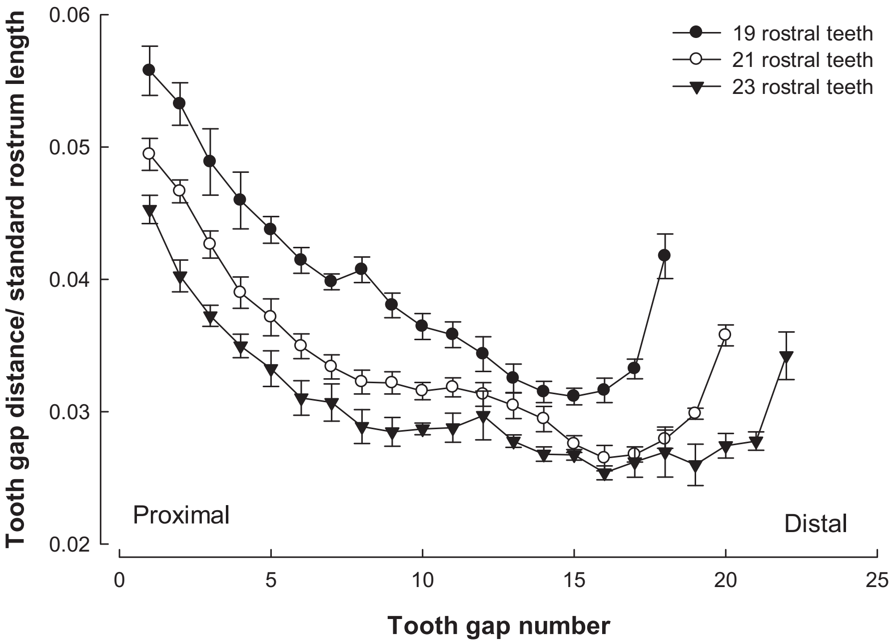


Figure 7 Representative (rostrum with 19, 21 and 23 teeth per left side) relative inner-tooth spacing (gap length/standard rostrum length) of *Pristis microdon* captured in Western Australia (Whitty *et al*. unpublished data).

Size: Born between 76 and 91 cm (Compagno and Last 1989, Thorburn *et al*. 2007, Peverell 2008, Whitty *et al.* 2009a), *P. microdon* are estimated to attain maximum lengths of 600-700 cm TL (Peverell 2008, Last and Stevens, 2009), with the largest recorded individual at 656 cm TL (Compagno and Last 1999). In the Fitzroy River, Western Australia male and female juveniles have been recorded at between 76.3-258 cm and 78.9-277 cm TL, respectively (Thorburn *et al*. 2007, Whitty *et al*. 2009a).

Vertebral Count: 226-228 northern Australia (Taniuchi *et al*. 1991b), 218-228 Sepik River, Papua New Guinea), 213-230 (Lake Murray, Australia; Taniuchi *et al*. 1991a).

Biology

Distribution and habitats in Western Australia: Last and Stevens (2009) provide details on the global distribution of *P. microdon* and note the uncertainty of describing as accurate contemporary distribution due to local extinctions; but do confirm their presence from several major river systems in Indonesia and New Guinea, but possibly also in India. They state that a similar, if not conspecific, form occurs through tropical and subtropical Atlantic, eastern Pacific and southwestern Indian Oceans. Within Western Australia, *P. microdon* has been found from

Cape Naturaliste (Chidlow 2007) in the south-west, to the Ord River (Gill *et al*. 2006) in the north. However, most are recorded from the west Kimberley, and arguably the most important known nursery site is the Fitzroy River in the Kimberley (Thorburn *et al*. 2003, Morgan *et al*. 2004, Thorburn and Morgan 2005a, Thorburn *et al*. 2004, 2007, Whitty *et al*. 2008, 2009a) (Figure 8). Within the Fitzroy River, all *P. microdon* are immature, with few immature fish located elsewhere in Western Australia (Figure 9). The only records of immature *P. microdon* from outside of the Fitzroy River and the other major tributaries of King Sound include Goodenough Bay in King Sound and Willie Creek north of Broome (Figure 9), although they have been reported from the Ord River (Gill *et al*. 2006). Mature individuals are considered to be those >300 cm TL, which would have a rostrum length of >65 cm, and in Western Australia have been recorded from Cape Naturaliste (Chidlow 2007), 80 Mile Beach, Roebuck Bay (near Broome) and King Sound (Figure 9). Ontogenetic shift in habitat utilisation has recently been demonstrated for the species in the Fitzroy River (freshwaters and estuary) (see Whitty *et al*. 2008, 2009a, b). For example, the 0+ (new recruits) utilise very shallow waters (generally < 1m deep) whereas older fish occupy deeper habitats. Acoustic tracking has found fish in deeper pools of the Fitzroy River (~7 m deep) (Whitty *et al*. 2009a). Actual depth utilisation in the river and marine environments are likely to be much greater considering high tidal and wet season variation. Females are thought to be philopatric (see **Genetics**), and thus return to their natal river to pup (Phillips *et al*. 2009b). Thus, it is possible that each of those larger females found along 80 Mile Beach and in Roebuck Bay (see Figure 9), may move to the mouth of the Fitzroy River to pup. It is also likely that many juveniles will migrate past the James Price Point region on their migration south.

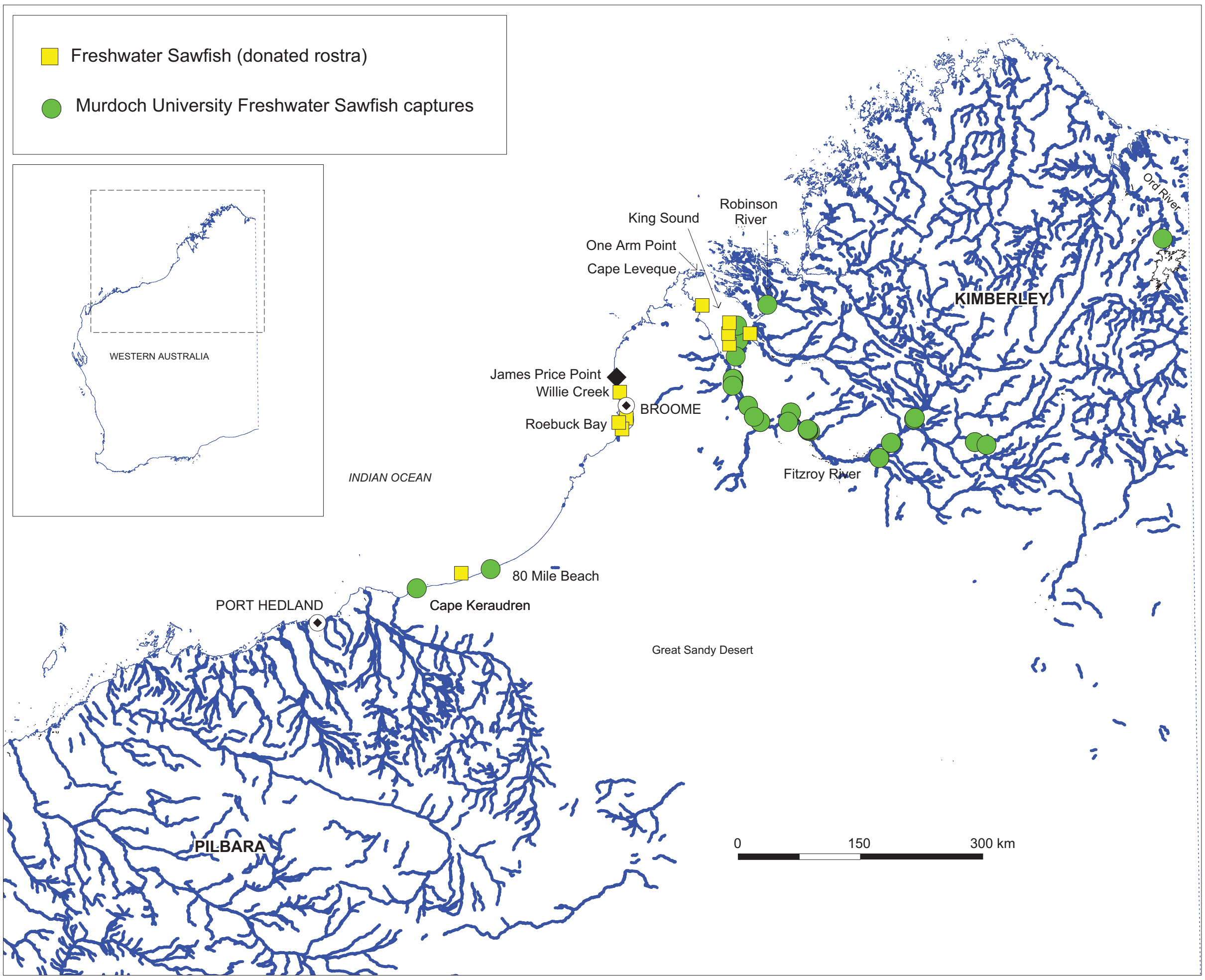


Figure 8 Catches of Freshwater Sawfish (*Pristis microdon*) in the Pilbara and Kimberley region of Western Australia (from Murdoch University collections and donated rostra). N.B. Chidlow (2007) reports on the capture of a mature male near Cape Naturaliste in south-western Australia. Data from Morgan *et al*. (2004), Thorburn *et al*. (2004, 2007), Gill *et al*. (2006), Whitty *et al*. (2008, 2009a, b), Phillips *et al*. (2008).

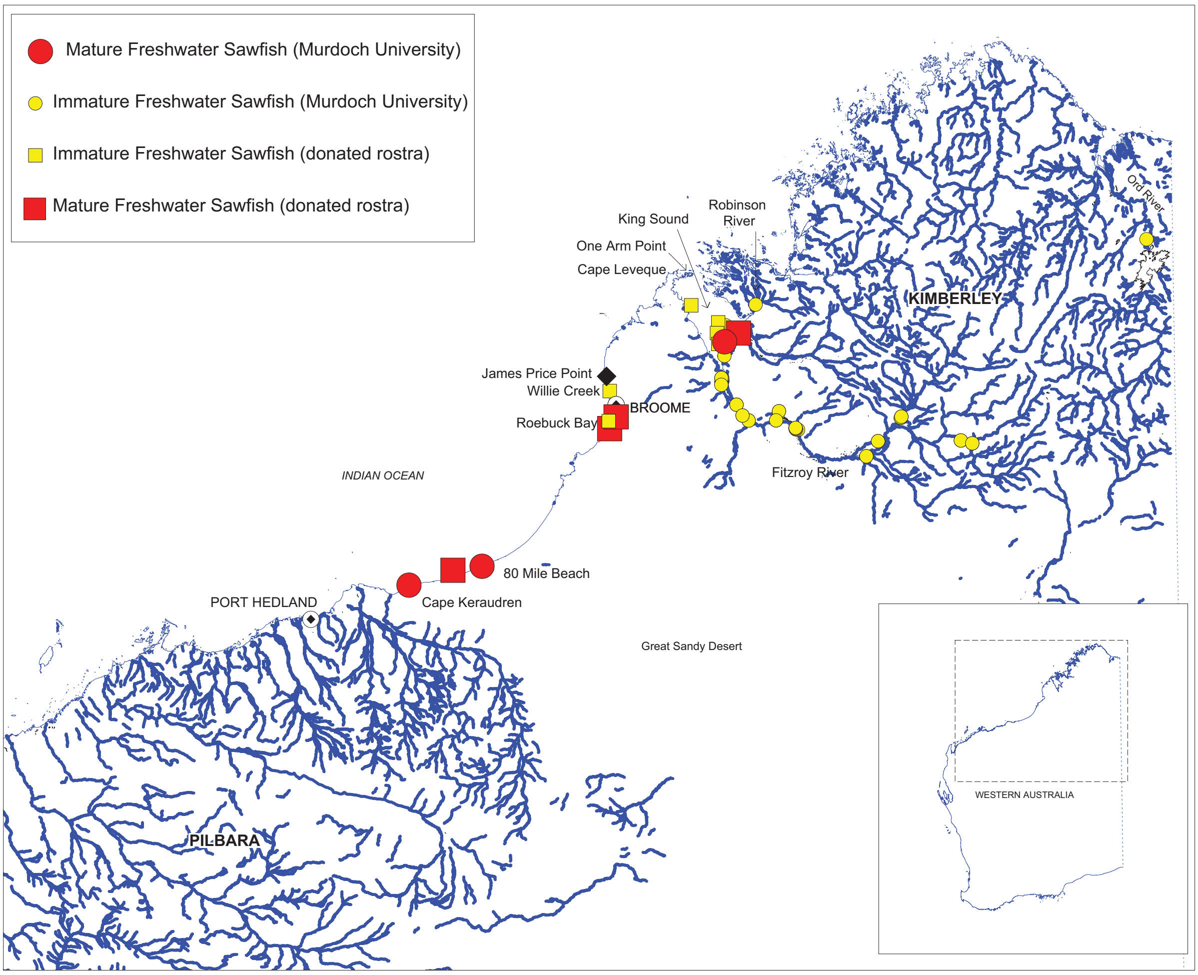


Figure 9 Catches of Freshwater Sawfish (*Pristis microdon*) in the Pilbara and Kimberley region of Western Australia, indicating maturity status (from Murdoch University and donated rostra).

Age and growth: Employing observed data (TL range = 77.1-361.1 cm) with a von Bertalanffy growth curve, Tanaka (1993) calculated a k-value (growth co-efficient) of 0.066 (L_∞ = 362.5 cm (length at infinity), t_0 = -4.073 (hypothetical age at length zero)). This curve puts growth at around 18 cm within the first year and 10 cm in the tenth year. Employing similar methods, but using a greater range in TL (up to 582 cm), Peverell (2008) calculated a k-value of 0.08 (L_∞ = 638 cm, t_0 = -1.55), estimating growth within the first year to be 52 cm, and growth in the fifth year to be 17 cm. The latter values appear to more closely correspond with the Fitzroy River population (Thorburn *et al*. 2007). Furthermore, Peverell (2008) comments that his k-value may be an underestimation, as mark and recapture methods demonstrated faster growth rates then did the von Bertalanffy growth curve, for the same aged animal.

Maximum age was estimated to be approximately 80 years (638 cm TL), although growth asymptotes at 35 years (606 cm TL; Peverell 2008). Using vertebral analysis Thorburn *et al.* (2007) estimated *P. microdon* in Western Australia of 100 cm, 140-160 cm, 180-220 cm, and 230-280 cm TL to be around one, two, three and four years of age, respectively. Also using vertebral analysis, Peverell (2008) produced similar age estimates, finding Queensland captured *P. microdon* ranging between 83-101 cm, 119-140 cm, 143-180 cm, 170-219 cm, 229-253 cm and 234-277 cm TL to be 0+, 1+, 2+, 3+, 4+ and 5+ year olds, respectively. Peverell (2008) also found a 582 cm TL female to be 28 years of age. Preliminary estimates of natural mortality suggest that only ~20% of new born pups live long enough to attain maturity (Simpfendorfer unpublished data).

Reproduction: Aplacental viviparity (lecithotropic nutrition) (Stevens *et al*. 2005, Last and Stevens 2009). Litters of 6-12 pups (Peverell 2008). Suggested to pup annually (Peverell 2008). In Western Australia, the Fitzroy River appears to be the most important nursery for the species (Thorburn and Morgan unpublished data, Thorburn *et al*. 2003, 2007), and while it is unknown where fertilisation occurs, the pupping location is likely to be near the mouth of the Fitzroy River. From catches in the Fitzroy River, pupping is likely to occur in the wet season (January to April) (Whitty *et al*. 2008, 2009a), with the length of the wet season (indicated by higher river discharge in the late wet) likely to be a significant factor in the survival of new-born pups (Whitty *et al*. 2009a). Higher water levels not only reduce interactions with predators (such as Bull Sharks and Saltwater Crocodiles), but also provide the juveniles with passage to upstream parts of the system that also have reduced numbers of predators (Whitty *et al*. 2008).

Maturity: Males mature at ~2.5 m TL, females mature at ~3.0 m TL (Compagno and Last 1998, Thorburn *et al*. 2007, Peverell 2008, Whitty *et al*. 2008). In Western Australia all captured and analysed male *P. microdon* <240 cm TL and female *P. microdon* <280 cm TL were found to be immature. Captured males of 258 cm and 300 cm TL were found to have semi-calcified and fully calcified claspers, respectively (N.B. fully calcified claspers are a sign of maturity). A female also captured in Western Australia of ~350 cm TL was found to be mature (Thorburn *et al*. 2007). The distribution of the few mature individuals captured ranged from Cape Keraudren in the south to King Sound in the north (see Figure 9).

Diet: Juvenile *P. microdon* in Western Australia were found to mostly consume *Neoarius graeffei* (Lesser Salmon Catfish), *Macrobrachium rossenbergii* (Cherabin) and insect parts, but also were found to have eaten molluscs, nematodes and other unidentified fish (Thorburn *et al*. 2007). Gut contents of *P. microdon* captured in marine, estuarine and freshwater habitats in Queensland included *Macrobrachium* spp. (freshwater prawns), *Penaeus* spp. (prawns), *Arius* spp. (Fork-tailed catfish) and *Nibea squamosa* (Scaly Croaker) (Peverell 2008). *Nematalosa erebi* (Bony Bream) scales have been found embedded on the rostral teeth of a number of individuals in the Fitzroy River (Morgan unpublished data), indicating that *P. microdon* may use its rostrum to attack schools of this species; which is found throughout the water column. Observations of feeding suggest that this primarily benthic species is not limited to feeding on the substrate and will take surface baits.

Genetics

Population structure: The population structure of *P. microdon* was investigated by Phillips *et al.* (2008, 2009b). This investigation was based on the analysis of nucleotide sequence variation in a 351-353 bp portion of the control region of the mitochondrial genome (which is maternally inherited) and preliminary information on allele frequency information at three tetranucleotide microsatellite loci (which is bi-parentally inherited). The results of the mitochondrial DNA analyses indicate that the amount of maternal gene flow between the west coast of Australia and the Gulf of Carpentaria is negligible. Hence, the assemblages of *P. microdon* in each of these locations should be regarded as independent management units (Phillips *et al.* 2008). Since maternal gene flow is negligible between these two regions, the reduction or loss of a population from one area, such as the west coast, would not be offset by immigration from the other location (see Phillips *et al.* 2008). However, even if dispersal in female sawfishes is philopatric, these individuals could be moving large distances from their natal region outside of critical breeding and/or pupping periods (Phillips *et al.* unpublished data).

The results from the preliminary microsatellite analyses, found no evidence of genetic subdivision in *P. microdon* between the Fitzroy River on the west coast of Australia and the Gulf of Carpentaria (Phillips *et al.* 2009b). Thus, while there is no effective dispersal (gene flow) in the female component of the population (Phillips *et al.* 2008), the amount of gene flow between these two regions has nevertheless been sufficient to prevent structuring in the nuclear genome (Phillips *et al.* 2009b). The apparent difference in the amount of genetic structuring using markers with different modes of inheritance (maternal versus bi-parental) suggests that *P. microdon* may have male-biased dispersal, where females are philopatric and males are more wide-ranging (Phillips *et al.* 2009b). While a decline in the number of females in one region, such as the Fitzroy River, would not be replenished by immigration of females from another region (i.e. the Gulf of Carpentaria), a decline in the abundance of this species in either the west coast or the Gulf of Carpentaria could have a direct effect on its abundance in other regions as males may disperse between regions (Phillips *et al.* 2009b). However, since the variance in the degree of differentiation at microsatellite loci can be quite large, more loci are needed to confirm this finding (Phillips *et al.* 2009b).

The relationship between Australian and Papua New Guinea populations of *P. microdon* is generally unknown. Watabe (1991) compared the lactate dehydrogenase isozyme patterns in *P. microdon*, finding no evidence of genetic subdivision between assemblages in Australia and Papua New Guinea. However, since isozymes are generally not as variable as other markers (such as microsatellites), and the sample size was small (n = 12), these isozyme data are not sufficient to draw solid conclusions about the levels of gene flow between these regions.

Genetic diversity: The levels of genetic diversity in the control region of the mtDNA, which were measured in terms of haplotype diversity and allelic richness are moderate for *P. microdon* (Phillips *et al.* 2008, 2009b). However, since it can take several generations for reductions in the amount of genetic diversity to become apparent in long-lived species with overlapping generations, like *P. microdon*, the full extent of any contemporary population declines may not yet be apparent (see Phillips *et al.* 2008). The levels of genetic diversity in the microsatellite loci were found to be very similar in assemblages in the Fitzroy River and the Gulf of Carpentaria (Phillips *et al.* 2009b). However, the levels of genetic diversity in the mtDNA in the assemblage in the Fitzroy River (n = 39) may be slightly lower than those in the assemblage in the Gulf of Carpentaria (n = 47) (Phillips *et al.* 2008, 2009b). This finding may be due to a lower abundance of females, possibly in association with the smaller number of river systems suitable for nursery areas on the west coast (Phillips *et al.* 2009b).

Much of the genetic diversity in the population in the Fitzroy River are present as rare alleles, which are the most likely to be lost via population declines and genetic drift. Since the assemblage of *P. microdon* in the Fitzroy River is genetically distinct from that in the Gulf of Carpentaria on the maternal side (mtDNA), and contains several haplotypes not found elsewhere in Australia (Phillips *et al.* 2008), there is the potential for substantial amounts of genetic diversity to be lost should the population in the Fitzroy River suffer a decline. As the Fitzroy River may be the only river system on the west coast that supports a substantial population of *P. microdon,* and since this population is genetically unique from other populations in Australia (mtDNA), and possibly elsewhere, it is paramount that the current levels of genetic diversity are maintained.

Conservation

***Population status*:** Unknown. While a population estimate is unknown, *Pristis microdon* assemblages have been observed to have greatly declined throughout their documented range, being completely eliminated in some areas throughout its range, particularly in south-eastern Asia and the east coast of Australia (Stevens *et al*. 2000, Pogonoski *et al*. 2002). Northern Australia appears to be one of the last regions with viable populations (Pogonoski *et al*. 2002). A previous survey throughout most rivers of northern Australia (Cape York to west Kimberley) found the greatest number of *P. microdon* in the Fitzroy River, Western Australia (Thorburn *et al*. 2003). Recent data highlight the possibility that the abundance of *P. microdon* is declining in this system. For example, catch per unit effort (CPUE) of juvenile *P. microdon* in the lower 150 km of the Fitzroy River was found to range between 3.9 and 12.4 fish per 100 hrs of 20-m net set between the early dry season (June) of 2006-2009 (Whitty *et al*. 2009a). This is lower than previous years where it was recorded as high as 56.7 fish per 100 hrs of 20-m net set (June, 2003) (Figure 10) (Whitty *et al*. 2009a). This recent decline in CPUE is of concern, but may simply be due to natural fluctuations in recruitment based on environmental influences such as length of the wet season (see Whitty *et al*. 2009a).

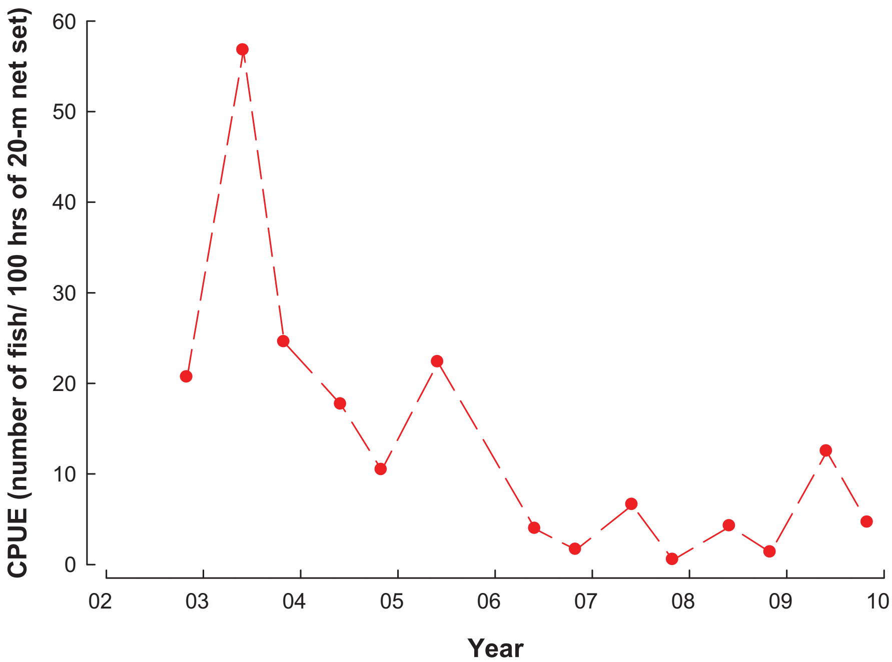


Figure 10 Catch per unit effort (CPUE) of *Pristis microdon* captured in the early and late dry season (2002-2009) in the Fitzroy River (from Whitty *et al*. 2009a, Thorburn unpublished data, Morgan unpublished data).

Protection status:

Table 2 Listing of various legislation protecting *Pristis microdon* at the international, national or state (Western Australia) level. 1 = collection for aquarium trade for conservation purposes only.

Legislation	Listing/Category
CITES	Appendix II [1]
IUCN red list	Critically Endangered (A2abcd+3cd+4bcd)
EPBC Act 1999	Vulnerable
Fish Resources Management Act 1994	Schedule II, Totally Protected

Interaction/Interest with fisheries: *Pristis* fins are greatly valued in the international fin trade as are their rostra, which are often used for curios (Bigelow and Schroeder 1953, Camhi *et al*. 1998, Seitz and Poulakis 2006). However, as all Australian *Pristis* spp. are protected in Australian waters, there are no direct fisheries for this group. By-catch of *Pristis* spp. does occur in several fisheries. Stevens *et al*. (2005) reported that gill net fisheries have the highest percent of *Pristis* by-catch (80.2%), followed by trawling (16.6%), line (9.2%) and recreational gears (0.3%). In the Northern Territory *P. microdon* is occasionally captured in the Offshore Net and Line fishery (two in 2006), but is more frequently captured in the near-shore Barramundi gill net fishery (Field *et al*. 2008). Peverell (2008) observed *P. microdon* to only be captured in the inshore fishery during the wet season in the Gulf of Carpentaria. In Western Australia, a range between 0.7 and 1.1 t (live weight) *P. microdon* was estimated to be captured in the northern regions of the Kimberley Gillnet and Barramundi Managed Fishery (KGBMF; excluding the Broome and Eighty Mile Beach area) in 2000-2004 (McAuley *et al*. 2005). There is also recreational and Indigeneous harvest (see Thorburn *et al*. 2003, 2004). Their distribution in the Ord system has been impacted by the regulation of the system (Doupé *et al.* 2005) and the Barrage on the Fitzroy River is also impacting their migration patterns (Morgan *et al*. 2005). An overview of the impacts to this species are summarised in Freshwater Sawfish Expert Review Committee (2009).

Green Sawfish (*Pristis zijsron* Bleeker, 1851)

Figure 11 *Pristis zijsron* (Photograph: Stirling Peverell).

Other common names: Longcomb Sawfish, Longsnout Sawfish, Narrowsnout Sawfish

Description

General appearance and coloration: A shark-like ray (gills on ventral surface), with a unevenly-spaced, relatively narrow and long, laterally toothed-lined rostrum or "saw" protruding anteriorly from a flattened head (Figure 11) (Compagno and Last 1999, Last and Stevens 2009). Similar in appearance to sawsharks (Pristiophormes), but can be differentiated by a few characteristics including a lack of barbels on the rostrum, gill slits located on the ventral surface and a dorsally-flattened head (Compagno and Last 1999). Olive-brown dorsal and white ventral coloration.

Fin position/markings: No discernable markings on fins. Reduced pectoral fin width (*c.f. P. microdon*) with a long base (Compagno and Last 1999, Last and Stevens 2009). Ventral lobe of caudal fin minimal, less than half the length of the upper lobe (Last and Stevens 2009); no subterminal notch (Compagno and Last 1999). Origin of first dorsal fin inline or just posterior with that of the pelvic fin (Compagno and Last 1999); dorsal fins large and similar in width and height. No anal fin.

Rostral teeth count and morphology: Narrow rostrum with 23-34 pairs of teeth (Compagno and Last 1999, Last and Stevens 2009). Western Australian captured *P. zijsron* were observed to have 24-30 left teeth (mean = 26.1 ± 0.16 SE), 23-30 right teeth (mean = 26.2 ± 0.16 SE) (Figure 12), 47-59 total rostral teeth (mean = 52.2 ± 0.41 SE) (Figure 13) and a difference of up to 3 teeth between left and right rostral tooth counts (Figure 14; Whitty unpublished data). TRL is 20.6-29.3% of TL based on 18 *P. zijsron* ranging between 73 cm and 230 cm TL (TRL = -1.926 + (0.281 * TL) (Figure 5) (Whitty unpublished data). Distal tooth gap for WA captured *P. zijsron* was found to be on average 20.6% (± 0.6 SE, range = 9.7- 34.5%) that of the proximal tooth gap (24-145 cm TRL). Compagno and Last (1999) recorded the two most distal tooth gaps to be 14-50% of the two most proximal tooth gaps for this species (origin unknown). The second most distal tooth gap is greater than the distal tooth gap (24-145 cm TRL; ~1.5% of *P. zijsron* were observed to have this relationship reversed on one side, but never on both; Figure 16; Whitty unpublished data). Groove on posterior margin of tooth extending to base on anterior teeth in juveniles and the majority of teeth in adults (Figure 16) (Compagno and Last 1999, Whitty unpublished data).

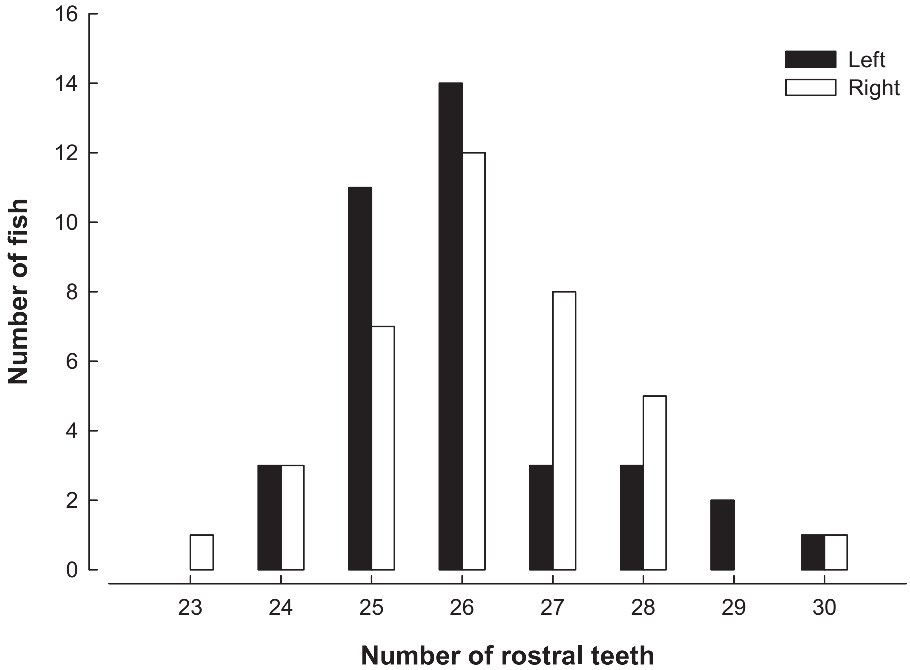


Figure 12 Left and right rostral tooth counts of *Pristis zijsron* captured in Western Australia.

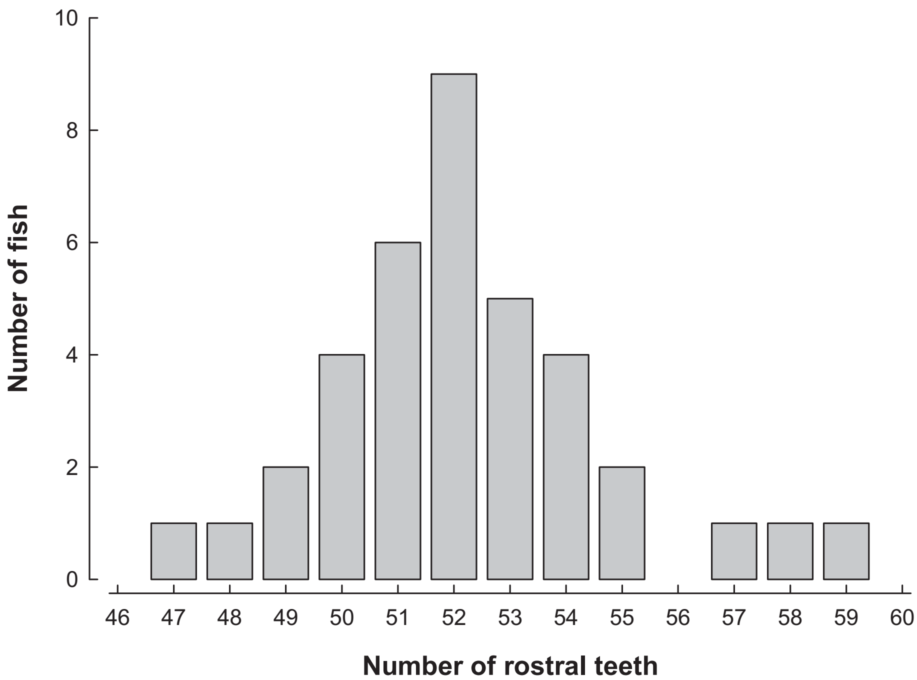


Figure 13 Total rostral tooth counts of *Pristis zijsron* captured in Western Australia.

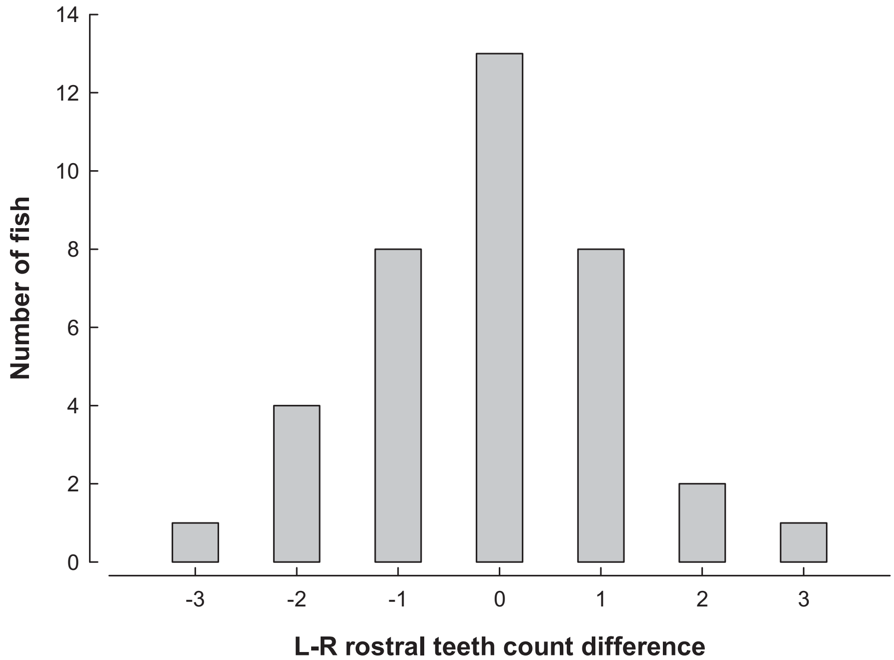


Figure 14 Difference between left and right rostral tooth counts of *Pristis zijsron* captured in Western Australia.

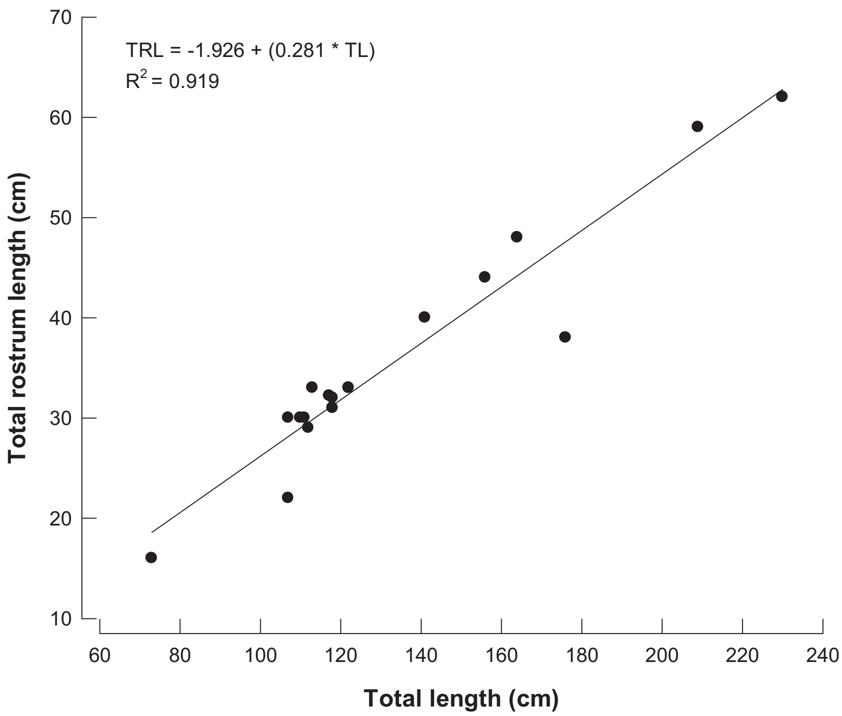


Figure 15 Relationship between total length (TL) and total rostrum length (TRL) of *Pristis zijsron* captured in Western Australia (McAuley unpublished data).

Size: Pupped at 61 (Compagno and Last 1999) to ~80 cm TL and estimated to reach at least 540 cm TL, with some reports indicating that they reach 730 cm TL (Last and Stevens 2009).

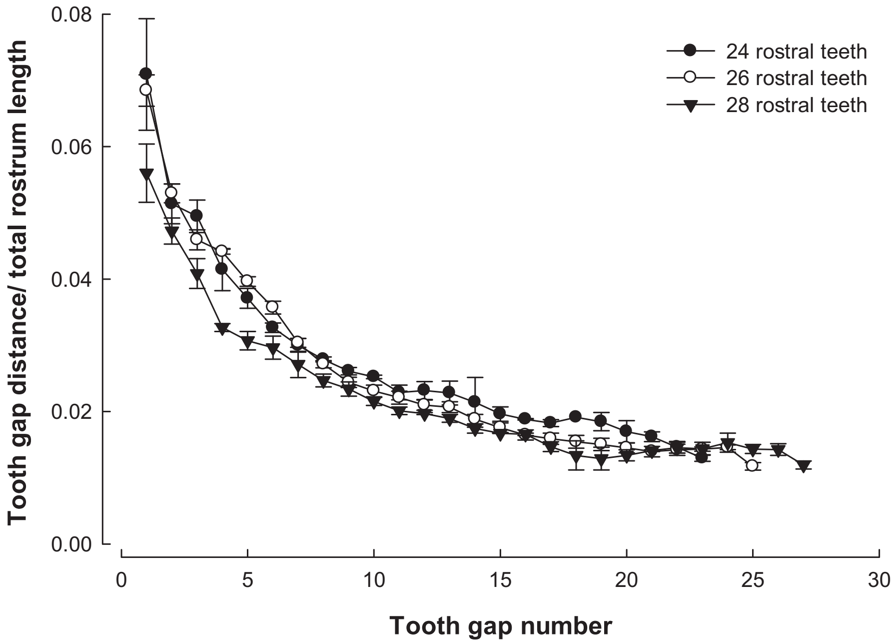


Figure 16 Representative (rostrum with 24, 26 and 28 teeth per side) relative inner-tooth spacing (gap length/ total rostrum length) of *Pristis zijsron* captured in Western Australia (N.B. Total rostrum length was used in place of standard rostrum length, slightly altering the ratio, but not the pattern) (Whitty *et al*. unpublished data).

Vertebral count: Undocumented.

Biology

Distribution and habitats in Western Australia: Last and Stevens (2009) state that *P. zijsron* is widely distributed in the Indian Ocean west to South Africa, in India, Indonesia and Australia. They indicate that the Australian distribution extends from Sydney north and west to Coral Bay (near Exmouth) in WA, with a single record off South Australia; however a decline in southward range appears to have occurred. In Western Australia *P. zijsron* has been recorded from Exmouth Gulf to the WA/NT border (sees Figure 17 and 18). However, the majority of capture locations are between Karratha and One Arm Point, with very few specimens recorded in King Sound, in contrast to *P. microdon* and *P. clavata* (Figure 17) (see also ***Maturity***). Further records include from the Ashburton River mouth (Thorburn unpublished data). Most captures of the species have been from nearshore, however, interactions have been reported from the Pilbara

Fish Trawl Fishery, which operates in depths between 30 and 200 m (Stephenson and Chidlow 2003). Unlike *P. microdon*, *P. zijsron* does not move into freshwaters and its life-cycle is completed in the marine environment.

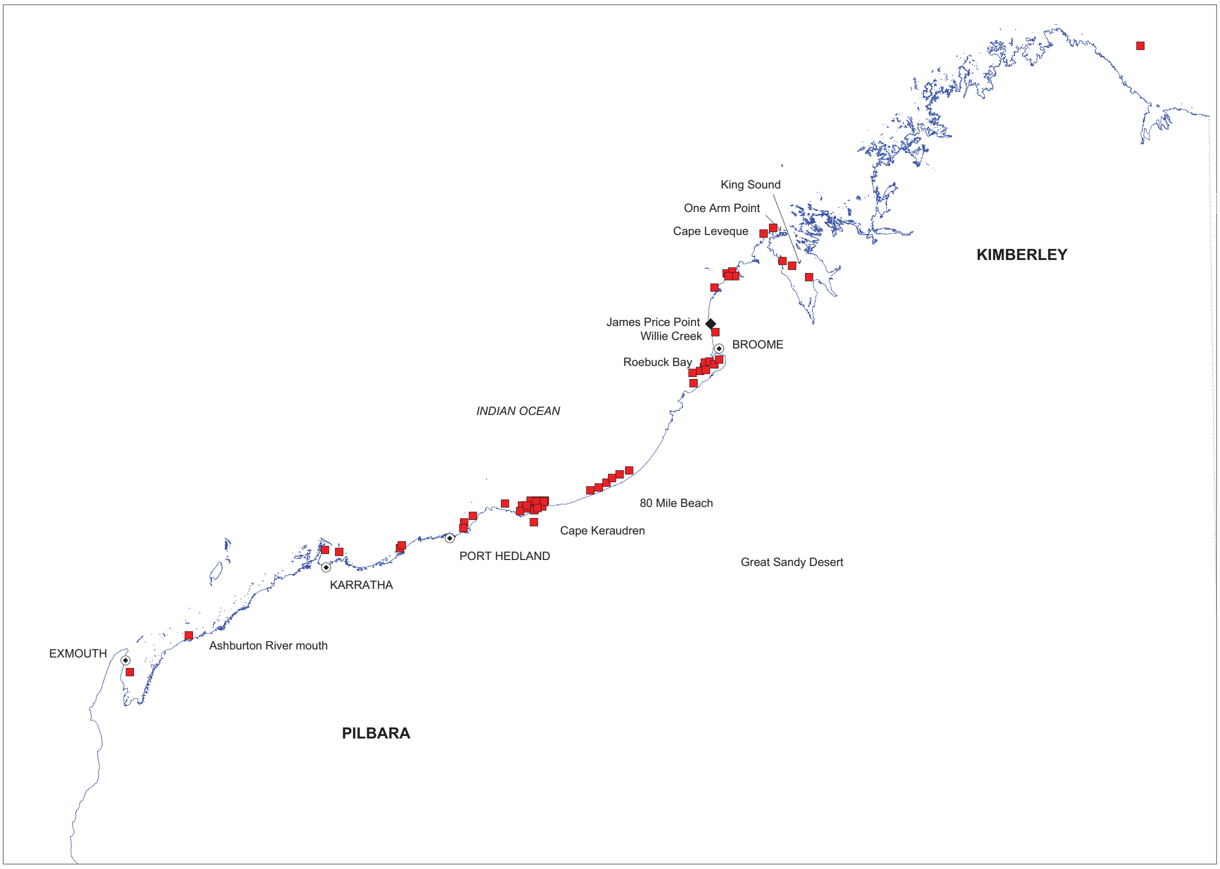


Figure 17 Capture locations of *Pristis zijsron* in Western Australia (data derived from CFFR, Murdoch University and Department of Fisheries, Stevens *et al*. 2008).

Age and growth: Using a von Bertalanffy growth curve with *P. zijsron* aged between one and 18 years (482 cm TL), Peverell (2008) produced a k-value of 0.12 (L_∞ = 540 cm, t_0 = -1.12). Growth within the first year is 52 cm, but slows to 33 cm within the second year (Peverell 2008). Maximum age was estimated to be 53 years (540 cm TL), reaching asymptotic growth by 24 years (513 cm TL) (Peverell 2008).

Vertebral analysis for aging demonstrated that *P. zijsron* of 83-102 cm (n = 8), 128 cm (n = 1), 157-166 cm (n = 2), 220 cm (n = 1), 254-257 cm (n = 2), 380 cm (n = 1), 438 cm (n = 1), 449 cm (n

= 1), and 482 cm (n = 1) in TL to be 0+, 1+, 2+, 3+, 5+, 8+, 10+, 16+ and 18+ years of age, respectively (Peverell 2008).

Reproduction: Aplacental viviparity (lecithotropic nutrition) (Stevens *et al*. 2005, Last and Stevens 2009). Litter sizes of approximately 12 pups (Last and Stevens 2009). Observed to pup in January (wet season) (Peverell 2005). Generation length is estimated to be 16 years (Stevens *et al*. 2005).

Maturity: Both sexes mature around 300 cm TL at ~ 9 years of age (Last and Stevens 2009). This was supported with the observation of a pregnant 458 cm TL female (Compagno and Last 1999) as well as a mature 380 cm TL female in Queensland (Peverell 2005). Based on the equation TRL = -1.926 + (0.281 * TL) given in Figure 15, it is estimated that a *P. zijsron* of 300 cm TL would have a rostrum length of >80 cm at maturity. It is from this size that we have delineated mature fish based on rostra donated the Murdoch University Sawfish Project; and plotted their distribution within Western Australia accordingly. Individuals that are in their first year of life are conservatively estimated to be <130 cm TL, whereby a rostrum length of <35 cm is expected; it is from our records that we have plotted the known locations in Western Australia of individuals of this size (see below). Based on a rostral length of >80 cm, mature individuals of *P. zijsron* in Western Australia are currently known from Whim Creek, Port Hedland, 80 Mile Beach, Roebuck Bay, Willie Creek, Beagle Bay, Pender Bay, King Sound (including Goodenough Bay) (Figure 18). A further two individuals (>400 cm TL) were caught by Stephenson and Chidlow (2003) in offshore waters of the Pilbara. The largest *P. zijsron* in our records was from Beagle Bay, which had a rostrum length of 165.5 cm, which would equate to ~600 cm in TL.

The smallest recorded pups in our collections include: Roebuck Bay (TRL = 16 cm and 22 cm), Karratha (TRL = 22.3 cm), Cape Leveque (TRL = 26.2 cm), One Arm Point (TRL = 27.3 cm), 80 Mile Beach (TRL = 30 cm), Cape Keraudren (TRL = 31 cm) and Port Hedland (TRL = 32.0 cm) (figure 18). Stevens *et al*. (2008) recorded a number of small juveniles near Cape Keraudren (at the southern end of 80 Mile Beach), which ranged in total length from 100 to 212 cm, with four <120 cm TL. These small individuals at 100, 107 (x2) and 111 cm TL would have had rostrum lengths of <30 cm.

From the above, it is likely that pupping occurs from at least Whim Creek in the south to at least One Arm Point in the north of Western Australia; however, there are limited data for the north Kimberley coast.

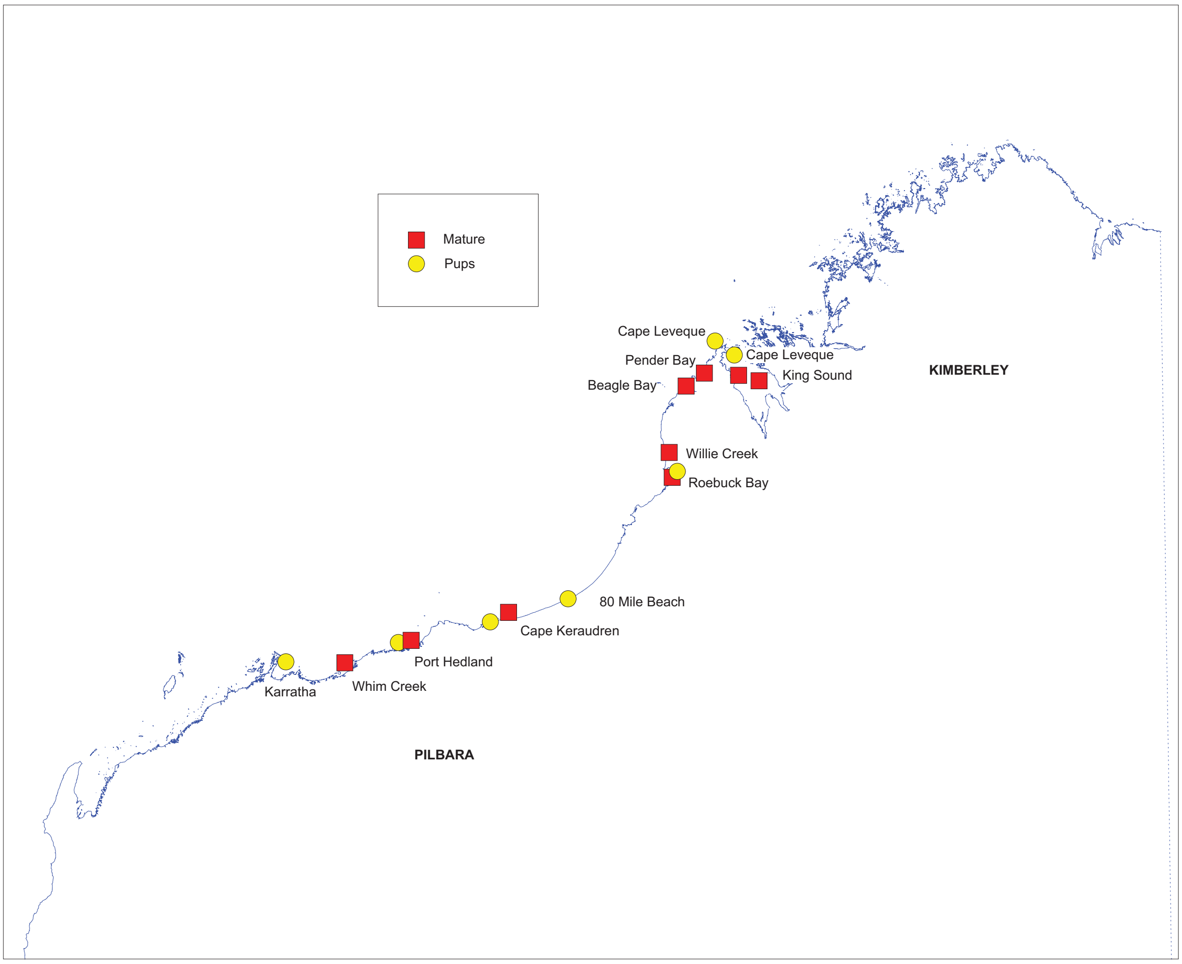


Figure 18 Locations of mature *Pristis zijsron* and new-born pups in Western Australian waters (data derived from CFFR, Murdoch University, Department of Fisheries, Stevens *et al*. 2008).

Diet: There is no information on the diets of this species in Western Australia. Queensland captured *P. zijsron* were found to have consumed *Eleutheronema tetradactylum* (Blue Salmon), Ambassidae (Asiatic Glassfish), *Nibea aquamosa* (Scale Croaker) and *Pomadasys kaakan* (Javelin Grunter; Peverell 2008) as well as *Penaeus merguiensis* (Banana Prawn) and *Leiognathus bindus* (Orangefin Ponyfish) (Stevens *et al*. 2005). Feeding is likely to involve the use of the rostrum to injure or kill prey (Last and Stevens 2009).

Genetics

Population structure: The population structure of *P. zijsron* was assessed using nucleotide sequence variation in a 352 bp portion of the mitochondrial control region, which is maternally inherited (Phillips *et al.* 2009b). The assessment demonstrated that this species is genetically sub-divided across northern Australia, with significant structure found between the west coast and both the Gulf of Carpentaria and the east coast of Australia (Phillips *et al.* 2009b, unpublished data). Since maternal gene flow is negligible between these regions, the reduction or loss of a population from one area, such as the west coast, would not be offset by immigration from the other locations (see Phillips *et al.* 2008, 2009b). There are currently no available data on the patterns of male gene flow in *P. zijsron* in northern Australia, however preliminary data for *P. microdon* suggest that dispersal may be male biased with female philopatry; it remains to be determined whether this is also the case for *P. zijsron* (see Phillips *et al.* 2008).

Genetic diversity: The overall level of genetic diversity in *P. zijsron,* in terms of haplotype diversity, is moderate (n = 51) (Phillips *et al.* 2009b, unpublished data). The samples of this species from the Gulf of Carpentaria have reduced levels of genetic diversity (n = 13), suggesting that the abundance of this species in this region has been substantially reduced compared to that on either the west (n = 24) or east coast (n = 14) of Australia (assuming that the historical population sizes in each region were similar) (Phillips *et al.* 2009b, unpublished data). Since the population(s) of *P. zijsron* on the west coast is genetically distinct from that in the Gulf of Carpentaria and contains several haplotypes not found elsewhere in Australia (Phillips *et al.* 2009b), there is the potential for substantial amounts of genetic diversity to be lost should the population(s) in the west coast suffer a decline. Similarly, the Gulf of Carpentaria population(s) of *P. zijsron* is unlikely to be replenished by those from the west coast of Australia (see Phillips *et al.* 2009b).

Conservation

***Population status*:** Unknown. While a population estimate is unknown, collected evidence demonstrates a large decline in *Pristis* spp. in Australian waters within the last 15-20 years (Giles *et al*. 2005). Previously found as far south as New South Wales in Australia, *P. zijsron* have not been reported in these waters since 1960 (Stevens *et al*. 2005) and are very rare on the entire east coast of Australia (Pogonoski *et al*. 2002). A great decline in *Pristis* spp. captures in Queensland's Beach Control Program between 1969 and 2003 (Stevens *et al*. 2005) provides further evidence of a major decline. Virtually extinct throughout South East Asia, northern Australia is likely the last place to host significant populations of *P. zijsron* (Stevens *et al*. 2005).

Protection status:

Table 3 Listing of various legislation protecting *Pristis zijsron* at the international, national or state (Western Australia) level.

Legislation	Listing/Category
CITES	Appendix I
IUCN red list	Critically Endangered (A2bcd+3cd+4bcd)
EPBC Act	Vulnerable
Fish Resources Management Act 1994	Schedule II, Totally Protected
Wildlife Protection Act 1950	Schedule I

Interaction/Interest with fisheries: *Pristis* fins are greatly valued in the international fin trade as are their rostra, which are often used for curios (Bigelow and Schroeder 1953, Camhi *et al*. 1998, Seitz and Poulakis 2006). However, as all Australian *Pristis* spp. are protected in Australian waters, there are no direct fisheries for this group. By-catch of *Pristis* spp. does occur in several fisheries. Stevens *et al*. (2005) reported the gill net fisheries to have the highest percent of *Pristis* by-catch (80.2%), followed by trawling (16.6%), line (9.2%) and recreational gears (0.3%). Peverell recorded *Pristis* spp. only in the inshore fishery in the Gulf of Carpentaria (Peverell 2008). In 2005 and 2006, 40 *P. zijsron* were reported to have been captured in the Northern Territory Offshore Net and Line (NTONL) fishery (*c.f.* 2 *P. microdon* and 670 *Anoxypristis cuspidata* (Narrow Sawfish)) (Field *et al*. 2008). An observer program reported a catch per day of 0.02 (49 days) *P. zijsron* for the NTONL fishery, but 0.23 in the near-shore Northern Territory Barramundi Gill Net Fishery (Field *et al*. 2008). In Western Australia it was estimated that in 2000-2004, tonnage of *P. zijsron* captured ranged between 5.3 and 9.6 t (live weight) in the Broome and Eighty Mile Beach Area of the Kimberly Gillnet and Barramundi Managed Fishery (McAuley *et al.* 2005) and between 4 t in the Pilbara Fish Trawl Fishery in 2001 which operates in ~50-200 m depth (Stephenson and Chidlow 2003).

Dwarf Sawfish (*Pristis clavata* Garman, 1906)

Figure 19 *Pristis clavata* (Photograph: Dean Thorburn).

Other common names: Queensland Sawfish

Description

General appearance and coloration: A shark-like ray (gills on ventral surface), with a relatively evenly-spaced and laterally toothed-lined rostrum or "saw" protruding anteriorly from a flattened head (Figure 19). Most similar with *Pristis microdon*, it can be distinguished from this species most easily by its first dorsal fin origin located inline to the origin of its pelvic fins (*c.f.* anterior of the pelvic fin origin) (Compagno and Last 1999, Last and Stevens 2009), no observable lower caudal lobe or fork in the caudal fin (*c.f*. apparent lower caudal lobe and fork in the caudal fin on *P. microdon*) (Compagno and Last 1999, Last and Stevens 2009), marginal grooves on rostral teeth that generally don't extend to the tooth base in juveniles and most adults (*c.f.* grooves that extend to the base of each rostral tooth) (Thorburn *et al*. 2007, 2008) and distal rostral tooth gaps that are less than the second most distal tooth gaps (relationship reversed in *P. microdon*) (Whitty unpublished data). Outside of the genus, *P. clavata* is also similar in appearance to sawsharks (Pristiophormes), but can be differentiated by a few characteristics including a lack of barbels on the rostrum, gill slits located on the ventral surface and a dorsally-flattened head (Compagno and Last 1999). Olive-brown dorsal coloration and white ventral coloration.

Fin position/markings: No discernable markings on fins. Reduced pectoral fin width (*c.f. P. microdon*) with a long base (Compagno and Last 1999, Last and Stevens 2009). Ventral lobe of caudal fin minimal (47-63% of upper caudal lobe) (Ishihara *et al*. 1991a); no apparent caudal fin fork. Origin of first dorsal fin inline or just posterior with that of the pelvic fin (Ishihara *et al*. 1991a, Compagno and Last 1999). Dorsal fins large with second dorsal fin only slightly lesser in size (Ishihara *et al*. 1991a). Lacks an anal fin.

Rostral teeth count and morphology: Proximal rostral teeth begin near base of rostrum (Compagno and Last 1999). In Western Australia, 18-23 left teeth (mean = 21.2 ± 0.1 SE) and 18-24 right teeth (mean = 21.2 ± 0.1 SE; Fig. 2); 37-46 total rostral teeth (mean = 42.4 ± 0.16 SE) (Figures 20-21). Differences between left and right tooth counts are between 0 and 2 (Figure 21) (Whitty *et al*. unpublished data). No significant difference in tooth counts between male and female *P. clavata* (Thorburn *et al.* 2007). TRL is between 17.9 and 23% of TL (TRL = 6.701 + 0.158TL) (Figure 23) (Thorburn *et al*. 2008, Whitty and Morgan unpublished data). This range encompasses previous recorded measurements of 19.0-21.2 % (Ishihara *et al*. 1991a) and the mean ratio of 20% documented by Thorburn *et al*. (2008). This range may increase with smaller individuals (i.e. neonates) as the holotype of the species (61.9 cm TL), had a TRL of ~25% of TL (Garmon 1906). A range of 22.1-25.8% (cited in Ishihara *et al*. 1991a) also supports a possible extension of this range for this species in other regions, however the TL of these individuals are unknown. Distal tooth gap is on average 47.6% (± 0.01 SE; range = 25.4- 86.5%) that of the proximal tooth gap (Figure 23) (Whitty unpublished data). The second most distal tooth gap is greater than most other distal tooth gaps (~5% of *P. clavata* will have this relationship reversed on one side, but very rarely (< 1 % of time) on both) (Figure 24) (Whitty unpublished data). Groove on posterior margin of tooth rarely (frequency increases with size) extends to tooth base (Phillips 2006, Thorburn *et al*. 2007).

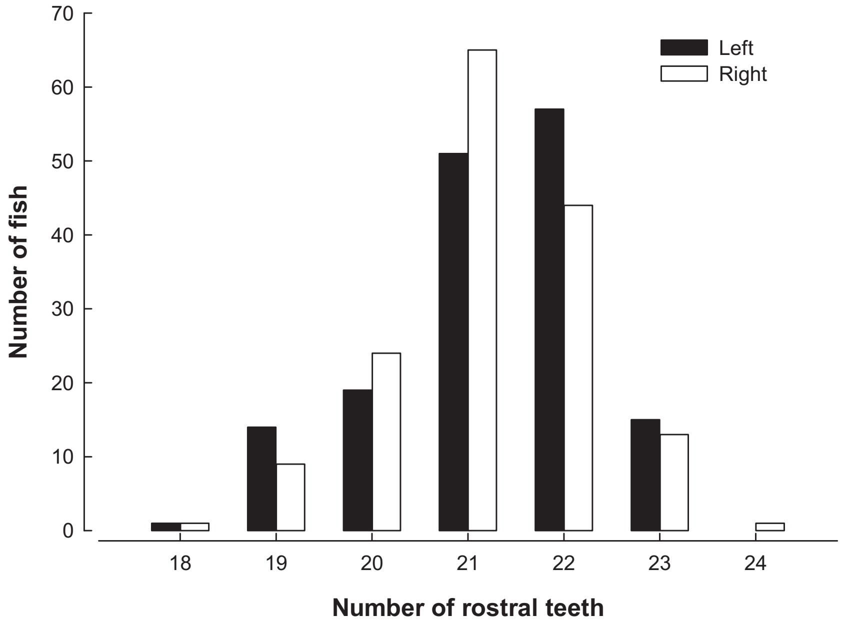


Figure 20 Left and right rostral tooth counts of *Pristis clavata* captured in Western Australia.

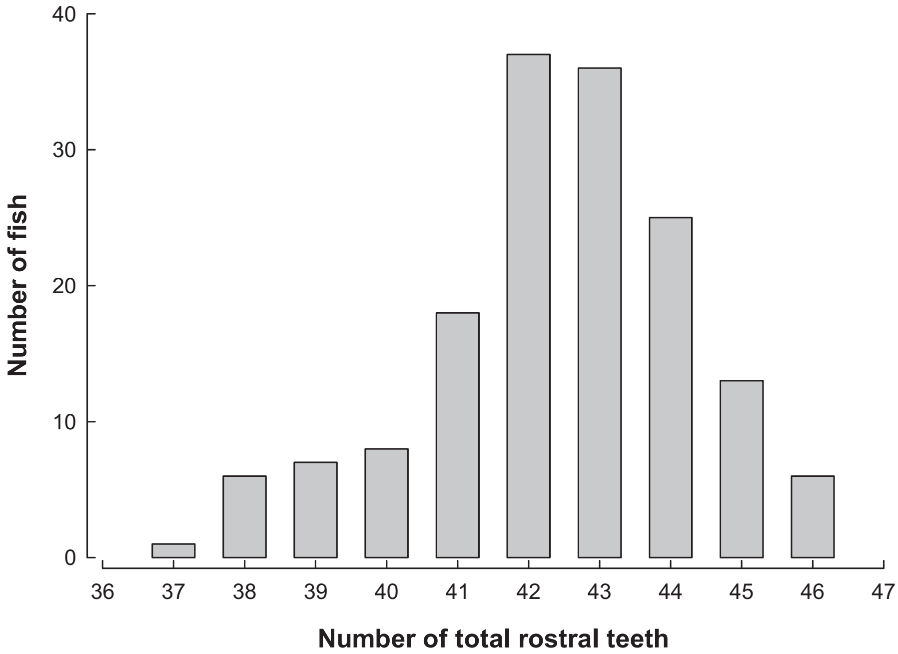


Figure 21 Total rostral teeth counts for *Pristis clavata* captured in Western Australia.

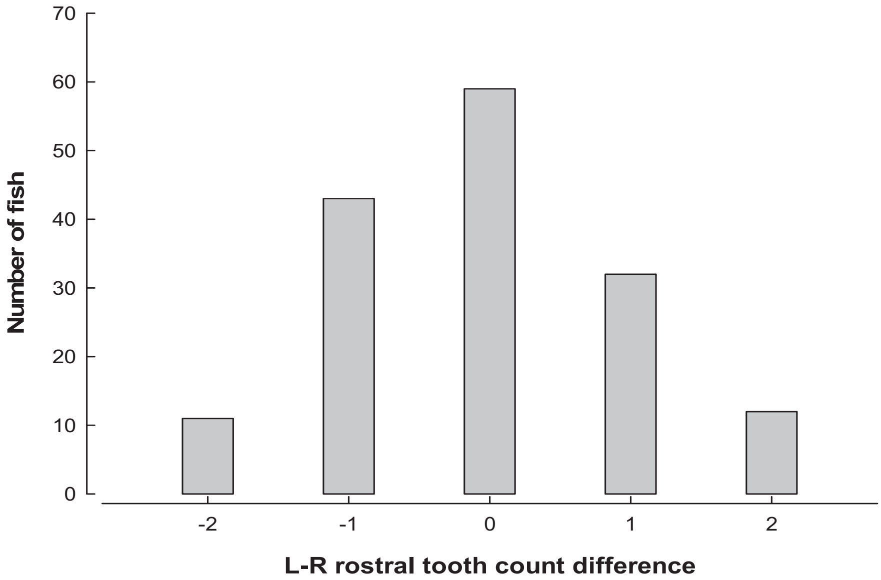


Figure 22 Difference between left and right rostral tooth counts for *Pristis clavata* captured in Western Australia.

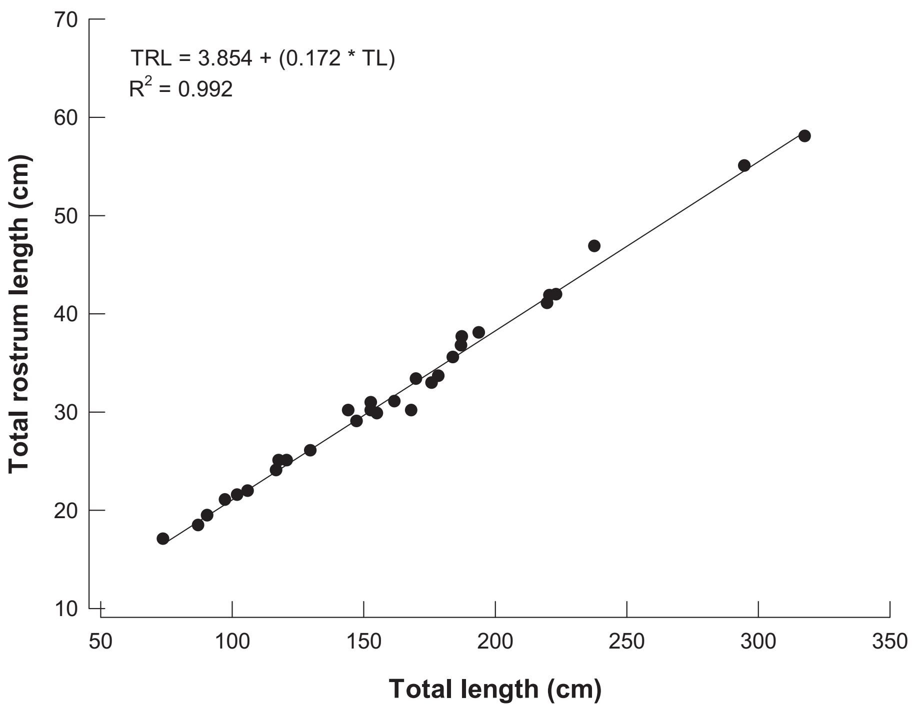


Figure 23 Relationship between total length (TL) and total rostrum length (TRL) of *Pristis clavata* captured in Western Australia.

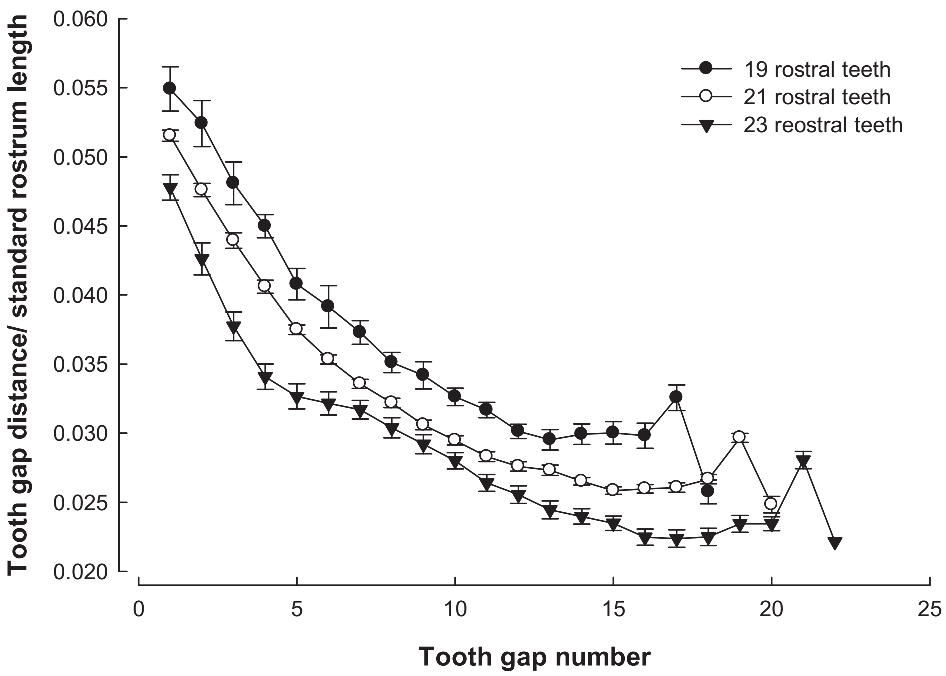


Figure 24 Representative (rostrum with 19, 21 and 23 teeth per side) relative inner-tooth spacing (gap length/ standard rostrum length) of *Pristis clavata* captured in Western Australia.

Size: Pupped at ~65 cm to 81 cm TL and estimated to reach at least 310 cm TL (Peverell 2008, Last and Stevens 2009). A maximum TL of 508 cm was calculated using a von Bertalanffy growth curve, based on data from 19 individuals < 306 cm TL (Peverell 2005). 2008 records from the Department of Fisheries, Government of Western Australia, include a 318 cm TL female confirming the above estimation that female *P. clavata* at least obtain a size of at least 310 cm TL.

Vertebral counts: Undocumented

Biology

Distribution and habitats in Western Australia: Last and Stevens (2009) suggest that *P. clavata* is restricted to northern Australia from Cairns to 80 Mile Beach, and that it is now rare in Queensland. They suggest that the species was probably once more widespread in the Indo-Pacific near Australia. In Western Australia the majority of capture locations for *Pristis clavata* are within King Sound and the lower reaches (tidally influenced) of the major rivers of King

Sound, i.e. Fitzroy River, May River and Robinson River, as well as from near Walcott Inlet in the Kimberley and Cape Keraudren and 80 Mile Beach in the Pilbara (Murdoch University unpublished data, Department of Fisheries unpublished data, Thorburn *et al*. 2003, 2008, Stevens *et al*. 2008). Ishihara *et al*. (1991a) recorded them in the Pentecost River system. In terms of rostra that have been donated for our genetic and morphological studies, a total of 109 have come from King Sound and three from Roebuck Bay (Figure 25) (Morgan *et al*. unpublished data). In terms of mature fish, based on a length at maturity of ~2.4 m (see below), which correspond to a rostrum length of ~45 cm, then mature individuals have been recorded from Hall Point in the north to Cape Keraudren in the south. However, numerous mature individuals have been recorded from King Sound. The smallest individuals recorded have been caught at the Fitzroy River mouth (n = 5, TRL <21 cm, TL <100 cm), while a further four individual rostra <21 cm in length from King Sound have been donated. A further three small individuals (TRL <25 cm) from 80 Mile Beach were recorded by the Department of Fisheries. Numerous reports of the species being present in Walcott Inlet have been provided, including photographs. While the majority of captures are from shallow, tidally influenced systems, some captures are from considerably deeper water (trawls) have been reported. See Stepheson and Chidlow (2003) for Pilbara Fish Trawl location.

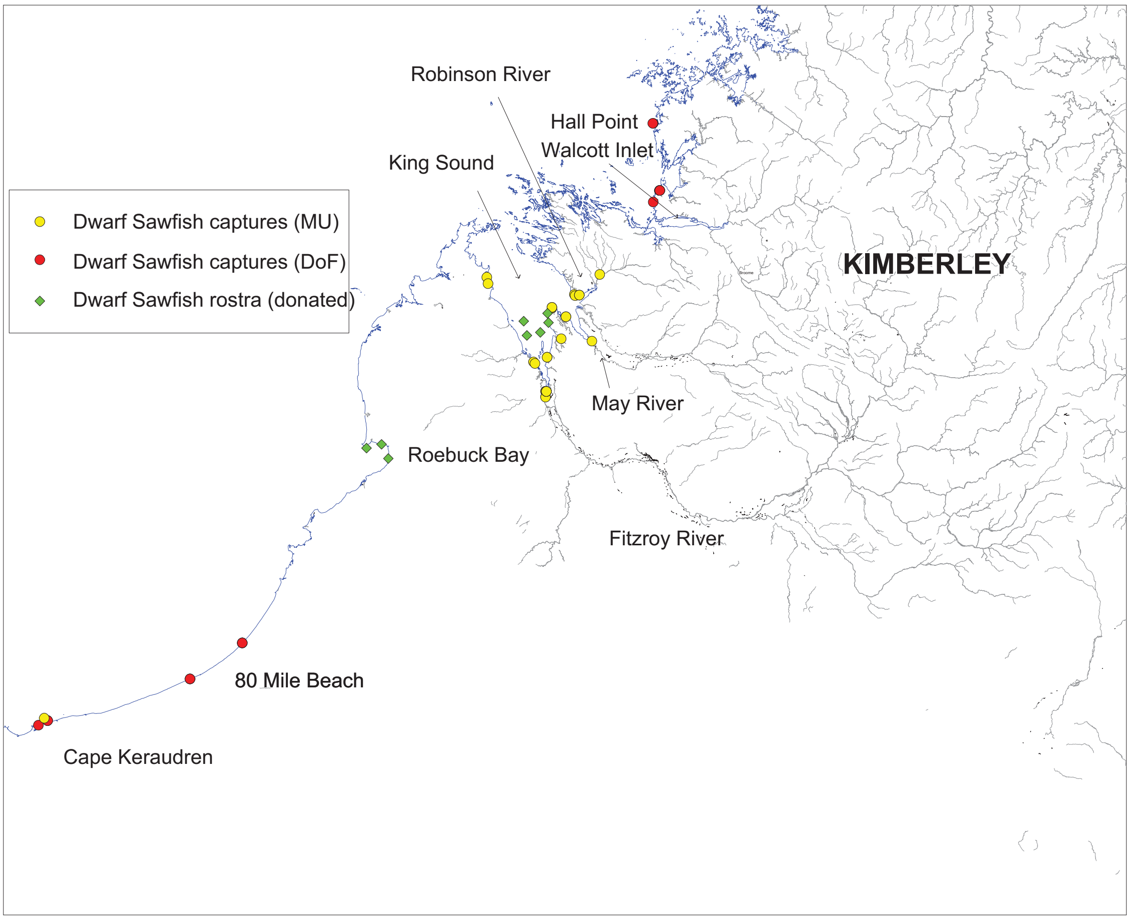


Figure 25 Capture locations of *Pristis clavata* in Western Australia (data derived from CFFR, Murdoch University and Department of Fisheries, Stevens *et al*. 2008). N.B. Donated rostra from King Sound are represented on the map by only a few samples, and are actually considerable in number (>100). DoF includes data presented in Stevens *et al*. (2008).

Age and growth: Using vertebral ring counts (n = 5), and assuming annuli corresponded to one years growth, Thorburn *et al*. (2008) estimated Western Australia captured *P. clavata* of 90 cm TL to be of one year of age, of 110-120 cm TL to be of two years of age and that of 160 cm TL to be of three years of age. These estimations were in close congruence with that of Peverell (2008) whom estimated Queensland captured *P. clavata* (n = 19) of 98 cm TL to be 0+ years of age, 175 cm TL to be 3+ years of age, 201 cm TL to be 4+, 225 cm TL to be 5+ years of age, 244 cm TL to be 6+ years of age, 299 cm TL to be 8+ years of age and 300 cm TL to be 9+ years of age. Employing a von Bertalanffy growth curve, Peverell (2008) produced a k-value of 0.08 (L_∞ = 508, t_0 = -2.09). Maximum size (508 cm TL) was estimated to be reached at age 94 (Peverell 2008), although asymptotic growth was reached at 34 years (389 cm TL).

Reproduction: Aplacental viviparity (lecithotropic nutrition) (Stevens *et al*. 2005, Last and Stevens 2009). Litter size has not been documented.

Maturity: *Pristis clavata* have been estimated to reach maturity around 255- 260 cm TL (Last and Stevens 2009). Discovery of male *P. clavata* measuring 194, 219 (Whitty unpublished data) and 233 (Thorburn *et al*. 2008) cm TL with semi-calcified claspers, and 295 and 306 cm TL male *P. clavata* with fully calcified and elongated claspers (N.B. fully calcified claspers are a sign of maturity) (Peverell 2005) suggest that males possibly mature in close approximation with the previously stated range, possibly even at a slightly smaller size. Age of female maturity is uncertain, however Thorburn *et al*. (2008) recorded all females <120 cm TL to be immature, while Peverell (2005) recorded a 210 cm TL female to be immature.

Diet: Prawn, *Rhinomugil nasutus* (Popeye Mullet), unidentified teleost and detrital matter were found in the gut contents of *P. clavata* captured in King Sound, Western Australia and its tributaries (Thorburn *et al.* 2008). Gut contents of *P. clavata* captured in Queensland included *Penaeus merguiensis* (Banana Prawn), *Penaeus esculentus* (Tiger Prawn), *Leptobrama muelleri* (Beachsalmon), Mugilidae (i.e. Mullet), Clupeidae (i.e. Herring) and *Nibea squamosa* (Scaly Croaker) (Peverell 2008).

Habitat: *Pristis clavata* are most often found on silt/sandflats in tropical shallow waters in marine and estuarine waters, often influenced by large tides; including flat sandy beaches as well as mangrove channels (Thorburn *et al*. 2003, 2008, Peverell 2005, Stevens *et al*. 2008). Environmental factors at times of capture have varied greatly, including salinity (1-41.1 ppt), depth (0.7-7 m), temperature (25-32^{o}C) and visibility (secchi 5-70 cm) (Thorburn *et al*. 2007).

Genetics

Population structure: Information about the population structure of *P. clavata* in Australian waters is limited to Phillips *et al.* (2008). Preliminary information, based upon nucleotide sequence variation in a 350-351 bp portion of the control region in the mitochondrial genome, has not revealed any evidence of genetic subdivision between the west coast of Australia and the Gulf of Carpentaria, although this is probably due to the small sample size from the latter region (n = 7) (Phillips *et al.* 2008). Based on the pattern of population structure in northern Australia for other *Pristis* species, (see Phillips *et al.* 2008, 2009b) it is possible that *P. clavata* is also genetically subdivided between at least the west coast and the Gulf of Carpentaria. There are currently no available data on the patterns of male gene flow in *P. clavata* in northern Australia, however preliminary data suggest that dispersal in *P. microdon* may be male biased with female philopatry; it remains to be determined whether this is also the case for *P. clavata* (see Phillips *et al.* 2008).

Genetic diversity: The overall level of genetic diversity in *P. clavata* in northern Australian waters was measured in terms of haplotype diversity and found to be moderate (Phillips *et al.* 2008). However, there may be spatial variation in genetic diversity in this species as the haplotype diversity of the assemblage in the King Sound/Fitzroy River region (n = 16) was relatively high compared to that in the Gulf of Carpentaria (n = 7), which was genetically depauperate with only a single haplotype despite sampling from throughout the gulf (Phillips *et al.* 2008). This finding suggests that population(s) of *P. clavata* in the Gulf of Carpentaria may have undergone a decline in abundance more severe than that experienced on the west coast (see Phillips *et al.* 2008, 2009b). Regardless, as with other *Pristis* species (see Phillips *et al.* 2008, 2009b), much of the diversity found in *P. clavata* is present as rare haplotypes, which are at risk of being lost via genetic drift and further declines in abundance.

Conservation

Population status: Unknown. While a population estimate is unknown, collected evidence demonstrates a large decline in *Pristis* spp. in Australian waters within the last 15-20 years (Stevens *et al*. 2005).

Protection status:

Table 4 Listing of various legislation protecting *Pristis clavata* at the international, national or state (Western Australia) level.

Legislation	Listing/Category
CITES	Appendix I
IUCN red list	Critically Endangered (A2bcd+3cd+4bcd)
EPBC Act	Vulnerable
Fish Resources Management Act 1994	Schedule II, Totally Protected

Interaction/Interest with fisheries: *Pristis* fins are greatly valued in the international fin trade as are their rostra, which are often used for curios (Bigelow and Schroeder 1953, Camhi *et al*. 1998, Seitz and Poulakis 2006). However, as all Australian *Pristis* spp. are protected in Australian waters, there are no direct fisheries for this group. By-catch of *Pristis* spp. does occur in several fisheries. Stevens *et al*. (2005) reported the gill net fisheries to have the highest percent of *Pristis* by-catch (80.2%), followed by trawling (16.6%), line (9.2%) and recreational gears (0.3%). Peverell recorded *Pristis* spp. only in the inshore fishery in the Gulf of Carpentaria (Peverell 2008). An observer program in the Northern Territory Barramundi Gill Net Fishery documented 0.38 *P. clavata* captured per day (52 days) (Field *et al*. 2008). In Western Australia it was estimated that in 2000-2004, tonnage of *P. clavata* captured ranged between 2.6 and 6.5 t (live weight) in the Broome and Eighty Mile Beach Area, and ranged between 6.6 and 11.1 t (live weight) in the more northern regions of the Kimberley Gillnet and Barramundi Managed Fishery (McAuley *et al*. 2005).

Northern River Shark (*Glyphis garricki*)

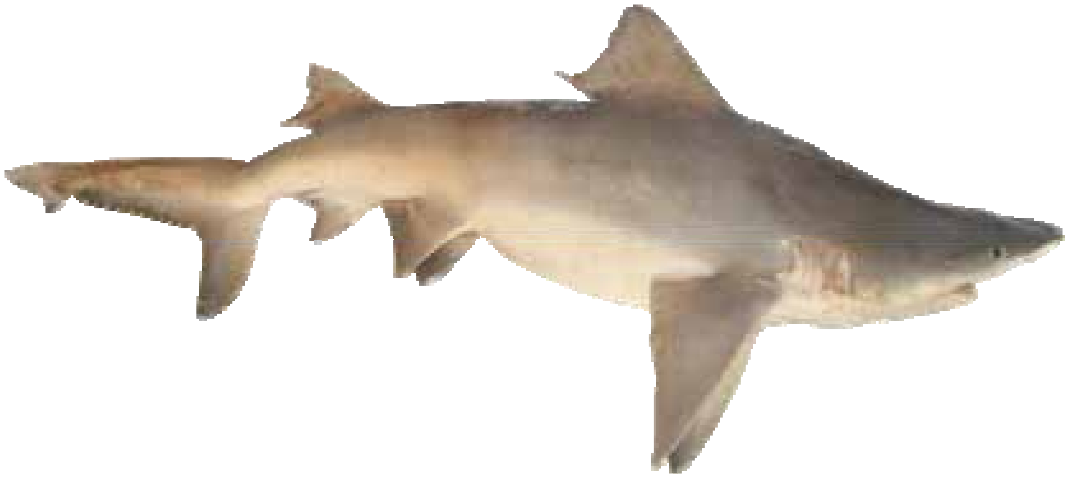


Figure 26 *Glyphis garricki* (Photograph: Jeff Whitty).

Other common or previously used names:

Glyphis sp. C, New Guinea River Shark, Adelaide River Shark

Description

General appearance and coloration: A medium-large carcharinid (whaler shark), similar in appearance to other members of this family (Figure 26). Greyish dorsal and white ventral colorations. Border of the ventral and dorsal surfaces, referred to as the watermark boundary or waterline (Compagno *et al*. 2008), exists approximately an eye diameter below the orbit (Compagno *et al*. 2008). Head is fairly elongated, sloping and rounded (Compagno *et al*. 2008). Small eyes, ranging from between 0.77% and 1.03% of the TL (Thorburn and Morgan 2004, Thorburn 2006) or 0.83-1.09 cm in length (Compagno *et al*. 2008). No pre, inter or postdorsal ridge (Thorburn 2006). Most similar in appearance to *Glyphis glyphis* (Speartooth Shark), it can be visually distinguished by location of the waterline (just below the orbit in *G. glyphis*). Also often confused with *Carcharhinus leucas* (Bull Shark) and *Carcharhinus ambionensis* (Pigeye Shark), it can be differentiated from these species by its large second dorsal fin, longitudinal triangular precaudal pit (*c.f.* crescentic precaudal pit) (Compagno and Niem 1998, Compagno *et al.* 2008) and cusped, spear-like lower teeth (*c.f.* triangular lower teeth).

Fin positioning/markings: First dorsal fin triangular in shape (Thorburn 2006, Compagno *et al*. 2008). Second dorsal fin 58-66% the height of the first (Thorburn and Morgan 2004, Compagno *et al*. 2008). Pectoral fins large and slightly curved with narrow bases (Thorburn 2006, Compagno *et al*. 2008). Anal fin is only slightly smaller (72-84%) in size compared to second dorsal, with the fin origin a little posterior to that of second dorsal fin (Thorburn 2006, Compagno *et al*. 2008). Anal fin lacks a notch observed in other similar species like *C. leucas* and *C. ambionensis* (Field *et al*. 2008). No discernible black demarcations, with exception of minor black tip on the terminal caudal lobe and faint black coloration on apex of terminal margin and ventral caudal lobe (Compagno *et al*. 2008). Asymmetric caudal fin, with a narrow and longer upper caudal lobe (*c.f*. lower caudal lobe); subterminal notch present (Thorburn 2006, Compagno *et al*. 2008).

Teeth: Upper jaw tooth count of 31-34; lower jaw tooth count of 30-35 (Last and Stevens 2009). Upper teeth broadly triangular, lower teeth slender, slightly curved back and cuspidate (Figure 27) (Thorburn 2006, Compagno *et al*. 2008).

Figure 27 *Glyphis garricki* upper and lower teeth.

Size: Pupped at 50-60 cm, *G. garricki* are estimated to reach up to 300 cm TL (Stevens *et al*. 2005, Last and Stevens 2009). Largest recorded capture of *G. garricki* in Australian waters is a 251 cm TL female, but in Western Australia the largest male and female recorded is 142 cm TL (18.64 kg) and 135 cm TL (16.83 kg), respectively (Thorburn and Morgan 2004, Thorburn 2006).

Vertebral count: 137-151 (precaudal =73-83) in Australian waters (Compagno *et al*. 2008, Last and Stevens 2009); 140-151 (avg =146 (+1.53 SE) in Western Australia (Thorburn and Morgan 2004). Fusion of vertebrae was documented in three *G. garricki* (142 cm TL male, 135 cm TL female, 994 cm TL male) captured in Western Australia in 2002 and 2003 (Thorburn and Morgan 2004, Thorburn 2006). Thorburn and Morgan (2004) hypothesised this to possibly be due to inbreeding associated with a small genetically effective population size, but not necessarily a small census size.

Biology

Distribution and habitats in Western Australia: In Western Australia the majority of capture locations for *G. garricki* are in King Sound in the west Kimberley (Figure 28) (see Morgan *et al*. 2004, Thorburn and Morgan 2004, 2005b, Whitty *et al*. 2008, 2009a), however, recent collections have also occurred in the Ord River mouth and Joseph Bonaparte Gulf (Thorburn 2006, Last and Stevens 2009, Pillans *et al*. 2009). Most collections in Western Australia have occurred in turbid, macrotidal mangrove systems of King Sound in salinities >20 ppt over sandy or silty substrates. Also known from a few locations in the Northern Territory (Field *et al*. 2008).

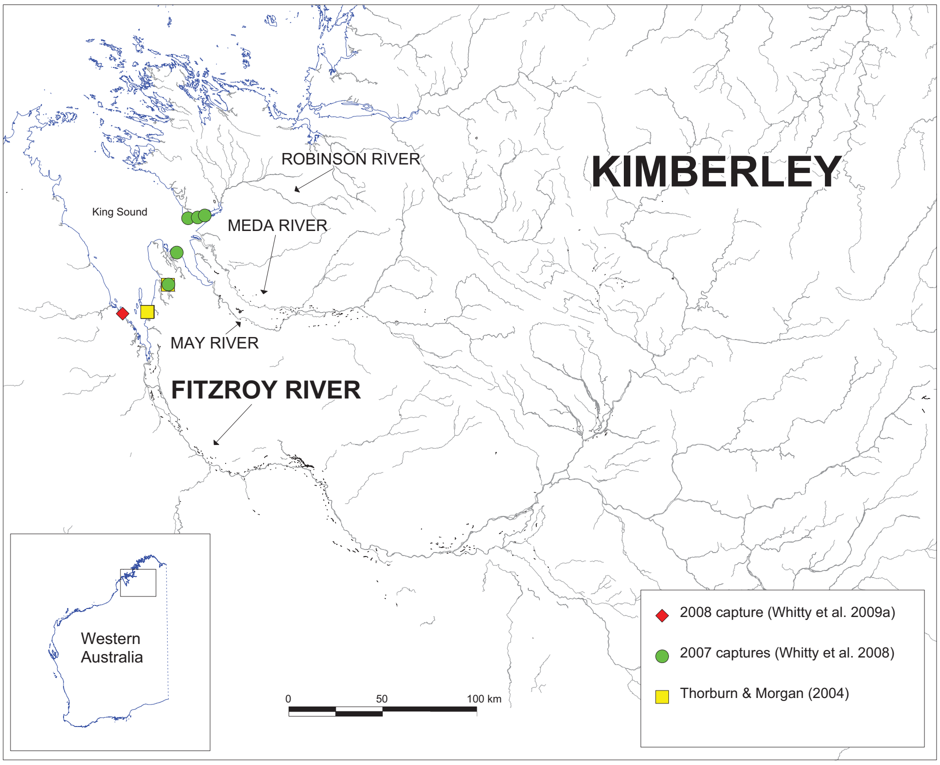


Figure 28 Known capture locations of *Glyphis garricki* in the west Kimberley (from Thorburn & Morgan 2204, Whitty *et al*. 2008, 2009a).

Age and growth: Little is known about the age and growth of *G. garricki*. Initial aging work by Tanaka (1991) estimated a 131 cm TL female in the Northern Territory to be four years of age. Using this information with an estimated pupping size of 50-60 cm TL, growth in the first four years was estimated to average 19 cm/year (Stevens *et al*. 2005).

Reproduction: Placental viviparity. Pillans *et al*. (2009) have reported that parturition likely occurs around October of each year (based on presence of neonates), but only occurring every other year for each individual. An observation in October of a female that had recently pupped also supports this hypothesis (Stevens *et al*. 2005). Last and Stevens (2009) confirmed the timing of parturition documenting a 251 cm TL female to have recently given birth. Litter size has been shown to be approximately nine (Stevens *et al*. 2005, Pillans *et al*. 2009).

Maturity: Stevens *et al*. (2005) estimated maturity to occur between 170 and 200 cm TL, based on the assumption that *G. garricki* has a similar growth rate to *C. leucas*. Males of 99.4 (Thorburn and Morgan 2004) and 109 cm TL (Whitty *et al*. 2009) were found to have semi-calcified claspers (i.e. were maturing). Whereas a 136.5 cm TL (Whitty *et al*. 2009a) and a 141.8 cm TL male (Thorburn and Morgan 2004, Thorburn 2006) were found to be mature, suggesting the estimate from Stevens *et al*. (2005) was high, or at least not accurate for males in the west Kimberley. Female maturity likely occurs at a size $\leq$ 177 cm TL as one female of this size was recorded to contain nine embryos (Last and Stevens 2009). Females between 147 and 157 cm (n = 4) were found to be immature (Stevens *et al*. 2005), supporting the view that maturity occurs beyond this size.

Diet: Prey items were found to include several teleost species including *Neoarius graeffei* (Lesser Salmon Catfish), *Polydactylus macrochir* (Threadfin Salmon) and *Lates calcarifer* (Barramundi) as well as crustaceans including *Scylla* sp. (Mud Crab) (Thorburn and Morgan 2004, Thorburn 2006, Whitty unpublished data).

Genetics

The only genetic study for *G. garricki* is that by Wynen *et al*. (2009). This was essentially performed to determine the extent and nature of genetic differences between the different *Glyphis* spp. No information is available on the genetic differences between the different populations of *G. garricki*.

Population structure: Virtually nothing is known about the population structure of *Glyphis garricki* in Australian waters. A recent study by Wynen *et al.* (2009) assessed whether a 500 bp fragment of the mitochondrial control region was sufficient to detect genetic differentiation within *Glyphis* species across northern Australia. No genetic variation was found within *G. garricki,* with the same haplotype found in the individuals from King Sound and the north coast of the Northern Territory (Wynen *et al.* 2009). Based on these results, it was concluded that more variable markers, such as microsatellite loci, would be necessary to investigate the population genetics of this species (Wynen *et al.* 2009). Given the small sample size (n = 2) used in this assessment (Wynen *et al.* 2009), no solid conclusions can be made about the population subdivision of *G. garricki* in Western Australia and the Northern Territory. Larger sample sizes and multiple genetic markers are needed to properly assess the population structure of *G. garricki* in northern Australia (see Wynen *et al.* 2009).

Genetic diversity: The study by Wynen *et al.* (2009) found no genetic variation in *G. garricki* in either the cytochrome oxidase subunit I gene (*cox1*) or the control region of the mitochondrial DNA, although the sample size for the latter region was small (n = 2). This preliminary information suggests that assemblages of this species have very low levels of genetic diversity, although larger samples sizes are needed to confirm this finding (see Wynen *et al.* 2009).

Conservation

***Population Status*:** Current population numbers are unknown, but are estimated to be small due to the rarity of encounters with *G. garricki* (Pogonoski and Pollard 2003). Between 1982 and 2006, only 32 *G. garricki* had been recorded in northern Australia, with 10 of these being captured in King Sound, Western Australia (see Thorburn and Morgan 2004). An additional 10 individuals have been recorded in King Sound since that period (see Whitty *et al*. 2008, 2009a). However, recent reports suggest that population numbers of *Glyphis* spp. may be greater than previously hypothesised in the Northern Territory (Field *et al*. 2008). Further research is needed to determine if this is true for either *Glyphis glyphis* or *Glyphis garricki* or both (the only two known *Glyphis* spp. in Australian waters). Also, distributional surveys outside of King Sound and the Ord River area are required to ascertain the extent of the species in Western Australia.

Protection Status:

Table 5 Legislation protecting *Glyphis garricki* at the international, national or state (Western Australia) level.

Legislation	Listing/Category
IUCN red list	Critically Endangered (C2a(i))
EPBC Act	Endangered
Fish Resources Management Act 1994	Schedule II, Totally Protected

***Interaction/Interest with fisheries*:** Targeting *G. garricki* is illegal in Australian waters and as a result there is no fishery for this species. The is limited information of commercial or recreational catches of this species, due largely to misidentifications and only very recent discovery in Western Australia (see Thorburn and Morgan 2004), together with recent morphological descriptions (Thorburn and Morgan 2004, Thorburn 2006, Compagno *et al*. 2008), records of the species are likely to be underestimated.

Summary and interactions with the James Price Point/Dampier Peninsula region

The marine, estuarine and freshwaters of the west Kimberley and the marine and nearshore environs of the northern Pilbara collectively host 50% of all of Australia's elasmobranchs that are listed as *Vulnerable* or higher under the EPBC Act, including the three sawfish species, *P. microdon*, *P. zijsron* and *P. clavata*, and the river shark *G. garricki*. Current information suggests that Dampier Peninsula hosts three of the species (the exception being the Northern River Shark (*G. garricki*)), but there is limited survey work from the region and much of this data is drawn from rostra in private collections. However, *G. garricki* has been found a relatively short distance from the peninsula (inside King Sound) and it is possible that it is found along the Dampier Peninsula; noting that it has only recently been formally described (Compagno *et al*. 2008), that it was only discovered in Western Australia in 2002 (Thorburn and Morgan 2004) and that there is a high probability of misidentification. With regard to James Price Point, there is a lack of data available, but it is likely that the three *Pristis* spp. utilise the area. In the case of *P. microdon*, which pup in the tributaries of King Sound, with the juveniles spending a number of years in the freshwaters of the larger river (although possibly not obligate in their freshwater stage), it is very likely to be in the migratory path to (as juveniles migrating south) and from (as pregnant females migrating north to pup) 80 Mile Beach and Roebuck Bay; as evidenced by the distribution of juvenile and mature individuals. For *P. zijsron*, both mature and immature individuals have been recorded from the Dampier Peninsula and it is thus likely to act as a nursery, feeding and breeding ground. *Prisits clavata* have not been recorded on the Dampier Peninsula but they have been recorded to coastal habitats at each extreme end of the peninsula, i.e. Roebuck Bay and throughout King Sound. King Sound appears to be an important nursery for the species.

References:

Bigelow, H.B. and Schroeder, W.C. (1953). Sawfishes, guitarfishes, skates and rays. In: Parr, E. and Olsen, Y.H. (Eds) *Fishes of the Western North Atlantic*. Memoirs of the Sears Memorial Foundation for Marine Research. Yale University, New Haven, Connecticut 11-514.

Camhi, M., Fowler, S., Musick, J., Bräutigan, A. and Fordhan, S. (1998). Sharks and their relatives. Ecology and Conservation. Occasional Paper of the IUCN Species Survival Commission. **20**: 1-39.

Chidlow, J.A. (2007). First record of the freshwater sawfish, *Pristis microdon*, from southwestern Australian waters. *Records of the Western Australian Museum* **23**: 307-308.

Compagno, L.J.V. and Niem, V.H. (1998). Carcharhinidae, Requiem Sharks. In: Carpenter, K.E. and Niem, V.H. (Eds) *FAO Species Identification Guide for Fisheries Purposes. The Living Marine Resources of the Western Central Pacific. Vol. 2. Cephalopods, Crustaceans, Holothurians and Sharks*. FAO, Rome, 1312-1360.

Compagno, L.J.V. and Last, P.R. (1999). Order Pristiphormes, Pristidae, Sawfishes. In: Carpenter, K.E. and Niem, V.H. (Eds) *FAO Species Identification Guide for Fishery Purposes.The Living Marine Resources of the Western Central Pacific. Volume 3. Batoid Fishes, Chimaeras and Bony Fishes Part 1 (Elopidae to Linophrynidae)*. FAO, Rome, 1410-1417.

Compagno, L.J.V., White, W.T. and Last, P.R. (2008). *Glyphis garricki* sp. nov., a new species of river shark (Carcharhiniformes: Carcharhinidae) from northern Australia and Papua New Guinea, with a redescription of *Glyphis glyphis* (Müller & Henle, 1839). In: Last, P.R., White, W.T., Pogonoski, J.J. (Eds) *Descriptions of New Australian Chondrichthyans.* CSIRO Marine and Atmospheric Research, Hobart, Tasmania, 203-225.

Doupé, R.G., Morgan, D.L. and Gill, H.S. (2005). Prospects for a restorative fishery enhancement of Lake Kununurra: a high-level tropical impoundment on the Ord River, Western Australia. *Pacific Conservation Biology* 11: 136-146.

Field, I.C., Carters, R., Buckworth, R.C., Meekan, M.G. and Bradshaw, C.J.A. (2008). Distribution and abundance of *Glyphis* and sawfishes in northern Australia and their potential interactions with commercial fisheries. Final report to the Department of the Environment, Water, Heritage and the Arts. 39 pp.

Freshwater Sawfish Expert Review Committee (2009). *Report of the Freshwater Sawfish Pristis microdon Scientific Workshop of 24 march 2009 Brisbane*. Prepared for DEWHA by the Freshwater Sawfish Expert Review Committee June 2009.

Gill, H.S., Morgan, D.L., Doupé, R.G. and Rowland, A.J. (2006). The fishes of Lake Kununurra, a highly regulated section of the Ord River in northern Australia. *Records of the Western Australian Museum* **23**: 1-6.

Giles, J., Pillans, R., Miller, M. and Salini, J. (2005). Sawfish catch data in northern Australia: a desktop study. Report produced for FRDC Project 2002/064 *Northern Australian Sharks and Rays: the sustainability of target and bycatch fisheries, phase 2*.

Ishihara, H., Taniuchi, T., Mitsuhiko, S. and Last P.R. (1991a). Record of *Pristis clavata* Garman from the Pentecost River, Western Australia, with brief notes on its osmoregulation and comments on the systematics of Pristidae. In: Shimizu, M. and Taniuchi, T. (Eds) *Studies on Elasmobranchs Collected From Seven River Systems in Northern Australia and Papua New Guinea*. The University Museum, University of Tokyo, Tokyo, Nature and Culture **3**: 43–53.

Ishihara, H., Taniuchi, T. and M. Shimizu, M. (1991b). Sexual dimorphism in number of rostral teeth in the sawfish, *Pristis microdon* collected from Australia and Papua New Guinea. In: Shimizu, M. and Taniuchi, T. (Eds)

Studies on Elasmobranchs Collected From Seven River Systems in Northern Australia and Papua New Guinea. The University Museum, University of Tokyo, Tokyo, Nature and Culture **3**: 83–89.

Last, P.R. and Stevens, J.D. (2009). *Sharks and Rays of Australia*. Second Edition. CSIRO Publishing, Melbourne.

McAuley, R., Lenanton, R., Chidlow, J., Allison, R. and Heist, E. (2005). *Biology and stock assessment of the thickskin (sandbar) shark, Carcharhinus plumeus, in Western Australia and further refinement of the dusky shark, Carcharhinus obscures, stock assessment. Final FRDC Perport – Project 2000/134*. Fisheries Research Report No. 151, Department of Fisheries, Western Australia, 132 p.

Morgan, D.L., Allen, M.G., Bedford, P. and Horstman, M. (2004). Fish fauna of the Fitzroy River in the Kimberley region of Western Australia – including the Bunuba, Gooniyandi, Ngarinyin, Nyikina and Walmajarri Aboriginal names. *Records of the Western Australian Museum* **22**: 147-161.

Morgan, D., Thorburn, D., Fenton, J., Wallace-smith, H. & Goodson, S. (2005). *Influence of the Camballin Barrage on fish communities in the Fitzroy River, Western Australia*. Murdoch University/Kimberley Land Council/Department of Environment report to Land and Water Australia.

Peverell, S.C. (2005). Distribution of sawfishes (Pristidae) in the Queensland Gulf of Carpentatria, Australia, with notes on sawfish ecology. *Environmental Biology of Fishes* **73**: 391-402.

Peverell, S.C. (2008). *Sawfish (Pristidae) of the Gulf of Carpentaria, Queensland Australia*. MSc Thesis, James Cook University, Townsville, Queensland.

Phillips, N.M. (2006). *Development of genetic and morphological methods for the study of sawfish (Pristidae) populations via analysis of old rostra*. Honours Thesis, Murdoch Univeristy, Perth, Western Australia.

Phillips, N., Chaplin, J., Morgan, D. and Peverell, S. (2009a). Extraction and amplification of DNA from the dried rostra of sawfishes (Pristidae) for applications in conservation genetics. *Pacific Conservation Biology* **15**: 128-134.

Phillips, N.M, Chaplin, J.A., Morgan, D.L., Peverell, S.C.[1] and Thorburn, D.C. (2008). *Genetic diversity and population structure of the Freshwater Sawfish (Pristis microdon) in Australian waters*. In J.M. Whitty, N.M. Phillips, D.L. Morgan, J.A. Chaplin, D.C. Thorburn & S.C. Peverell (eds). *Habitat associations of Freshwater Sawfish (Pristis microdon) and Northern River Shark (Glyphis sp. C): including genetic analysis of P. microdon across northern Australia*. Centre for Fish & Fisheries Research (Murdoch University) report to the Department of the Environment, Water, Heritage and the Arts, Australian Government.

Phillips, N. M., Chaplin, J. A., Morgan, D. L., and Peverell, S. C. (2009b). *Preliminary results of a microsatellite and mitochondrial DNA assessment of the genetic diversity and population structure of, respectively, the freshwater sawfish, Pristis microdon, and the green sawfish, Pristis zijsron, in Australian waters*. In N. M. Phillips, J. M. Whitty, D. L. Morgan, J. A. Chaplin, D. C. Thorburn, & S. C. Peverell (eds) *Freshwater Sawfish, Pristis microdon, movements and population demographics in the Fitzroy River, Western Australia and genetic analysis of P. microdon and Pristis zijsron*. Report to the Department of the Environment, Water, Heritage, and the Arts, Australian Government.

Pillans, R.D., Stevens, J.D., Kyne, P.M. and Salini, J. (2009). Observations on the distribution, biology, short-term movements and habitat requirements of river sharks *Glyphis* spp. in northern Australia. *Endangered Species Research* 1-12.

Pogonoski, J. and Pollard, D. (2003) *Glyphis garricki*. In: IUCN 2009. IUCN Red List of Threatened Species. Version 2009.2. <www.iucnredlist.org>. Downloaded on 04 December 2009.

Pogonoski, J.J., Pollard, D.A. and Paxton, J.R. (2002). *Conservation overview and action plan for Australian threatened and potentially threatened marine and estuarine fishes 2002*. Environment Australia, Australia.

Seitz, J.C. and Poulakis, G.R. (2006). Anthropogenic effects on the smalltooth sawfish (*Pristis pectinata*) in the United States. *Marine Pollution Bulletin* **52**: 1533-1540.

Simpfendorfer, C.A. (2000). Predicting population recovery rates for endangered western Atlantic sawfishes using demographic analysis. *Environmental Biology of Fishes* **58**: 371-377.

Stephenson, P. and Chidlow, J. (2003). *Bycatch in the Pilbara Trawl Fishery*. WA Marine Research Laboratories, Department of Fisheries, Government of Western Australia report to Natural Heritage Trust.

Stevens, J.D., Bonfil, R., Dulvy, N.K. and Walker, P.A. (2000). The effects of fishing on sharks, rays, and chimaeras (chondrichthyans), and the implications for marine ecosystems. *ICES Journal of Marine Science* **57**: 476-494.

Stevens, J.D., McAuley, R.B., Simpfendorfer, C.A. and Pillans, R.D. (2008). *Spatial distribution and habitat utilisation of sawfish (Pristis spp) in relation to fishing in northern Australia*. A report to the Department of the Environment, Water, Heritage and the Arts.

Stevens, J.D., Pillans, R.D. and Salini, J. (2005). *Conservation assessment of Glyphis sp. A (Speartooth Shark), Glyphis sp. C (Northern River Shark), Pristis microdon (Freshwater Sawfish) and Pristis zijsron (Green Sawfish)*. Final report to the Department of Environment and Heritage, Australian Government. 84 pp.

Stobutzki, I., Blaber, S., Brewer, D., Fry, G., Heales, D., Jones, P., Miller, M., Milton, D., Salini, J., Van der Velde, T., Wang, Y-G., Wassenberg, T., Dredge, M., Courtney, A., Chilcott, K. and Eayrs, S. (2000). *Ecological Sustainability of Bycatch and Biodiversity in Prawn Trawl Fisheries***.** *Final Report to the Fisheries Research and Development Corporation*. Project No. 96/257. 512 pp.

Tanaka, S. (1991). Age estimation of Freshwater Sawfish and sharks in northern Australia and Papua New Guinea. In: Shimizu, M. and Taniuchi, T. (Eds) *Studies on Elasmobranchs Collected From Seven River Systems in Northern Australia and Papua New Guinea*. The University Museum, University of Tokyo, Tokyo, Nature and Culture **3**: 71–82.

Taniuchi, T., Kan, T.T., Tanaka, S. and Otake, T. (1991a). Collection and measurement data and diagnostic characters of elasmobranchs collected from three river systems in Papua New Guinea. In: Shimizu, M. and Taniuchi, T. (Eds) *Studies on Elasmobranchs Collected From Seven River Systems in Northern Australia and Papua New Guinea*. The University Museum, University of Tokyo, Tokyo, Nature and Culture **3**: 27-41.

Taniuchi, T., Shimizu, M., Sano, M., Baba, O. and Last, P.R. (1991b). Descriptions of freshwater elasmobranchs collected from three rivers in Northern Australia. In: Shimizu M, Taniuchi T (Eds) *Studies on Elasmobranchs Collected From Seven River Systems in Northern Australia and Papua New Guinea*. The University Museum, University of Tokyo, Tokyo, Nature and Culture **3**: 11–26.

Thorburn, D.C. (2006). *Biology, ecology and trophic interactions of elasmobranchs and other fishes in riverine waters of northern Australia*. PhD Thesis, Murdoch University, Perth, Western Australia.

Thorburn, D.C. and Morgan, D.L. (2004). The northern river shark *Glyphis* sp. C (Carcharhinidae) discovered in Western Australia. *Zootaxa* **685**: 1-8.

Thorburn, D.C. and Morgan, D.L. (2005b). Threatened fishes of the world: *Glyphis* sp. C (Carcharhinidae). *Environmental Biology of Fishes* **73**: 140.

Thorburn, D.C. and Morgan, D.L. (2005a). Threatened fishes of the world: *Pristis microdon* Latham 1794 (Pristidae). *Environmental Biology of Fishes* **72**: 465-466.

Thorburn, D., Morgan, D., Gill, H., Johnson, M., Wallace-Smith, H., Vigilante, T., Croft, I. and Fenton, J. (2004). *Biology and cultural significance of the freshwater sawfish (Pristis microdon) in the Fitzroy River Kimberley, Western Australia*. Report to the Threatened Species Network.

Thorburn, D.C., Morgan, D.L., Rowland, A.J. and Gill, H.S. (2007). Freshwater Sawfish *Pristis microdon* Latham, 1794 (Chondrichthyes : Pristidae) in the Kimberley region of Western Australia. *Zootaxa* **1471**: 27-41.

Thorburn, D.C., Morgan, D.L., Rowland, A.J., Gill, H.S. and Paling, E. (2008). Life history notes of the critically endangered dwarf sawfish, *Pristis clavata*, Garmon 1906 from the Kimberley region of Western Australia. *Environmental Biology of Fish* **83**: 139-145.

Thorburn, D. C., Peverell, S., Stevens, J.D., Last, P.R. and Rowland, A.J. (2003). Status of freshwater and estuarine elasmobranchs in northern Australia. Final Report to Natural Heritage Trust. 75 pp.

Watanabe, S. (1991). Electrophoretic analyses of freshwater elasmobranchs from northern Australia and Papua New Guinea. *The University Museum, the University of Tokyo, Nature and Culture* **3**: 103-109.

Whitty, J.M., Morgan, D.L., Peverell, S.C., Thorburn, D.C. and Beatty, S.J. (2009b). Ontogenetic depth partitioning by juvenile freshwater sawfish (*Pristis microdon*: Pristidae) in a riverine environment. *Marine and Freshwater Research* **60**: 306-316.

Whitty, J.M., Morgan, D.L., Thorburn, D.C., Fazeldean, T. and Peverell, S.C. (2008). Tracking the movements of Freshwater Sawfish (*Pristis microdon*) and Northern River Sharks (*Glyphis* sp. C) in the Fitzroy River. In: Whitty, J.M., Phillips, N.M., Morgan, D.L., Chaplin, J.A., Thorburn, D.C. and Peverell, S.C. (Eds). *Habitat associations of Freshwater Sawfish (Pristis microdon) and Northern River Shark (Glyphis sp. C): including genetic analysis of P. microdon across northern Australia*. Centre for Fish & Fisheries Research (Murdoch University) report to the Department of the Environment, Water, Heritage and the Arts, Australian Government.

Whitty, J.M., Morgan, D.L. and Thorburn, D.C. (2009a). Movements and interannual variation in the morphology and demographics of Freshwater Sawfish (Pristis microdon) in the Fitzroy River. In: Phillips, N.M., Whitty, J.M., Morgan, D.L, Chaplin, J.A., Thorburn, D.C. and Peverell, S.C. (Eds). *Freshwater Sawfish (Pristis microdon) movements and population demographics in the Fitzroy River, Western Australia and genetic analysis of P. microdon and Pristis zijsron*. Centre for Fish & Fisheries Research (Murdoch University) report to the Department of the Environment, Water, Heritage and the Arts, Australian Government.

Wynen, L., Larson, H., Thorburn, D., Peverell, S., Morgan, D., Field, I. and Gibb, K. (2009). Mitochondrial DNA supports the identification of two endangered river sharks (*Glyphis glyhpis* and *Glyphis garricki*) across northern Australia. *Marine and Freshwater Research* **60**: 554-562.