

Distribution, relative abundance and risks from fisheries to threatened *Glyphis* sharks and sawfishes in northern Australia

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ABSTRACT: *Glyphis* sharks and pristid sawfishes are globally threatened. While some populations still exist in northern Australia, their distributions are poorly quantified. We used catch records from commercial fisheries and independent surveys to estimate the broad distribution and relative abundances of 2 *Glyphis* sharks (*G. glyphis* and *G. garricki*) and 4 pristid sawfishes (*Pristis pristis*, *P. zijsron*, *P. clavata* and *Anoxypristis cuspidata*) along the coast, estuaries and river systems of the Northern Territory, Australia. Coarse-scale catch data and records from commercial fishing logbooks that report encounters with Threatened, Endangered and Protected species confirm that small, fragmented populations are distributed across the Northern Territory coastline and suggest limited fishery interactions, although underreporting might occur.

KEY WORDS: Sharks · Habitat · Fishing · Conservation · Management · *Pristis* spp. · *Anoxypristis* spp.

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INTRODUCTION

Recent studies have questioned the likely persistence of many populations of large marine predators, such as sharks, due to increasing mortality from fishing and loss of critical habitats (Gray 1997, Hutchings 2000, Worm et al. 2006, Field et al. 2009b). Coastal species are arguably under the greatest threat due to their proximity to anthropogenic pressures and their dependence on climate-sensitive inshore habitats (Chin et al. 2010). Extinction risk is further elevated for those coastal species with restricted ranges and

limited dispersal capabilities (Roberts & Hawkins 1999, Dulvy et al. 2003, Field et al. 2009b, Frankham et al. 2012). For such species, appropriate conservation strategies require, at the very least, accurate data describing species' distribution and abundance, as well as a clear understanding of current threats to populations (Caughley & Gunn 1996).

Glyphis sharks and sawfishes (Pristidae) are threatened coastal elasmobranchs with fragmented regional distributions (IUCN 2010). Accurate demographic and distributional data is limited for these taxa, with occurrences recorded at only a few loca-

tions, thus hindering conservation planning (IUCN 2010). Two species of *Glyphis* sharks have been described in northern Australia, *G. glyphis* (the speartooth shark, previously known as *Glyphis* sp. A) and *G. garricki* (the northern river shark, previously known as *Glyphis* sp. C) (Larson 2002, Martin 2005, Peverell et al. 2006, Compagno et al. 2008, Wynen et al. 2009). Both species have restricted distributions; *G. glyphis* has only been recorded in the Northern Territory (Adelaide River, East, South and West Alligator Rivers, Murganella Creek and Marrakai Creek) and in Queensland (Wenlock and Ducie Rivers, Port Musgrave and the Bizant River) (Peverell et al. 2006, Compagno et al. 2008). The only other record of this species globally is from Papua New Guinea (Compagno et al. 2008). *G. garricki* is also found in Australia in the Northern Territory (Adelaide, East and South Alligator and Mary Rivers) but unlike *G. glyphis*, it has also been recorded in Western Australia (King Sound in the Kimberley region) (Taniuchi et al. 1991, Thorburn & Morgan 2004, 2005). Similar to *G. glyphis*, the only other place where this species has been recorded is Papua New Guinea (Taniuchi et al. 1991, Compagno et al. 2008). Both *Glyphis* spp. are considered extremely rare, although no population estimates are available for either species. *G. glyphis* and *G. garricki* are currently listed as Critically Endangered in the IUCN Red List (www.iucnredlist.org), and critically endangered and endangered under the Australian Commonwealth Environment Protection and Biodiversity Conservation (EPBC) Act 1999, respectively. Due to these classifications, both species are identified as 'key' species for conservation planning (National Oceans Office 2004).

There are 4 sawfishes in Australia: the freshwater sawfish *Pristis pristis* (previously known as *P. microdon*), green sawfish *P. zijsron*, dwarf sawfish *P. clavata* and narrow sawfish *Anoxypristis cuspidata* (Thorburn et al. 2003, Faria et al. 2013). As for *Glyphis* sharks, knowledge of the distribution of these species is based on a few records across tropical Australia. Although there have been no direct estimates of abundance, all species are considered 'rare' (Pogonoski et al. 2002, Thorburn et al. 2003, Martin 2005). Some suggestion of contemporary declines in populations in northern Australia has been made based on a low genetic diversity in *P. zijsron* and *P. clavata* in the Gulf of Carpentaria (Phillips et al. 2011). All 4 sawfishes are classified as Critically Endangered by the IUCN Red List, but only *P. clavata*, *P. pristis* (as *P. microdon*) and *P. zijsron* are listed (as vulnerable) under the Australian EPBC Act.

Commercial fishing has been implicated as a key threat to Australian populations of *Glyphis* sharks and sawfishes (Compagno & Cook 1995, Stevens et al. 2000, Pogonoski et al. 2002, Martin 2005, IUCN 2010). In the Northern Territory, the offshore net and line and the barramundi *Lates calcarifer* fisheries are the 2 principal commercial fisheries where by-catch of *Glyphis* sharks and sawfishes have been recorded (Northern Territory Department of Primary Industry Fisheries and Mines 2010). Although the reporting of by-catch in commercial logbooks is a requirement of fishing licences (Northern Territory Department of Primary Industry Fisheries and Mines 2010), reporting is often inaccurate, incomplete and compromised by misidentification, hindering effective management of fishery interactions with these threatened species (Tillett et al. 2012). Many fisheries now employ trained scientific observers to improve identification of by-catch (Tillett et al. 2012), but overall coverage is low.

We use a combination of catch records, observer data and fishery-independent survey data to improve the knowledge of distribution and relative abundance of *Glyphis* sharks and sawfishes in the Northern Territory, Australia, and investigate the potential threat to populations posed by commercial fisheries.

MATERIALS AND METHODS

Commercial catches

In the Northern Territory Offshore Net and Line (NTONL) fishery, operators may use either longlines or pelagic set nets, but the use of bottom set nets is prohibited. Most licensees uses pelagic gillnets (1000 to 2000 m in length with a square mesh size of 160 to 185 mm and a 50 to a maximum 100 mesh drop) (Northern Territory Department of Primary Industry Fisheries and Mines 2010). Between 1983 and 2005, *Glyphis* sharks and sawfishes were recorded in the fishery catch data as combined-species groups (i.e. either '*Glyphis*' or 'sawfish'). During that time, captured individuals were only recorded if they were retained and harvested, but not if they were discarded or released alive. In 2005, both *Glyphis* species and 3 sawfishes (*Pristis clavata*, *P. pristis*—as *P. microdon*—and *P. zijsron*) were added to the Australian Commonwealth Government's threatened, endangered and protected species list under the EPBC Act. Consequently, it became illegal to kill, take, trade, keep or move these species, and compulsory to report all fisheries interactions in commercial

logbooks irrespective of whether an individual was kept, discarded or released. A voluntary 'no take' policy on all sawfishes was also implemented in the NTONL fishery at that time. The data included in our study were recorded from 2005 to 2006.

The Northern Territory Barramundi fishery (NTBarr) uses monofilament gillnets (square mesh size of 150 mm if set outside river mouths and 175 mm if set within the mouths of a select number of rivers) (Northern Territory Department of Primary Industry Fisheries and Mines 2010). Between 1983 and 2005, commercial logbooks for the fishery only required reporting of *Glyphis* sharks and sawfishes collectively as 'sharks'. Although species-specific reporting was required after that time, few interactions were recorded in logbooks between 2005 and 2006 and so we do not present the data here.

All commercial fishing locations were recorded at a 0.1° resolution (longitude and latitude), but we present them here at 1° resolution for reasons of commercial confidentiality.

Fisheries observer programmes

The observer programmes combined data from 3 projects along the Northern Territory coastline: (1) the offshore net and line fishery observer programme by Northern Territory Fisheries from 2002 to 2007, (2) an Australian Fisheries Research and Development Corporation-funded Sustainability Project (FRDC-SP), for both the offshore net and line and barramundi fisheries (Salini 2007) from 2002 to 2004, and (3) observations we made from 2007 to 2008 for the barramundi fishery. Observers for the offshore net and line fishery were deployed on commercial vessels for a total of 49 d (13 d as part of the FRDC-SP and 36 d as part of the Northern Territory observer programme; Fig. 1). Observers were on board the barramundi vessels for 52 d (40 d as part of our study and 12 d as part of the FRDC-SP; Fig. 1).

Observers monitored routine fishing operations, recording catch composition and size of individuals (± 5 mm) (Salini 2007). Where possible, every elasmobranch was measured; however, when catches were large, a random subsample was taken. Data collected by observers included species

caught, sex, total length, location, date, time and whether the animal was kept or discarded. Effort was measured as the number of boat days but could not be directly compared between fisheries due to the different gears and shot patterns. Unlike commercial catch records, *Glyphis* sharks and sawfishes were identified to genus and species where possible.

Fisheries-independent surveys

We did fishery-independent surveys using hook and line, gillnet (150 to 250 mm square mesh size with a 16 mesh drop) and long-line (approximately 50 m in length and with 50 snoods, size 11/0, positioned 1 m apart) approaches. We surveyed in the lower reaches of the Wildman, West, South and East Alligator and Daly Rivers (Fig. 2). Data collected included species, total and fork lengths, sex and capture location. We also assessed male maturity based on clasper calcification.

Analysis

We estimated the broad-scale distributions of *Glyphis* sharks and sawfishes from the offshore net and line fishery's commercial logbooks between 1983 and 2005. We determined finer- (species-)resolution distributions by mapping the location of threatened/

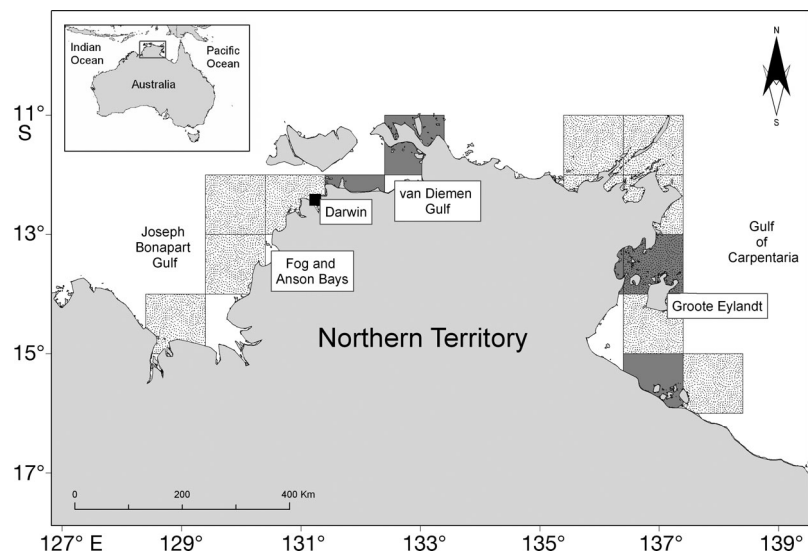


Fig. 1. Areas of fishing operations for the Northern Territory Offshore Net and Line (light background) and Northern Territory Barramundi fisheries (dark grey background) monitored by observers for the Northern Territory Fisheries and Fisheries Research and Development Corporation's sustainability projects (Salini 2007)

endangered/protected species interactions, observer data and fishery-independent surveys. We made all resultant maps using ArcGIS Software (Version 9.1). Due to low sample sizes, we could not estimate total population sizes; instead, we estimated relative abundances by calculating the number of individuals from each species caught per day from observer data for each fishery.

We calculated the proportion of *Glyphis* sharks and sawfishes of the total catch of elasmobranchs based on observer data for each fishery. We also determined the mean size of individuals caught within each fishery by calculating the mean fork length and standard deviation from observer data for each fishery.

RESULTS

Species' distributions

Catch records from the offshore net and line fishery show that *Glyphis* sharks and sawfishes were caught in coastal waters across the Northern Territory. Fishery interactions with *Glyphis* sharks ($n = 1$) and *Pristis pristis* ($n = 2$) were too few to provide definitive information on distribution. Interactions by fisheries with *Anoxypristis cuspidata* ($n = 189$ [2005] and 481 [2006]) and *P. zijsron* ($n = 26$ [2005] and 14 [2006]) were recorded in similar locations (Fig. 3). Interestingly, observed interactions with *A. cuspidata* occurred more frequently in the Gulf of Carpentaria than those reported with *P. zijsron* (Fig. 3).

Observer data provided similar capture locations. The observers for the offshore net and line fishery recorded and measured 4634 individual elasmobranchs during 49 d at sea. Few *Glyphis glyphis* ($n = 1$), *G. garricki* ($n = 4$), *Anoxypristis cuspidata* ($n = 8$) and *Pristis zijsron* ($n = 1$) were identified in the catch. These samples were too low to provide robust distributional information for these species. Conversely, there were higher catches of *Glyphis* sharks and sawfishes in the barramundi fishery. Observers

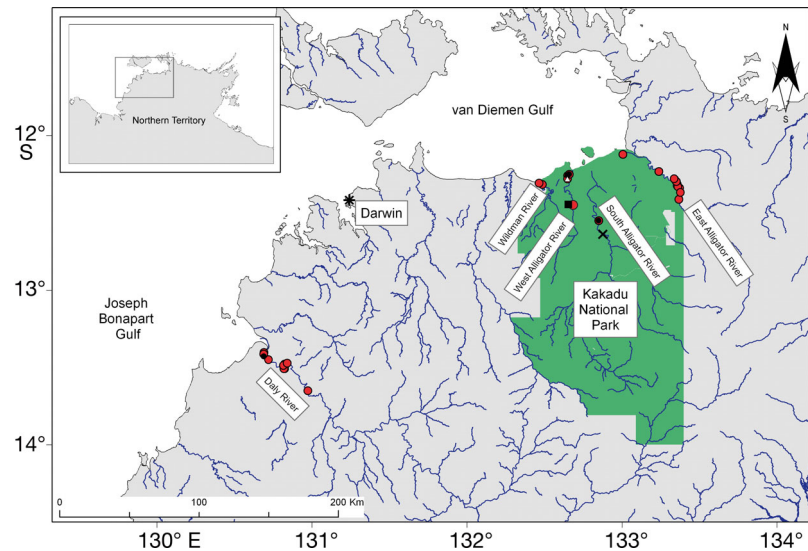


Fig. 2. Locations of *Glyphis glyphis* (West Alligator River; ■), *G. garricki* (●), *Glyphis* spp. (lower West Alligator River; △) and *Pristis pristis* (×) during fishery-independent surveys (●) around the Northern Territory

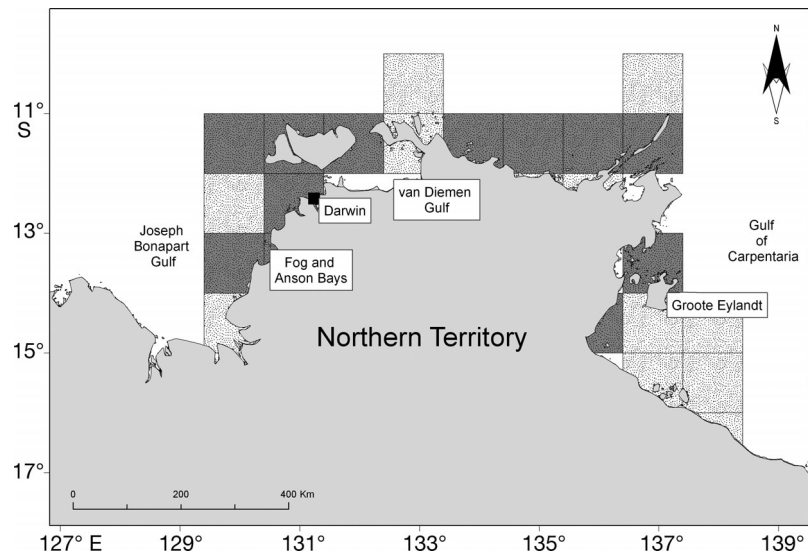


Fig. 3. The areas where *Pristis zijsron* ($n = 40$, dark grey background) and *Anoxypristis cuspidata* ($n = 670$, light background) were caught by the Northern Territory offshore net and line fishery from threatened, endangered and protected catch records

in this fishery recorded and measured 639 individuals of 23 species during 52 d at sea, of which 37 were *A. cuspidata*, 20 were *P. clavata*, 12 were *P. zijsron* and 17 were *G. glyphis*. All 3 species of sawfish were caught near Grootte Eylandt, and *G. glyphis* were caught in Van Diemen Gulf (Fig. 4).

Glyphis garricki specimens were caught in the fishery-independent surveys in the West and South Alligator Rivers and the Daly River, but only *G. glyphis* in the West Alligator River. Mean fork length

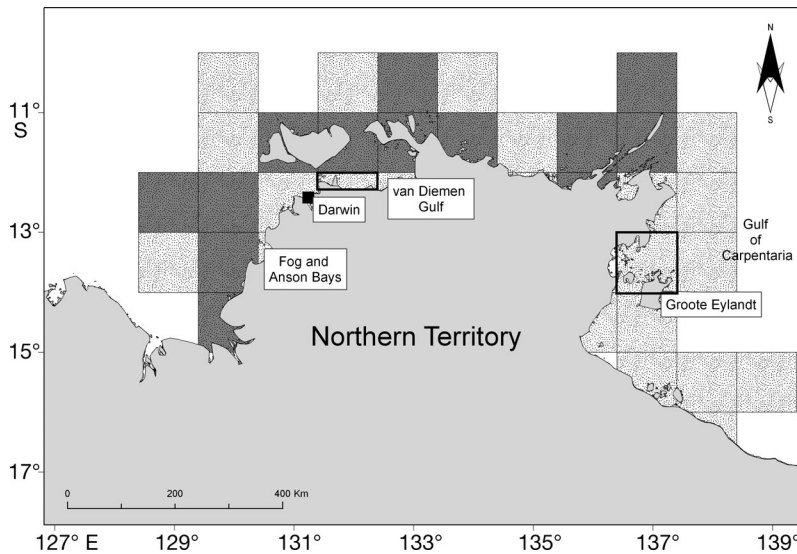


Fig. 4. Areas where *Glyphis* spp. (dark grey background) and sawfishes (light grey background) were caught by the Northern Territory Offshore Net and Line fishery from combined aggregated catch data. Outlined grids indicate where *G. glyphis* (from Van Diemens Gulf) and all sawfish species (near Groote Eylandt) were recorded by observers of the barramundi fishery

of the *Glyphis* sharks was 920 ± 151 mm (mean \pm SD, $n = 7$) and ranged from 690 to 1160 mm (Table 1). We did not record the biological details for the individual caught in the Daly River because it had been damaged by another shark. All males caught were immature. Interestingly, we caught no *Glyphis* at the same time that we were catching bull sharks *Carcharhinus leucas*. Only 1 sawfish (*Pristis pristis*) was caught in the South Alligator River.

Relative abundance

All *Glyphis* sharks and sawfishes reported by observers in the offshore net and line fishery had relatively low abundance (Table 2). *Anoxypristis cuspidata* were caught most frequently. *G. garricki* were caught once every 12 d of observation. *G. glyphis* and *Pristis zijsron* were recorded once every 50 d of observation (Table 2).

Anoxypristis cuspidata was the most abundant focal species caught at a similar frequency as *Carcharhinus leucas* in observer data from the barramundi fishery (Table 3), with around 2 individuals caught every 3 d. Individuals of *Glyphis glyphis*, *Pristis clavata* and *P. zijsron* were caught every 3 to 4 d, as were spinner sharks *C. brevipinna* and common shovelnose rays *Rhinobatos typus*. The most common species in catches were blacktip sharks *C. tilstoni*—

they were 13 times more abundant than *G. glyphis*, *P. clavata* and *P. zijsron* (Table 3).

Fishery interactions

Glyphis sharks were reported in offshore net and line catch records only in 1999, 2000 and 2004 and were rare (around 0.01, 0.003 and 0.0003% of total catches of sharks in these years, respectively). Catches of sawfishes by weight varied over time and were highest between 1999 and 2004 (Fig. 5). Even during that period, sawfishes accounted for less than 0.05% of the total harvest of elasmobranchs per year.

The offshore net and line observers recorded and measured *Glyphis glyphis*, *G. garricki*, *Anoxypristis cuspidata* and *Pristis zijsron* in the catches (Table 2). These 4 species were relatively minor components accounting for only 0.29% of the total catch of elasmobranchs (Table 2). The mean fork length of *A. cuspidata* ($n = 6$) was 2347 ± 515 mm and ranged from 1420 to 2810 mm. Only a single 1400 mm (fork length) specimen of *G. glyphis* was caught. No measurements were taken of the single *P. zijsron* or 4 *G. garricki* that were caught by the fishery.

Barramundi fishery observers recorded and measured *Anoxypristis cuspidata*, *Pristis clavata*, *P. zijsron* and *Glyphis glyphis* in the catches (Tables 3 & 4). These 4 species accounted for 13.5% of the total catch of elasmobranchs. Observers in this fishery

Table 1. Size of all *Glyphis* spp. and sawfish individuals caught during the independent surveys in the Northern Territory. (-): Not measured

Species	Sex	Total length (mm)	Fork length (mm)	Location (river)
<i>G. glyphis</i>	F	930	800	West Alligator
	F	850	690	West Alligator
	M	1320	1160	West Alligator
<i>G. garricki</i>	M	1060	840	West Alligator
	F	1100	910	South Alligator
	F	1280	1030	West Alligator
	-	-	-	Daly River
<i>Glyphis</i> sp.	M	1060	910	West Alligator
<i>Pristis pristis</i>	F	1200	-	South Alligator

Table 2. Number of individuals, proportion of catch and measure of fishery interactions (number caught per day) of *Glyphis* spp. and sawfishes (shaded) and for all other elasmobranch species caught by the Northern Territory Offshore Net and Line fishery as recorded by observers during 49 d at sea from the Northern Territory Observer Programmes and Fisheries Research and Development Corporation's sustainability project

Species	Individuals caught (n)	Proportion of catch (%)	Relative abundance (n d ⁻¹)
<i>Anoxypristis cuspidata</i>	8	0.17	0.16
<i>Carcharhinus amblyrhynchoides</i>	28	0.60	0.57
<i>C. amblyrhynchos</i>	22	0.47	0.45
<i>C. amboinensis</i>	92	1.99	1.88
<i>C. brevipinna</i>	34	0.73	0.69
<i>C. cautus</i>	3	0.06	0.06
<i>C. dussumieri</i>	23	0.50	0.47
<i>C. fitzroyensis</i>	31	0.67	0.63
<i>C. leucas</i>	6	0.13	0.12
<i>C. limbatus</i>	3	0.06	0.06
<i>C. macloiti</i>	1	0.02	0.02
<i>C. melanopterus</i>	48	1.04	0.98
<i>C. sorrah</i>	882	19.03	18.00
<i>C. tilstoni</i>	2768	59.73	56.49
<i>Eusphyra blochii</i>	222	4.79	4.53
<i>Galeocerdo cuvier</i>	65	1.40	1.33
<i>Glyphis glyphis</i>	1	0.02	0.02
<i>Glyphis garricki</i>	4	0.08	0.08
<i>Hemigaleus microstoma</i>	1	0.02	0.02
<i>Hemipristis elongata</i>	29	0.63	0.59
<i>Manta birostris</i>	1	0.02	0.02
<i>Mobula eregoodootenkee</i>	6	0.13	0.12
<i>Nebrius ferrugineus</i>	44	0.95	0.90
<i>Negaprion acutidens</i>	27	0.58	0.55
<i>Pristis zijsron</i>	1	0.02	0.02
<i>Rhinobatos typus</i>	1	0.02	0.02
<i>Rhizoprionodon acutus</i>	73	1.58	1.49
<i>Rhizoprionodon taylori</i>	2	0.04	0.04
<i>Rhynchobatus australiae</i>	3	0.06	0.06
<i>Sphyrna lewini</i>	132	2.85	2.69
<i>Sphyrna mokarran</i>	74	1.60	1.51
<i>Stegostoma fasciatum</i>	1	0.02	0.02
<i>Triaenodon obesus</i>	2	0.04	0.04

recorded more interactions with all sawfish and *Glyphis* sharks (excluding *G. garricki*) than in the offshore net and line fishery. *A. cuspidata* were again the most commonly captured sawfish followed by *P. clavata*, *G. glyphis* and *P. zijsron* (Table 3). Around half of the sawfish caught in the barramundi fishery were dead when retrieved from the nets (Table 5).

DISCUSSION

Knowledge of the distribution and abundance of threatened *Glyphis* sharks and sawfishes in northern Australia is based on only a few studies (IUCN 2010). Our results provide an assessment of the available

fisheries data and our independent surveys improve our understanding of what are possibly the last population strongholds for these species (Halpern et al. 2008). The capture locations we reported appear to confirm the suspected broad-scale distribution of *Glyphis* sharks across the west and north of the Northern Territory (Taniuchi et al. 1991, Larson 2000, Thorburn & Morgan 2004, Compagno et al. 2008). Finer-scale data provided a more comprehensive picture, showing that *G. glyphis* was most often found in rivers draining into the Van Diemen Gulf; however, we could not confirm the presence of this species in the western Gulf of Carpentaria (eastern Northern Territory). This is surprising, given the similarity in coastal habitats, but might simply reflect the need for even greater sampling effort in this region. Overall, the picture that emerges for *G. glyphis* is a fragmented distribution across northern Australia (Peverell et al. 2006, Last & Stevens 2009). For *G. garricki*, our study has enhanced current knowledge of its distribution and provided the first formal reports of this species in the Daly and West Alligator Rivers (Taniuchi et al. 1991, Larson 2000, Thorburn & Morgan 2004), a region where anecdotal reports suggested that they occurred.

The few *Glyphis* sharks caught by the NTONL fishery reported in this and past studies (Stevens & McLoughlin 1991, Salini 2007), and the higher

incidence of catches by the NTBarr, show that these species are rarely caught away from estuaries and nearshore waters. This challenges the use of 'freshwater' sharks as one of their common names. From our independent survey data and others (Tanaka 1991, Larson 2000, Thorburn et al. 2003, Martin 2005, Pillans et al. 2005, Peverell et al. 2006), all *Glyphis* sharks encountered to date have been juveniles caught in coastal estuarine environments. This result also supports earlier suggestions that adults occupy different habitats (i.e. they are probably fully marine) than the estuaries where juveniles are caught (IUCN 2010). Other evidence that the adult phase is likely to be marine is provided by historical fisheries data of larger (estimated from landed weight) and presum-

ably much older animals caught by longliners using bottom-set gear farther offshore. This pattern of smaller, juvenile sharks inshore and larger individuals offshore is similar to the ontogenetic patterns observed in other coastal species (Stevens et al. 2000)

such as blacktip sharks *Carcharhinus tilstoni* and bull sharks *C. leucas* (Keeney et al. 2005, Yeiser et al. 2008). Previous studies have suggested that *G. garricki* generally select turbid, freshwater and brackish reaches of rivers (Larson 2000), but the higher abundance of *G. garricki* in the fisheries we examined supports growing evidence for a greater tolerance to salinity than originally suspected (IUCN 2010).

Table 3. Number of individuals, proportion of catch and measure of fishery interactions (number caught per day) of *Glyphis* spp. and sawfishes (shaded) and other elasmobranchs caught by the Northern Territory Barramundi fishery as recorded by observers during 52 d at sea from the Fisheries Research and Development Corporation's (FRDC) sustainability project and this study

Species	Individuals caught (n)	Proportion of elasmobranch catch (%)	Relative abundance (n d ⁻¹)
<i>Aetobatus narinari</i>	6	0.94	0.12
<i>Anoxypristis cuspidata</i>	37	5.79	0.71
<i>Carcharhinus amboinensis</i>	1	0.16	0.02
<i>C. brevipinna</i>	22	3.44	0.42
<i>C. cautus</i>	30	4.69	0.58
<i>C. fitzroyensis</i>	1	0.16	0.02
<i>C. leucas</i>	47	7.36	0.90
<i>C. maclohi</i>	1	0.16	0.02
<i>C. sorrah</i>	1	0.16	0.02
<i>C. tilstoni</i>	230	35.99	4.42
<i>Dasyatis</i> sp.	1	0.16	0.02
<i>Eusphyra blochii</i>	59	9.23	1.13
<i>Glyphis glyphis</i>	17	2.66	0.33
<i>Himantura uarnak</i>	4	0.63	0.08
<i>Negaprion acutidens</i>	67	10.49	1.29
<i>Pastinachus sephan</i>	1	0.16	0.02
<i>Pristis clavata</i>	20	3.13	0.38
<i>Pristis zijsron</i>	12	1.88	0.23
<i>Rhinobatos typus</i>	22	3.44	0.42
<i>Rhizoprionodon acutus</i>	38	5.95	0.73
<i>Rhynchobatus australiae</i>	2	0.31	0.04
<i>Rhynchobatus djiddensis</i>	13	2.03	0.25
<i>Sphyrna lewini</i>	7	1.10	0.13

The capture locations of sawfishes also confirm their suspected distribution across the Northern Territory. *Anoxypristis cuspidata* appears to have the widest distribution of all sawfishes around the Northern Territory coast. In contrast, *Pristis zijsron*, *P. clavata* and *P. pristis* were all caught in discrete locations, most of which had been recorded in earlier studies. This result supports the idea that these 3 species have fragmented populations, most likely due to previous depletions (Last & Stevens 2009). The absence of *P. clavata* in waters around Groote Eylandt supports previous assessments of their rarity in the Gulf of Carpentaria (Thorburn et al. 2003). The occurrence of *P. pristis* around Groote Eylandt is the first record of an individual of this species east of the Wessel Islands in the Northern Territory and supports the idea of a distribution across the Gulf of Carpentaria (Thorburn et al. 2007). The first record of *P. pristis* in the South Alligator River also

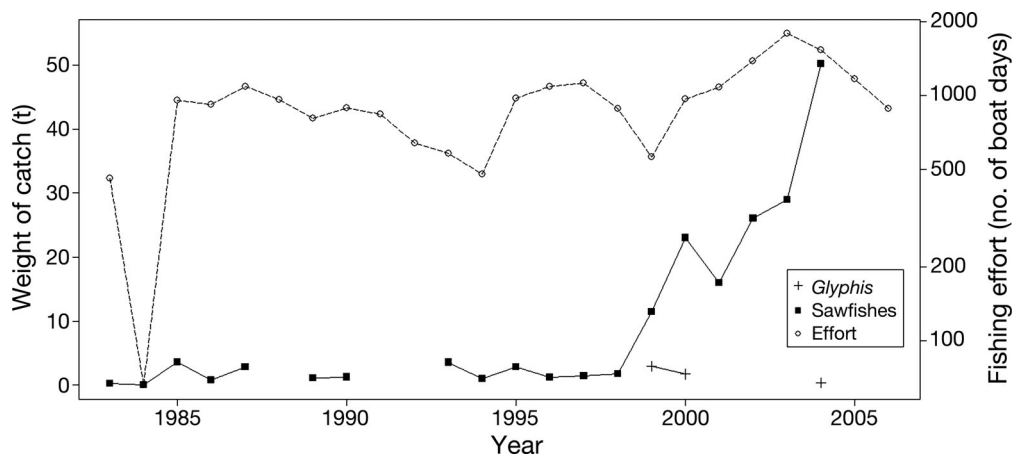


Fig. 5. The aggregated weight of *Glyphis* spp. and sawfishes caught each year by the Northern Territory Offshore Net and Line fishery between 1983 and 2005. Also shown is the fishing effort as the number of boat days per year

Table 4. Mean (\pm SD) and range of fork lengths (mm) for *Glyphis glyphis* and sawfishes caught by the Northern Territory Barramundi fishery as measured by observers from the Fisheries Research and Development Corporation's (FRDC) Sustainability Project (Salini 2007) and the present study

Species	n	Mean \pm SD (mm)	Min (mm)	Max (mm)
<i>Anoxypristis cuspidata</i>	37	1064 \pm 133	675	1190
<i>Glyphis glyphis</i>	17	1005 \pm 277	620	1390
<i>Pristis clavata</i>	20	800 \pm 84	680	870
<i>Pristis zijsron</i>	12	1213 \pm 251	860	1505

Table 5. Number of narrow, dwarf, and green sawfishes caught alive and dead as by-catch in the Northern Territory Barramundi fishery, and as recorded by observers in the present study

Species	Alive	Dead	Total
<i>Anoxypristis cuspidata</i>	18	19	37
<i>Pristis clavata</i>	11	9	20
<i>Pristis zijsron</i>	5	6	11

confirms predictions of a distribution of the species across Van Diemen Gulf (Thorburn et al. 2003), and few captures in both fisheries suggests that they occupy predominately freshwater habitats (Thorburn et al. 2007).

The higher catches of sawfishes in the estuary-based barramundi fishery compared to the more coastal offshore net and line fishery (similar to *Glyphis* sharks) is consistent with the view that this species uses shallow coastal/estuarine nurseries (Thorburn et al. 2003, Thorburn & Morgan 2005). However, more frequent catches of *Anoxypristis cuspidata* in the barramundi fishery than the offshore net and line fishery contradicts earlier work that suggested that *A. cuspidata* was more common in marine than estuarine environments (Peverell 2005). However, such patterns must be interpreted with caution, because our results might reflect changes in fishing technique as a result of the ban of bottom-set gill nets in the offshore net and line fishery.

Low capture rates in both the offshore net and line and barramundi fisheries confirm the rarity of *Glyphis* sharks and sawfishes across the Northern Territory (Pogonoski et al. 2002, Thorburn et al. 2003, Martin 2005). Within these shallow coastal/estuarine environments, abundances of *Anoxypristis cuspidata* are greater than other sawfishes, and *Pristis pristis* is likely to be the rarest of all species, possibly a reflection of their preference for freshwater habitat (Thor-

burn et al. 2007). Of the spear-tooth sharks, *G. garricki* appears to be less abundant than *G. glyphis*, despite the former species being caught more frequently in the offshore net and line fishery (Thorburn et al. 2003). Comparison with biomass data would confirm these trends as there is growing evidence to suggest that fishery catch rates are not necessarily linearly associated with species abundance (Cooke & Beddington 1984, Branch et al. 2011).

Low capture probabilities suggest that current commercial fishing practices potentially have little influence on the population dynamics of *Glyphis* sharks and sawfishes in the Northern Territory, although discrepancies between data sources (at least in the offshore net and line fishery) indicate that catches might be under-reported and thus, fishery interactions could be higher. One likely source of error is misidentification, particularly of *Glyphis* sharks due to morphological similarities among carcharhinids (Tillett et al. 2012). Genetic techniques provide a proven means to remove such uncertainty from catch data (e.g. Tillett et al. 2012), allowing better monitoring of impacts on these threatened species.

The diversity of reported interactions in the barramundi fishery lends support to the call to introduce species-specific reporting of elasmobranch by-catch. The by-catch problem is further confounded by the high mortality among caught sawfish in the barramundi fishery, suggesting that changes in fishing effort (such as banning bottom set nets) to reduce by-catch of threatened species are also necessary. Since completion of our study, logbook reporting of threatened species in the barramundi fishery has changed and the reporting of fishery interactions and fishing effort has been reduced by the removal of fishing licenses.

Further research is needed to determine the rates of survival of released *Glyphis* sharks and sawfish. The impacts of increased juvenile mortality on species persistence also needs to be examined, given the capture of juvenile *Glyphis* sharks and sawfish in both commercial fisheries. Modelling indicates that juvenile mortality greatly influences the persistence of a species (Tribuzio & Kruse 2011) and although few individuals are captured by these fisheries, persistence is likely to be compromised if population sizes are already very low (Bijlsma & Loeschcke 2012). *Anoxypristis cuspidata* could be particularly vulnerable due to the relatively high fishing mortality in 2 size cohorts (small juveniles in the barramundi fishery and larger juveniles in offshore net and line fisheries). The biological consequences of

fisheries interactions are at present unknown and need further investigation to facilitate effective conservation and fisheries management.

By combining observer and independent datasets, we have increased the current state of knowledge of the distributions and relative abundance of the rare and endangered *Glyphis* sharks and sawfishes of northern Australia, and we have provided the first regional assessment of the impacts of commercial fishing on these species. Our results have both confirmed suspected distributions and identified new locations that extend species' ranges into additional catchments, information that has already been incorporated in the Australian Government's North Marine Bioregional Plan (DEWHA 2009). Although our results suggest that current interactions with fisheries are probably low, we cannot yet disregard the possibility that this is merely indicative of once larger populations already reduced by heavy fishing (particularly illegal, unreported and unregulated fishing) as observed for *Pristis zijsron* along the coast of eastern Australia (Stevens et al. 2005, Field et al. 2009a). Furthermore demands on marine resources in the region are growing rapidly and better reporting is required to monitor the resulting impacts.

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