Status of Freshwater and Estuarine Elasmobranchs in Northern Australia

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3 INTRODUCTION

3.1 Background

3.1.1 Australian shark and ray fauna

Australia has an extremely rich shark and ray fauna with the most recent taxonomic review estimating that of the approximately 1025 species of sharks and rays worldwide (Leonard Compagno, South African Museum, Cape Town, pers. comm), at least 297 species inhabit Australian waters (Last and Stevens 1994). Of these species more than half (54%) are endemic to Australian waters (Shark Advisory Group 2001).

While there is still much to be learnt of the taxonomy, biology and distribution of chondrichthyan species found in Australia, a recent comprehensive review of the fauna (Last and Stevens 1994), and international synopses such as those produced by the Food and Agriculture Organisation of the United Nations (FAO, several authors, 1998; 1999), reveal significant advances in our knowledge compared to the earlier accounts of Whitley (1940), covering 162 species, and of Paxton *et al.* (1989), covering 177 species.

3.1.2 The estuarine and freshwater component

Some 118 species (40%) of Australian elasmobranchs penetrate estuaries and the lower freshwater reaches of rivers (Last 2002). However, only two rays (*Pristis microdon* and *Himantura chaophraya*) and three sharks (*Carcharhinus leucas, Glyphis* sp. A and *Glyphis* sp. C) occur in oligohaline environments of the upper reaches of rivers far from the coast.

In tropical northern Australia, the speartooth shark and northern river shark (*Glyphis* sp. A and *Glyphis* sp. C) are confirmed from freshwater or weakly saline, riverine habitats. Records of members of this genus from the sea are few, and reports of their occurrence in coastal habitats of Van Diemens Gulf and the Wessel Islands (Arnhem Land) need validation. Hence, their provisional classification by Last (2002) as 'obligate freshwater species' may change.

The taxonomic status and distribution of the freshwater sawfish (*Pristis microdon*) is unresolved but, based on current definitions, it is known from both coastal marine and inland habitats across northern Australia. The freshwater whipray (*Himantura chaophraya*), which was first discovered in the early 1990's in the northern rivers, is known to occur only in fresh and estuarine waters. These rays are best described as 'brackish marginal species'.

The bull shark (*C. leucas*) occurs in both marine and freshwater habitats. Classified as an 'estuarine species', this widespread shark is often referred to as a 'facultative freshwater species' because it has been reported from numerous freshwater systems in warm temperate and tropical Australia (and in other countries) (Last and Stevens 1994).

The size of the Australian continent, and difficulties associated with accessing some of the most remote riverine systems have limited the ability of researchers to document the estuarine and freshwater faunas. This deficiency in available data and problems associated with the past misidentification of these species has led to some of them being unaccounted for until only recently.

3.1.3 Previous freshwater surveys of northern Australia

Prior to this study, there have been only two reported surveys of rivers in northern Australia with the specific aim of surveying freshwater sharks and rays. The first was conducted in four rivers of the eastern Gulf of Carpentaria (Gilbert and Mitchell Rivers) and Northern Territory (Adelaide and Daly Rivers) in 1989 (Taniuchi *et al.*1991a). The following year a similar survey was made of the Ord and Pentecost Rivers of the northern Kimberley (Ishihara *et al.* 1991). Although numerous ad hoc surveys of freshwater teleost fishes have been undertaken in northern Australian rivers, very few of them have included records of freshwater elasmobranchs. Those surveys that identified freshwater shark and ray species are summarised in Table 1 (*C. leucas* is not included in this table because there are numerous reports of its occurrence in Australia).

In addition, there are many records of "sawfish" occurring in freshwater reaches of Queensland rivers (Normanby, Kennedy, Bizant, Norman and Staaten Rivers) from fish surveys conducted during 1979-1991 (R. Garrett, Northern Fisheries Centre, Qld, pers. comm.).

3.2 Research Needs

3.2.1 Concern for shark and ray faunas globally

International concern over the population status of elasmobranchs around the globe has been expressed through the World Conservation Union (IUCN) Shark Specialist Group and the FAO International Plan of Action for Sharks (IPOA). The catch of sharks and rays has increased dramatically throughout the world's oceans in the past 30 years, both from target fishing and as a bycatch of increased fishing for other species. Elasmobranchs are more vulnerable to human exploitation than bony fishes because of their different life-history strategy. Compared to teleost fishes, which produce high numbers of eggs and develop rapidly, sharks and rays are generally slow growing animals that mature after an extended period and produce low numbers of well-developed offspring. Due to these factors, these fishes require additional management strategies to avoid overfishing. The recovery of overfished populations may take decades (Compagno 1990).

3.2.2 Estuarine and freshwater elasmobranchs

Estuarine and freshwater elasmobranchs are even more at risk than their marine counterparts as they combine the above life history strategies with all the problems associated with more size-restricted habitats (eg. water quality, habitat availability, local extinction through overfishing). Currently, international concern for freshwater elasmobranch populations has been expressed through the IPOA that aims to "determine and protect critical habitats and identify and provide special attention, in particular, to vulnerable or threatened shark stocks" (IPOA 2000).

Members of the genus *Glyphis* are an enigmatic group confined to localised freshwater and estuarine systems in the Indo-West Pacific region. In Australia, *Glyphis* sp. A and

Table 1: Previous Australian records of freshwater sharks and rays. Records for each species include author, year, State/Territory and river in which they were recorded. WA- Western Australia, NT- Northern Territory, Qld- Queensland.

Author	Year	*Glyphis* sp.	*Glyphis* sp. *A*	*Glyphis* sp. *C*	*P. microdon*	*H. chaophraya*
Whitley	1945				NT: no river specified (*P.leichhardti*)[1]	
Midgley (in Larson 1999)	1981				NT: Keep	
McPherson pers.comm.[2.]	1983		Qld: Bizant			
Bishop *et al*. 1986	1986				NT: Alligator Rivers (*P.leichardti*)	
Taniuchi *et al*. 1991	1989	NT: Adelaide, West Alligator			NT: Daly Qld: Gilbert	NT: Daly
Johnson pers.comm.[3]	1991				Qld: Norman	
Larson 1999	1999				NT: Keep	
Larson 2000	1999	NT: East, West , South Alligator				
Berra pers comm.[4]	2001		NT: Adelaide	NT: Adelaide		
Morgan *et al*. 2002 [5]	2002			WA: Fitzroy	WA: Fitzroy	
Hyland pers.comm.[6]	2001				Qld: Normanby	
Last 2002	2002		Qld: Bizant	NT: South Alligator		WA: Ord, Pentecost NT: Alligator Qld: Gilbert
Squires pers.comm.[7]	2003				Qld: Flinders, Norman, Wenlock	Qld: Wenlock

1. *P. leichardti* is now considered synonymous with *P. microdon* (Section 1.2.3)
2. Geoff McPherson, Fisheries Biologist, Northern Fisheries Centre, Qld Department of Primary Industries.
3. Jeff Johnson, Fish Section, Queensland Museum.
4.Tim Berra, Professor Emeritus, Dept. of Evolution, Ecology & Organismal Biology, The Ohio State University
5. From a project studying barramundi, and other fish fauna in the Fitzroy River by Dr David Morgan (Murdoch University) that collaborated with this NHT study. The findings were first presented in Morgan *et al.* 2002, and contain data collected during the current study.
6. Stuart Hyland, Fisheries Biologist, Northern Fisheries Centre, Qld Department of Primary Industry
7. Lyle Squires, Cairns Marine Aquarium Fish

sp. C, and *Pristis microdon,* are all protected under Commonwealth legislation and listed as critically endangered, endangered and vulnerable, respectively (Table 2). This listing under the *Environment Protection Biodiversity and Conservation Act 1999* (*EPBC Act 1999*) requires recovery plans for these species to be developed and demonstrates the extremely high conservation concern for these species.

Table 2: Commonwealth legislation protecting Australian freshwater sharks and rays.

Species	Legislation	Status
Glyphis sp. A	*EPBC Act 1999*	Critically Endangered (since Oct. 2001)
Glyphis sp. C	*EPBC Act 1999*	Endangered (since Oct. 2001)
Pristis microdon	*EPBC Act 1999*	Vulnerable (since July 2000)

These three species are also listed by international and national conservation organisations as having extremely high conservation status (Table 3). These organisations also list other elasmobranch species: sawfishes *P. clavata* and *P. zijsron* as Endangered and *Anoxypristis cuspidata* as Vulnerable; and the whipray *Himantura chaophraya* as Vulnerable.

From these conservation assessments, concern for sawfishes also extends to marine species. Members of this group, which are large, long-lived predators with inshore distributions, are particularly susceptible to fishing because their saw-like snout is readily entangled by nets. In the United States, the National Marine Fisheries Service announced their decision in April 2003 to list the smalltooth sawfish (*Pristis pectinata*) as Endangered under the U.S. Endangered Species Act, the first such listing for a marine fish found in U.S. waters. Sawfishes appear to have been extirpated from many regions of the world where they once occurred (Compagno and Cook 1995) and Australia may retain some of the last healthy populations.

Currently, the number of *Glyphis* species that exist is uncertain, however there are considered to be at least four to five: *Glyphis glyphis* (speartooth shark), *G. gangeticus* (Ganges river shark), *Glyphis* sp. B (Borneo river shark) and two species from Australia, *Glyphis* sp. A and sp. C. The first two nominal species are listed as Critically Endangered and Endangered respectively on the IUCN 2002 Red List (IUCN 2002).

The Australian *Glyphis* species (*G*. sp. A and sp. C) are known from few specimens (two from the Bizant River, Qld; five from the Adelaide River, NT; eight from the Alligator Rivers, NT; and one from Murganella Creek, NT) (Last and Stevens 1994, Last unpublished data). More material is required to solve current taxonomic problems within this genus. *Glyphis* sp. A. has not been seen in the Bizant River or any other part of Queensland for 20 years despite several surveys and commercial fishing occurring in the area.

Table 3: Other conservation listings of freshwater sharks and rays.

Species	Common names	Organisation/report	Status
Glyphis sp. A.	Speartooth shark/ Bizant river shark	Pogonoski *et al.* 2002	Critically Endangered
		IUCN Regional Red List 2003	Critically Endangered
Glyphis *sp. C*	Northern river shark	Pogonoski *et al.* 2002	Endangered
		IUCN Regional Red List 2003	Critically Endangered
Pristis microdon	Freshwater sawfish	Pogonoski *et al.* 2002	Critically Endangered
		ASFB[1] List of Australian Threatened Fishes	Potentially Threatened
		IUCN 2002 (for Australia)	Endangered
Pristis clavata	Dwarf sawfish	Pogonoski *et al.* 2002	Endangered
		IUCN 2002 (for Australia)	Endangered
Pristis zijsron	Green sawfish	Pogonoski *et al.* 2002	Endangered
Anoxypristis cuspidata	Narrow sawfish	Pogonoski *et al.* 2002	Vulnerable
Himantura chaophraya	Freshwater whipray	Pogonoski *et al*. 2002	Vulnerable
		IUCN 2002 (for Australia)	Vulnerable

1. ASFB: Australian Society for Fish Biology

There is also uncertainty in the number of valid *Pristis* species (Compagno and Cook 1995). Currently, there are between five and seven species in the family Pristidae, four or five of which occur in Australian waters (Pogonoski *et al.* 2002). In Australia, the distribution of *Pristis microdon* is not clearly defined due to confusion with other members of the genus. Australia's largest freshwater fishes appear to have very specific habitat requirements and are highly vulnerable to netting and poaching.

Surveys of Australia's northern rivers were identified as being urgently needed to determine the regional status of these elasmobranchs, and to assess their:

- distribution in rivers and estuaries across the north
- spatial occupancy in each catchment
- relative abundance in particular river systems

The information gained from these surveys will provide baseline data for the Recovery Plans and management of the species. It will also provide information on other elasmobranchs found in brackish or freshwater, in particular the bull shark, *Carcharhinus leucas* that is found throughout northern Australia. As stated earlier, bull sharks occur in both freshwater and marine areas and as such are sometimes described as freshwater elasmobranchs due to the well-documented occurrence of juveniles in Australian rivers (Merrick and Schmida 1984, Taniuchi *et al.* 1991, Herbert and Peeters, 1995).

3.2.3 Priority estuarine and freshwater elasmobranchs

Limited information is available on the distribution and abundance of potentially threatened freshwater elasmobranchs, *Glyphis* spp, *Pristis microdon* and *Himantura chaophraya*. The relatively recent discovery of some of these species, and problems identifying them, suggests that additional unrecorded or undescribed freshwater elasmobranchs could occur in Australia.

The elasmobranchs discussed below (and those in Section 1.2.4) are referred to as 'priority species' throughout this study.

***Glyphis* spp**

Two of the four to five known species of *Glyphis* have been recorded in Australian river systems in recent years. However, the taxonomy of these two species is unclear with initial records listing only one species. *Glyphis* sp. A was originally identified in 1982 from two specimens found in relatively deep waters, near the saltwater interface of the upper reaches of the Bizant River in Queensland (Table 1). In 1989, one specimen of *Glyphis* sp. C (as *Glyphis* sp.) was recorded from a freshwater habitat in the Adelaide River in the Northern Territory (Taniuchi *et al.* 1991, Taniuchi and Shimizu 1991). Soon after in 1996, an adult male of *Glyphis* sp. C was captured 60 km up the South Alligator River (Last 2002).

In subsequent years, fish monitoring surveys conducted in Kakadu National Park, NT (Larson 2000) resulted in the capture of an additional seven specimens. Taxonomic work by one of us (P.Last), including vertebral counts, subsequently led to *Glyphis* sp. A and *G*. sp. C being distinguished in this collection. It has also been suggested that the *Glyphis* sp. C is identical to *Glyphis glyphis* (Leonard Compagno, South African Museum, Cape Town, pers. comm), however additional specimens and taxonomic research is required to substantiate this suggestion.

Pristis microdon

The freshwater sawfish is another species for which accurate distribution data is limited and the taxonomy confused. It has been known for some time that this species is often encountered in freshwater, in the upper reaches of rivers, several hundred kilometres upstream (Whitley 1940, Herre 1955**,** Merrick and Schmida 1984). It has been recorded from several drainages in northern Australia in fresh or weakly saline habitats including the Fiztroy, Durack and Ord Rivers (WA), the Adelaide, Keep, Victoria, Daly Rivers and Alligator Rivers (NT) and the Gilbert, Mitchell, Norman, Normanby, Wenlock and Flinders Rivers (Qld) (Last and Stevens 1994, Table 1 of this report).

Of the four *Pristis* species reported to occur in Australia, *P. microdon* is the species most often associated with freshwater. Compagno and Last (1999) state that this species occupies inshore, intertidal and freshwater habitats. However, Last and Stevens (1994), suggest that in Australia, this sawfish may be confined to freshwater drainages and the upper reaches of estuaries. The maximum length of *P. microdon* recorded in freshwater in Australia marginally exceeds 2.8 m with males maturing at about 2 m (Peter Last, CSIRO Marine Research, Hobart, pers. comm.), while outside Australia it is reputed to reach 7 m (Last and Stevens 1994). Some saws removed from large specimens caught in Australia exist in regional fish collections but collection data for them is poor.

Due to the similarity of sawfish species, misidentifications are frequent and records often questionable. These trends extend to the literature. For example, Gloerfelt-Tarp and Kailola (1987) considered *P. microdon* to be synonymous with *P. pristis.* Herbert and Peeters also considered this the case, as recently as 1995. Additionally, *P. leichardti* described by Whitley (1945), and recorded as recently as 1986 by Bishop *et al.,* is now considered synonymous with *P. microdon.* The two species were formerly separated on the structure of the lower lobe of the caudal fin.

Himantura chaophraya

It was not until 1989 that *H. chaophraya* was collected from Australia based on a specimen from the Daly River, and documented by Taniuchi *et al.* (1991). Prior to this, all long-tailed stingrays caught in tropical freshwater habitats of Australia were identified as the estuarine stingray, *Dasyatis fluviorum* (Last and Stevens 1994). An example of this is seen in Merrick and Schmida (1984). Despite its presence being documented in 1991, Herbert and Peeters describe this species as *D. fluviorum* as late as 1995 (both these references provide a photo of *H. chaophraya*). *Himantura chaophraya* is the only Australian stingray to live entirely in fresh and estuarine waters (Last and Stevens 1994) and it has not been recorded from euhaline marine waters anywhere in its known range (Pogonoski *et al.* 2002). This freshwater ray has been reported from the Ord, Fitzroy and Pentecost Rivers (WA), Daly and South Alligator Rivers (NT) and the Gilbert and Wenlock Rivers (Qld) (Last and Stevens 1994, Table 1 of this report). The maximum size of this species currently recorded from Australia is at least 1 m disc width and around 2.7 m total length. Elsewhere, it is reported to reach a disc width of almost 2 m and about 600 kg (Last and Stevens 1994).

Carcharhinus leucas

The bull shark has a cosmopolitan distribution in tropical and warm temperate seas with an Australian range extending south to Sydney (NSW) and Perth (WA). It occurs in a wide range of habitats including coastal, estuarine, riverine and lake systems and is the only widely distributed shark known to penetrate well into freshwater systems for extended periods of time. Tropical rivers in which it has been reported include the Adelaide, Daly and East Alligator Rivers (NT), and the Herbert River (Qld). Whaler sharks reported from the Ord and Pentecost Rivers (WA), and the Victoria River (NT), are also likely to be this species (Last and Stevens 1994). Bull sharks are sometimes confused with other coastal whaler sharks, and in particular with the very similar pigeye shark (*Carcharhinus amboinensis*). The maximum known length of the bull shark in Australia is about 3.4 m (Last and Stevens 1994).

3.2.4 Other sawfish species

Four other species of sawfish are documented from Australian waters and these species, *Anoxypristis cuspidata*, *Pristis clavata*, *P. zijsron* and *P. pectinata*, are of

conservation concern. All except *P. pectinata* are listed by conservation organisations in Australia (Table 3).
The distribution of *Anoxypristis cuspidata* in the northern waters of Australia is unclear, although it is moderately common in the Gulf of Carpentaria. It is mainly a coastal marine species but has been reported from salinities of 20-25 ppt in Papua New Guinea (Pogonoski *et al*. 2002). *Pristis clavata* is a tropical Australian species distributed from Cairns (Qld) to the Kimberleys (WA) in coastal and estuarine habitats. It has been reported well inland, almost into freshwater, and is common on mudflats in the Gulf of Carpentaria (Last and Stevens 1994). In Australia, *P. zijsron* occurs mainly in the tropics and was once the most commonly encountered sawfish. It enters estuaries and used to be common inshore at certain times of the year (Pogonoski *et al.* 2002, Last and Stevens 1994). The distribution of *P. pectinata* in northern Australia is unclear as the only Australian records are based on unconfirmable photographs of specimens from the Gulf of Carpentaria. It is one of the largest sawfishes and is considered to be a marine species that usually enters estuaries rather than rivers (Pogonoski *et al.* 2002).

3.3 Objectives

The main objectives of this project were:

- To determine the occurrence, distribution and abundance of freshwater elasmobranchs in selected rivers and estuaries of northern WA, NT, and Qld Gulf drainage and east coast rivers

- To provide baseline data for the Recovery Plans of *Glyphis* sp. A and sp. C and *Pristis microdon* and make specific recommendations for management of their populations

- To determine the occurrence, distribution and abundance of sawfishes in the inshore marginal zone of northern WA, the NT and the Gulf regions of Queensland

- To determine whether sawfish species in northern Australian waters should be classified as nationally threatened species and to provide information on which to base recovery plans if necessary

Australia is signatory to a number of international agreements which commit to sustainable exploitation of resources, conservation of ecosystems and preservation of biodiversity, including: the United Nations Convention on the Law of the Sea (1982), the FAO International Code of Conduct for Responsible Fisheries (1995), the FAO International Plan of Action for Sharks (1999), the Convention on Biological Diversity (1992) and the World Charter for Nature (1982). The long-term goal of this work, which is essential in fulfilling Australia's international obligations, is to ensure the preservation of freshwater elasmobranch and sawfish populations in northern Australia.

This project will contribute to greater scientific understanding of freshwater elasmobranch populations, which should also assist in similar international conservation work. Information will also be collected that may help to clarify current taxonomic uncertainties within these freshwater shark and ray species.

4 METHODS

4.1 Sampling strategy

The strategy was to sample a broad range of rivers across northern Australia that included both those in which there have been previous sightings of freshwater elasmobranchs and those in which there have been no documented freshwater elasmobranch records. A range of habitats from freshwater and estuarine river systems were sampled including the coastal marginal zone, tidal feeder creeks, main channels, tributaries and waterholes.

Sites were selected on the basis of accessibility and anecdotal evidence of sightings of freshwater elasmobranchs from traditional owners, station managers, recreational fishers and researchers. For some sites, it was necessary to seek permission to sample from the relevant land-owners and management authorities. The aim was to conduct the sampling during the dry season to avoid logistical and access difficulties associated with sampling these northern Australian rivers during the wet season.

4.1.1 Survey teams

Sampling in the Northern Territory and in Western Australia was primarily conducted by Dean Thorburn (Murdoch University) and Andrew Rowland (Murdoch University). In Queensland, sampling was mainly carried out by Stirling Peverell. Both 'core' teams were joined and assisted at various points by a number of co-investigators and other participants.

4.1.2 Northern Territory

Eighty one sites from 14 river/creek systems were sampled throughout the Northern Territory between June and September 2002. The survey team was initially joined by Dr Peter Last and Dr John Stevens (CSIRO Marine Research), Dr Andrew Storey (University of Western Australia), Steven Gregg (Museum and Art Gallery of the Northern Territory) and members of the Australian Conservation Volunteers. Throughout the survey, the sampling team also liaised with National Park Rangers, and local Aboriginal groups in collaboration with the Northern Land Council.

Sampling in Arnhem Land was conducted on the Liverpool/Mann, Caddell/Blyth, Goyder/Glyde River systems and Darbilla Creek. It was also hoped that rivers on the eastern coast of Arnhem Land could be surveyed; however at the time of sampling traditional owners closed this region. In the north, the Mary and Adelaide Rivers were sampled. Surveys of rivers entering the Gulf of Carpentaria included the Roper, Towns, Limmen, McArthur, Wearyan and Robinson Rivers. In the west of the Territory, the Daly/Katherine Rivers and sites throughout the Victoria River system were sampled (Figure 1).

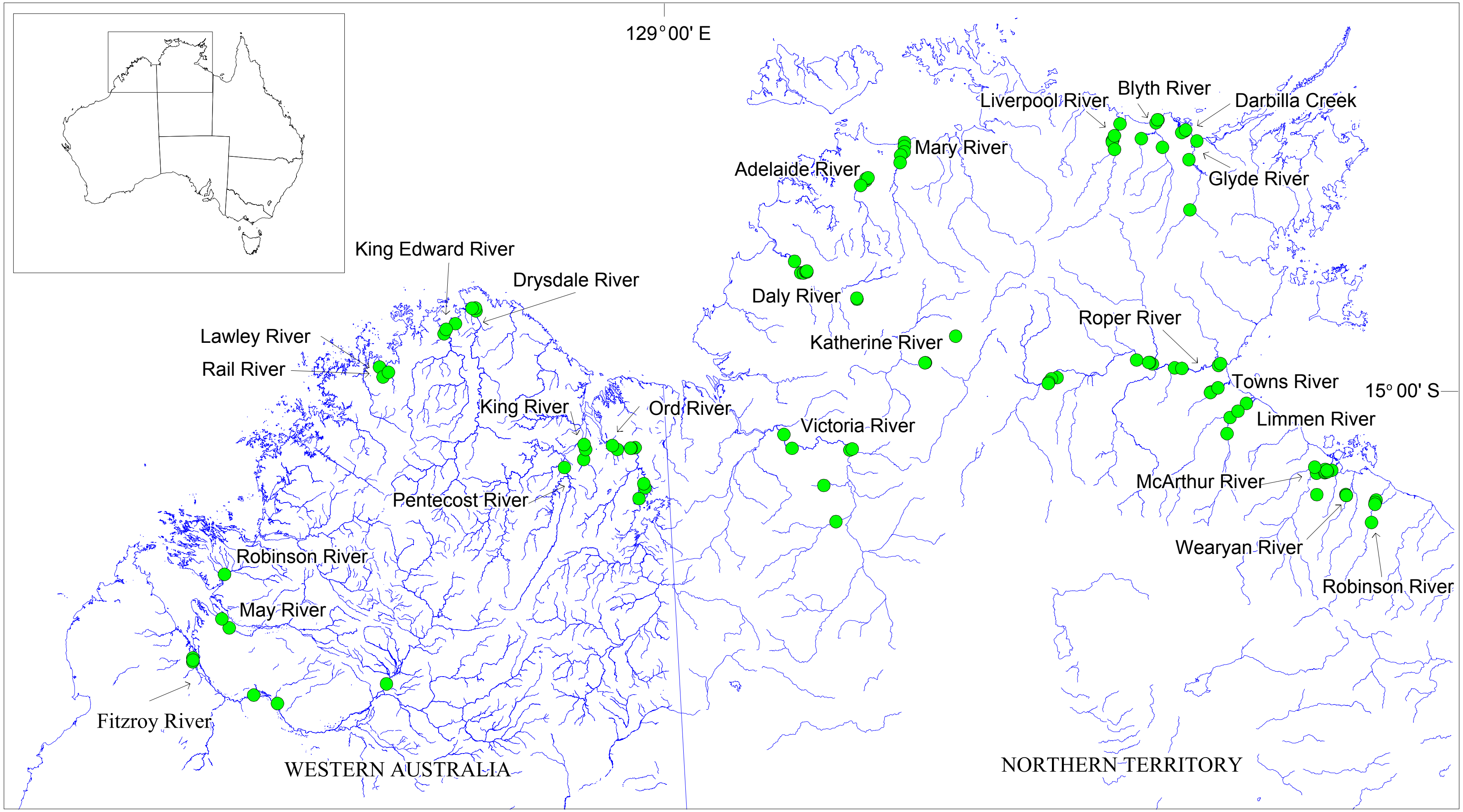


Figure 1: The sites sampled for elasmobranchs in the Kimberley region of Western Australia and in the Northern Territory.

4.1.3 Western Australia

Thirty sites from 12 river/creek systems were sampled throughout the Kimberley region, WA, between September and November 2002. There are fewer accessible rivers in this region with larger distances between them than in the NT. Sampling was also restricted in comparison to the NT due to early rains and unfavourable weather in late November 2002. During the survey, the sampling team was joined by Dr Andrew Storey (University of Western Australia). The survey team also collaborated with other Murdoch University researchers conducting barramundi research, and studies of the Fitzroy River.

Work initially commenced in the north of the Kimberley region (based out of Kalumburu Aboriginal Mission) and included sampling in the Drysdale and King Edward Rivers and Dominic Creek. On the west coast, the Rail and Lawley Rivers and tidal creeks accessible from Walsh Point were sampled, while further south sampling was conducted on the Robinson, May and Fitzroy Rivers. In the eastern part of the Kimberley region, sampling was conducted in the Pentecost, King and Ord Rivers (Figure 1).

4.1.4 Queensland

Twenty six sites from 13 river/creek systems were sampled in far north Qld between August and December 2002. Commercial fishermen from the Gulf of Carpentaria and Qld east coast assisted in all of the surveys. On one sampling trip the team worked in co-operation with Cairns Marine Aquarium Fish. Many of the sites were on private land and on cattle stations and permission to access sites was sought from individual land owners and station managers. To sample in Lakefield National Park and Olive Vale Station permission was gained from an elder of the Laura Community Ang-gnrra Aboriginal Corporation and the head ranger of Lakefield National Park. Sampling in these areas was conducted with the assistance of an indigenous ranger from Queensland Parks and Wildlife Service.

Rivers sampled on the north east of Cape York included the Laura, Kennedy, Bizant and Normanby Rivers. The Cape York Gulf drainage rivers surveyed included the Wenlock, Pine, Mission Rivers and Albatross Bay while further south in the southern Gulf of Carpentaria drainage the Mitchell, Gilbert and Saxbury Rivers and Alice Creek were sampled (Figure 2).

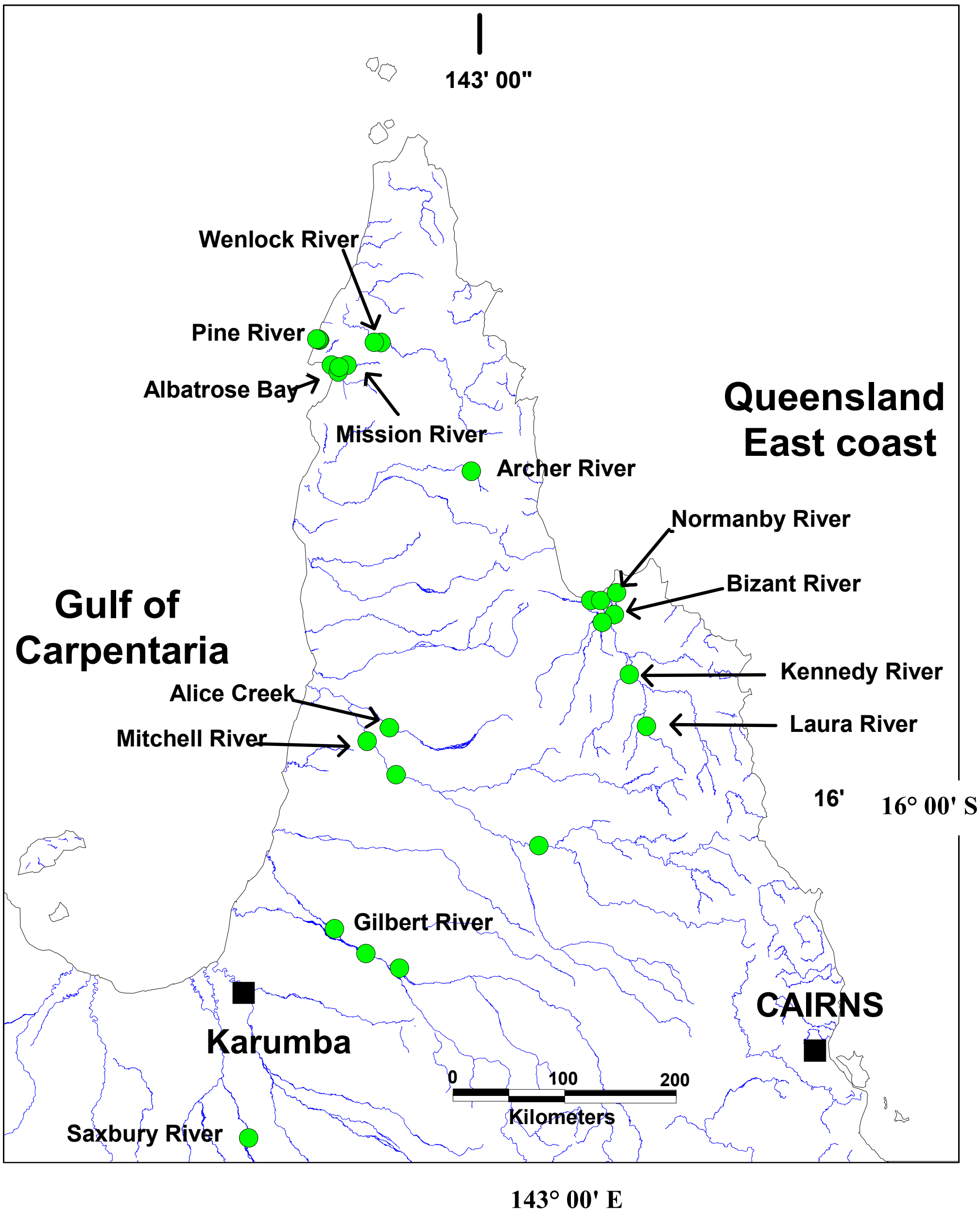


Figure 2: Sites sampled for elasmobranchs in Queensland.

4.2 Sampling equipment

4.2.1 Northern Territory and Western Australia

Sampling was conducted in the NT and WA with a 4.4 m aluminium dinghy or 4.6 m aluminium centre console, and a 2.7 m car topper dinghy. Ideally, the larger vessels were utilised as a greater amount of equipment could be carried, larger distances on rivers or along the coast could be covered, and rougher waters sampled. Although both the 4.4 and 4.6 m boats were carried on heavy-duty trailers suitable for off-road use, in the case of severely degraded tracks, or launching sites being unavailable, the car topper dinghy was used. On several occasions when vehicle and boat access were completely restricted, a reduced amount of gear was carried to the rivers and waded or hauled across.

Gill nets

Sampling was primarily conducted with a combination of 30 m (2.5 m drop) monofilament gill net panels, of 10, 15 and 20 cm stretched mesh, respectively. The number of panels used at each site was determined by factors such as the channel width and the density of snags. These panels were often joined to fish a greater proportion of the river channel. In general, gill nets were set for a minimum of three hours, however set times were highly variable and dependent upon factors such as catch rate and tidal influence, and were reduced if other people utilizing the river were in the vicinity. When nets were set overnight, only the larger meshes (i.e. the 15 and 20 cm mesh) were used to minimise by-catch. Gill nets were primarily anchored to run at right angles to the river bank, however they were set parallel to it when the flow rate was high. At sampling sites that were affected by excessive tidal influence, gill netting was conducted at periods of slow and slack water, associated with the turn of the tide.

Long-lines

Forty metre sinking long-lines were set at right angles to river banks. Each long-line consisted of a 250 kg nylon main line, with a maximum of 20 4/0 all rounder and/or tuna circle hooks, spaced approximately two metres apart. Each hook was connected to the main line via a shark clip and 70 kg trace wire (49 strand). Any commonly available bait was used, such as catfish (Ariidae spp) or mullet (Mugilidae spp).

Additional fishing techniques and observations

Both sunken and floating baits were often used on hand lines for opportunistic catches. During transit in shallow waters or while surveying from the riverbanks, freshwater elasmobranchs were occasionally observed. Where a positive identification could be made, locality and habitat data were recorded. These animals were often pursued and captured with the use of a throw net or hand spear

4.2.2 Queensland

In Qld all surveys were conducted with a roof mounted 3.6 m v-bottom aluminium dinghy (surveyed) and 15hp outboard motor. The use of a fully equipped 4-wheel drive was a necessity because of the isolation involved. The project team had to adhere to the remote area corporate standard of both the Department of Primary Industries and Queensland National Parks. Sites were chosen on their level of accessibility and whether there had been previous sighting of whaler sharks, stingrays or sawfish. A species identification poster, several project radio announcements and other media releases generated public interest and greatly assisted in refining proposed site locations.

Both gill nets and long-lines were deployed at all sample sites unless the habitat prevented the use of one type of gear. Some sites had a high abundance of weeds and snags that made the use of gill nets difficult, so only long-lines were used. At other sites the waterholes were too small to deploy long-lines, so only gill nets were used. A cd-rom was compiled that illustrates the Qld survey methodology, sampling procedures, habitat types and some of the priority species captured (available from Environment Australia).

Gill nets
Sampling was carried out with a number of different types of gill nets with the most appropriate net deployed in each habitat with respect to water depth, length and velocity for that site. Monofilament gill nets of 5 cm, 10 cm, 12.5 cm, 15 cm and 169 cm stretched mesh were used (25 or 30 mesh drop). The length of monofilament gill nets set varied from 18–550 m. A multifilament gill net of 12.5 cm mesh, 25 mesh drop and 50 m length was used once (at Albatross Bay). Black cord gill nets of 17.5cm and 18.8 cm, 25 mesh drop were set at lengths of 8.5-50 m, and white cord gill nets of 17.5 cm, 33 mesh drop and 30 m length were also used. Cord gill nets were used to reduce the interactions with unwanted bycatch, predominantly barramundi and catfish.

At each site nets were set at dusk and removed around dawn. The nets were checked at intervals depending on the amount of bycatch present; at sites with high bycatch the nets were checked every hour. The nets were secured to the river/creek bank and anchored using 5.4 kg danforth anchors. In areas of high flow, or where there was considerable net drag (as in the case of the 500 m monofilament net) anchors as heavy as 18 kg were used. Strobe net lights were also deployed in areas of public passage as a requirement stipulated by the Queensland Boating and Fisheries Patrol.

Long-lines
Long-lines were deployed in areas of sandbanks, snags, weed beds and open water, being 25 or 50 m in length, and consisting of 10 mm silver rope main line, with 15 cm polystyrene floats spaced according to the water depth. Where possible within one set, the baited hooks would be fishing on the bottom or in mid water, depending on the water depth. The bait was locally sourced and consisted predominantly of catfish (Ariidae spp or Mugilidae spp). Hooks were either 12/O or 14/O tuna circles, as stipulated in the QLD Animal Ethics Permit, to reduce unnecessary mortality. Snoods consisted of 182 kg monofilament line (1.5 m long) connected to a 90 kg nylon-coated wire trace equally spaced at 5 m intervals. The snoods were connected to the mainline using shark clips. Long-lines were deployed in the late afternoon and fished through the night. Regular checks were conducted on the gear and all animals were identified and released.

4.3 Protocols for fish sampling

One of the key priorities of this study was to avoid mortality and minimise stress to the target species, and to reduce bycatch of other species. In Qld and WA, approval for the capture of live animals for research was obtained from Animal Ethics, QDPI and Murdoch University, respectively.

In all regions, no site was sampled for more than two successive days/nights (with the majority of sites only sampled for a single night) to minimise the impact on animals and on the habitat. In WA and NT, gill nets were set for limited periods (usually about 3 h) and monitored closely for captures. Where nets were set for an extended period, such as overnight, only the larger 15 or 20 cm mesh nets were deployed. Alternatively, only long-lines were used to sample overnight.

In Qld, the nets were set overnight and monitored closely; if captures were observed the net was checked every hour. Any bycatch was immediately released, if necessary by cutting the net or line. Any dead bycatch were kept for bait. The life-status and release condition of all captures was recorded as a requirement of Animal Ethics Approval (not reported in this document).
All sampling teams kept fish handling time to a minimum. Once free of the net and positively identified, digital images were taken, sex recorded and a total length (or disc width) measured. A genetic sample for DNA analysis was collected by taking a finclip from the trailing edge of the pectoral fin (posterior part of disc for *H. chaophraya*). In Qld, animals were also tagged. The specimen was then released, but only after recovery (which sometimes involved swimming the animals). Some dead specimens were lodged with the Australian National Fish Collection (CSIRO), Museum and Art Gallery of the Northern Territory (MAGNT), Western Australian Museum (WAM), Murdoch University or QDPI.

4.4 Environmental variables

Water chemistry
In NT and WA, the salinity (ppt), temperature (^{o}C) and dissolved oxygen (mg/L) were recorded at each sample site using an YSI Model 85 handheld meter, and a secchi disc used to obtain water clarity values.

At each site in Qld, salinity (ppt), temperature (^{o}C) and turbidity (NTU) were recorded with a Horiba U-10 water quality meter.

Habitat
In WA and NT, the depth, estimated flow rate and direction of the tide (if present) were recorded for each site. Each sample site was also classified as being in the lower, middle or upper reach of the river. The habitat surface area was described on the basis of the following categories: Mineral substrate, Emergent Macrophyte, Submerged Macrophyte, Floating Macrophyte, Algal Cover Detritus, Riparian vegetation, Root mats, or Large Woody Debris. The type of mineral substrate of the immediate sampling area was assigned to one of the following substrate categories: Bedrock, Boulders, Cobbles, Pebbles, Gravel, Sand, Mud/Silt, and Clay.

In Qld, stream structure, velocity and habitat descriptions were based on those used by the QDPI Long Term Monitoring Project (Hutchison *et* al. 2003)**.** The water depth and velocity were recorded and the type of substrate was assigned to one of the following categories: Boulder/cobble, Cobble/gravel, Sand, Fine material and Rock Bar. Stream habitat was described as: Snags, Overhanging vegetation, Rocks, Leaf litter (detritus) and Aquatic macrophytes, and riparian vegetation was rated by type and continuity. An overview of habitat types sampled during the Qld survey can be seen on the cd-rom associated with this report (available from Environment Australia).

4.5 Locality maps

Latitude and longitude were recorded at each site using a Global Positioning System (GPS). Sampling site and species distribution maps were created using the above GPS data and MAPINFO (MapInfo Corporation 1998). The river system, site location and the latitude and longitude of all sites sampled are provided in Appendix 1.

4.6 Interpretation of catch data

The data collected during this survey are shown in two ways. Catches are presented for each State/Territory, as management decisions regarding these fisheries are conducted within each of these jurisdictions. With respect to biodiversity and species distributions, the data are considered in relation to the three biogeographic units (provinces and biotones collectively referred to as bioregions in this study) that are recognized across the survey area. The classification used follows that described by the Interim Marine and Coastal Regionalisation for Australia Technical Group (1998). The survey area is divided into the North Western Biotone (NWB), which incorporates those rivers from the Fitzroy River to the Daly River; the Northern Province (NP), which incorporates those from the Adelaide River to Wenlock River; and the North Eastern Biotone (NEB), which incorporates those rivers on the east coast of Cape York.

When interpreting catch data, it is appropriate to take into account the fishing effort at each sample site. Due to the variation in methodologies used by the core teams, and at each individual sampling site, abundance data in the form of catch per unit effort is not presented. The length of gill net and long-line used, and set times at each sample site are shown in Appendix 2.

5 RESULTS

5.1 Species distribution and catch composition

Thirty six species of elasmobranchs were encountered during this survey with 14, 17 and 25 of these species recorded in the NT, WA and Qld, respectively (Table 4). In comparison, the number of species recorded within each bioregion was 17, 30 and 6 species respectively in each of the NWB (47 sample sites), NP (83 sample sites) and NEB (7 sample sites) (Table 5). The bycatch species encountered during the survey are listed in Appendix 3.

A total of 502 individual elasmobranchs were caught or observed during the surveys. Of the 36 species recorded, *C. leucas* was the most abundant with 126 individuals (24% of the total catch) encountered throughout the survey (Table 6). The lemon shark (*Negaprion acutidens*), white spotted eagle ray (*Aetobatus narinari*), nervous shark (*Carcharhinus cautus*) and Australian blacktip shark (*Carcharhinus tilstoni*) were (in descending order) the next most frequently encountered species. Two of the priority species, *P. microdon* and *H. chaophraya*, followed with 28 (6.2%) and 27 (5.4%) individuals, respectively.

In the NT, the most frequently encountered elasmobranchs were *C. leucas* (65.8%), *H. chaophraya* (8.1%), *R. taylori* (7.2%) and *P. microdon* (6.3%) (Table 6). Although *C. leucas* was the most commonly encountered species in WA, it only comprised 17% of the total catch for this State (94 individuals caught). Fifteen freshwater sawfish (*P. microdon)* and 15 *P. clavata* were encountered (16% of the total catch) followed by *C. cautus* and *H. chaophraya*. A comparatively high number of elasmobranchs were recorded from Queensland (297 individuals) with *N. acutidens* constituting 16.5% of the total catch, followed by *A. narinari*, *C. leucas*, *C. tilstoni*, and *C. cautus*.

A total of 133, 349 and 20 individual elasmobranchs were collected from the NWB, NP and NEB bioregions respectively (Table 7). As was the case when comparing abundances between States/territory, the effort for each bioregion was not equal. The bull shark was the most frequently encountered species in all bioregions varying from 22-33% of the elasmobranch catch. *Himantura chaophraya* comprised 30% of the catch in the NEB but only 11.3% in the NWB and 1.7% in the NP. Between 3 (NP) and 13% (NWB) of the catch was represented by *P. microdon* with the remaining sawfish species comprising 1.2% or less of the catch (although *P. clavata* was 12 % of the NWB).

Table 4: Species of elasmobranchs encountered in WA, NT and Qld during the current survey.

Species	WA	NT	QLD
Carcharhinidae			
Carcharhinus amblyrhynchoides	X	X	X
Carcharhinus amboinensis	X		
Carcharhinus cautus	X		X
Carcharhinus dussumieri			X
Carcharhinus fitzroyensis		X	X
Carcharhinus leucas	X	X	X
Carcharhinus limbatus	X	X	
Carcharhinus melanopterus			X
Carcharhinus plumbeus	X		
Carcharhinus tilstoni	X		X
Galeocerdo cuvier		X	
Negaprion acutidens	X	X	X
Rhizoprionodon acutus		X	X
Rhizoprionodon oligolinx		X	
Rhizoprionodon taylori		X	X
Carcharhinus sp.			X
Sphyrnidae			
Sphyrna mokarran	X		X
Sphyrna lewini			X
Eusphyra blochii			X
Rhinobatidae			
Rhinobatos typus			X
Rhynchobatidae			
Rhynchobatus australiae			X
Pristidae			
Anoxypristis cuspidata		X	
Pristis clavata	X	X	X
Pristis microdon	X	X	X
Pristis zijsron			X
Dasyatidae			
Himantura sp. A	X		
Himantura chaophraya	X	X	X
Himantura granulata	X		
Himantura toshi			X
Himantura uarnak	X		
Himantura undulata	X		X
Pastinachus sephen			X
Myliobatidae			
Aetobatus narinari	X		X
Aetomylaeus nichofii			X
Rhinopteridae			
Rhinoptera javanica		X	
Rhinoptera neglecta			X

Table 5: Species of elasmobranchs caught by bioregion (Interim Marine and Coastal Regionalisation for Australia, Technical Group 1998) during the current survey.

Species	North Western Biotone	Northern Province	North Eastern Biotone
Carcharhinidae			
Carcharhinus amblyrhynchoides	X	X	
Carcharhinus amboinensis	X		
Carcharhinus cautus	X	X	
Carcharhinus dussumieri		X	
Carcharhinus fitzroyensis		X	X
Carcharhinus leucas	X	X	X
Carcharhinus limbatus	X	X	
Carcharhinus melanopterus		X	
Carcharhinus plumbeus	X		
Carcharhinus tilstoni	X	X	
Galeocerdo cuvier		X	
Negaprion acutidens	X	X	
Rhizoprionodon acutus		X	
Rhizoprionodon oligolinx		X	
Rhizoprionodon taylori		X	
Unidentified *Carcharhinus* sp.		X	
Sphyrnidae			
Eusphyra blochii		X	
Sphyrna lewini		X	
Sphyrna mokarran	X	X	
Rhinobatidae			
Rhinobatos typus		X	
Rhynchobatidae			
Rhynchobatus australiae		X	
Pristidae			
Anoxypristis cuspidata		X	
Pristis clavata	X	X	
Pristis microdon	X	X	X
Pristis zijsron		X	
Dasyatidae			
Himantura sp. A	X		
Himantura chaophraya	X	X	X
Himantura granulata	X		
Himantura toshi		X	
Himantura uarnak	X		
Himantura undulata	X		X
Pastinachus sephen		X	X
Myliobatidae			
Aetobatus narinari	X	X	
Aetomylaeus nichofii		X	
Rhinopteridae			
Rhinoptera javanica		X	
Rhinoptera neglecta		X	

Table 6: Elasmobranch catch composition by State/Territory. Catch composition is expressed as a percent of the total elasmobranch catch for each of the States/Territory.

Species	**Total catch**		**WA**		**NT**		**QLD**	
	n	**% comp**	**n**	**% comp**	**n**	**% comp**	**N**	**% comp**
Carcharhinus leucas	126	24.0	16	17.0	73	65.8	37	12.5
Negaprion acutidens	55	11.0	4	4.3	2	1.8	49	16.5
Aetobatus narinari	40	8.0	1	1.1	0	0	39	13.1
Carcharhinus cautus	39	7.8	11	11.7	0	0	28	9.4
Carcharhinus tilstoni	37	7.4	2	2.1	0	0	35	11.8
Pristis microdon	28	6.2	15	16.0	7	6.3	6	2.0
Himantura chaophraya	27	5.4	7	7.4	9	8.1	11	3.7
Rhinoptera neglecta	21	4.2	0	0	0	0	21	7.1
Pristis clavata	19	3.8	15	16.0	1	0.9	3	1.0
Unid. *Carcharhinus* sp.	16	3.2	0	0	0	0	16	5.4
Carcharhinus amblyrhynchoides	14	2.8	3	3.2	1	0.9	10	3.4
Rhizoprionodon taylori	11	2.2	0	0	8	7.2	3	1.0
Rhinobatos typus	11	2.2	0	0	0	0	11	3.7
Himantura granulata	7	1.4	7	7.4	0	0	0	0
Carcharhinus fitzroyensis	6	1.2	0	0	1	0.9	5	1.7
Himantura uarnak	5	1.0	5	5.3	0	0	0	0
Sphyrna mokarran	5	1.0	1	1.1	0	0	4	1.3
Rhizoprionodon acutus	4	0.8	0	0	3	2.7	1	0
Rhynchobatus australiae	4	0.8	0	0	0	0	4	1.3
Carcharhinus limbatus	3	0.6	2	2.1	1	0.9	0	0
Himantura undulata	3	0.6	2	2.1	0	0	1	0.3
Pastinachus sephen	3	0.6	0	0	0	0	3	1.0
Pristis zijsron	3	0.6	0	0	0	0	3	1.0
Anoxypristis cuspidata	2	0.4	0	0	2	1.8	0	0
Carcharhinus dussumieri	2	0.4	0	0	0	0	2	0.7
Aetomylaeus nichofii	1	0.2	0	0	0	0	1	0.3
Carcharhinus amboinensis	1	0.2	1	1.1	0	0	0	0
Carcharhinus melanopterus	1	0.2	0	0	0	0	1	0.3
Carcharhinus plumbeus	1	0.2	1	1.1	0	0	0	0
Galeocerdo cuvier	1	0.2	0	0	1	0.9	0	0
Himantura sp. A	1	0.2	1	1.1	0	0	0	0
Himantura toshi	1	0.2	0	0	0	0	1	0.3
Rhinoptera javanica	1	0.2	0	0	1	0.9	0	0
Sphyrna lewini	1	0.2	0	0	0	0	1	0.3
Eusphyra blochii	1	0.2	0	0	0	0	1	0.3
Rhizoprionodon oligolinx	1	0.2	0	0	1	0.9	0	0
Total number of individuals	**502**		**94**		**111**		**297**	

Table 7: Elasmobranch catch composition by bioregion (Interim Marine and Coastal Regionalisation for Australia, Technical Group 1998).

Species	North Western Biotone		Northern Province		North Eastern Biotone	
	n	**% comp.**	**n**	**% comp.**	**n**	**% comp.**
Carcharhinus amblyrhynchoides	3	2.3	11	3.2	0	0
Carcharhinus amboinensis	1	0.8	0	0	0	0
Carcharhinus cautus	11	8.3	28	8.0	0	0
Carcharhinus dussumieri	0	0	2	0.6	0	0
Carcharhinus fitzroyensis	0	0	1	0.3	5	25
Carcharhinus leucas	44	33.1	76	21.8	6	30
Carcharhinus limbatus	2	1.5	1	0.3	0	0
Carcharhinus melanopterus	0	0	1	0.3	0	0
Carcharhinus plumbeus	1	0.8	0	0.0	0	0
Carcharhinus tilstoni	2	1.5	35	10.0	0	0
Galeocerdo cuvier	0	0	1	0.3	0	0
Negaprion acutidens	4	3.0	51	14.6	0	0
Rhizoprionodon acutus	0	0	4	1.1	0	0
Rhizoprionodon oligolinx	0	0	1	0.3	0	0
Rhizoprionodon taylori	0	0	11	3.2	0	0
Unid. *Carcharhinus* sp.	0	0	16	4.6	0	0
Eusphyra blochii	0	0	1	0.3	0	0
Sphyrna lewini	0	0	1	0.3	0	0
Sphyrna mokarran	1	0.8	4	1.1	0	0
Rhinobatos typus	0	0	11	3.2	0	0
Rhynchobatus australiae	0	0	4	1.1	0	0
Anoxypristis cuspidata	0	0	2	0.6	0	0
Pristis clavata	16	12.0	3	0.9	0	0
Pristis microdon	17	12.8	10	2.9	1	5
Pristis zijsron	0	0	3	0.9	0	0
Himantura sp. A	1	0.8	0	0	0	0
Himantura chaophraya	15	11.3	6	1.7	6	30
Himantura granulata	7	5.3	0	0	0	0
Himantura toshi	0	0	1	0.3	0	0
Himantura uarnak	5	3.8	0	0	0	0
Himantura undulata	2	1.5	0	0	1	5
Pastinachus sephen	0	0	2	0.6	1	5
Aetobatus narinari	1	0.8	39	11.2	0	0
Aetomylaeus nichofii	0	0	1	0.3	0	0
Rhinoptera javanica	0	0	1	0.3	0	0
Rhinoptera neglecta	0	0	21	6.0	0	0
Total number of individuals	**133**		**349**		**20**	

5.2 Influence of salinity on species distribution

To describe the influence of salinity on distribution and partitioning of species throughout a catchment, the salinity at each site was categorised and the abundance of the species within each category presented (Appendix 4, Tables 1-3). The number of sites sampled during this survey within each salinity interval are shown in Figure 3. The majority of sites sampled were in salinities of 5 ppt or less.

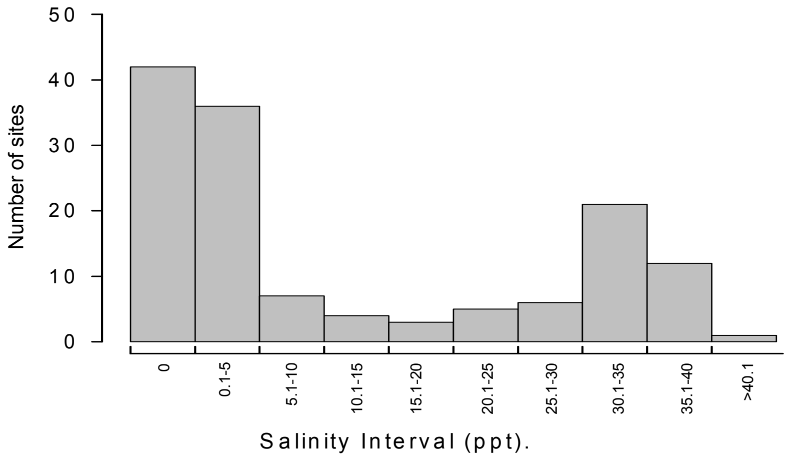


Figure 3: The number of sample sites at each salinity level.

The salinity category of 0 ppt represents a large part of the middle and upper catchment that is 'pure' freshwater. The 0.1-5 ppt interval includes any waters with even the slightest measure of salinity. On several occasions, a small quantity of salt was detected in the water at sites several hundred kms inland, such as on the Roper River where 0.8 ppt was recorded. The 0.1-5 ppt interval thus contains some sites that are essentially freshwater.

The number of individuals of each of the six priority species caught at each salinity interval are shown in Figures 4a-f. (the percentage occurrence of each species at each salinity interval is given in Appendix 4, Table 2). A large proportion *of C. leucas* were caught in freshwater and waters below 5ppt, however they were also present in saltwater. Higher numbers of *H. chaophraya* and *P. microdon* were caught in freshwater, and fewer were encountered as the salinity increased (Figures 4b and 4c). These 'species were, however, still recorded from salt-influenced waters. In contrast, the numbers of *P. clavata* were highest in higher salinity waters (Figure 4d). Although the number of *Pristis zijsron* and *Anoxypristis cuspidata* encountered were low, these species were only recorded from higher salinity waters (Figures 4e and 4f).

The number of individuals of the six most abundant species (excluding the six priority species and *Carcharhinus* sp.) caught at each salinity interval are presented in Figure 5. These six species (Figures 5a -f) were all only encountered in saltwater (30 ppt or more), and in a narrower salinity range than *P. microdon, H. chaophraya* and *C. leucas* that were commonly associated with freshwater.

Due to variations in sampling techniques and fishing effort, abundance data cannot be accurately represented. However, the average number of individuals of each species caught at each site within each salinity interval provides some information on the species distribution with respect to salinity. These data for the six priority species and six most abundant species are presented in Figures 6a-f and 7a-f (see also Appendix 4, Table 3). The relative abundance of *C. leucas* appears, to some extent, evenly distributed throughout the salinity intervals, although catches at low salinity sites remain marginally higher (Figure 6a). The highest catches of *H. chaophraya* and *P. microdon* occurred in waters of between 5.1 and 10 ppt, in upper-estuary riverine reaches (Figure 6b and c). In contrast, there was a low average catch of *P. clavata.* Although, an average of nine individuals per site are represented in the >40.1ppt salinity interval, these specimens were all collected from one site (Figure 6d). There were only low catches of *P. zijsron* and *A. cuspidata* (Figures 6e and 6f).

While the six most abundant species were only encountered in a narrow salinity range (representative of lower estuaries), they were generally in higher abundance than the priority species (with the exception of *C. leucas*) (Figures 7 a-f).

Figure 4(a-f): The total number of individuals of the six priority species caught at each salinity interval during this study. The number of sites sampled at each salinity interval are given in parenthesis

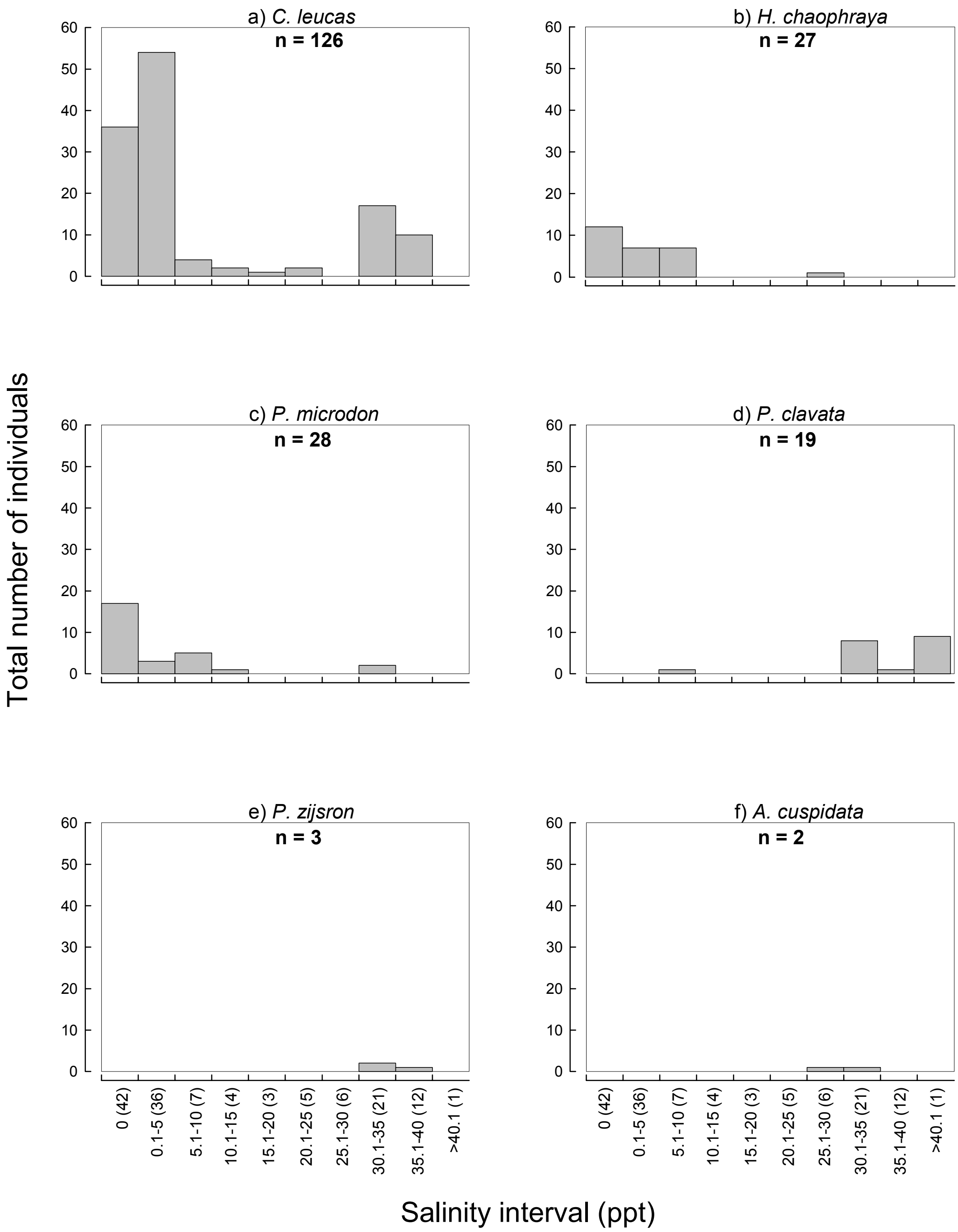


Figure 5(a-f): The total number of individuals of the six most abundant species (excluding the priority species) caught at each salinity interval during this study. The number of sites sampled at each salinity interval are given in parenthesis.

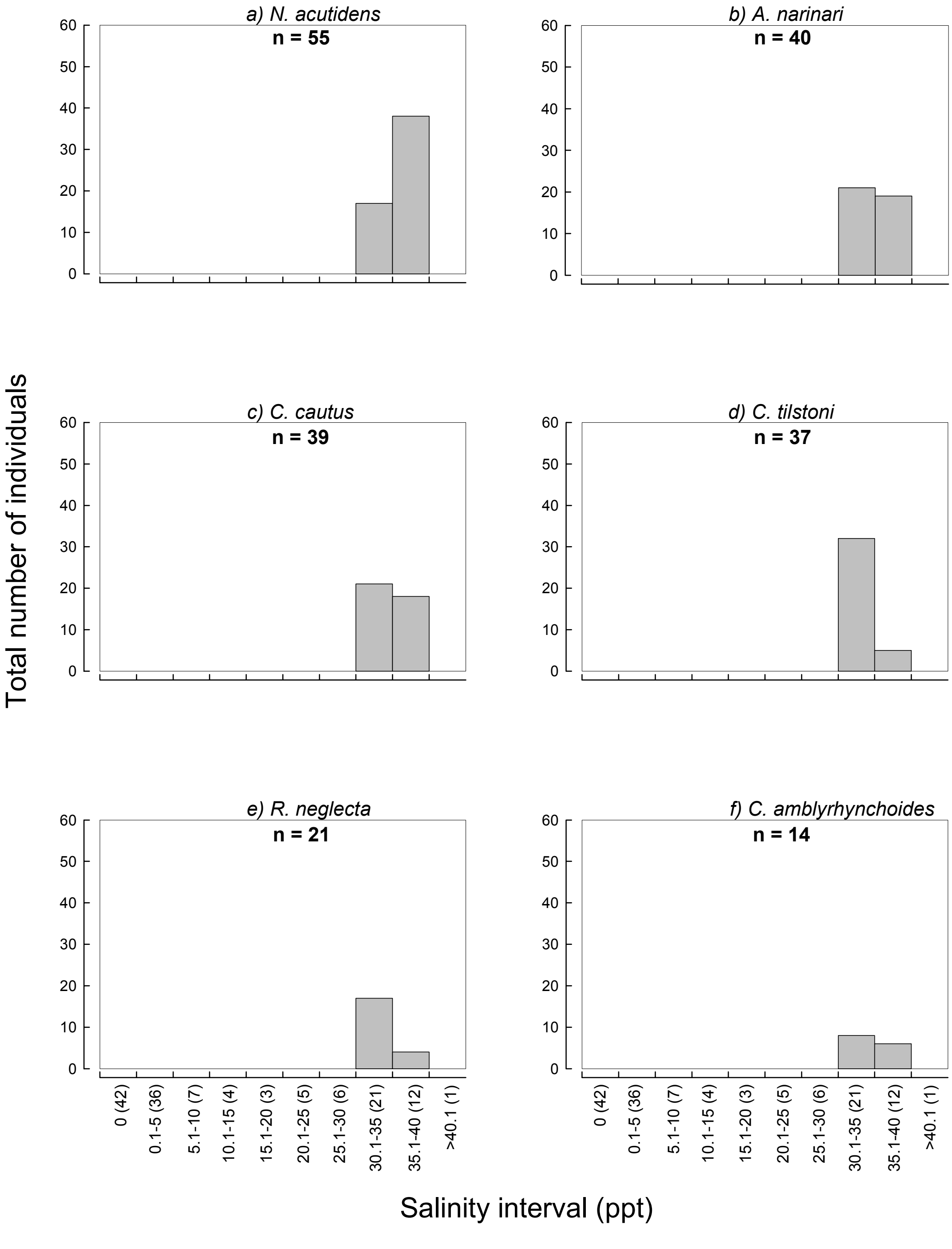


Figure 6(a-f): The average number of individuals caught at each site within each salinity interval for the six priority species targeted during this study. The number of sites sampled at each salinity interval are given in parenthesis.

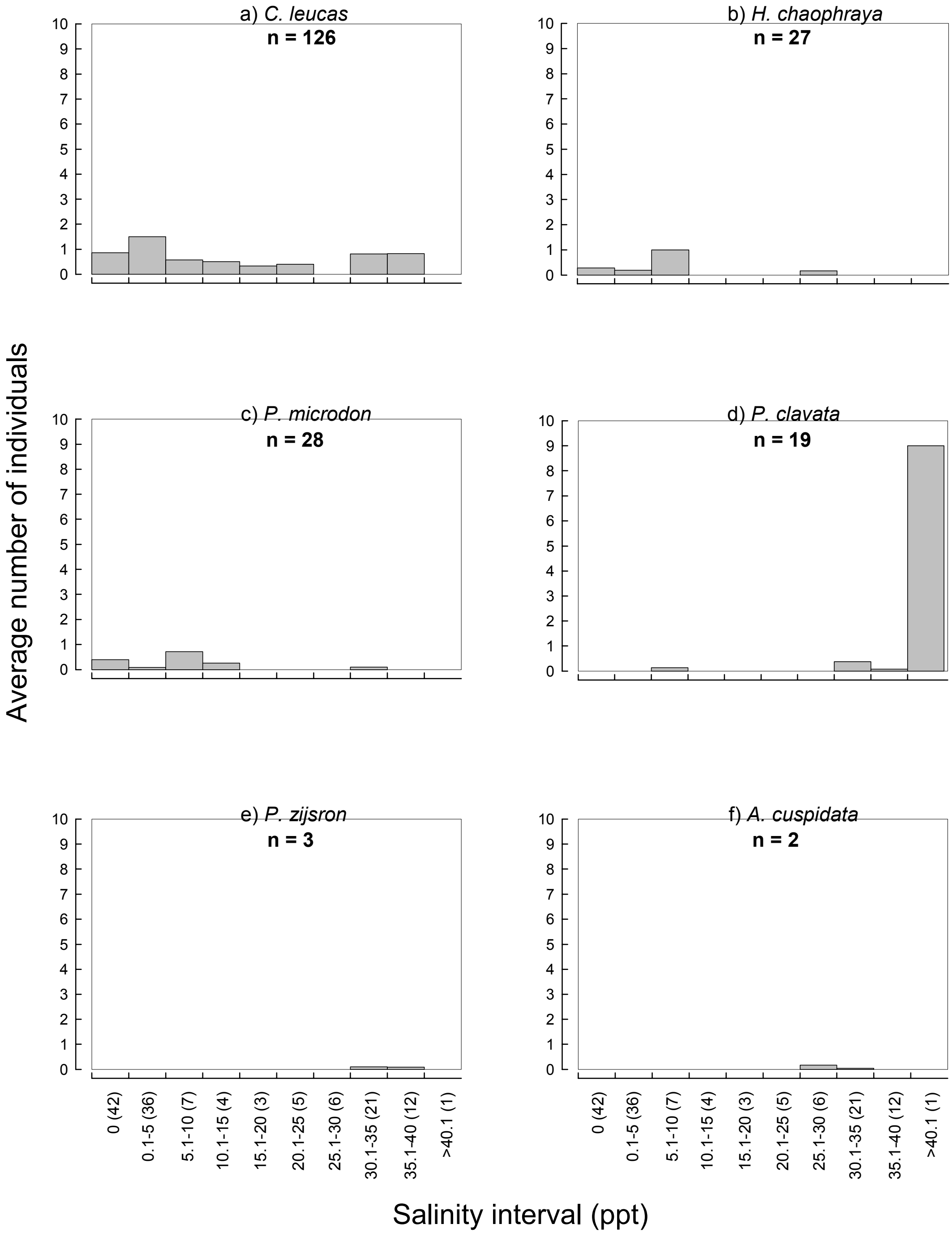
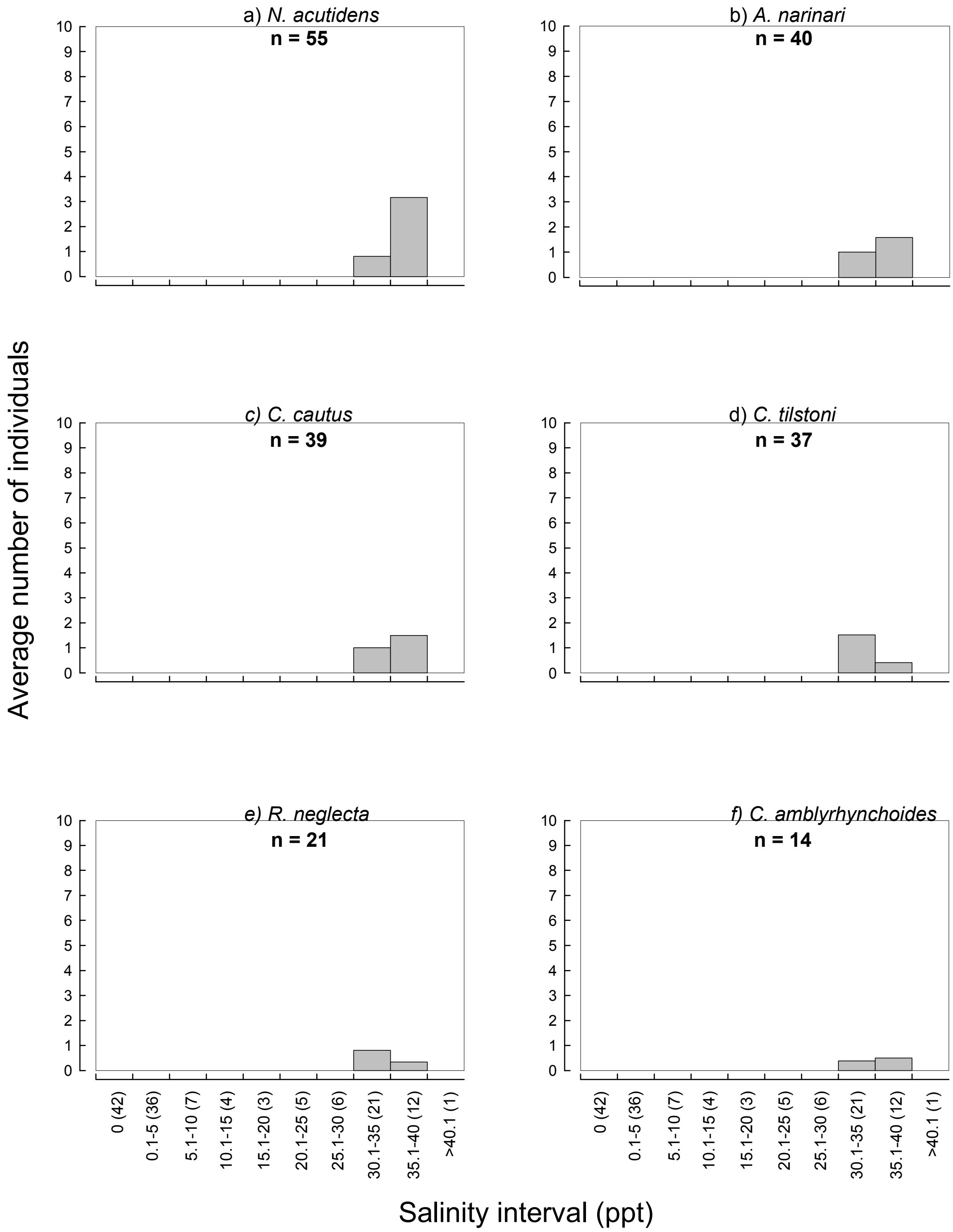


Figure 7(a-f): The average number of individuals caught at each site within each salinity interval for the six most abundant species encountered during this study (excluding priority species). The number of sites sampled at each salinity interval are given in parenthesis.



6 SPECIES SYNOPSES

The following species synopses cover the priority elasmobranchs for this project, and are a compilation of distributional and biological data obtained throughout this study.

6.1 Estuarine and freshwater elasmobranchs:

Pristis microdon
Himantura chaophraya
Glyphis sp. C
Carcharhinus leucas

6.2 Other priority species:

Pristis clavata
Anoxypristis cuspidata
Pristis zijsron

6.3 Estuarine and freshwater elasmobranchs

6.3.1 Freshwater sawfish (*Pristis microdon*)

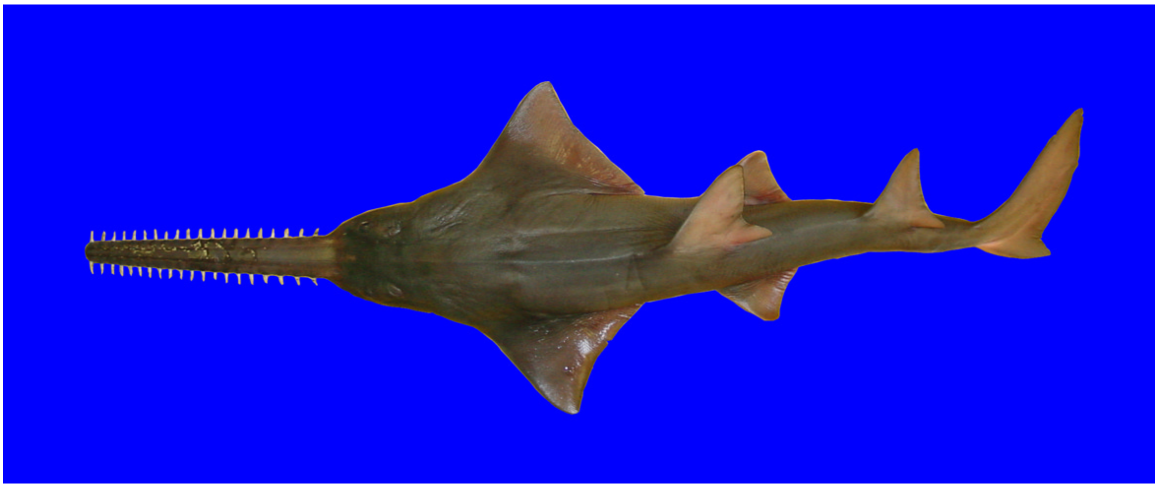


Plate 1 *P. microdon* (1587 mm TL). Photograph: Dean Thorburn.

Distribution: The freshwater sawfish (Plate 1) was encountered in 12 of the river systems sampled, between the Fitzroy River in Western Australia and Normanby River in Queensland (Figures 8 and 9). This species was captured near river mouths, such as the Robinson River (WA), and also encountered several hundred kms from the sea, such as at Elsey Station on the Roper River (site 41) and Geike Gorge (over 350 km from the sea) on the Fitzroy River (site 134). Additional data collected by Morgan *et al*. (2002) indicated the presence of this species in Margaret River Gorge (a tributary of the Fitzroy River), over 400 km inland.

Physical Habitat: During this study, the freshwater sawfish was caught in the main channel, larger tributaries and in backwaters, in lower, middle and upper riverine reaches. This species was most commonly encountered over finer substrates, such as sand and silt (Appendix 5, Table 1). Field notes indicated that it was usually caught in a deeper section of a river adjacent to a sand or silt shallow, such as a sandbar or shallow backwater. It was recorded from waters ranging in depth from 0.7 m (the deepest section of sample site 99 in the Robinson River, WA, at the bottom of the tide) to 6 m and was encountered in both tidal and non-tidal reaches with generally low flow rates.

Water Chemistry: This species was mainly collected from fresh or low salinity water (<10 ppt). However, one site (99) on the Robinson River (WA) was 35 ppt. This site also had the highest turbidity (secchi disc reading of 5 cm) and temperature (32.5^{o}C), and the lowest levels of dissolved oxygen (4.3 mgL^{-1}) of any site at which *P. microdon* was collected. Although this species was found in both turbid and clear water, capture sites were generally clear, and had relatively high dissolved oxygen levels.

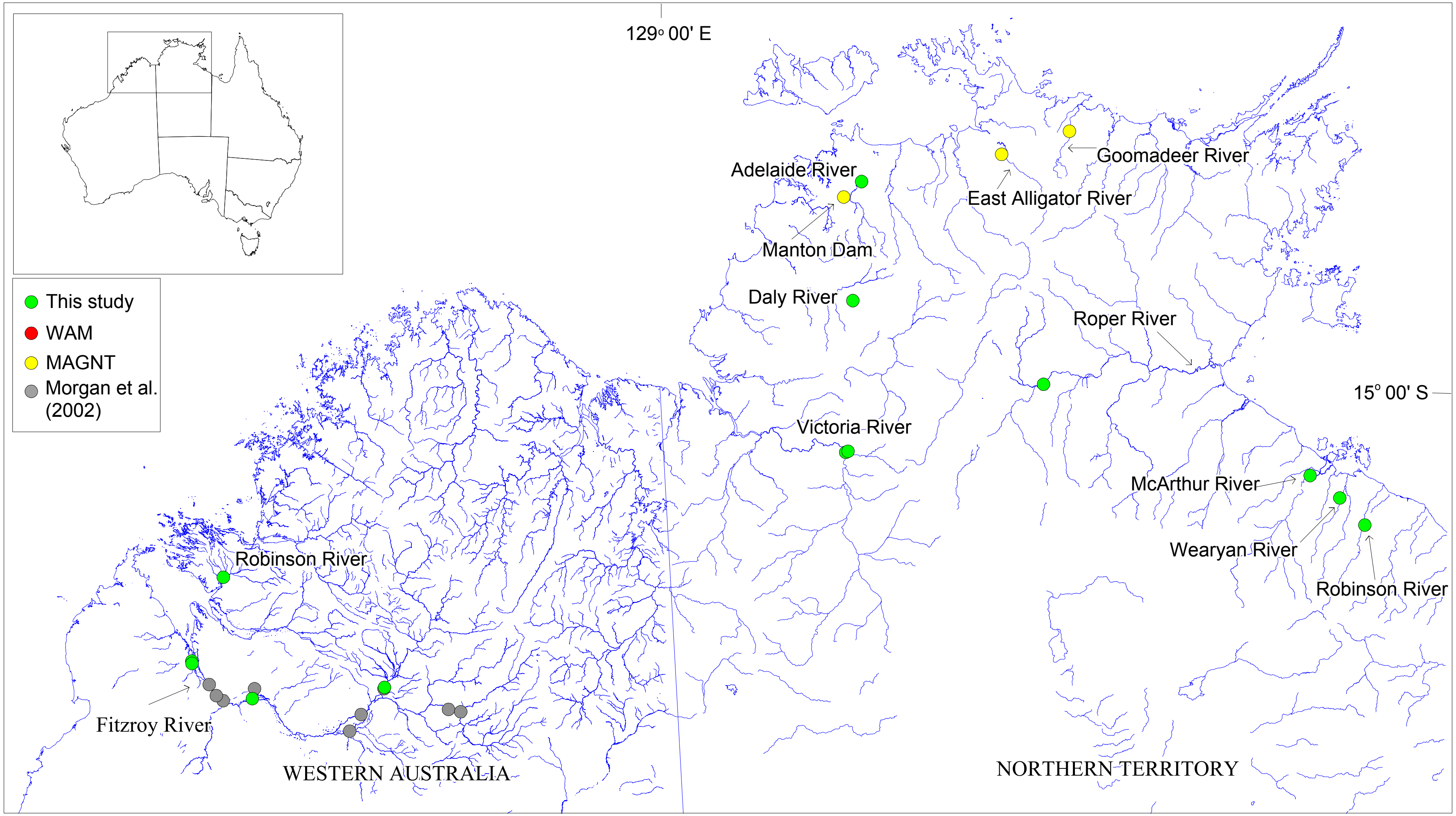


Figure 8: The sites in WA and NT at which *P. microdon* was captured during this study, including records from the Museum and Art Galleries of the Northern Territory (MAGNT) and Morgan *et al.* (2002).

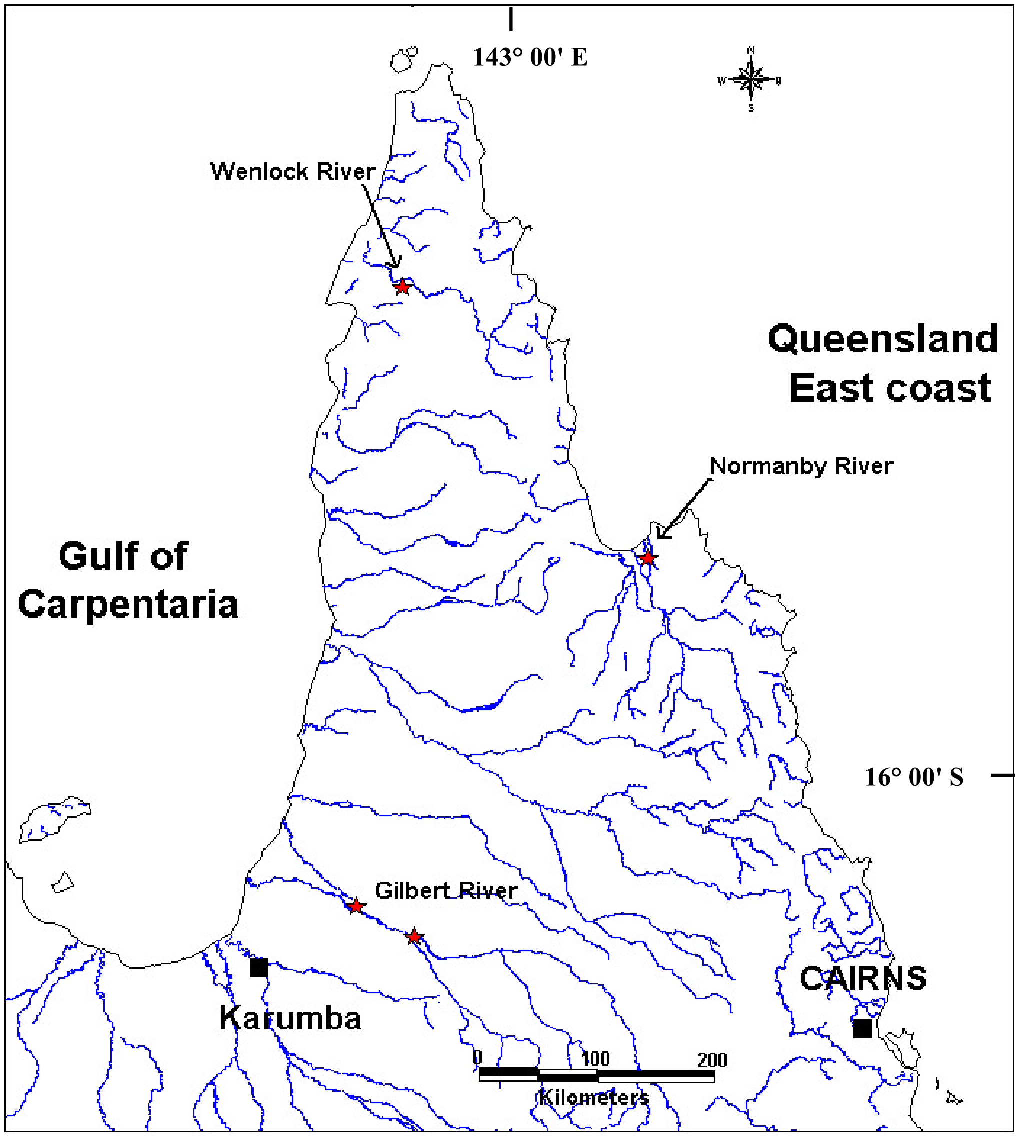


Figure 9: Sites in Queensland at which P. microdon was captured during this study.

Size: Specimens captured during this study ranged from 832 – 2612 mm TL, both the smallest and largest specimens being female. While it was not possible to determine the maturity state of females, lengths of non-calcified claspers (46 – 91 mm) of captured males (1472 – 2160 mm TL) indicated that they were all immature. As this species may attain 7 m TL, the limited size range we encountered may reflect the use of rivers by juveniles.

Other: The consistent capture of freshwater sawfish in the Fitzroy River in this survey, and their relatively higher abundance in this system may indicate that this is a significant 'stronghold' for the species. However, at one site sampled on the Fitzroy River, Telegraph Pool (site 91), 12 specimens were observed dead on the sand banks of this popular fishing destination (Plate 2 and 3), some of which had fishing line and hooks attached (Plate 4). A witness to the catching and killing of several other sawfish stated that it was to retrieve the hooks. Researchers also witnessed the killing of one specimen, for the removal of the fishers hook and the 'trophy' rostrum (similar to Plate 5). More dead sawfish were recorded on the return of researchers to Telegraph Pool three weeks later; three bull sharks and one freshwater whipray had also been caught and killed. These specimens were not included in the catch data, but further emphasise the significant numbers of freshwater sawfish encountered in the Fitzroy River and the need for conservation measures to be implemented.

One specimen captured during an afternoon set from site 76 on the Victoria River was recaptured at site 77, about 4 km downstream, some 13 hours later. Interestingly, no other individuals were taken from the six sites sampled in this river.

An 868 mm TL freshwater sawfish (Plate 6) collected from the Wearyan River (site 68), had an evident, but well healed umbilical scar (Plate 7). This site was several kms from the tidal limit, where the river became a series of large pools interconnected by a shallow riffle. The specimen was caught in early August, when river levels were heavily contracted, and its emaciated appearance may indicate that it had resided in the pool for some time. This animal may have become trapped after travelling upstream following its birth during the wet season, or it may have been born in freshwater as a large, deep pool capable of sustaining an adult was connected to this site.

Like all sawfish, this species is susceptible to capture with gill nets and all specimens in this survey were caught by this method (Appendix 5, Table 1). Mesh size appeared to be unrelated to the size of the specimens captured, due to entanglement of the rostrum. Gill netting in other parts of the world has posed a major threat to populations of sawfish.

A large degree of colour variation was observed in collected individuals. The trunks of animals collected further inland, and in clear waters, were commonly a deeper green (and on several occasions almost black). Specimens from Telegraph Pool (site 91) tended to be lighter green or yellow/brown. Fins are more uniformly yellowish.

Anecdotal Reports: The presence of this species in Lake Kununarra (above the diversion dam wall on the Ord River) has been reported. This is a closed system, bordered upstream by the Lake Argyle Dam. Steven Macintosh, a local wilderness and fishing guide who accompanied researchers for a period during the survey, captured two specimens on separate occasions from Emu Creek, and another from the west side of the Lake. He speculates that they entered through the connection with the Keep River floodplain during the wet season. A small specimen was observed by another source while snorkelling in Spillway Creek (near site number 105) only days before we sampled there.

Plate 2 Dead sawfish at Telegraph Pool

Plate 3 Dead sawfish at Telegraph Pool

Plate 4 Fishing tackle in the sawfish

Plate 5 Sawfish with rostrum removed

Plate 6 Small sawfish (868 mm TL)

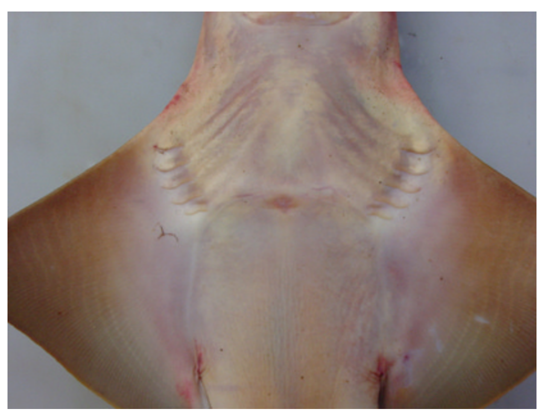


Plate 7 Umbilical scar on 868 cm TL specimen

6.3.2 Freshwater whipray (*Himantura chaophraya*)

Plate 8 *H. chaophraya* (426 mm DW). Photograph: Dean Thorburn

Distribution: The freshwater whipray (Plate 8) was encountered in six of the river systems sampled between the Fitzroy River in Western Australia, and the Normanby River in Queensland (Figure 10 and 11).

Physical Habitat: This species was encountered in lower and middle reaches of the main channel of rivers over sparsely covered finer substrates, such as sand and silt (Table2, Appendix 5). The freshwater whipray was observed in the Daly and Fitzroy Rivers in shallow depths of 0.3-1.0 m, and was caught in a maximum depth of 3.5 m. It was encountered in both tidal and non-tidal river reaches, and in flow rates of up to 0.7 ms^{-1}.

Water Chemistry: Although most commonly encountered in waters of low salinity, one specimen was taken from the Roper River estuary (site 49) in 26.1 ppt. It was present in both turbid and very clear waters, and in temperatures from 22.3 and 31.3^{o}C, with dissolved oxygen values of about 7 mgL^{-1}.

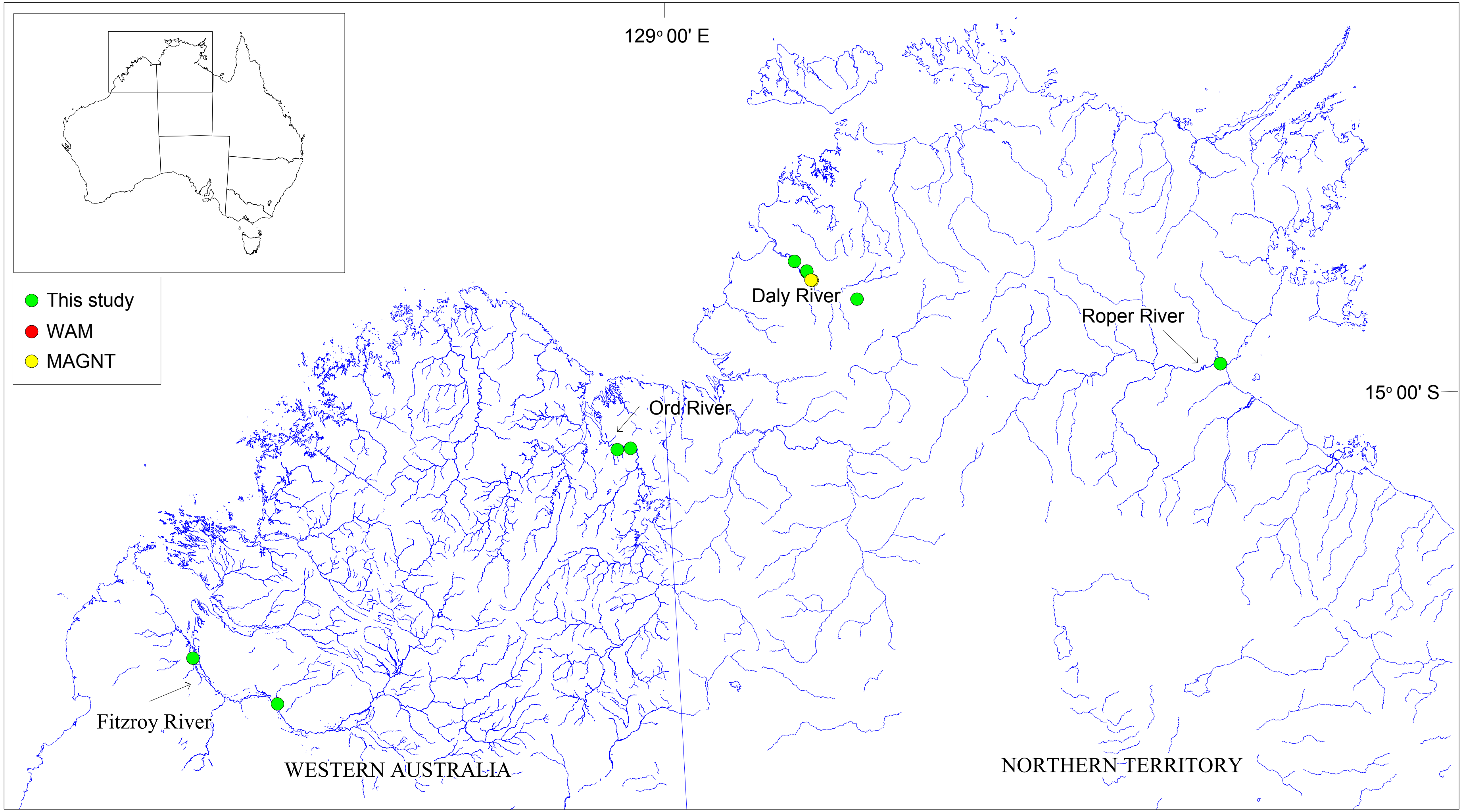


Figure 10: The sites in WA and NT at which *H. chaophraya* was captured during this study, including records from the Museum and Art Galleries of the Northern Territory (MAGNT).

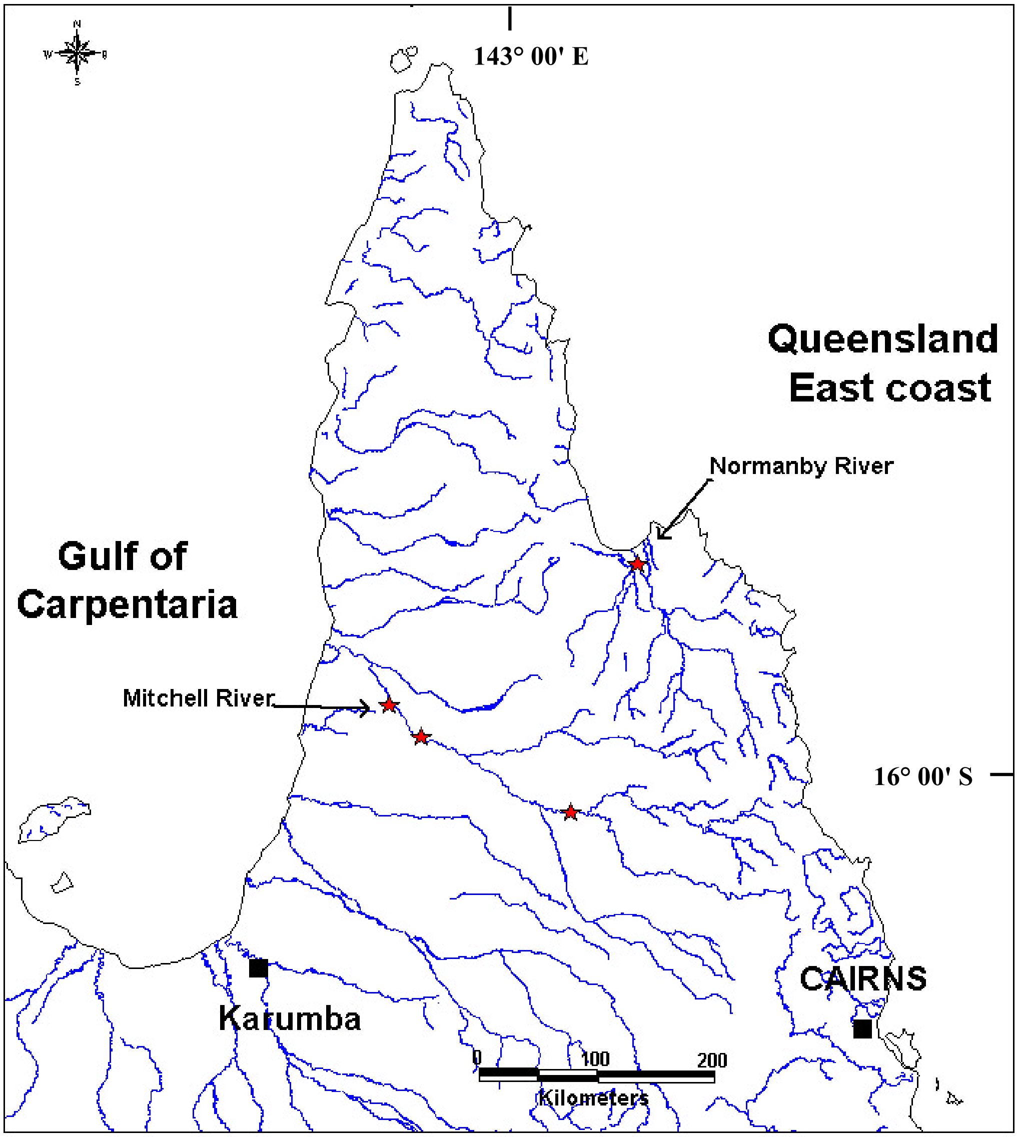


Figure 11: Sites in Queensland at which *H. chaophraya* was captured during this study.

Size: The freshwater whiprays ranged in disc width (DW) from 426 – 1240 mm (the latter being the largest specimen recorded from Australian waters) (Plate 9). Most of the specimens caught were less than 1 m DW.

Other: It was not uncommon for several individuals to be encountered at the one sample site. Although only five individuals were captured, many rays were observed feeding (and subsequently pursued) on three consecutive days, near dusk, on a large sand bar on the Daly River (site 34). Similarly, four individuals were taken at site 109 (Ord River) (three from site 119 (Mitchell River) and six from site 129 (Normanby River).

All specimens in Western Australia were caught by long-line, handline, or by hand (Table 2, Appendix 5).

Anecdotal Reports: Several sources described rays feeding along the banks of the Daly, Ord and Fitzroy Rivers during the wet season. The rays have been reported to charge up the banks in a wash of water, feeding on small fish or shrimp that were caught in the wash, then working their way back into the river.

Although no freshwater whiprays were recorded from Arnhem Land, Charles Godjwa, a Djelk Ranger with the Bowanunga Aboriginal Corporation who accompanied the research party, described seeing rays at the Blythe River road crossing (near site 11) a few months earlier than the time of sampling. Water levels would have been higher during this period (late wet).

Although numerous animals were recorded from the Daly River, one source described seeing several rays moving downstream at the junction of the Katherine and King Rivers (tributaries of the Daly River), two weeks before we sampled there (site 28). Other sources reported the presence of rays even further upstream at the Lower Level Crossing at Katherine, although these had not been seen for some years.

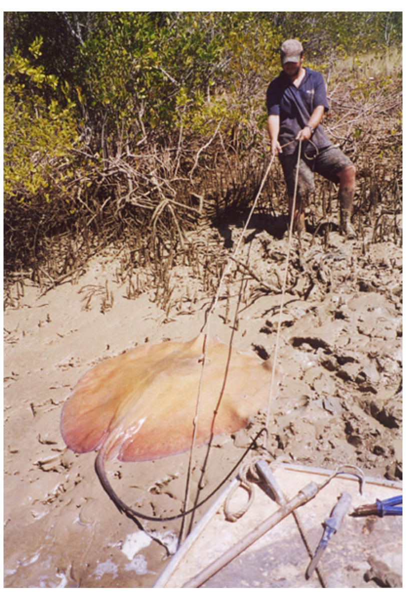


Plate 9. The largest (1240 mm DW) freshwater whipray caught during the survey (caught in 26.1 ppt in the Roper River).

6.3.3 Northern river shark (*Glyphis* sp. C)

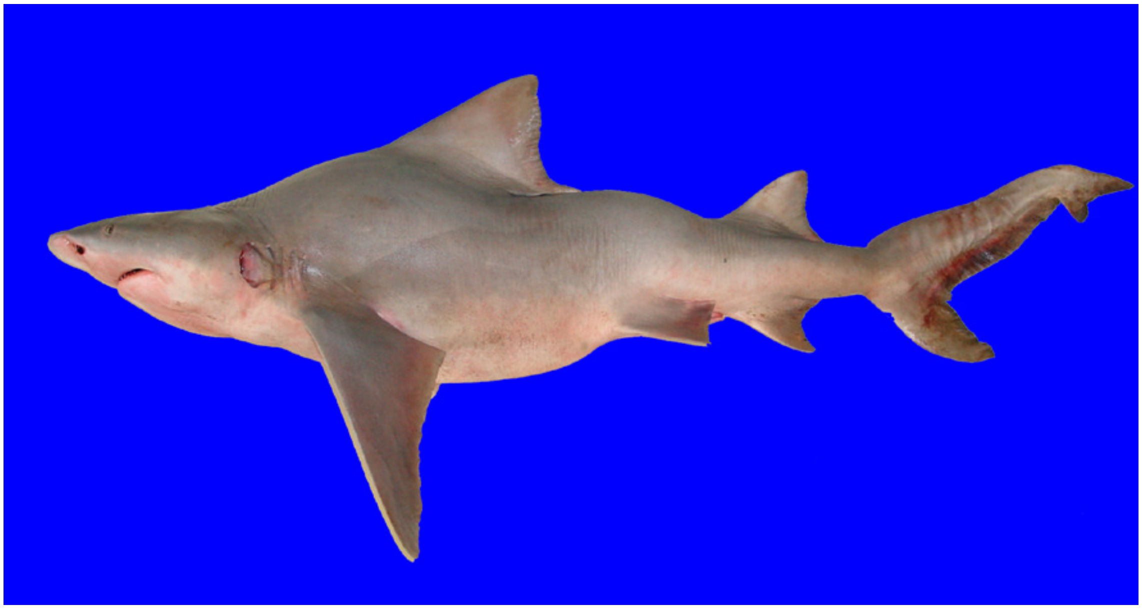


Plate 10 *Glyphis* sp. C (998 mm TL). Photograph: William White

Distribution: Previously known only from the East and South Alligator Rivers and Adelaide River, NT, one specimen was collected from Doctors Creek (north of Derby, WA) (Figure 12).

Physical Habitat: This area is subject to high tidal influence (over 10 m). The rivers and creeks in this region are characterised by silt bottoms, and due to the high tidal influence are commonly devoid of much instream structure.

Water Chemistry: The specimen was collected from waters of 36.6 ppt. Due to the high tidal influence, waters are subject to large variations in salinity with hypersaline conditions often occurring in the upper reaches of the tidal feeders.

Size: The Doctor's Creek specimen was 998 mm TL. The adult male taken from the South Alligator River was about 1.5 m TL suggesting that this species is an medium-sized carcharhinid.

Other: The Kimberley specimen was collected by Dr David Morgan (Murdoch University, Western Australia) during a research project on barramundi (*Lates calcarifer)* in Doctors Creek. We had asked Dr Morgan to collect sharks for us during his work in north western rivers. On the return of the frozen specimen to Murdoch University, the specimen was identified by one of us (Dean Thorburn) as *Glyphis sp. C*.

As can be seen in Plate 10, and subsequently verified by X-ray, this specimen has an atypical curvature of the spine.

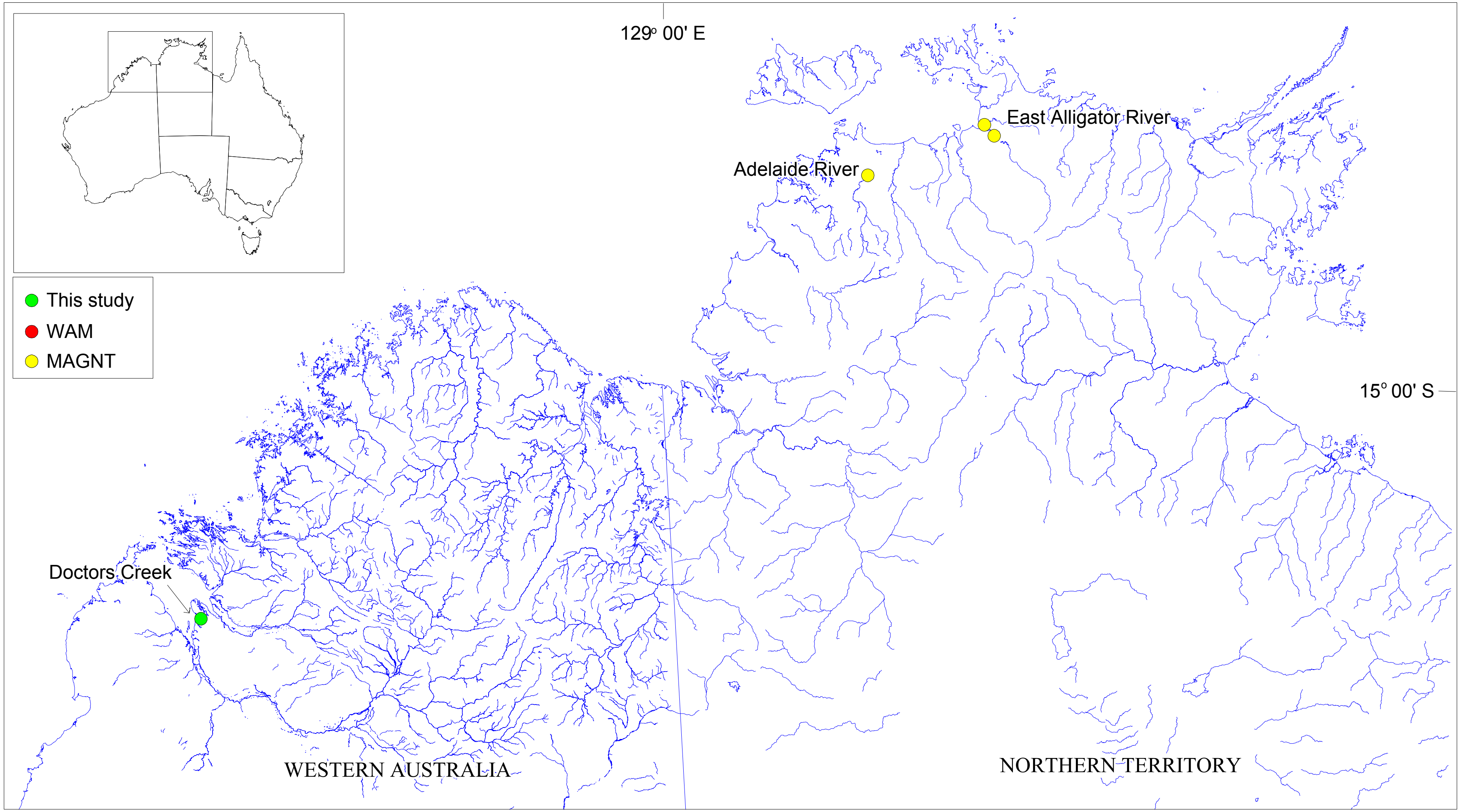


Figure 12: The sites in WA and NT at which *Glyphis* sp. C was captured during this study (in conjunction with Morgan *et al*. 2002), including records from the Museum and Art Galleries of the Northern Territory (MAGNT).

6.3.4 Bull shark (Carcharhinus *leucas*)

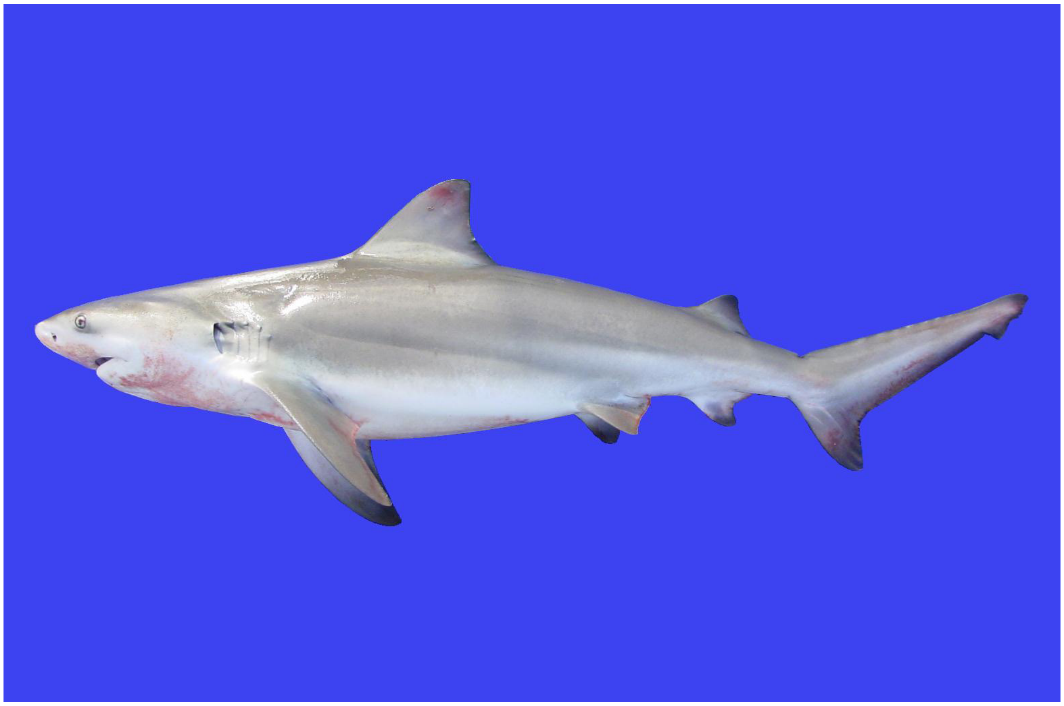


Plate 11 *C. leucas* (804 mm TL). Photograph: Dean Thorburn

Distribution: The bull shark (Plate 11) was encountered in 15 of the river systems sampled, between the Fitzroy River in Western Australia and the Normanby River in Queensland (Figures 13 and 14). This species was captured from river mouths, and was commonly encountered over 100 kms from the sea. On several occasions aggregations of juveniles were encountered at the first major upstream restriction of the river channel, such as a rock bar, road crossing or barrage. These aggregations might indicate that this species would travel much further inland if unimpeded.

Physical Habitat: This highly mobile shark was encountered at sites in both the main channel and in tributaries, in lower and middle riverine reaches. It was widespread over a range of habitats, including all substrate categories, and there was no evident habitat preference (Table 3, Appendix 5). The bull shark was commonly encountered in upper tidally effected reaches, and in flow rates that ranged from negligible to $0.5ms^{-1}$. Capture depths were generally less than 5 m, however one specimen was taken by a sunken long-line from a 21 m deep hole in the Roper River.

Water Chemistry: The bull shark was encountered at salinities ranging from zero to 37.3 ppt, however it was most commonly found in brackish and fresh waters, which reflects the general distance upstream that it occurred. This species was collected from both highly turbid lower estuarine sites (Robinson River, WA; 5 cm secchi depth), to waters with a high clarity of 273 cm secchi depth in the Daly River. It was present in

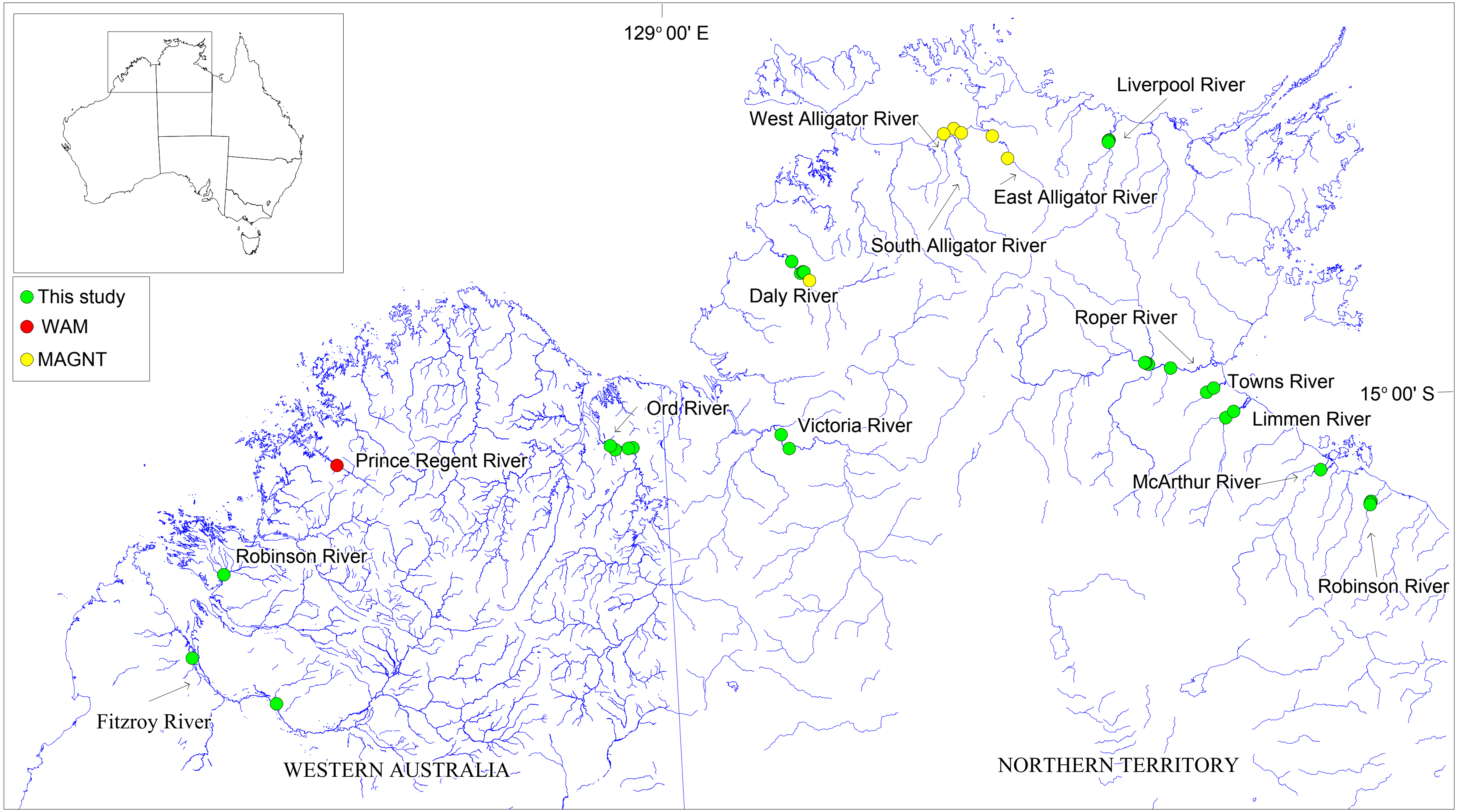


Figure 13: The sites in WA and NT at which *C. leucas* was captured during this study, including records from the Western Australian Museum (WAM), and the Museum and Art Galleries of the Northern Territory (MAGNT).

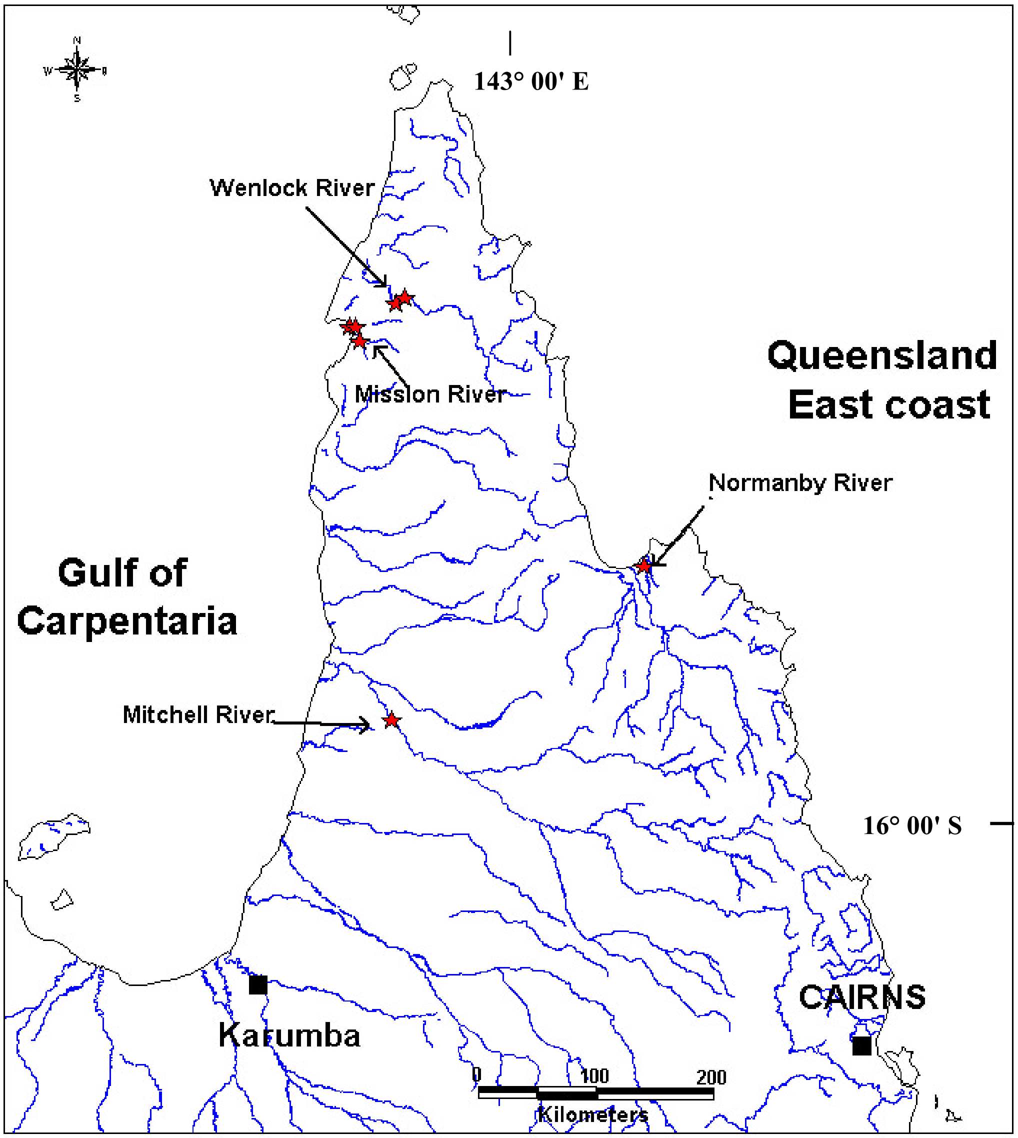


Figure 14: Sites in Queensland at which C. leucas was captured during this study.

waters ranging from 22.1 – 32.5°C that had generally high dissolved oxygen (approximate average over 7 mgL^{-1}).

Size: Captured specimens ranged from 687 – 1500 mm TL. Approximately 75% of the individuals were less than 1 m in length, and several of the smaller specimens had a distinct umbilical scar (Plate 12). Although no work on the maturity of this species has been conducted in Australia, it can be assumed from other studies that all these individuals were immature (Last and Stevens, 1994).

Other: The bull shark was the most common elasmobranch encountered (126 individuals caught), with high numbers recorded from the Daly River (26 individuals) and the Mission River (20 individuals). This species was effectively caught by gill nets and long-lines, and readily took a baited hook. On numerous occasions, several individuals were caught in a single gill net or long-line set. Teleost fishes caught in the gill net were often bitten in half by bull sharks, which on numerous occasions caused them to become entangled. The voraciousness of the species was also witnessed on the Daly River when a specimen hooked on a hand line was pursued and attacked by other bull sharks.

Plate 12 Umbilical scar on small bull shark.

4.2 Other Priority Species

6.3.5 Dwarf sawfish (*Pristis clavata*)

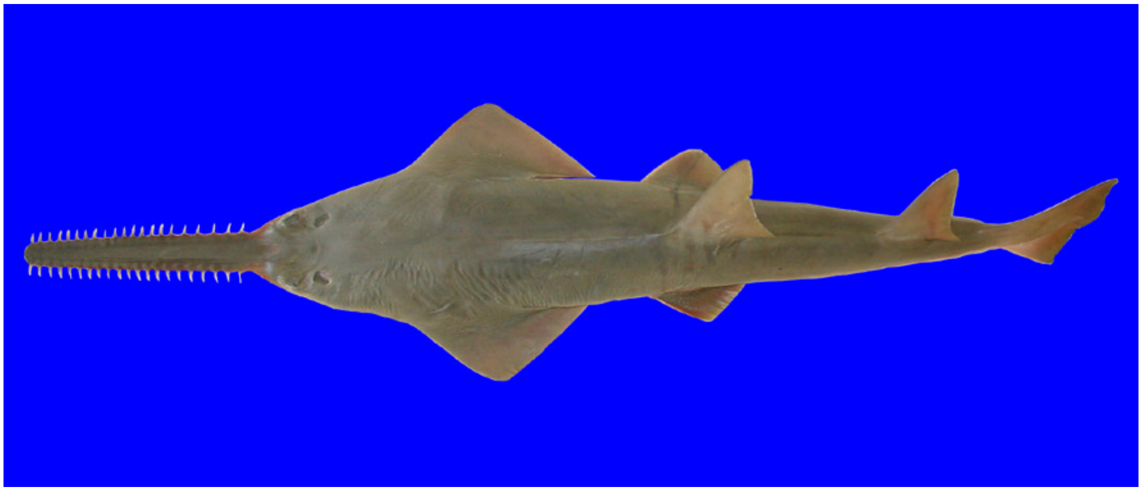


Plate 13 *P.* clavata (1123 mm TL). Photograph: Dean Thorburn

Distribution: The dwarf sawfish (Plate 13) was encountered from the May River in Western Australia to the Mission River in Queensland (Figures 15 and 16). However, Morgan *et al*. (2002) recorded this species further south, in the Fitzroy River (Telegraph Pool). Although most commonly encountered in estuaries, one specimen was taken in the Victoria River over 100 kms from the sea. Distributional knowledge of this species was particularly poor prior to this study and the Mission River record constitutes the first formal account of the species from Queensland since its discovery in 1906.

Physical Habitat: All individuals were caught over fine substrates (mainly silt) in sections of the river channels almost completely devoid of instream structure (Table 4, Appendix 5). The tidal reaches from which these individuals were caught ranged in depth from 0.7 – 3 ms^{-1}. Flow rates varied from negligible to high, and at times excessive due to large 10 m tides in the May and Robinson Rivers (sites 98 and 99). Sampling at the site on the May River was subject to a tidal bore.

Water Chemistry: Excluding one specimen caught in the Victoria River (9.7 ppt)**,** all dwarf sawfish were taken from saltwater (up to 41.1 ppt) at lower estuarine sites with high turbidity (where measured) and low dissolved oxygen.

Size: Specimens ranged from 915 – 2332 mm TL. The documented maximum size of this species, thought to be at least 140 cm (Last and Stevens, 1994), was based on limited material available at the time. However, approximately 75% of the animals caught during this survey were greater than this length and several of the animals exceeded 2000 mm. A 2332 mm TL male is the largest known specimen of the species. Like all other males caught, it had short claspers that indicate immaturity. This suggests that adult *P. clavata* are likely to attain 2.5 m or more in length.

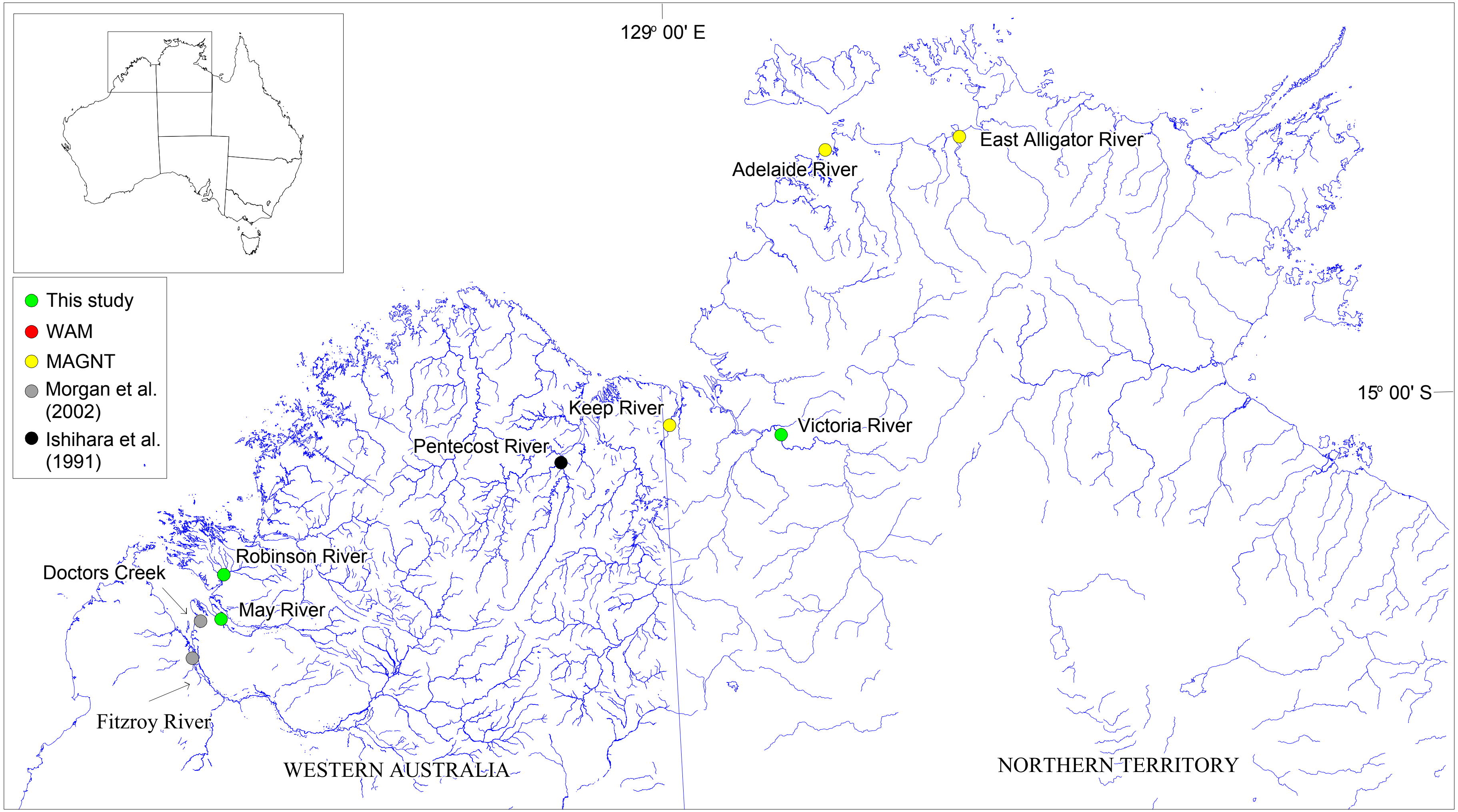


Figure 15: The sites in WA and NT at which *P. clavata* was captured during this study, including records from the Museum and Art Galleries of the Northern Territory (MAGNT), Ishihara *et al.* (1991) and Morgan *et al.* (2002).

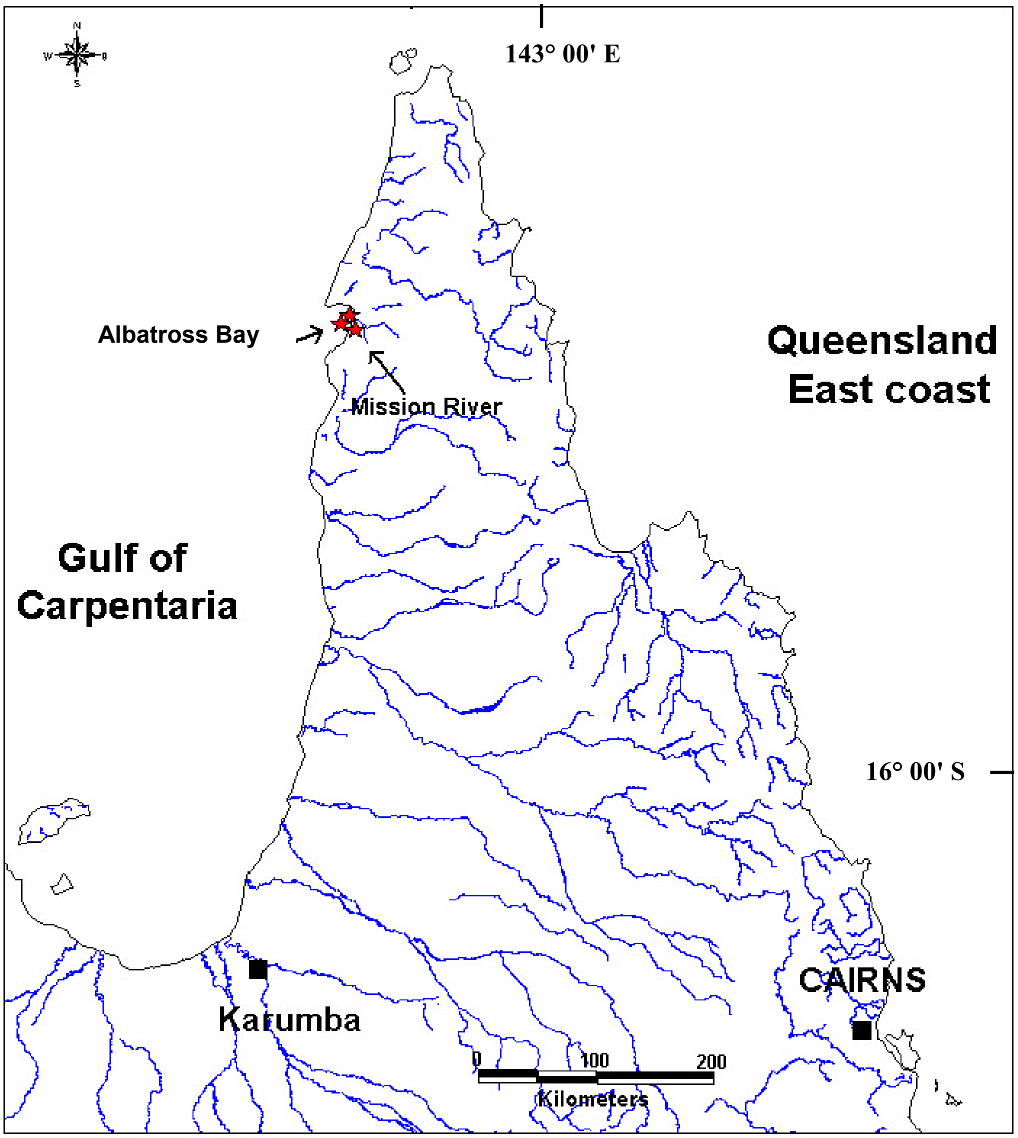


Figure 16: Sites in Queensland at which *P. clavata* was captured during this study.

6.3.6 Narrow sawfish (*Anoxypristis cuspidata*)

Distribution: Only two specimens were caught during this survey, one from each of the Liverpool and Blythe Rivers in Arnhem Land, Northern Territory (Figure 17).

Physical Habitat: Both specimens were caught in the mouth of each river (sites 1 and 8), where the river bed was clay/silt, denuded by tidal effects. One specimen was taken in 5 m, the other in 4 m water depth. Flow rates at both sites were $0.5ms^{-1}$ (Table 5, Appendix 5).

Water Chemistry: Although both sites were at river mouths, salinities were 30 and 31 ppt.

Size: The two individuals were 1010 and 1162 mm TL. Specimens this small are rare in Australian collections but have been reported anecdotally from the coastal fringe of northern Australia (Dr Peter Last, CSIRO Marine Research, Hobart, pers. comm.).

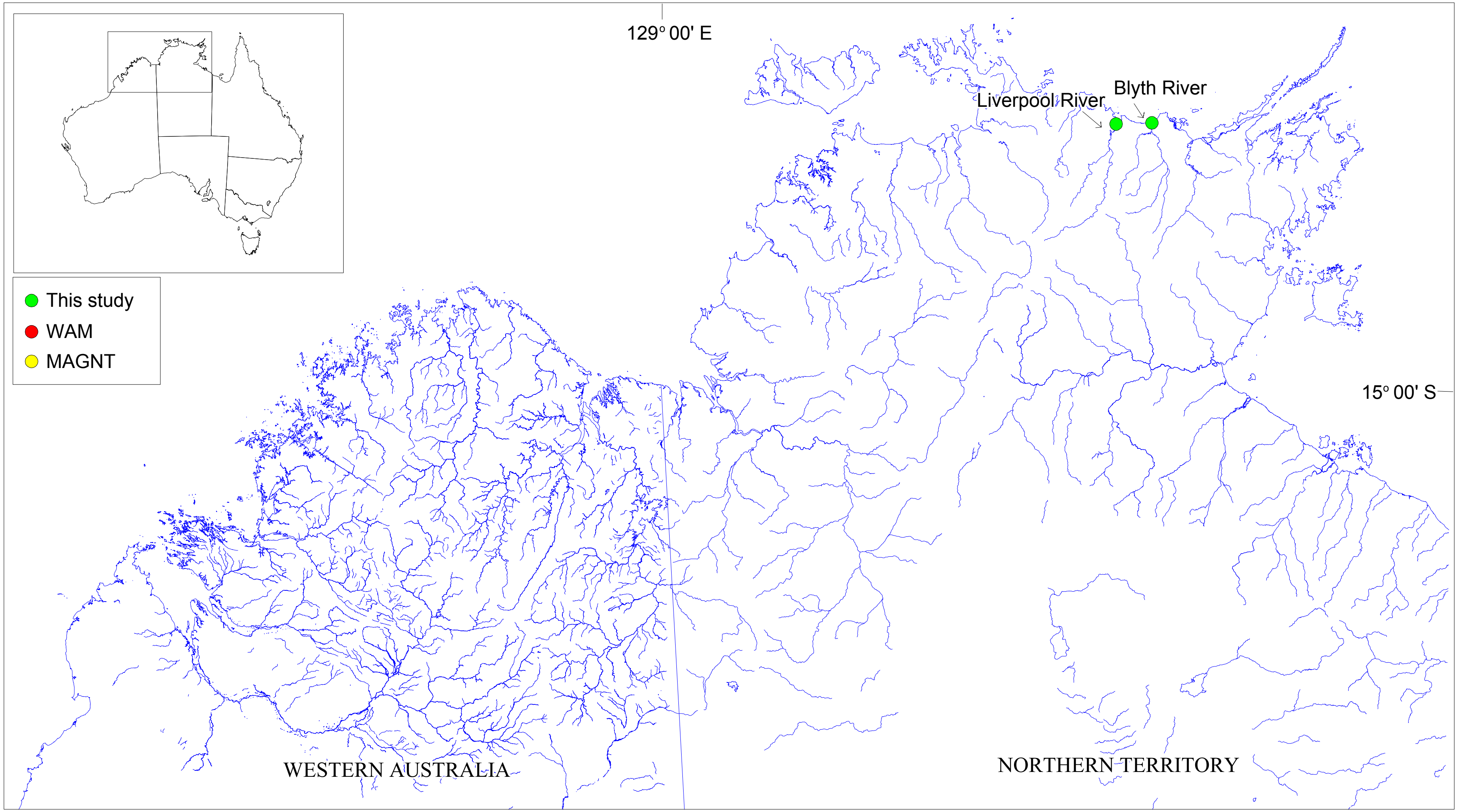


Figure 17: The sites in WA and NT at which *A. cuspidata* was captured during this study.

6.3.7 Green sawfish (*Pristis zijsron*)

Distribution: During this survey, the green sawfish was encountered in the Mission River, and at two sites in Albatross Bay, Queensland. It was not encountered in the Northern Territory or Western Australia (Figure 18).

Physical Habitat: Of the three specimens caught, two were encountered over sand, and the other over fine silt (Table 6, Appendix 5). All sites at which it was present were subject to tidal influence with high flow, and captures occurred in waters of 1.2 and 3 m depth. All three sites had sparse coverings of detritus and snags.

Water Chemistry: Salinities at the sites where the green sawfish were encountered ranging from 34.2 – 35.1 ppt.

Size: Specimens ranged from 1960 – 2540 mm TL.

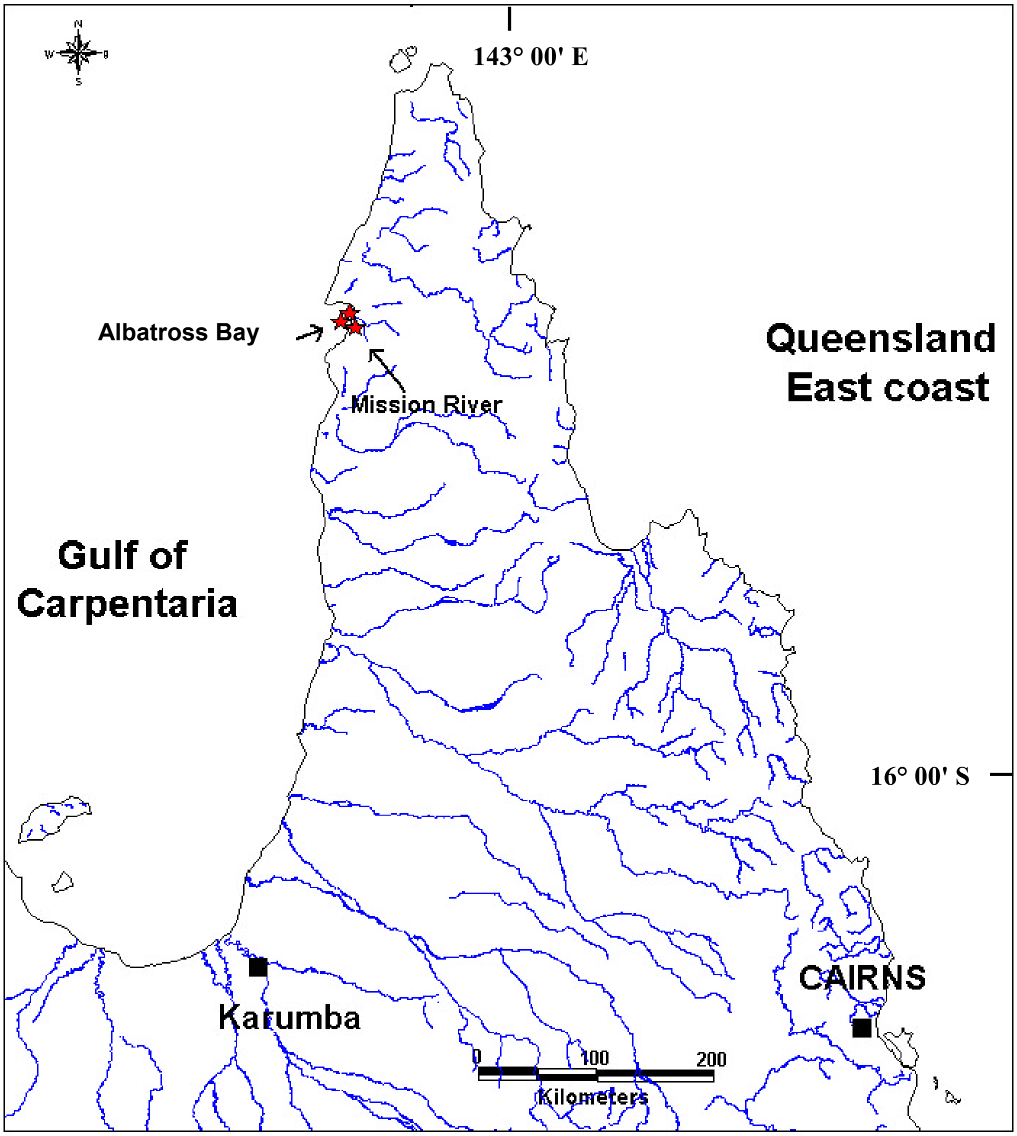


Figure 18: Sites in Queensland at which *P. zijsron* was captured during this study.

7 DISCUSSION

7.1 The current survey

The purpose of this broad field-based survey was to obtain information on the distribution, occurrence and abundance of freshwater elasmobranchs in as many northern Australian drainage systems as possible. In six months the project teams traversed northern Australia, to survey a total of 137 sites within 39 river/creek systems in WA, the NT and Qld. Over thirty thousand kilometres were travelled during the project.

The baseline data collected during this survey will assist resource managers and research scientists in determining the appropriate conservation status for these species. This survey is the first of its kind to specifically look at freshwater elasmobranchs over such a vast area. Although our findings indicate that the distribution of the priority species are patchy, several of them occur over a wide range, and in some systems were relatively abundant. No other studies of this type are available for comparison, and although abundance data in the form of catch per unit effort are not presented, our findings support the elevated conservation status of all of the target species. This conclusion is based on a number of findings that are summarised below.

Glyphis species appear to have similar physiology and to occur in similar habitats to *C. leucas*. As such, it might be expected that *Glyphis* spp and *C. leucas* have similar catchability with respect to the survey gear. However, 126 *C. leucas* were caught compared to one *Glyphis* sp. C. (and no *Glyphis* sp. A). While there may be currently unaccounted for differences between these genera the results of this survey suggest that the conservation status of Endangered and Critically Endangered for *Glyphis* spp is deserved. Currently, *Glyphis* sp. A is only known from the Northern Province and North Eastern Biotone, and *Glyphis* sp. C from the Northern Province and now additionally from the North Western Biotone.

Our results have provided additional distributional records for *Pristis microdon*, *Pristis clavata*, *Pristis zijsron* and *Anoxypristis cuspidata*, from several drainage systems.

Pristis microdon was recorded in all of the northern bioregions and was the most commonly encountered sawfish species. It appears to be locally abundant in the Fitzroy River. *Pristis clavata* was recorded in the North Western Biotone and Northern Province. While there are no museum records in Australia for *P. clavata* from the North Eastern Biotone, their range is known to extend along the north eastern coast of Queensland (Last and Stevens, 1994). Its absence from the North Eastern Biotone during this study is of concern and requires investigation. *Pristis zijsron* and *A. cuspidata* were only recorded in the Northern Province during our survey. However, records from FRDC project 2002/064 (Northern Australian sharks and rays: the sustainability of target and bycatch species, phase 2) confirms the marine distributions of these species in the other two bioregions. The absence of these species in our survey is most likely due to the appropriate habitats not being sampled (foreshore and offshore coastal waters as apposed to estuarine and freshwater habitat).

The populations of *Pristis* spp would be greatly impacted by the level of both commercial gill netting and recreational line fishing. Our results suggest that in areas of lower fishing pressure, greater numbers of *Pristis* spp were found. In Queensland, *P. zijsron* and *P. clavata* were only recorded from an area closed to netting. Greater numbers of *P. microdon* were recorded in the Fitzroy River in Western Australia, where there is little or no commercial fishing in the estuarine/freshwater habitat. Comparatively high numbers of *P. clavata* were also encountered in two other rivers entering King Sound.

Himantura chaophraya was found to occupy all three northern bioregions. Anecdotal reports from traditional owners, park rangers and station personnel suggest that this species is observed free-swimming more often than sawfishes. Improved information on the occurrence of this species (and of other elasmobranchs) might have resulted if more time had been available to follow up on anecdotal sightings. *Himantura chaophraya* was the second most frequently caught (or observed) priority species, and was encountered in groups on several occasions during this study. However, there is still a lack of distributional, biological and life history information data for this species.

7.2 Survey techniques and species susceptibility to capture

A total of 502 elasmobranchs comprising 36 species were recorded during the survey. Although sampling methodologies varied between the two core teams, the strategy and gear used was effective in the capture of freshwater and estuarine elasmobranchs. The capture data provides some indication of the susceptibility of these species to our fishing techniques, in particular gill netting and long-lining (all legally permitted under commercial fishery regulations in WA, NT and Qld). Carcharhinids, for example, were vulnerable to capture using all the methods employed, while gill netting was especially effective in the capture of sawfish, including *Pristis microdon* (Appendix 5; CD-ROM). Handline and rod and line fishing was also effective for capturing carcharhinids, with our only record of *Glyphis* sp. C obtained using this method. Gill net or hook and line fishing in these restricted riverine habitats could pose a threat to the future conservation of the priority species.

Unlike sawfish that are easily caught by entanglement of the rostrum in gill nets, *H. cha*ophraya was observed evading gill nets on several occasions. The use of long-lines, handlines, and rod and line were effective methods for the capture of *H. chaophraya*. While we caught no pristids using these techniques during our survey, we did observe line-caught *P. microdon* at a number of locations. These dead specimens appeared to be the result of fishers wanting to retrieve their hooks, or cutting off the rostrums as trophies.

The vulnerability of elasmobranchs to capture by line fishermen in accessible areas of confined waterways is an issue of concern. These areas include National Parks, where *Glyphis* spp has been recorded from Kakadu, and the Bizant River. Lakefield National Park receives 30 thousand tourists annually of which 95% visit for the sole purpose of recreational fishing. In Queensland, the conservation status of *P. microdon* has been recognised by the recreational fishing sector. In response to preliminary findings during the early stages of this study, INFO Fish Services dedicated a page within their "Released

Fish Survival Website" to the safe handling and release of this species (www.info-fish.net/releasefish). The website addresses the issues relating to the release of all commonly caught teleosts and elasmobranchs through the National Strategy for the Survival of Released Line Caught Fish.

7.3 Limitations

Accessibility to rivers was one of the main restrictions imposed on our sampling regime. An even geographical distribution of sampling localities over the vast area of northern Australia was often compromised by physical access or permission from traditional owners, land managers or management agencies. While permission was often forthcoming, it was sometimes too late for the timing of our survey.

Seasonal weather patterns also played a major part in the timing of the project. Sampling during the wet season at many of the sites would have been impossible due to limited access and excessive flow rates. Early pre-season rains (making tracks impassable) in November affected sampling in WA and drought conditions in the dry season of 2002 (experienced in Qld, and to a lesser extent NT) meant rivers and water holes were heavily contracted. This survey could only provide information on dry season distributions of the target species.

Given the funding and time constraints of this project, and the huge distances involved, it was not possible to provide intensive sampling of all habitats within an individual river system as well as covering all major river systems in northern Australia. To determine the specific habitat requirements of, for example, a *Glyphis* sp. would require an intensive study of a system where they are known to occur.

Catch rates of target species will be influenced by catchability factors associated with the gear used, and the way in which it was fished. The necessary skills in catching a particular species can only be developed with increased knowledge and experience of that species. However, wherever possible local knowledge was sought and traditional owners employed from the areas sampled.

8 CONCLUSION

8.1 Recommendations for future research

Our results have shown generally low catches of the priority elasmobranch species throughout northern Australian riverine systems, and reinforce the need to understand all their life-history stages to be able to manage them. They have also identified the potential threat of gill netting and line fishing to the future sustainability of these species.

While we can make some inferences about the abundance of these species from this survey, additional sampling incorporating standardised gear and fishing effort would allow more direct comparison of river systems throughout the north of Australia, and further clarify their true status. These data would allow management or conservation authorities to consider each river, or particular habitat, with respect to the overall status of these species. The necessary action to protect individual systems could then be taken, with special consideration for those systems in which elasmobranch numbers are in decline, and those systems that appear to be significant 'strongholds'.

Sampling in embayments and offshore areas adjacent to rivers (to complement data collected from freshwater and estuarine reaches), may provide insight into the habitat preferences of different life-stages of these species. As for *C. leucas*, it seems that juvenile *P. microdon* may utilise the rivers, while larger mature animals (up to 7 m TL) generally remain offshore.

Due to the high conservation status and level of protection of most of the priority species targeted in this survey, the collection of specimens and biological data is problematic. A lack of biological knowledge can often limit the efficacy of conservation actions, which aim to preserve or protect threatened species. Even answering basic questions such as the number of sawfish species occurring in Australian waters becomes more difficult. Similarly, morphological comparison of *H. chaophraya* specimens collected in Australia with those from south-east Asia is required to resolve taxonomic questions. This highlights the benefits of non-destructive techniques, such as genetic biopsies for taxonomy and stock structure, hormonal assays, ultra-sound and endoscopy for reproductive status, electronic tags for tracking and behavioural data, and stomach flushing for information on diet.

We recommend implementation of the following:

- A detailed survey of one or two systems known to contain *Glyphis* spp, *P. microdon* and *H. chaophraya* to determine specific habitat requirements and critical habitat. This could include areas of low recreational and commercial fishing pressure such as the Kakadu World Heritage Area (NT), or Fitzroy River (WA), as well as a higher disturbance area, such as Lakefield National Park (Qld). This would allow better evaluation of potential management regimes, with the provision of a comparative 'control'.

- A biological study to elucidate the life-history of the priority species, particularly movements, based on non-destructive techniques

- Sampling of the coastal marginal zone where *Glyphis* spp and *P. microdon* are thought to occur (i.e. Van Diemens Gulf or the Kimberley coast), and understanding links with adjacent wetlands.

- A program that investigates recreational/indigenous fishing practices in important habitat areas such as the Fitzroy River, together with a program to educate these sectors on the conservation status of the priority species.

There are logistic benefits in implementing these studies as soon as possible to take advantage of the large number of contacts and professional networks developed across a number of sectors during this study.

8.2 Conservation recommendations

Although there are still large gaps in our knowledge of the target species, rapid implementation may prevent the extirpations observed in other countries. The following conservation recommendations are based on information collected during this survey:

1. Recognition of systems of special significance:
Rivers of the Kimberley, such as the Fitzroy River (WA), which contained relatively high population numbers of *P. microdon* throughout its catchment, should be subject to special consideration. Preventing impacts which contribute to population decline is more effective than implementing a recovery program at a later date. Similarly, systems such as the Daly and Normanby Rivers with large numbers of *H. chaophraya* should be recognised for their special status.

2. Closed areas
Determining strongholds where multiple species of the priority elasmobranchs occur. Restricting access or closing sections of rivers and adjacent coast, perhaps on a seasonal basis, are a management tool that may alleviate pressures on these populations.

3. Education of fisher practices:
The dead sawfish specimens left by fishers in the lower Fitzroy River were a clear example of a lack of education with respect to these species. Educational materials including information pamphlets and signs at popular tourist/fishing destinations, as well as articles about these species in fishing publications, is a cost effective way to cover a wide range of sectors. Information on the correct handling and release procedures of these species is also essential.

4. Legislation
While the EPBC Act (1999) carries penalties for the deliberate capture or killing of listed species, many people are still ignorant of the law. Improved education and publicity are required to better inform people of the conservation status of these species, and the penalties imposed if they are caught killing them.

9 ACRONYMS

AFFS	Agency for Food and Fibre Sciences
ASFB	Australian Society for Fish Biology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
FAO	Food and Agriculture Organisation of the United Nations
IUCN	International Union for the Conservation of Nature (now World Conservation Union)
IPOA	Food and Agriculture Organisation of the United Nations International Plan of Action for the Conservation and Management of Sharks
NT	Northern Territory
NEB	North Eastern Biotone
NP	Northern Province
NWB	North Western Biotone
QBFP	Queensland Boating and Fisheries Patrol
QDPI	Queensland Department of Primary Industries
QFS	Queensland Fisheries Service
Qld	Queensland
QPWS	Queensland Parks and Wildlife Service
WA	Western Australia

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11 APPENDIX 1: Location of sampling sites

Table 1a: Sites sampled for freshwater and estuarine elasmobranchs in the Northern Territory.

River System & Site Location	Site Number	Latitude	Longitude
Liverpool River (Mouth)	1	12.079	134.192
Liverpool River (Feeder)	2	12.256	134.111
Liverpool River	3	12.264	134.105
Liverpool River (Manggabor Creek)	4	12.280	134.105
Liverpool River (Paperbark Swamp)	5	12.209	134.128
Liverpool River (Mann River)	6	12.360	134.129
Blyth River (Cadell River)	7	12.241	134.431
Blyth River (Mouth)	8	12.068	134.595
Blyth River (Ji Marda Beach)	9	12.034	134.617
Blyth River (Ji Marda Offshore)	10	12.034	134.613
Blyth River	11	12.338	134.668
Glyde River (Goyder River)	12	13.029	134.975
Glyde River (Arafura Swamp)	13	12.476	134.965
Glyde River	14	12.268	135.053
Darbilla Creek	15	12.159	134.916
Darbilla Creek	16	12.176	134.884
Darbilla Barge Landing	17	12.146	134.927
Mary River (Mouth)	18	12.266	131.774
Mary River	19	12.309	131.773
Mary River	20	12.370	131.769
Mary River	21	12.406	131.730
Mary River	22	12.487	131.721
Adelaide River (Marrakai Creek)	23	12.681	131.336
Adelaide River	24	12.661	131.337
Adelaide River	25	12.649	131.359
Adelaide River (Feeder)	26	12.734	131.277
Daly River (Katherine River)	27	14.410	132.325
Daly River (Katherine River; King R. Junction)	28	14.696	131.978
Daly River (Katherine River; King R. Junction)	29	14.698	131.973
Daly River (Charlie Creek)	30	13.685	130.588
Daly River	31	13.688	130.618
Daly River	32	13.673	130.643
Daly River	33	13.677	130.655
Daly River	34	13.668	130.655
Daly Rivern (Elliot Creek)	35	13.558	130.519
Daly River	36	13.985	131.216
Daly River	37	13.975	131.213
Roper River	38	14.687	134.371
Roper River	39	14.876	133.468
Roper River	40	14.889	133.405
Roper River	41	14.927	133.372

Roper River	42	14.940	133.368
Roper River	43	14.730	134.551
Roper River	44	14.713	134.519
Roper River	45	14.713	134.508
Roper River (Mountain Creek)	46	14.774	134.802
Roper River (Lomarieum Lagoon)	47	14.780	134.884
Roper River	48	14.748	135.299
Roper River (Feeder)	49	14.727	135.322
Towns River	50	15.041	135.213
Towns River	51	14.994	135.294
Towns River	52	15.046	135.209
Limmen River	53	15.320	135.433
Limmen River (North Arm)	54	15.166	135.616
Limmen River	55	15.251	135.522
Limmen River (Round Hole)	56	15.499	135.398
Mcarthur River	57	15.900	136.592
Mcarthur River (Batten Creek)	58	15.890	136.517
Mcarthur River	59	15.928	136.421
Mcarthur River (Backwater)	60	15.931	136.420
Mcarthur River	61	15.927	136.513
Mcarthur River	62	15.918	136.522
Mcarthur River (Batten Creek)	63	15.865	136.398
Mcarthur River	64	15.916	136.544
Mcarthur River	65	15.902	136.537
Wearyan River	66	16.168	136.423
Wearyan River	67	16.164	136.755
Wearyan River	68	16.175	136.761
Wearyan River	69	16.174	136.759
Wearyan River	70	16.175	136.762
Robinson River	71	16.470	137.050
Robinson River	72	16.224	137.102
Robinson River	73	16.232	137.098
Robinson River	74	16.248	137.089
Robinson River	75	16.268	137.088
Victoria River	76	15.646	131.105
Victoria River	77	15.635	131.133
Victoria River	78	15.614	130.449
Victoria River	79	15.461	130.359
Victoria River (Humbert River)	80	16.431	130.932
Victoria River (Jasper Creek)	81	16.031	130.802

Table 1b: Sites sampled for freshwater and estuarine elasmobranchs in Western Australia.

River System & Site Location	Site Number	Latitude	Longitude
Dominic Creek	82	14.142	126.696
Drysdale River	83	14.008	126.930
Drysdale River	84	13.978	126.925
Drysdale River	85	13.978	126.887
King Edward River (Monger Creek)	86	14.248	126.563
King Edward River	87	14.199	126.590
Walsh Point	88	14.583	125.828
Rail River	89	14.693	125.862
Lawley River	90	14.644	125.925
Fitzroy River	91	17.638	123.567
Fitzroy River	92	17.682	123.562
Fitzroy River	93	17.663	123.566
Fitzroy River	94	18.081	124.227
Fitzroy River	95	18.188	124.492
Fitzroy River	96	18.038	125.744
May River	97	17.338	123.996
May River	98	17.235	123.919
Robinson River	99	16.755	123.978
King River	100	15.676	128.086
King River	101	15.566	128.112
King River	102	15.512	128.096
Pentecost River	103	15.756	127.864
Ord River (Spillway Ck)	104	15.961	128.758
Ord River (Spillway Ck)	105	16.008	128.770
Ord River	106	15.563	128.672
Ord River	107	15.569	128.625
Ord River	108	15.568	128.620
Ord River	109	15.578	128.469
Ord River	110	15.532	128.415
Ord River	111	16.124	128.698

Table 1c: Sites sampled for freshwater and estuarine elasmobranchs in Queensland.

River System & Site Location	Site Number	Latitude	Longitude
Laura River (Olive Vale Hole)	112	15.531	144.441
Archer River (Foxs Waterhole)	113	13.450	142.981
Wenlock River (Woodfords Lagoon)	114	12.389	142.209
Wenlock River (Stones Crossing)	115	12.393	142.165
Pine River (Foreshore)	116	12.523	141.679
Mitchell River (Koolatah Lake)	117	15.792	142.407
Alice Creek	118	15.548	142.283
Mitchell River (Shark Hole)	119	15.661	142.101
Mitchell River (Koolatah Lake)	120	15.792	142.407
Mitchell River (Gamboola Water Hole)	121	16.510	143.605
Mission River	122	12.570	141.92
Albatross Bay (Mangrove Island)	123	12.584	141.795
Albatross Bay (Weipa Caravan Park)	124	12.638	141.854
Mission River (Red Beach)	125	12.595	141.856
Mission River	126	12.585	141.928
Albatross Bay (Opposite Weipa Race Track)	127	12.640	141.851
Normanby River	128	14.611	144.196
Normanby River (Whip Handle)	129	14.385	144.111
Bizant River (German Bar)	130	14.670	144.131
Kennedy River (Kennedy Junction)	131	15.108	144.314
Gilbert River	132	17.198	141.827
Gilbert River (Police Waterhole)	133	17.420	142.093
Saxbury River (Pump Hole)	134	19.056	141.115
Gilbert River (Trainers Waterhole)	135	17.515	142.376
Normanby River (Mid Estuarine)	136	14.327	144.103
Normanby River (Mouth)	137	14.243	144.871

12 APPENDIX 2: Fishing effort

Table 1a: The lengths and set times of gill nets and long-lines used at sampling sites in the Northern Territory. * Hooks on long-lines approximately 2 m apart.

	Gill net						Long-line*	
	10 cm		15 cm		20 cm			
Site #	Length (m)	Set (hrs)	Length (m)	Set (hrs)	Length (m)	Set (hrs)	Length (m)	Set (hrs)
1	30	1	30	1	30	1	-	-
2	30	1	30	1	30	1	-	-
3	30	3	30	3	30	18	40	3
4	30	2	30	2	30	2	-	-
5	30	2	30	2	30	2	-	-
6	30	14	30	14	30	14	40	14
7	60	16	90	16	60	16	80	16
8	30	6	30	6	30	6	-	-
9	60	24	30	24	30	24	40	12
10	-	-	30	12	30	12	-	-
11	30	17	30	17	60	17	80	17
12	30	15.5	30	15.5	60	15.5	40	15.5
13	30	12	30	12	60	12	40	12
14	-	-	30	15	-	-	40	15
15	30	15	30	15	-	-	-	-
16	30	16	30	16	30	16	-	-
17	-	-	-	-	-	-	40	14
18	30	1	30	2	30	2	40	2
19	30	3	30	3	30	3	40	3
20	30	1	30	1	30	1	40	1
21	30	2	30	2	30	2	40	2
22	-	-	-	-	-	-	40	3
23	-	-	30	2	30	2	40	2
24	-	-	-	-	-	-	40	13.5
25	30	1	30	1	30	1	-	-
26	30	2	30	2	30	2	-	-
27	30	15.25	30	15.25	30	15.25	40	14.25
28	30	1	30	1	30	1	80	24
29	-	-	-	-	-	-	40	20.5
30	30	1	30	1	30	1	-	-
31	30	1	30	1	30	1	-	-
32	-	-	-	-	-	-	40	13
33	30	3	30	3	30	3	40	3
34	(Spear)	-	-	-	-	-	-	-
35	30	2	30	2	30	2	40	2
36	60	1.5	30	1.5	30	1.5	40	13
37	-	-	-	-	-	-	40	15
38	-	-	30	13	30	13	40	13
39	-	-	-	-	-	-	40	16.5
40	30	2	30	2	30	2	40	2
41			30	13	60	13	40	13
42	-	-	-	-	60	13.5	-	-
43	30	2	30	2	30	2	40	2
44	30	2	30	2	30	2	40	2
45	-	-	-	-	-	-	40	2
46	30	2	30	2	30	2	40	2

47	-	-	-	-	60	14	-	-
48	30	2.5	30	2.5	30	2.5	40	2.5
49	30	2.5	30	2.5	-	-	40	2.5
50	30	2	30	15	30	15	40	15
51	-	-	30	3	30	3	40	3
52	30	3	-	-	-	-	40	17
53	30	3	30	3	30	3	40	3
54	60	3	60	3	60	3	40	3
55	-	-	-	-	-	-	80	14
56	-	-	-	-	-	-	40	13
57	60	3	60	3	60	3	40	3
58	60	3	60	3	60	3	40	3
59	-	-	-	-	-		80	3
60	30	2	-	-	-	-	-	-
61	30	1	30	1	30	1	-	-
62	-	-	-	-	-	-	80	14.5
63	60	3	60	3	60	3	40	3
64	30	2	30	2	-	-	-	-
65	-	-	-	-	-	-	40	2
66	30	15	30	15	30	15	-	-
67	-	-	-	-	-	-	40	13
68	-	-	30	14	30	14		
69	-	-	-	-	-	-	40	14
70	-	-	-	-	-	-	40	14
71	60	2.5	60	15	60	15	-	-
72	30	2	30	2	30	2	40	2
73	-	-	-	-	-	-	40	13.5
74	-	-	-	-	30	12.5	-	-
75	60	2.5	60	2.5	60	2.5	-	-
76	30	2	30	2	30	2	-	-
77	-	-	-	-	30	12.5	40	12.5
78	30	2	30	2	30	2	40	2
79	-	-	30	14	30	14	-	-
80	-	-	30	14	30	14	-	-
81	30	3	30	3	30	3	-	-

Table 1b: The lengths and set times of gill nets and long-lines used at sampling sites in Western Australia. * Hooks on long-lines approximately 2 m apart.

	Gill net						Long-line*	
	10 cm		15 cm		20 cm			
Site #	Length (m)	Set (hrs)	Length (m)	Set (hrs)	Length (m)	Set (hrs)	Length (m)	Set (hrs)
82	30	4	30	3	30	3	80	3
83	30	2	30	2	30	2	40	2
84	30	2	30	2	30	2	40	2
85	30	2.5	30	2.5	30	2.5	40	3
86	30	1	-	-	-	-	-	-
87	30	2	30	2	30	2	-	-
88	30	6	30	6	-	-	40	2
89	30	2	30	2	-	-	40	2
90	30	2	30	2	-	-	-	-
91	60	4	60	2	-	-	80	17
92	60	3	60	3	60	3	-	-
93	-	-	60	13	-	-	40	13
94	60	6	60	16	-	-	40	18
95	30	20.5	30	13.5	-	-	40	24
96	60	5	60	13.5	60	13.5	-	-
97	30	12	30	12	30	12	-	-
98	60	6.5	60	6	-	-	-	-
99	60	2	60	2.25	-	-	-	-
100	30	3	30	12.5	30	12.5	-	-
101	60	2	60	2	60	2	40	2
102	30	3	60	3	60	3	40	3
103	-	-	30	12	30	12	-	-
104	60	2	30	2	30	2	-	-
105	(Line)	-	-	-	-	-	-	-
106	60	3	60	3	60	3	-	-
107	60	2	60	2	60	2	-	-
108	60	2	30	2	30	2	40	2
109	60	3	60	3	60	3	40	8
110	60	1.5	60	1.5	60	1.5	40	1.5
111	60	2	30	2	30	2	-	-

Table 1c: The lengths and set times of gill nets and long-lines used at sampling sites in Queensland.

Site #	Set time (hrs)	Gear (Net type)	Length (m)	Gill net Mesh (mm)	Net Depth (# of Meshes)	Long-line # of Hooks
112	18	mono	18	15	33	-
112	17.17	cord	12.5	17.5	25	-
112	16.83	cord	12.5	17.5	25	-
112	16.67	cord	25	17.5	25	-
112	16.5	mono	25	15	25	-
113	16.17	long-line	28	-	1.5	5
113	16.08	long-line	28	-	1.5	5
113	15.08	mono	18	15	33	-
113	14.83	mono	25	15	25	-
113	14.75	cord	25	17.5	25	-
113	15.17	mono	35	15	33	-
113	15.08	cord	12.5	17.5	25	-
113	15	cord	12.5	17.5	25	-
114	18.08	long-line	50	-	1.5	10
114	17.75	long-line	50	-	1.5	10
114	17.25	cord	50	17.5	25	-
114	17.25	mono	50	15	33	-
114	17.5	cord	50	17.5	25	-
115	16.45	long-line	50	-	1.5	10
115	9.58	long-line	50	-	1.5	10
115	14.83	cord	50	18.75	25	-
115	15.25	cord	25	17.5	25	-
115	15.25	cord	25	17.5	25	-
115	15.17	mono	30	15	33	-
115	15.08	mono	50	15	33	-
116	3.67	mono	550	16.875	25	-
117	13.77	cord	25	17.5	25	-
117	13.5	cord	25	17.5	25	-
117	13.1	cord	12.5	17.5	25	-
118	13.8	cord	8.5	17.5	25	-
118	13.58	cord	25	17.5	25	-
118	13.33	cord	25	17.5	25	-
118	13.33	cord	25	17.5	25	-
118	13.08	mono	25	12.5	25	-
119	13.5	long-line	24	-	1.5	10
119	14.67	cord	25	17.5	25	-
119	14	mono	25	12.5	25	-
119	14.67	cord	25	17.5	25	-
119	14.67	cord	25	17.5	25	-
119	13	long-line	24	-	1.5	10
120	13	long-line	24	-	1.5	10
120	13.08	long-line	24	-	1.5	10
120	14.08	cord	25	17.5	25	-
120	13.92	cord	31	17.5	25	-
120	13.75	cord	25	17.5	25	-
120	13.58	mono	25	12.5	25	-
121	14.25	cord	25	17.5	25	-
121	14.08	cord	25	17.5	25	-
121	14.08	mono	25	12.5	25	-
121	14.08	cord	18.5	17.5	25	-
121	13.25	long-line	24	-	1.5	10
121	13.33	long-line	24	-	1.5	10
121	13.92	cord	12.5	17.5	25	-

122	14.25	mono	150	16.875	25	-
122	13.25	mono	150	16.875	25	-
122	19.67	mono	200	16.875	25	-
123	4.67	mono	150	16.875	25	-
123	3.67	mono	150	16.875	25	-
123	7.23	mono	200	16.875	25	-
125	9.5	mono	150	16.875	25	-
125	9.33	mono	150	16.875	25	-
125	9.08	mono	200	16.875	25	-
125	8.5	long-line	50	-	1.5	15
126	6.67	mono	150	16.875	25	-
126	4.67	mono	150	16.875	25	-
124	6.83	mono	300	16.875	25	-
127	9.17	mono	300	16.875	25	-
127	7.25	multifilament	50	12.5	25	-
128	14.17	cord	32	17.5	25	-
128	14.17	mono	20	15	33	-
128	13.33	white cord	30	17.5	33	-
128	13	cord	25	17.5	25	-
129	4.83	cord	25	17.5	25	-
129	4.42	white cord	30	17.5	33	-
129	4.5	mono	30	12.5	25	-
129	2.73	mono	30	10	25	-
129	2.75	mono	30	15	33	-
129	3.83	mono	30	15	33	-
129	4.17	long-line	50	-	1.5	15
130	4.92	long-line	30	-	1.5	10
130	5.25	white cord	30	17.5	33	-
130	4.17	mono	30	15	33	-
130	7.08	mono	30	15	33	-
130	8	cord	25	17.5	25	-
130	2	mono	20	10	33	-
131	11.42	long-line	25	-	1.5	10
131	11.53	long-line	25	-	1.5	10
132	4.33	cord	25	17.5	25	-
132	14.58	cord	25	17.5	25	-
132	7.92	white cord	30	17.5	33	-
132	4.25	mono	50	15	33	-
133	14.92	cord	38	17.5	25	-
133	14.08	mono	50	15	33	-
133	13.83	cord	25	17.5	25	-
133	13.75	white cord	30	17.5	33	-
133	12.92	long-line	50	-	1.5	20
134	12.83	cord	38	17.5	25	-
134	16.58	cord	25	17.5	25	-
134	12.67	white cord	30	17.5	33	-
134	12.5	mono	50	15	33	-
135	14	cord	38	17.5	25	-
135	13.75	cord	25	17.5	25	-
135	13.5	white cord	30	17.5	33	-
135	13.25	mono	50	15	33	-
136	3.08	mono	35	12.5	33	-
136	3.17	mono	35	10	33	-
136	3.25	mono	50	15	33	-
136	2.42	mono	50	15	33	-
136	3.5	mono	50	15	33	-
137	1.5	mono	35	12.5	33	-
137	1.75	mono	35	10	33	-
137	2.75	mono	50	15	33	-
137	2.83	mono	50	15	33	-
137	3.25	mono	50	15	33	-

13 APPENDIX 3: Bycatch species

Table 1: Bycatch species encountered during the survey.

Species	Common names	Species	Common names	Species	Common names
Acanthopagrus latus	Western yellowfin bream	*Drepane punctata*	Sicklefish	*Nibea sp. 1*	
Alectis indicus	High-brow pennantfish	*Dugong dugong*	Dugong	*Nibea sp. 2*	
Amniataba caudavittata	Yellowtail trumpeter	*Eleutheronema tetradactylum*	Blue salmon	*Nibea squamosa*	Scale croaker
Anodontiglanis dahli	Toothless catfish	*Epinephelus coioides*	Estuary cod	*Oxyeleotris lineolatus*	Sleepy cod
Ariidae spp	Catfish	*Epinephelus lanceolatus*	Groper	*Paraplotosus albilabris*	White-lipped catfish
Arius argypleuron	Long snouted catfish	*Gerres filamentosus*	Spotted silver-belly	*Parastromateus niger*	Black pomfret
Arius armiger	Copper catfish	*Gnathanodon speciosus*	Golden trevally	*Plectorhinchus gibbosus*	Brown sweetlips
Arius dioctes	Warrior catfish	*Haemulidae* spp	Brown morwong / Sweetlip	*Plotosidae* spp	Eel-tailed catty
Arius graeffei	Blue catfish	*Hephaestus fuliginosus*	Sooty grunter	*Polydactylus macrochir*	Threadfin salmon
Arius hainesi	Ridged catfish	*Hephaestus jenkinsi*	Western sooty grunter	*Polydactylus sheridani*	King salmon
Arius insidiator	Flat catfish	*Lates calcarifer*	Barramundi	*Pomadasys kaakan*	Javelin fish
Arius leptaspis	Salmon catfish	*Liza tade*	Diamond-scaled mullet	*Scatophagus argus*	Spotted scat
Arius mastersi	Master’s catfish	*Liza vaigiensis*	Square tail mullet	*Scleropages jardinii*	Saratoga
Arius midgleyi	Silver cobbler	*Lobotes surinamensis*	Jumping cod	*Scomberoides commersonnianus*	Queenfish
Arius proximus	Arafura Sea catfish	*Lutjanis johnii*	Fingermark seaperch	*Scomberoides tala*	Deep leatherskin
Arius thalassinus	Golden catfish	*Lutjanus argentimaculatus*	Mangrove jack	*Scomberoides tol*	Needleskin queenfish
Carangidae spp	Trevally	*Lutjanus carponotatus*	Stripey seaperch	*Scomberomorus semifasciatus*	Grey mackerel
Carangoides gymnostethus	Bludger trevally	*Megalops cyprinoides*	Tarpon	*Strongylura krefftii*	Freshwater longtom
Caranx ignobilis	Giant trevally	*Monodactylus argenteus*	Diamond-fish / Butterfish	*Syncomistes butleri*	Butlers grunter
Chanos chanos	Milkfish	*Mugil cephalus*	Sea mullet	*Tandanus tandanus*	Freshwater catfish
Chelonia mydas	Green sea turtle	*Mugilidae* spp	Mullet	*Toxotes chatareus*	Seven-spot archer fish
Cinetodus froggatti	Small-mouthed catfish	*Nematalosa erebi*	Freshwater bony bream	*Trachinotus blochii*	Snub-nosed dart
Crocodylus johnstoni	Freshwater crocodile	*Nematolosa come*	Bony bream	*Valamugil buchanani*	Buchanan's mullet
Crocodylus porosus	Saltwater crocodile	*Neosilurus ater*	Narrow-fronted catfish	*Valamugil seheli*	Blue-tailed mullet

14 APPENDIX 4: Capture sites and associated salinities

Table 1: Sampling sites at which elasmobranch species were encountered.

Species	Site numbers
Carcharhinus amblyrhynchoides	8, 87, 88, 89, 122, 124, 125, 126, 127
Carcharhinus amboinensis	102
Carcharhinus cautus	82, 88, 123, 124, 127
Carcharhinus dussumieri	125
Carcharhinus fitzroyensis	8, 128
Carcharhinus leucas	2, 3, 4, 31, 32, 33, 35, 43, 44, 45, 46, 50, 51
	53, 55, 58, 73, 74, 75, 78, 79, 91, 95, 99, 106
	108, 109, 110, 114, 115, 119, 122, 125, 126, 136
Carcharhinus limbatus	8, 89
Carcharhinus melanopterus	116
Carcharhinus plumbeus	90
Carcharhinus tilstoni	87, 90, 122, 123, 124, 125, 126
Galeocerdo cuvier	8
Negaprion acutidens	17, 88, 89, 116, 122, 123, 124, 125, 126, 127
Rhizoprionodon acutus	1, 125
Rhizoprionodon oligolinx	15
Rhizoprionodon taylori	8, 15, 17, 122, 125
Carcharhinus sp.	122, 127
Eusphyra blochii	122
Sphyrna lewini	125
Sphyrna mokarran	89, 123, 124, 127
Rhinobatos typus	123, 124, 125, 126
Rhynchobatus australiae	123, 126, 127
Anoxypristis cuspidata	1, 8
Pristis clavata	79, 98, 99, 122, 124, 125
Pristis microdon	23, 36, 41, 60, 68, 71, 76, 77**, 91, 93, 94
	94, 96, 99, 115, 129, 132, 135
Pristis zijsron	123, 124, 126
Himantura sp.A	87
Himantura chaophraya	33, 34, 35, 36, 49, 91, 95, 108, 109
	119, 120, 121, 129
Himantura granulata	82, 87
Himantura toshi	124
Himantura uarnak	82, 85, 87
Himantura undulata	85, 128
Pastinachus sephen	127, 130
Aetobatus narinari	82, 122, 123, 125, 126, 127
Aetomylaeus nichofii	122
Rhinoptera javanica	10
Rhinoptera neglecta	122, 123, 126, 127

*(**Recapture from site 76)*

Table 2: The percentage of individuals of each species caught at each salinity interval. n- total number of individuals.

Salinity (ppt)	**0**	**0.1-5**	**5.1-10**	**10.1-15**	**15.1-20**	**20.1-25**	**25.1-30**	**30.1-35**	**35.1-40**	**40.1+**	
No. sites per interval	**42**	**36**	**7**	**4**	**3**	**5**	**6**	**21**	**12**	**1**	**n**
C. amblyrhynchoides								57.1	42.9		14
C. amboinensis								100.0			1
C. cautus								53.8	46.2		39
C. dussumieri									100.0		2
C. fitzroyensis							83.3	16.7			6
C. leucas	28.6	42.9	3.1	1.6	0.8	1.6		13.5	7.9		126
C. limbatus								33.3	66.7		3
C. melanopterus									100.0		1
C. plumbeus									100.0		1
C. tilstoni								86.5	13.5		37
G. cuvier								100.0			1
N. acutidens								30.9	69.1		55
R. acutus							75.0		25.0		4
R. oligolinx								100.0			1
R. taylori								100.0			11
Unid. Carcharhinus sp.								75.0	25.0		16
E. blochii								100.0			1
S. lewini									100.0		1
S. mokarran								40.0	60.0		5
R. typus								18.2	81.8		11
R. australie								25.0	75.0		4
A. cuspidate							50.0	50.0			2
P. clavate			5.3					42.1	5.3	47.4	19
P. microdon	60.7	10.7	17.9	3.6				7.1			28
P. zijsron								66.7	33.3		3
Himantura sp. A									100.0		1
H. chaophraya	44.4	25.9	25.9				3.7				27
H. granulata								85.7	14.3		7
H. toshi								100.0			1
H. uarnak								80.0	20.0		5
H. undulata							33.3	66.7			3
P. sephen									100.0		3
A. narinari								52.5	47.5		40
A. nichofii								100.0			1
R. javanica								100.0			1
R. neglecta								81.0	19.0		21

Table 3: The average number of individuals of each species caught at each site within each salinity interval. n- number of individuals. The average refers to the total numbers of individuals caught in the salinity interval divided by the number of sites in that salinity interval.

Salinity (ppt)	**0**	**0.1-5**	**5.1-10**	**10.1-15**	**15.1-20**	**20.1-25**	**25.1-30**	**30.1-35**	**35.1-40**	**40.1+**	
No. sites per interval	**42**	**36**	**7**	**4**	**3**	**5**	**6**	**21**	**12**	**1**	**n**
C. amblyrhynchoides								0.38	0.50		14
C. amboinensis								0.05			1
C. cautus								1.00	1.50		39
C.dussumieri									0.17		2
C. fitzroyensis							0.83	0.05			6
C. leucas	0.86	1.50	0.57	0.50	0.33	0.40		0.81	0.83		126
C. limbatus								0.05	0.17		3
C. melanopterus									0.08		1
C. plumbeus									0.08		1
C. tilstoni								1.52	0.42		37
G. cuvier								0.05			1
N. acutidens								0.81	3.17		55
R. acutus							0.50		0.08		4
R. oligolinx								0.05			1
R. taylori								0.52			11
Unid. *Carcharhinus* sp.								0.57	0.33		16
E. blochii								0.05			1
S. lewini									0.08		1
S. mokarran								0.10	0.25		5
R. typus								0.10	0.75		11
R. australie								0.05	0.25		4
A. cuspidata							0.17	0.05			2
P. clavata			0.14					0.38	0.08	9.00	19
P. microdon	0.40	0.08	0.71	0.25				0.10			28
P. zijsron								0.10	0.08		3
Himantura sp. A									0.08		1
H. chaophraya	0.29	0.19	1.00				0.17				27
H. granulata								0.29	0.08		7
H. toshi								0.05			1
H. uarnak								0.19	0.08		5
H.undulata							0.17	0.10			3
P. sephen									0.25		3
A. narinari								1.00	1.58		40
A.nichofii								0.05			1
R. javanica								0.05			1
R. neglecta								0.81	0.33		21

15 APPENDIX 5: Habitat data

Table 1: *Pristis microdon* habitat and catch data. Fishing method: GN: gill net, HS: hand/observed, LL: long-line.

			Water Chemisty				Main Substrate	Habitat Surface Area Density (1=sparse 5=dense)								Physical Properties			Fishing	Individuals
Site #	River System	Reach	Secchi (cm)	Temp. (oC)	Salinity (ppt)	DO (mg/L)		Macrophyte Emergent	Macrophyte Submerged	Macrophyte Floating	Algae	Detritus	Rip. Veg. (Emersed)	Root Mats	Woody Debris	Depth (m)	Tidal	Velocity (m/sec)	Method	# Caught
23	ADELAIDE RIVER	MIDDLE	20	24.4	0.5	6.28	SILT	1	1	1	1	2	2	2	2	6	TOP TURN	0.1	GN	1
36	DALY RIVER	MIDDLE	200	31.3	0	6.72	SAND/GRAVEL	2	2	1	2	1	1	1	1	2	NON	0.35	HS	1
41	ROPER RIVER	UPPER	250	25.4	0.8	7.84	SAND	2	4	2	1	1	3	2	2	2.5	NON	NEG	GN	1
60	McARTHUR RIVER	MIDDLE	120	24	13.1	7.14	SAND	0	0	0	1	1	1	1	0	2.2	TOP TURN	NEG	GN	1
68	WEARYAN RIVER	MIDDLE	200	21.7	0.3	7.05	BEDROCK/SAND	1	3	1	3	1	2	1	1	2.5	NON	ZERO	GN	1
71	ROBINSON RIVER	MIDDLE	212	23.9	0	7.63	BEDROCK/SILT	1	2	1	3	3	3	2	2	3	NON	ZERO	GN	1
76	VICTORIA RIVER	MIDDLE	175	29.9	0	7.31	SILT/BEDROCK	1	1	1	3	2	2	2	2	5	NON	0	GN	1
77	VICTORIA RIVER	MIDDLE	201	28.5	0	6.91	CLAY/SAND	1	1	1	2	2	1	1	2	5	NON	0	GN	Recap. 76
91	FITZROY RIVER	LOWER	113	30.5	6	-	SILT/SAND	0	2	0	0	1	0	0	1	2	OUT	NEG	GN	4
93	FITZROY RIVER	LOWER	46	29.5	0	-	SILT/SAND	0	1	1	2	2	1	1	1	1	NON	NEG	GN	3
94	FITZROY RIVER	MIDDLE	123	27.8	0	-	SILT/SAND	0	1	1	4	2	2	2	1	2	NON	NEG	GN	4
96	FITZROY RIVER	UPPER	134	29	0	-	SAND	1	0	0	3	2	1	2	2	2.5	NON	NEG	GN	2
99	ROBINSON RIVER	LOWER	5	32.5	35	4.3	SILT	1	0	0	0	0	0	0	0	0.7	OUT	0.1	GN	2
			Turbidity NTU	Temp (oC)	Salinity ppt			Aquatic macrophyte				Detritus	Rip. Veg.		Snags	Depth (m)	Tidal	Velocity	Method	# Caught
115	WENLOCK RIVER		N/A	28.6	0		SAND	3				2	5		4	3	YES	MED	GN/LL	1
129	NORMANBY RIVER		-	30.8	7		SAND	3				5	5		3	3	YES	MED	GN/LL	1
132	GILBERT RIVER		-	-	0		SAND	0				3	5		2	2.5	NON	-	GN	6
135	GILBERT RIVER		-	-	0		SAND	0				3	5		1	3	NON	-	GN	1

Table 2: *Himantura chaophraya* habitat and catch data. Fishing method: GN: gill net, HS: hand/observed, LL: long-line.

			Water Chemisty				Main Substrate	Habitat Surface Area Density (1=sparse 5=dense)								Physical Properties			Fishing	Individuals
Site #	River System	Reach	Secchi (cm)	Temp. (oC)	Salinity (ppt)	DO (mg/L)		Macrophyte Emergent	Macrophyte Submerged	Macrophyte Floating	Algae	Detritus	Rip. Veg. (Emersed)	Root Mats	Woody Debris	Depth (m)	Tidal	Velocity (m/sec)	Method	# Caught
33	DALY RIVER	MIDDLE	273	24.4	0.2	7.29	SAND	1	1	1	2	1	1	1	1	2.5	BOTTOM TURN	0.05	LL	1
34	DALY RIVER	MIDDLE	218	24.3	0.2	7.26	SAND	0	0	0	1	0	0	0	1	1	OUT	0.7	HS	2
34	DALY RIVER	MIDDLE	218	24.3	0.2	7.26	SAND	0	0	0	1	0	0	0	1	1	OUT	0.7	HS	3
35	DALY RIVER	MIDDLE	26	25.3	0.2	7.56	SILT	2	2	1	1	1	1	1	1	2.5	TOP TURN	0.5	BH (2)	1
36	DALY RIVER	MIDDLE	200	31.3	0	6.72	SAND/GRAVEL	2	2	1	2	1	1	1	1	0.9	NON	0.35	HS	1
49	ROPER RIVER	LOWER	30	22.3	26.1	6.95	SILT	0	0	0	1	2	4	4	2	5	TOP OUT	0.1	LL	1
91	FITZROY RIVER	LOWER	113	30.5	6	-	SILT/SAND	0	2	0	0	1	0	0	1	1.1	OUT	NEG	LL	1
95	FITZROY RIVER	MIDDLE	INF	27.5	0	-	SAND/GRAVEL	0	1	0	2	0	0	0	1	0.25	NON	0.4	HS	1
108	ORD RIVER	MIDDLE	78	29	0	-	SAND/SILT	0	1	1	1	2	2	1	1	3.5	OUT	0.2	BH (2)	1
109	ORD RIVER	MIDDLE	60	31	0	-	SAND/SILT	2	2	0	1	2	2	1	2	1.8	IN	0.2	LL/BH	4
			Turbidity NTU	Temp (oC)	Salinity ppt			Aquatic macrophyte				Detritus	Rip. Veg.		Snags	Depth	Tidal	Velocity	Method	# Caught
119	MITCHELL RIVER		79	27	0		FINE MATERIAL	-				5	4		2	3.5	NON	-	GN/LL	3
120	MITCHELL RIVER		56	25.8	0		FINE MATERIAL	-				5	4		2	3.5	NON	-	GN/LL	1
121	MITCHELL RIVER		20	26.9	0		SAND	-				4	3		2	2.5	NON	-	GN/LL	1
129	NORMANBY RIVER		-	30.8	7		SAND	3				5	5		3	3	YES	MED	GN/LL	6

Table 3: *Carcharhinus leucas* habitat and catch data. Fishing method: GN: gill net, HS: hand/observed, LL: long-line, BH: baited hook.

			Water Chemisty				Main Substrate	Habitat Surface Area Density (1=sparse 5=dense)								Physical Properties			Fishing	Individuals
Site #	River System	Reach	Secchi (cm)	Temp. (oC)	Salinity (ppt)	DO (mg/L)		Macrophyte Emergent	Macrophyte Submerged	Macrophyte Floating	Algae	Detritus	Rip. Veg. (Emersed)	Root Mats	Woody Debris	Depth (m)	Tidal	Velocity (m/sec)	Method	# Caught
2	LIVERPOOL	MIDDLE	30	27	0	7	CLAY	2	2	3	1	1	1	1	1	2.5	TOP TURN	0.1	GN	1
3	LIVERPOOL	MIDDLE	45	27	0	7.4	CLAY	1	1	0	0	2	2	2	2	6.5	IN/OUT	0.1/0.5	GN/LL/BH	9
4	LIVERPOOL	MIDDLE	120	27	0	9.4	SAND/SILT	2	2	2	1	2	1	1	1	3	BOTTOM TURN	0.2	GN	1
31	DALY RIVER	MIDDLE	160	25.1	0.3	7.55	SAND	0	0	0	1	1	0	0	1	3.5	OUT	0.1	GN	3
32	DALY RIVER	MIDDLE	200	23.7	0.3	-	BEDROCK/SILT	0	0	0	1	1	0	0	0	1.5	NON	0.1	LL/BH	9
33	DALY RIVER	MIDDLE	273	24.4	0.2	7.29	SAND	1	1	1	2	1	1	1	1	2.5	BOTTOM TURN	0.05	GN/LL/BH	5
35	DALY RIVER	MIDDLE	26	25.3	0.2	7.56	SILT	2	2	1	1	1	1	1	1	2.5	TOP TURN	0.5	GN/LL/BH	9
43	ROPER RIVER	MIDDLE	130	23.1	0.6	8.09	COBBLES/SAND	1	2	1	2	2	1	2	2	21	OUT	0.5	LL	1
44	ROPER RIVER	MIDDLE	130	23.3	0.7	8.23	BEDROCK/SAND	1	1	1	1	1	1	1	2	6	OUT	NEG	BH (2)	2
45	ROPER RIVER	MIDDLE	130	23.3	0.7	8.23	BEDROCK/SAND	1	1	1	1	1	1	1	2	6	OUT	NEG	LL	6
46	ROPER RIVER	MIDDLE	80	24.3	0.3	7.96	SILT	2	2	1	2	2	3	3	3	3.5	BOTTOM TURN	NEG	GN	3
50	TOWNS RIVER	MIDDLE	60	25.7	4.7	7.22	BEDROCK/PEBBLES	2	2	1	0	2	1	1	1	3.5	OUT/COMPLETE	NEG	GN	12
51	TOWNS RIVER	MIDDLE	70	25	14.1	6.85	SAND/BEDROCK	1	1	0	1	1	1	1	1	2.5	OUT	NEG	GN	2
53	LIMMEN RIVER	MIDDLE	110	24.4	15.6	6.35	SAND	1	0	0	1	1	1	1	1	2.5	BOTTOM TURN	0.2	GN	1
55	LIMMEN RIVER	LOWER	100	22.1	21.4	6.27	SAND	0	0	0	1	1	0	0	0	1	COMLETE	0.5	LL	1
58	McARTHUR RIVER	LOWER	60	23.6	21.3	7.01	SILT/BEDROCK	1	1	1	1	2	2	3	1	2.5	OUT	0.2	GN	1
73	ROBINSON RIVER	MIDDLE	200	24.5	9.7	-	SAND/GRAVEL	3	2	0	1	1	2	1	1	1	COMPLETE	0.2	LL	1
74	ROBINSON RIVER	MIDDLE	200	24.5	9.7	-	GRAVEL/SILT	4	4	2	2	2	1	1	0	3.5	COMPLETE	NEG	GN	2
75	ROBINSON RIVER	MIDDLE	267	23.8	0.9	7.95	SAND/BOULDERS	3	4	2	2	1	1	1	1	3	OUT	NEG	GN	2
78	VICTORIA RIVER	MIDDLE	79	29	2.9	5.9	SAND	0	1	0	2	1	0	0	1	5	IN	NEG	GN	1
79	VICTORIA RIVER	MIDDLE	93	29.7	9.7	6.17	SAND	0	1	0	1	1	0	1	1	4	OUT	NEG	LL	1
91	FITZROY RIVER	LOWER	113	30.5	6	-	SILT/SAND	0	2	0	0	1	0	0	1	2	OUT	NEG	HS	2
95	FITZROY RIVER	MIDDLE	213	27.5	0	-	GRAVEL/SAND	1	0	0	3	1	1	0	1	2.5	NON	NEG	GN/BH/HS	8
99	ROBINSON RIVER	LOWER	5	32.5	35	4.3	SILT	1	0	0	0	0	0	0	0	0.7	OUT	0.1	GN	1
106	ORD RIVER	MIDDLE	123	28	0	-	SAND	1	3	1	1	0	2	0	1	4	NON	0.4	BH	1
108	ORD RIVER	MIDDLE	78	29	0	-	SAND/SILT	0	1	1	1	2	2	1	1	3.5	OUT	0.2	GN/LL	3
109	ORD RIVER	MIDDLE	60	31	0	-	SAND/SILT	2	2	0	1	2	2	1	2	1.8	IN	0.2	GN/LL	2
110	ORD RIVER	MIDDLE	73	31	3	-	SAND/SILT	2	1	1	0	3	2	1	1	3	TOP TURN	0.2	GN	1
			Turbidity NTU	Temp (oC)	Salinity ppt			Aquatic macrophyte				Detritus	Rip. Veg.		Snags	Depth	Tidal	Velocity	Method	# Caught
114	WENLOCK RIVER		8	28.7	0		FINE MATERIAL	5				5	5		2	5	NON	LOW	GN/LL	2
115	WENLOCK RIVER		N/A	28.6	0		SAND	3				2	5		4	3	YES	MED	GN/LL	2
119	MITCHELL RIVER		5	27.3	0		FINE MATERIAL	-				5	4		2	3.5	NON	LOW	GN	7
122	MISSION RIVER		-	-	34.9		FINE MATERIAL	-				1	5		1	3	YES	HIGH	GN	13
125	MISSION RIVER		-	-	35.1		FINE MATERIAL	-				1	5		1	2.5	YES	HIGH	GN/LL	4
126	MISSION RIVER		-	-	34.2		SAND	-				1	5		0	3	YES	HIGH	GN	3

Table 4: *Pristis clavata* habitat and catch data. Fishing method: GN: gill net, LL: long-line.

			Water Chemisty				Main Substrate	Habitat Surface Area Density (1=sparse 5=dense)								Physical Properties			Fishing	Individuals
Site #	River System	Reach	Secchi (cm)	Temp. (oC)	Salinity (ppt)	DO (mg/L)		Macrophyte Emergent	Macrophyte Submerged	Macrophyte Floating	Algae	Detritus	Rip. Veg. (Emersed)	Root Mats	Woody Debris	Depth (m)	Tidal	Velocity (m/sec)	Method	# Caught
79	VICTORIA RIVER	MIDDLE	93	29.7	9.7	6.17	SAND/SILT	0	1	0	1	1	0	1	1	1.5	OUT	NEG	GN	1
98	MAY RIVER	LOWER	6	30.15	41.1	3.3	SILT	0	0	0	0	0	0	0	0	2	BOTTOM/TURNC	0.1/0.2	GN	6
98	MAY RIVER	LOWER	6	30.15	41.1	3.3	SILT	0	0	0	0	0	0	0	0	2	OUT	0.2	GN	3
99	ROBINSON RIVER	LOWER	5	32.5	35	4.3	SILT	1	0	0	0	0	0	0	0	0.7	OUT BOTTOM	0.1	GN	6
			Turbidity NTU	Temp (oC)	Salinity ppt			Aquatic macrophyte				Detritus	Rip. Veg.		Snags	Depth (m)	Tidal	Velocity	Method	# Caught
122	MISSION RIVER		-	-	34.9		FINE MATERIAL	-				1	5		1	3	YES	HIGH	GN	1
124	ALBATROSE BAY		-	-	34.7		SAND	-				1	4		1	1.2	YES	HIGH	GN	1
125	MISSION RIVER		-	-	35.1		FINE MATERIAL	-				1	5		1	2.5	YES	HIGH	GN/LL	1

Table 5: *Anoxypristis cuspidata* habitat and catch data. Fishing method: GN: gill net.

			Water Chemisty				Main Substrate	Habitat Surface Area Density (1=sparse 5=dense)								Physical Properties			Fishing	Individuals
Site #	River System	Reach	Secchi (cm)	Temp. (oC)	Salinity (ppt)	DO (mg/L)		Macrophyte Emergent	Macrophyte Submerged	Macrophyte Floating	Algae	Detritus	Rip. Veg. (Emersed)	Root Mats	Woody Debris	Depth (m)	Tidal	Velocity (m/sec)	Method	# Caught
1	LIVERPOOL	MOUTH	150	27	30	9.1	CLAY/SILT	0	0	0	0	0	1	1	1	5	BOTTOM TURN	0.5	GN	1
8	BLYTHE	MOUTH	60	25.2	31	6.93	CLAY/SILT	0	0	0	0	1	1	0	0	4	IN	0.5	GN	1

Table 6: *Pristis zijsron* habitat and catch data. Fishing method: GN: gill net.

		Water Chemisty			Main Substrate	Habitat Surface Area Density (1=sparse 5=dense)							Fishing	Individuals
Site #	River System	Turbidity NTU	Temp (oC)	Salinity ppt		Aquatic macrophyte	Detritus	Rip. Veg.	Snags	Depth (m)	Tidal	Velocity	Method	# Caught
123	ALBATROSE BAY	-	-	35.1	FINE MATERIAL	-	1	5	1	1.2	YES	HIGH	GN	1
124	ALBATROSE BAY	-	-	34.7	SAND	-	1	4	1	1.2	YES	HIGH	GN	1
126	MISSION RIVER	-	-	34.2	SAND	-	1	5	0	3	YES	HIGH	GN	1