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Department of the Environment

Sawfish and River Sharks

Multispecies Issues Paper

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Front Cover:
Largetooth sawfish (*Pristis pristis*) in the Daly River (© Copyright, Richard Pillans).

Back Cover:
Green sawfish (*Pristis zijsron*) juvenile from Pilbara (© Copyright, Richard Pillans).

SAWFISH AND RIVER SHARKS

MULTISPECIES ISSUES PAPER

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Abbreviations

Abbreviation	Title
ACIAR	Australian Centre for International Agricultural Research
AFMA	Australian Fisheries Management Authority, Commonwealth
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Convention on the Conservation of Migratory Species
DAFF	Queensland Department of Agriculture, Fisheries and Forestry, Commonwealth
DEEDI	Queensland Department of Employment, Economic Development and Innovation
DEWHA	Department of Environment, Water, Heritage and the Arts, Commonwealth
DoR	Northern Territory Department of Resources
DPIF	Queensland Department of Primary Industries and Fisheries
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities, Commonwealth
ECIFF	East Coast Inshore Finfish Fishery
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
FRMA	*Fish Resources Management Act 1994*
IUCN	International Union for Conservation of Nature
IUU	Illegal, unreported and unregulated fishing
KGBMF	Kimberly Gillnet and Barramundi Managed Fishery
NAILSMA	North Australian Indigenous Land and Sea Management Alliance
NPF	Northern Prawn Fishery
ONLF	Offshore Net and Line Fishery
PDTF	Pilbara Demersal Trawl Fishery
SOCI	Species of Conservation Interest
TL	Total Length
TSSC	Threatened Species Scientific Committee
UNEP	United Nations Environment Programme

1 Summary

This issues paper has been developed to provide background information to support the recovery plan for three species of sawfish and two species of river shark. The species covered under the plan are:

- Largetooth sawfish (*Pristis pristis*) [previously known as the freshwater sawfish, *Pristis microdon*]
- Green sawfish (*Pristis zijsron*)
- Dwarf sawfish (*Pristis clavata*)
- Speartooth shark (*Glyphis glyphis*)
- Northern river shark (*Glyphis garricki).*

All of these species inhabit the rivers, estuaries and inshore marine environments of northern Australia. The largetooth sawfish has a circumtropical distribution, however population structuring results in four geographic groupings in the eastern Pacific, eastern Atlantic, western Atlantic and Indo-west Pacific. While the green sawfish and dwarf sawfish were once known to occur across the Indo-west Pacific region, distribution of dwarf sawfish is now possibly limited to Australia. The two river shark species are only found in Australia and Papua New Guinea.

There is little information on current population sizes or long-term rates of population change for any of these species. However, the information that is available suggests that the species have experienced substantial population declines within a few generations and some populations are considered to be extirpated from former parts of their range. Remaining populations are also often isolated, raising concerns about their viability.

Australia probably represents the last secure populations of green sawfish, dwarf sawfish, speartooth shark and northern river shark species across their global ranges (Stevens et al., 2005; Phillips, 2012). Regional population structuring of largetooth sawfish means Australia probably represents the last secure population in the Indo-west Pacific regional population, and a globally important population centre (Kyne et al., 2013).

This issues paper has been developed to support the Sawfish and River Sharks Multispecies Recovery Plan, available at: http://www.environment.gov.au/resource/recoveryplansawfish-and-river-shark. This issues paper summarises the biology and ecology of the five species and details immediate and identifiable threats to their long-term survival in the wild. The cumulative impact of these threats varies across the range of the species, with some threats having more prominence in certain areas. Fisheries bycatch from commercial fisheries; recreational fishing; Indigenous fishing and illegal unreported and unregulated fishing activity appear to pose the greatest threats based on current knowledge, along with habitat degradation and modification. Secondary threats include collection of animals for display in aquaria and entanglement in marine debris.

2 Introduction

2.1 Purpose

The purpose of this paper is to provide a summary of the biology, population ecology and current threats to largetooth sawfish (*Pristis pristis*) [previously known as the freshwater sawfish, *Pristis microdon*], green sawfish (*Pristis zijsron*); dwarf sawfish (*Pristis clavata);* speartooth shark (*Glyphis glyphis*); and northern river shark (*Glyphis garricki*) in Australian waters, and to make recommendations on the future research necessary to protect these species.
This document was created to support the development of the Sawfish and River Sharks Multispecies Recovery Plan.

2.2 Objectives

The objectives of this issues paper are to:

- collate the most recent scientific information (published and, where appropriate, unpublished) on distribution, abundance and population trends for the three sawfish and two river shark species
- identify gaps in our knowledge of the biology and threats to these species and make recommendations on future research
- discuss any natural and anthropogenic factors that are currently limiting the recovery of the species in Australian waters.

2.3 Scope

This document provides a contemporary picture of the biology and ecology of the five species, and identifies threats to their long-term persistence in the wild. This document is not a recovery plan and does not prescribe management actions necessary to address population decreases.

2.4 Sources of information

This document was prepared following a review of the literature and consultation with key stakeholders including relevant agencies, researchers and interested organisations.

2.5 Recovery planning process

2.5.1 Purpose of recovery plans

The Australian Government Minister responsible for the environment may make or adopt recovery plans for threatened fauna, threatened flora (other than conservation dependent species) and threatened ecological communities listed under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).

Recovery plans set out the research and management actions necessary to stop the decline of, and support the recovery of, listed threatened species or threatened ecological communities. The aim of a recovery plan is to maximise the long-term survival in the wild of a threatened species or ecological community.

2.5.2 Objectives of the recovery plan for the five listed species

The overarching objective of the Sawfish and River Sharks Multispecies Recovery Plan is to assist the recovery of these species throughout their range in Australian waters by increasing total population size, with a view to:

- improving the population status leading to the removal of these species from the threatened species list of the EPBC Act
- ensuring that anthropogenic activities do not hinder recovery in the near future, or impact on the conservation status of these species in the future.

3 Biology and ecology

The three sawfish and two river shark species addressed by this document inhabit the rivers, estuaries and inshore marine habitats of northern Australia. The largetooth sawfish is known to occur in four distinct regional populations globally, while the green sawfish and dwarf sawfish were once known to occur across the Indo-west Pacific region. The two river shark species are only found in Australia and Papua New Guinea.

This section provides background information for each of the five species and includes information on:

- taxonomy
- species description
- life history
- habitat
- distribution.

3.1 Largetooth sawfish (*Pristis pristis*)

3.1.1 Taxonomy

Scientific name: *Pristis pristis;* Family Pristidae; Order Pristiformes

Other scientific names used previously: *Pristis microdon*; *Pristis perotetti*; *Pristis zephreus* (Faria et al., 2013); *Pristiopsis leichhardti* north Queensland (Whitley, 1945).

Common names: Largetooth sawfish, freshwater sawfish, common sawfish, Leichhardt's sawfish, great-tooth sawfish.

There has been some uncertainty about the status of the *P. pristis* group, which was previously recognised as containing three species—including *Pristis microdon, Pristis pristis/perottetti* and *Pristis zephyreus.* Research by Faria et al. (2013) uses genetics and morphology to suggest these are a single species called *P. pristis,* with the common name being largetooth sawfish. Further, structuring of the population discussed by Faria et al. (2013) shows a distinct Indo-west Pacific regional population that correlates with the range of the former *P. microdon.* As no other species grouped under *P. pristis* occur in the Indo-west Pacific region, the change in taxonomy does not alter abundance, biology, population trajectory or threats to this species in Australian waters.

This change in taxonomy has been accepted by the Australian Biological Resources Study and the Australian Faunal Directory, and has been reflected in an update to the EPBC Act threatened species list. This issues paper, and the accompanying recovery plan, substitutes all references in the scientific literature to freshwater sawfish *(Pristis microdon)* with largetooth sawfish *(Pristis pristis)* to reflect this taxonomic change.

3.1.2 Species description and growth rates

Appearance: Largetooth sawfish are large, slender sawfish with shark-like bodies; the pectoral fins distinct; the head flattened with a blade-like snout or saw; five pairs of gill slits positioned on ventral surface; pectoral fins broadly triangular with a straight posterior margin; dorsal fins tall and pointed; rostral teeth start near the rostral-base. This species has the following key characteristics (based on Last & Stevens, 1994; Compagno & Last, 1999; Faria et al., 2013):

- Rostrum broad and stout, with 14–24 (mainly 20–22), evenly–spaced rostral teeth and each tooth has a groove along its posterior margin. Number of teeth sexually dimorphic with males possessing more teeth than females. Also varying on a regional basis;
- Rostral teeth are relatively evenly spaced, though slightly closer towards the rounded tip of the rostrum;
- Caudal fin with a short but distinct lower lobe (much less than half the length of the upper lobe);
- Pectoral fins distinct from head and broadly triangular;
- First dorsal-fin origin well in advance of the pelvic-fin origins; and
- Usually yellowish to greyish dorsally, white ventrally; posterior margins of the fins are a richer yellowish brown. Thorburn et al. (2004) noted a large degree of colour variation in juvenile individuals collected from riverine environments in northern Australia; the trunks of individuals collected further inland from clear waters were often a deep green, and sometimes almost black. Specimens from Telegraph Pool on the Fitzroy River (Western Australia) were lighter green or yellow/brown.

Maximum size: The largetooth sawfish is the largest fish found in freshwater in Australia. Individuals up to 280 cm total length have been recorded from freshwater environments (Thorburn et al., 2004, 2007a) and a 582 cm female has been recorded from the estuarine habitat of the Mitchell River in the Gulf of Carpentaria (Peverell, 2009). Throughout its global range, the largetooth sawfish is considered to reach a maximum size of between 600 and 700 cm (Last & Stevens, 1994), with records confirming the species reaches at least 656 cm (Compagno & Last, 1999) and a maximum weight of 600 kg (Stehman, 1981). Length and mass data from a limited number of animals are shown in Figure 1 (Adapted from Giles et al., 2007).

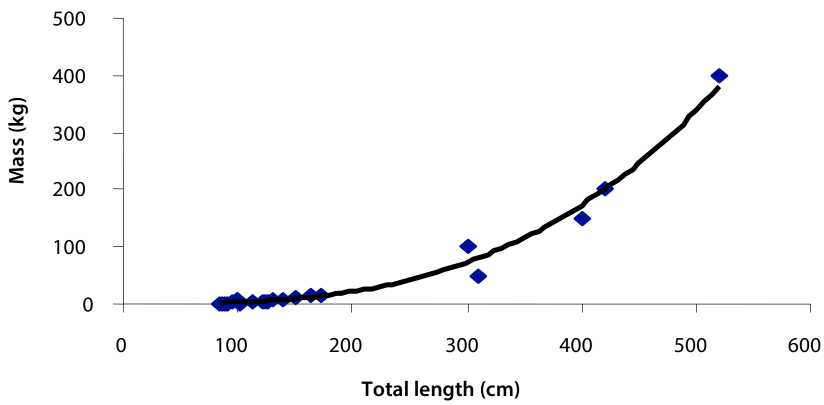

Figure 1. Length–mass relationship for largetooth sawfish in Australian waters

Growth rates and longevity: Growth rates of largetooth sawfish have been examined using three different techniques; examination of vertebral bands, tag recapture studies and studies of captive animals (Peverell, 2009). All three techniques suggest that growth is fastest in the early years and slows down in later years, but growth rates may vary from this pattern. Peverell (2009) examined vertebral bands on 41 largetooth sawfish from the Gulf of Carpentaria (Figure 2). The data sets are made up of young of the year animals (20%) followed by animals in the one to eight year old age classes (78%). In this study, size at birth varied between 72–90 cm. The average growth in the first year was 52 cm, reducing to about 17 cm in their fifth year. Longevity was estimated to be about 80 years (Peverell, 2009). Based on the observations of a single pupping female, size and age at maturity was estimated to be 300 cm and eight years. Thorson (1976) corroborates this with evidence from the western Atlantic population, suggesting female sexual maturity is reached at approximately three metres. Male maturity is estimated at between 280 and 300 cm. Growth rates from recaptured largetooth sawfish support these growth estimates (Thorburn et al., 2007a; Peverell, 2009). These growth estimates are considerably faster than those reported by Tanaka (1991) who estimated that they may take 20 years or more to reach maturity based on vertebral ageing.

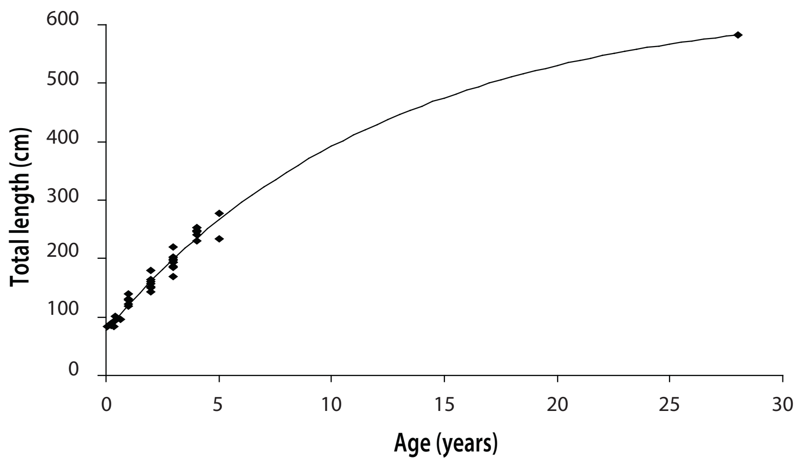

Figure 2. Size and age data for Gulf of Carpentaria largetooth sawfish (n=41)

Data are pooled for both sexes and the regression line indicates the von Bertalanffy growth function (Peverell, 2009).

Tag and release programs for largetooth sawfish have been undertaken across northern Australia since 2000. A total of three, 90 and 164 largetooth sawfish were tagged and released in the Northern Territory, Western Australia and Queensland respectively (Thorburn et al., 2007a; Whitty et al., 2008; S. Peverell unpublished data), up until 2008. In these studies, the fastest growing individual recorded averaged 48 cm a year at an approximate age of four to five years (Peverell, 2009) and the slowest growth rate recorded was eight centimetres a year from an individual at an approximate age of five years (D. Morgan unpublished data). These data suggest that growth rates can vary. In addition, analysis of captive growth of five specimens ranging in ages of between one and four years ranged between 45 and 101 cm per year (Peverell, 2009). The tag-recapture data and the captive growth rates suggest that the vertebral ageing results of Peverell (2009) provide a more realistic estimate than those of Tanaka (1991).

3.1.3 Life history

Habitat: Largetooth sawfish have been recorded in river and estuarine environments, as well as up to 100 km offshore. They inhabit the sandy or muddy bottoms of shallow coastal waters, estuaries and river mouths, as well as the central and upper reaches of freshwater rivers and isolated water holes, with records of largetooth sawfish up to 400 km inland (Giles et al., 2007). Largetooth sawfish have an ontogenetic shift in habitat utilisation with neonate and juvenile animals primarily occurring in the freshwater reaches of rivers and estuaries and adult animals being found in marine and estuarine environments. This ontogenetic shift in habitat use is supported by tagging and microchemistry research (Peverell, 2009).

In Australia, many of the rivers which largetooth sawfish use as nursery areas fragment into a series of pools in the dry season, reducing the available habitat (Last, 2002). Captures of largetooth sawfish by Thorburn et al. (2003) were made in the main channels, larger tributaries and in backwaters, lower, middle and upper reaches of river systems. Largetooth sawfish were most commonly encountered over finer substrates, such as sand and silt and were usually caught in a relatively deeper section of a river adjacent to a shallower section, such as a sandbar or shallow backwater. Capture sites ranged in depth from 70 cm to six metres and animals were encountered in both tidal and non-tidal reaches of the river, which generally had low flow rates. There is also some indication they will move into shallow waters when travelling upstream or while hunting prey. Further, there is habitat partitioning for different size classes of largetooth sawfish, with research suggesting that older and larger individuals show a preference for deeper water (Whitty et al., 2008, 2009).

The generally accepted model of movement and migration of largetooth sawfish in Australian waters is that young are born at the mouths of rivers and in estuaries and then migrate up river where they spend the first several years of life (Thorburn et al., 2004). As they reach maturity they move out of the rivers and into the marine environment.

In the Fitzroy River in Western Australia males leave the river at about 240 cm, and females at about 280 cm (Thorburn et al., 2007a). Once individuals enter the marine environment little is known of their movements. Data from a variety of surveys and fisheries indicate that they probably remain in coastal areas, but have been recorded at least 100 km offshore (Giles et al., 2007). More data are needed to understand the movement and habitat requirements of adult largetooth sawfish.

Diet and feeding: Pristids feed on a variety of fish and crustaceans (Thorburn et al., 2007a). The rostrum may be used to rake through the substratum or to stun schooling fishes with sideswipes of the snout (Wueringer et al., 2012). Specimens of largetooth sawfish collected for aquaria from the Gulf of Carpentaria region have had barramundi (*Lates calcarifer*), northern saratoga (*Scleropages jardini*) and jewfish (*Protonibea diacanthus*) scales on their rostrum; the size of scales suggesting they may feed on quite large fish. In the Flinders River, Queensland, they have been observed congregating to eat freshwater prawns (*Macrobrachium rosenbergii*), and have been taken by fishers also targeting freshwater prawns using cast nets (L. Squire, Cairns Marine Aquarium Fish, pers. comm.). Observations of juvenile largetooth sawfish in the Daly River indicate that they actively seek prey species such as mullet (*Mugil cephalus*) and oxeye herring (*Megalops cyprinoides*) in shallow (<30 cm) water. Guts of largetooth sawfish examined by Peverell (2009) contained prawns (*Penaeus* spp.), eel tailed catfish (Plotosidae), jewel fish (*Nibea squamosa*), mullet (*Rhinomugil nasutus*), threadfin salmon (*Polydactylus macrochir*) and freshwater prawns (*M. rosenbergii*). Stable isotope analysis indicated a broad diet in the Fitzroy River with fork tailed catfish (*Arius graeffei*) and freshwater prawns (*M. rosenbergii*) being important (Thorburn, 2006; Thorburn et al., 2007a).

Reproduction: Little is known about reproduction in largetooth sawfish. As in other pristids, the reproductive mode is aplacental viviparity with lecithotrophic nutrition of the embryos (energy reserves come from the egg).

Litter size is thought to be around 12 pups and pups are about 72–91 cm at birth after a five month gestation period (Thorson, 1976; Last & Stevens, 1994; FSERC, 2009; Peverell, 2009). It is believed that mature largetooth sawfish enter less saline water to give birth and that pupping may occur late in the wet season, at least in the Gulf of Carpentaria (Peverell, 2005). Breeding frequency is unknown; however the presence of large yolky ova in the ovary of a female carrying near term pups suggests that in Australia this species may breed every year (Peverell, 2009). The western Atlantic population is thought to breed every second year (Thorson, 1976).

Recent genetic evidence suggests that female largetooth sawfish are philopatric, that is, they return to the area where they were born to give birth to their own pups. Males, however, are thought to disperse more widely, perhaps moving between different geographic areas and populations (Phillips, 2012, Faria et al. 2013).

3.1.4 Distribution

Global distribution: Largetooth sawfish are circumtropical, with distinct populations in the eastern Atlantic, western Atlantic, eastern Pacific and Indo-west Pacific. The eastern Atlantic population is believed to be extirpated from the Mediterranean part of its former range and severely depleted in its west African range, which once reached from Morocco to Angola. In the western Atlantic, the population range once extended from the United States of America to Brazil, though this population has also been extirpated from most of its former range and the status of the remaining population is known to be critical, especially in Lake Nicaragua and other Central/South American sites. The eastern Pacific range extends from Mexico to Peru, but little information is available on its distribution. In the Indo-west Pacific, largetooth sawfish were considered to be widely distributed, but are now thought to be rare or extirpated across most of their former range (Last & Stevens, 2009; Phillips, 2012; Kyne et al., 2013).

Global population overview: Largetooth sawfish have a wide global distribution across the Atlantic, Indo-West Pacific and the eastern Pacific (Figure 3). However, no quantitative data are available on the global population size of largetooth sawfish. For the Indo-west Pacific regional population, comprehensive surveys of fish landing sites in eastern Indonesia between 2001 and 2006, only two sawfish, both largetooth, were recorded (White & Dharmadi, 2007). These two were caught by tangle net fishers in the Arafura/Banda Sea region in the marine environment. Further information on the global population of largetooth sawfish is available in Kyne et al. (2013).

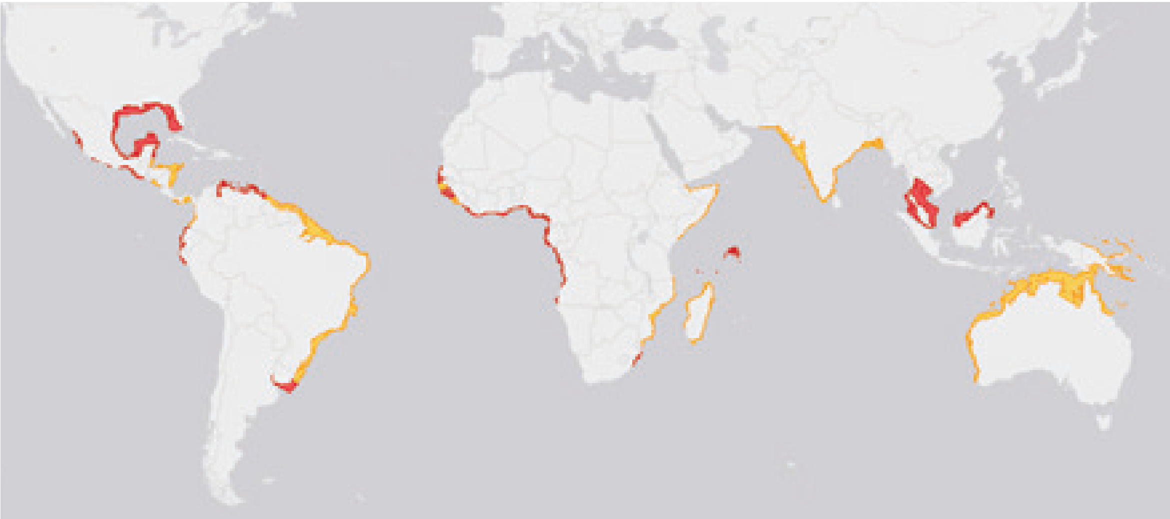

Figure 3. Global distribution of largetooth sawfish (yellow) and areas of possible extinction (red) (IUCN 2013a)

Relationship between the Australian and the global population: Phylogenetic analyses show considerable geographic structuring in the global largetooth sawfish population. Maximum parsimony analysis assigns the largetooth sawfish into three distinct lineages within the Atlantic, Indo-west Pacific and the eastern Pacific, with geographic structuring between the eastern and western Atlantic populations and some structuring between the Indian Ocean and the Australian populations (Faria, et al,. 2013).

The Australian populations of largetooth sawfish are likely to comprise a high proportion of the Indo-west Pacific population, and form a globally important population centre (Phillips, 2012; Kyne et al., 2013). Further, there is most likely negligible maternal gene flow in largetooth sawfish between south-east Asia and Australia. If there is genetic exchange between south-east Asia and Australia, it is likely the result of male gene flow (Phillips et al., 2011; Faria et al., 2013).

Australian distribution and abundance: Largetooth sawfish have been recorded from rivers, estuaries and marine environments. Juvenile animals have been captured several hundred kilometres inland in places such as Geike Gorge, over 350 km from the sea on the Fitzroy River, and in Margaret River Gorge, over 400 km inland, while adults have been captured up to 100 km offshore (Morgan et al., 2002, 2004; Thorburn et al., 2003, 2007a; Giles et al., 2007)(Figure 4).

The majority of records are of juvenile and sub-adult animals (<300 cm) from rivers. They have been recorded in numerous drainage systems in northern Australia in fresh and saline water including the Fitzroy, Durack, Robinson and Ord Rivers (Western Australia), the Adelaide, Victoria, Daly, East and South Alligator, Goomadeer, Roper, McArthur, Wearyan and Robinson Rivers (Northern Territory), and the Gilbert, Mitchell, Normanby, Wenlock, Mission, Embley and Leichhardt Rivers (Queensland).

In Western Australia, largetooth sawfish have been recorded from the Fitzroy, Durack, Robinson, May and Ord Rivers. There are coastal records from Cape Keraudren to King Sound (Thorburn et al., 2007a). One large individual was also captured in south-west Western Australia, off Cape Naturaliste, however this occurrence is considered an anomaly and outside the normal range for the species (Chidlow, 2007).

In the Northern Territory, largetooth sawfish have been recorded from the Adelaide, Victoria, Daly, East Alligator, South Alligator, Goomadeer, Roper, McArthur, Wearyan and Robinson Rivers. Records for the species occurrence offshore are limited, and the data on these captures are poor. A single record is known from offshore localities in the western Gulf of Carpentaria, in the vicinity of Groote Eylandt (Field et al., 2008).

Records of largetooth sawfish from the east coast of Queensland in the last seven years suggest that they are largely restricted to the rivers draining into Princess Charlotte Bay and their distribution and abundance is patchy and low (Pillans, 2012).

It is unclear whether there are discontinuities in the coastal distribution of largetooth sawfish within their range. It is also unclear whether the lack of records from certain river systems within their area of occupancy reflects a real absence or merely limited sampling effort.

As there are few quantitative species-specific data on largetooth sawfish abundance in Australia, determining long-term population trends is difficult. Anecdotal information indicates widespread declines but some evidence suggests that largetooth sawfish populations in some areas may remain healthy (such as the Kimberley region of Western Australia) (Stevens et al., 2005).

Population structure and genetic diversity: The population structure of largetooth sawfish was assessed by Phillips (et al., 2011; 2012) based on data from a portion of the control region of the mitochondrial genome and seven microsatellite loci. Genetic analyses suggest that largetooth sawfish show female philopatry coupled with male biased dispersal in Australian waters. This means that females are thought to return to their natal river systems to give birth and that males disperse between geographic regions to breed. An alternate explanation is that there are breeding aggregations where largetooth sawfish gather, with females returning to their natal areas to pup (Phillips, 2012). Regardless, the evidence supports a level of paternal mixing in Australian waters, between populations from the west and north coast regions and the Gulf of Carpentaria region but limited maternal gene flow. The genetic results also suggest that the largetooth sawfish from the east coast may be a distinct matrilineal population(s), but the sample size from that region was small, limiting the ability to draw robust conclusion about the stock structure of the east coast population (Phillips et al., 2011; Phillips, 2012). A total of nineteen separate haplotypes were identified in the global population, including one Indian Ocean haplotype, one Vietnam–New Guinea haplotype and two Australian haplotypes.

Phillips (2012) also notes that the presence of male gene flow between assemblages in Australian waters suggests that a decline (e.g. removal) of males in one location could affect the genetic 'health' of assemblages in other locations. For example, the take of males from the Gulf of Carpentaria could have an impact not only on the Gulf of Carpentaria assemblage(s), but also those found along the north and west coasts of Australia. This is coupled with the fact that philopatric behaviour of females tends to increase the risk of extirpation, since once a population has been lost for a generation it would be difficult to re-establish naturally (i.e., because females are likely to pup at their natal river) (Phillips, 2012).

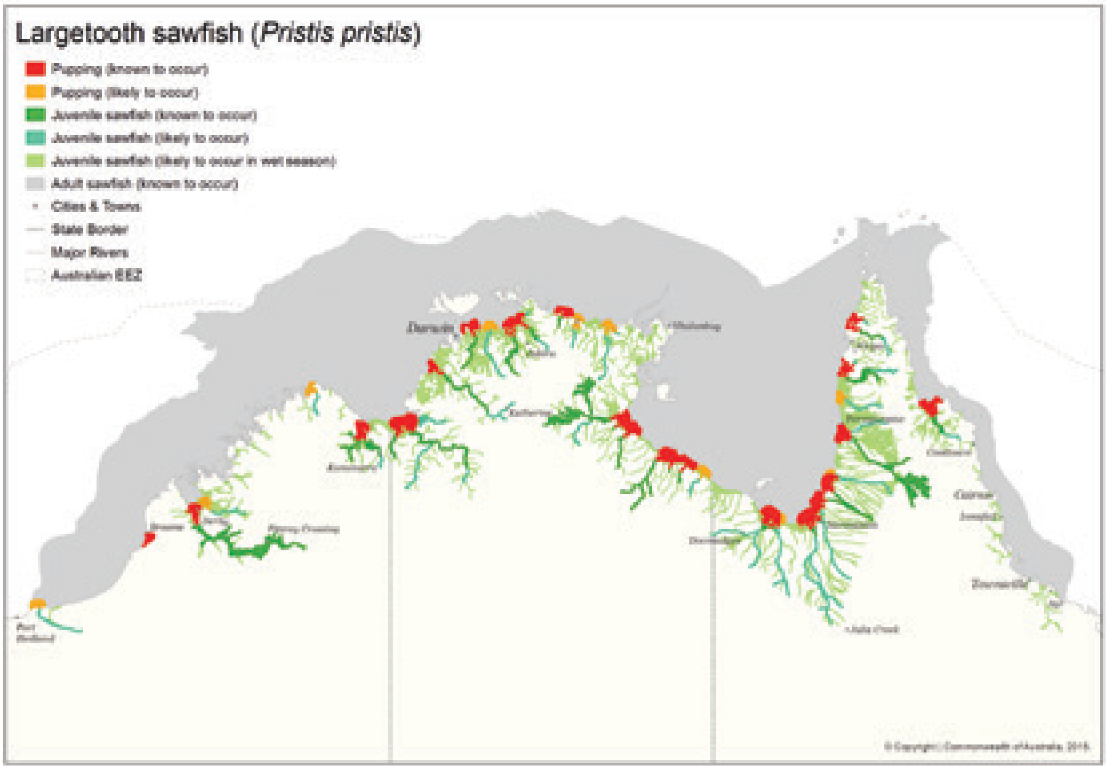

Figure 4. Map showing Australian distribution of largetooth sawfish

The levels of mitochondrial DNA (mtDNA) and nuclear DNA (nDNA) diversity in largetooth sawfish in Australian waters are moderate to low and high, respectively, and within the range of values reported for other elasmobranchs including other species of *Pristis* (Phillips et al., 2011; Phillips, 2012). The pattern of moderate to low levels of mtDNA and high levels of nDNA diversity (based on heterozygosity) suggests that the Australian population of largetooth sawfish was founded by small numbers of individuals followed by population expansion and growth (Phillips, 2012). The signature of the genetic bottleneck/founder effect for the largetooth sawfish, green sawfish and dwarf sawfish is stronger than those reported to date for any other elasmobranch (Phillips, 2012). This suggests that in addition to the founder effect, there have been contemporary declines in abundance and the continual pressure has prevented any recovery of alleles (Phillips, 2012).

Important populations: The presence of female philopatry in largetooth sawfish has implications for the conservation of this species because a decline in females at one location would not be replenished by the immigration of females from another location, at least in the short to medium term. This finding suggests that effort should be concentrated on protecting river systems that are known to be important. Some of the more important regions include: King Sound, and the Fitzroy, Durack, Robinson and Ord Rivers in Western Australia, as they contain significant nursery areas and individuals with unique haplotypes; the Van Diemen Gulf drainages and the Daly and Victoria Rivers in the Northern Territory as they represent an important nursery area that is not fished by commercial fisheries; the Gulf of Carpentaria as it contains unique haplotypes in a number of the rivers; and Princess Charlotte Bay (Queensland) drainages as they also contain individuals with unique haplotypes and the region represents the current eastern extremity of the species (Phillips et al., 2011; Phillips, 2012).

3.2 Green sawfish (*Pristis zijsron*)

3.2.1 Taxonomy

Scientific name: *Pristis zijsron*; Family Pristidae; Order Pristiformes

Other scientific names used previously: *Pristis zysron* is an older spelling (Pogonoski et al., 2002).

Common names: Green sawfish, longcomb sawfish, narrowsnout sawfish

This species is conventionally accepted (e.g. Last & Stevens, 1994; Compagno & Last, 1999; Compagno et al., 2005; Faria et al., 2013).

3.2.2 Species description and growth rates

Appearance: Green sawfish are very large, slender sawfish with a shark-like body; the pectoral fins distinct; the head flattened with a blade-like snout or rostrum; gill openings positioned on the ventral surface; pectoral fins broadly triangular with a straight posterior margin; dorsal fins tall and pointed; and rostral teeth starting near the rostral-base. This species has the following key characteristics (based on Compagno & Last, 1999; Last & Stevens, 2009):

- Rostrum narrow and slender, with 24–28, unevenly-spaced rostral teeth and each tooth has a groove along its posterior margin in adults (smooth in juveniles);
- Interspace between two posterior most rostral teeth two to seven times distance between first two rostral teeth;
- Caudal fin lower lobe small (posterior margin of caudal fin almost straight);
- Broad based pectoral fins;
- First dorsal-fin origin slightly posterior to pelvic-fin origins; and
- Greenish brown or olive dorsally, white ventrally.

Maximum size: The maximum length recorded in Australian waters is 730 cm (Compagno & Last, 1999).

Growth rates and longevity: Peverell (2009) examined vertebral bands on 18 green sawfish from the Gulf of Carpentaria (Figure 5). In this study average size at birth was 76 cm. The average growth in the first year was 52 cm, and 33 cm in the second year. Longevity was estimated to be 53 years (based on a maximum size of 540 cm, the locally recorded maximum size). Based on the observations of a single post partum female, size and age at maturity was estimated at 380 cm and nine years. The size at maturity of males is unknown.

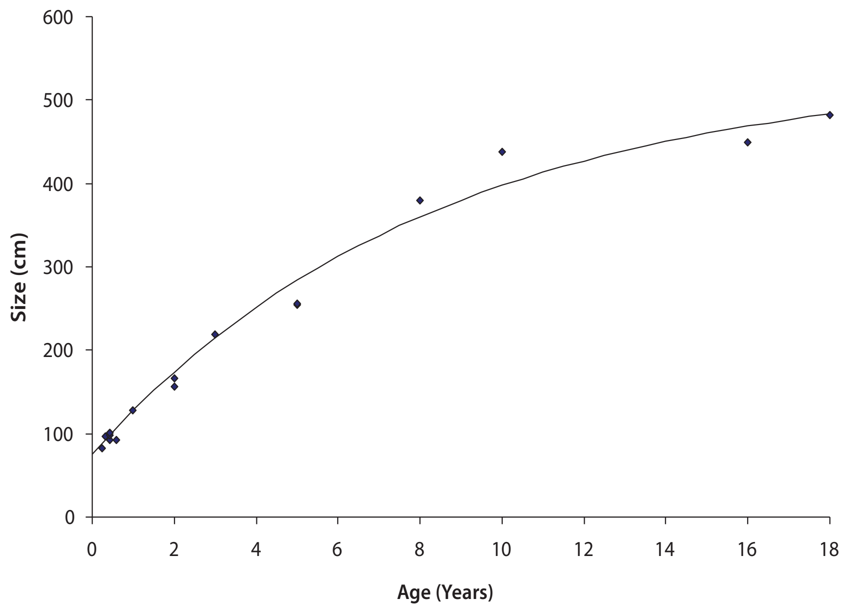

Figure 5. Size and age data for Gulf of Carpentaria green sawfish (n=18)

Data are pooled for both sexes and the line indicates von Bertalanffy growth function (from Peverell, 2009).

3.2.3 *Life history*

Habitat: Green sawfish occur in inshore coastal environments including estuaries, river mouths, embayments and along sandy and muddy beaches, as well as offshore marine habitats (Stevens et al., 2005; Thorburn et al., 2004). They have been recorded in very shallow water (less than one metre) to offshore trawl grounds in over 70 m of water (Stevens et al., 2005). Green sawfish do not, however, utilise freshwater environments.

Despite being found in deep water, evidence suggests that the range of green sawfish is mostly restricted to the inshore coastal fringe, with a strong association with mangroves and adjacent mudflats (Stevens et al., 2008). Peverell and Pillans (2004) tracked a 350 cm female green sawfish in Port Musgrave, Queensland. Over 27 hours, the sawfish moved 28.7 km and was at all times within 200 m of the shoreline in very shallow water. Stevens et al. (2008) tracked a 256 cm male green sawfish intermittently for approximately 26 hours over a period of four days in 2008. After tagging in Firewood Creek, Cape Keraudren, Western Australia, it moved out with the ebb tide and travelled some four and a half kilometres across the bay. It then showed more restricted movements, moving towards the shore on the rising tide and away from the shore on the falling tide but remaining in water mostly less than one and a half metres deep.

Diet and feeding: Green sawfish appear to actively pursue schools of baitfish and prawns (Peverell & Pillans, 2004). One green sawfish captured in a prawn trawl targeting banana prawns (*Penaeus merguiensis*) in Joseph Bonaparte Gulf had a banana prawn and two eight centimetre orangefin ponyfish (*Leiognathus bindus*) in its stomach (Stevens et al., 2005).

Reproduction: Little is known about reproduction in green sawfish. As in other pristids, the reproductive mode is aplacental viviparity with lecithotrophic nutrition of the embryos (energy reserves come from the egg). Based on other sawfish species, the litter size in green sawfish is estimated to be about 12 (J. D. Stevens, unpublished data).

Peverell (2005) inferred that pupping occurs during, or just before, the wet season. Pupping frequency is unknown but is likely to be every two years given the similarity in size to the Atlantic population of *Pristis pristis* which reproduces biennially (Thorson, 1976).

3.2.4 Distribution

Global distribution: Green sawfish have a broad Indo-west Pacific distribution (Last & Stevens, 1994) (Figure 6). Countries in the range include Australia (New South Wales—Possibly Extinct, Northern Territory, Queensland, Western Australia), Bahrain; Eritrea, Indonesia, Kenya, Malaysia, Papua New Guinea, Qatar, Sudan, Timor-Leste and United Arab Emirates (Figure 6). It is thought to be extinct from Mauritius, Réunion, South Africa and Thailand (Simpfendorfer, 2013). No quantitative data are available on global population size of green sawfish.

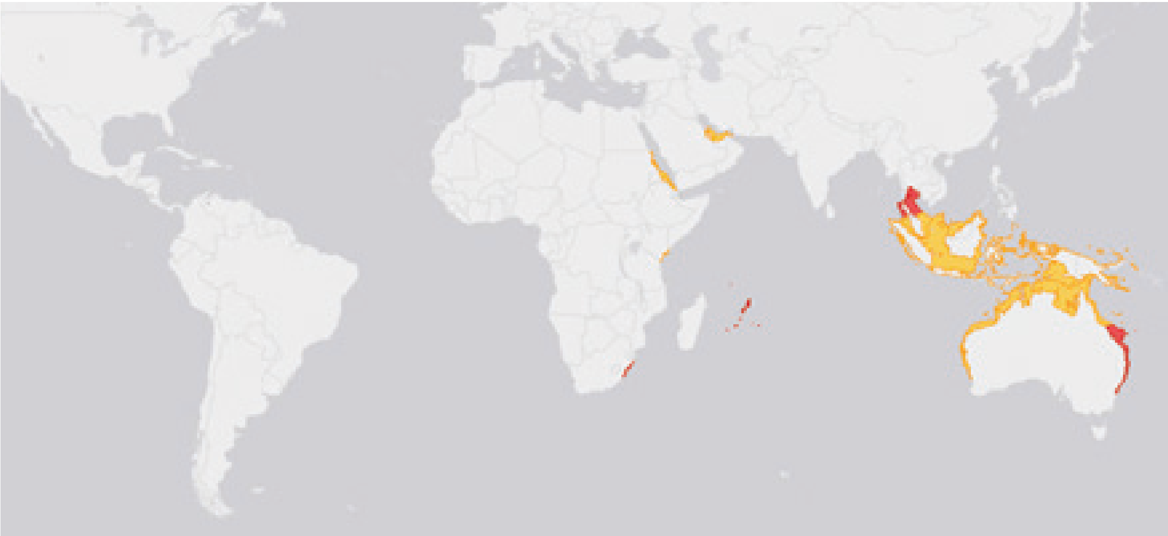

Figure 6. Global distribution of green sawfish (yellow) and areas of possible extinction (red) (IUCN 2013b)

Global population overview: Anecdotal information suggests that this species' Indo-west Pacific distribution has been severely impacted by anthropogenic factors in recent years. The available catch records indicate that it is now virtually extinct in most of south-east Asia. Green sawfish were not recorded in comprehensive fish landing site surveys of eastern Indonesia in a six year (2001–2006) Australian Centre for International Agricultural Research (ACIAR) funded shark and ray project, visiting markets from Jakarta to West Papua (White & Dharmadi, 2007). Further information on the global population is available in Simpfendorfer (2013).

Relationship between the Australian and the global populations: Genetic data from Australia suggests green sawfish populations in Western Australia and the Gulf of Carpentaria are distinct genetic stocks (Phillips et al., 2011; Phillips, 2012). Genetic data are not available for the remainder of the range, but given the Australian data, the global population is likely to consist of a number of stocks (Simpfendorfer, 2013).

Australian distribution and abundance: Green sawfish are currently distributed from about the Whitsundays (Harry et al., 2011) in Queensland across northern Australian waters to Shark Bay in Western Australia (Figure 7). Individuals have been recorded in inshore coastal environments and estuaries but the species does not penetrate into freshwater. There are also records of green sawfish hundreds of kilometres offshore in relatively deep water (Stevens et al., 2005).

Evidence from gillnet fisheries in the eastern Gulf of Carpentaria indicate that green sawfish are not uniformly distributed within their range (Peverell, 2005)(Figure 8). Surveys and captures in commercial fisheries on the Queensland east coast also show a non-uniform distribution (S. Peverell unpublished data). Limited data on short term movement of green sawfish suggest repeated habitat utilisation and utilisation of small core areas (Peverell & Pillans, 2004; Stevens et al., 2008).

Their current distribution is significantly less than it was 40–60 years ago when they were also found as far south as New South Wales, where the species is now considered extinct (NSW DPI, 2007).

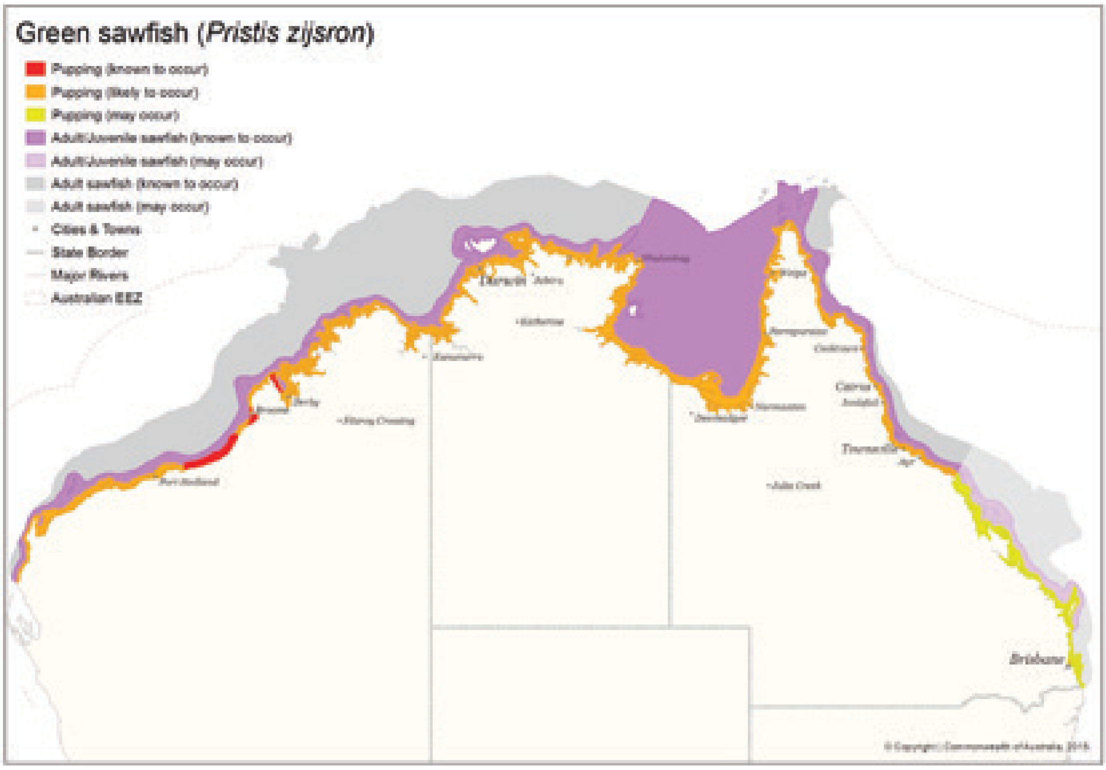

Figure 7. Map showing Australian distribution of green sawfish

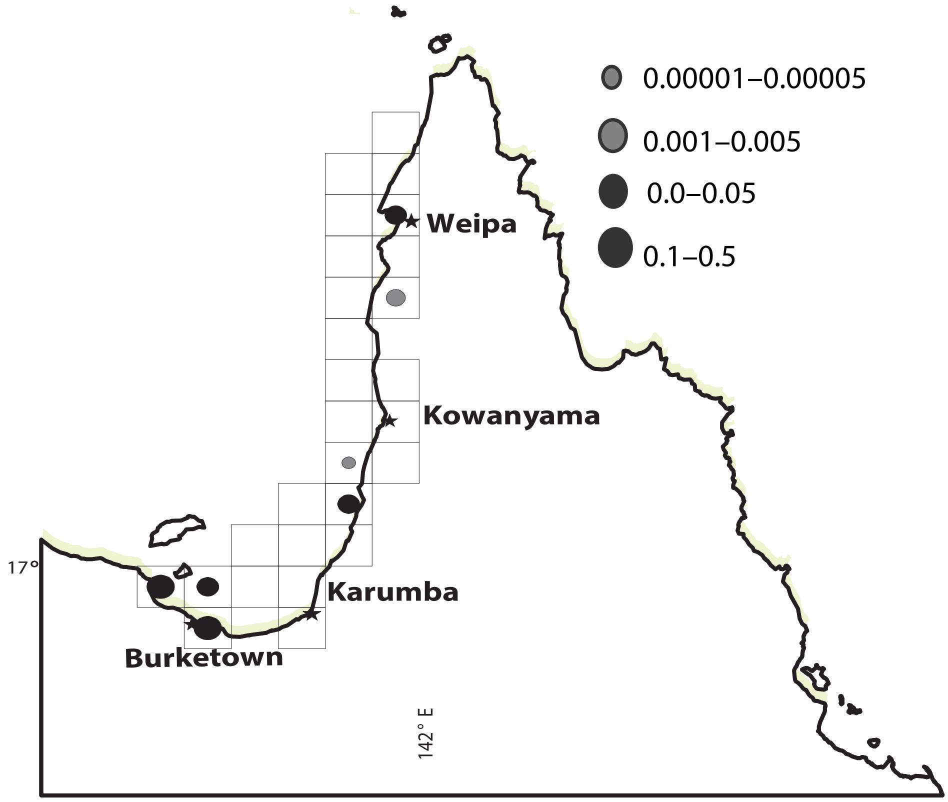

Figure 8. Green sawfish catch per unit effort data for the Queensland Gulf of Carpentaria fisheries (Peverell, 2005)

Population structure and genetic diversity: The population structure of green sawfish was assessed based on data from a portion of the control region of the mitochondrial genome and eight microsatellite loci (Phillips et al., 2011; Phillips, 2012). The results indicate that green sawfish are genetically structured in northern Australian waters with at least the assemblages from the west coast, the Gulf of Carpentaria and the east coast being genetically distinct, although precise population boundaries are unclear (Phillips et al., 2011; Phillips, 2012). Genetic analysis also showed evidence of both maternal and paternal philopatry, at least at a regional scale. Unlike the largetooth sawfish, the genetic results did not find evidence of sex-biased dispersal at broad spatial scales in the green sawfish in Australian waters.

Population genetic diversity of green sawfish from northern Australia was also investigated. The levels of mtDNA and nDNA diversity in green sawfish were moderate to low and high, respectively, and within the range of values reported for other elasmobranchs, including other species of *Pristis* (Phillips et al., 2011; Phillips, 2012). However, the levels of mtDNA diversity in green sawfish in the Gulf of Carpentaria are reduced compared to those for the west and east coasts and are amongst the lowest reported for elasmobranchs.

The pattern of moderate to low levels of mtDNA and high levels of nDNA diversity suggest that the Australian population of green sawfish was founded by small numbers of individuals followed by population expansion and growth (Phillips, 2012). The signature of the genetic bottleneck/founder effect is very pronounced in the green sawfish, largetooth sawfish and dwarf sawfish and for all three species is stronger than those reported to date for any other elasmobranch. For both the green sawfish and dwarf sawfish, this signature is particularly strong in the Gulf of Carpentaria. This suggests that in addition to the founder effect, there have been contemporary declines in abundance and the continual pressure has prevented any recovery of alleles, especially in the Gulf of Carpentaria where levels of MtDNA diversity are reduced and the signature of the founder effect/genetic bottleneck is very strong (Phillips, 2012).

Important populations: The genetic analysis suggests that green sawfish form regional assemblages with little maternal or paternal movement between populations. Although the boundaries of these regions remain unknown, the implication is that local extinction will not be replenished in the short to medium term by outside migration. This means that the individual assemblages, or regions, should be identified and managed as independent populations (Phillips, 2012).

One of the more important assemblages identified for green sawfish include the Cape Keraudren region in northern Western Australia (Stevens et al., 2008). In 2008 several green sawfish were captured in gillnets at Cape Keraudren and large numbers of individuals were seen swimming in shallow water along a beach. This high abundance of animals potentially represents one of the highest densities of green sawfish in Australia. This assemblage is probably the southern stronghold of this species in Western Australia.

The Gulf of Carpentaria assemblage may also warrant special status as the levels of genetic diversity appear to be reduced compared to those for the west coast of Australia (Phillips, 2012) and green sawfish are considered rare in the Gulf (Peverell, 2005, 2009).

Also, any remaining populations on the east coast should be considered "near the edge of the species range" and are important in order to maintain genetic diversity.

3.3 Dwarf sawfish (*Pristis clavata*)

3.3.1 Taxonomy

Scientific name: *Pristis clavata*; Family Pristidae; Order Pristiformes. This species is conventionally accepted as *Pristis clavata* (dwarf sawfish; Garman, 1906).

Common names: Dwarf sawfish, Queensland sawfish (Last & Stevens, 2009; Kyne et al., 2013).

3.3.2 Species description

Appearance: Dwarf sawfish are small, robust sawfish with shark-like bodies. They are greenish-brown on the dorsal surface and white underneath, with paler fins. This species has the following key characteristics (based on Last & Stevens, 1994; Larson et al., 2006; Thorburn et al., 2007b):

- The pectoral fins are triangular with broad bases and the dorsal fins are tall and pointed, with the first dorsal fin positioned over or just forward of the pelvic fin origin;
- There is no distinct lower lobe of the tail fin and the margin of the tail fin is almost straight;
- The head is flattened with a broad rostrum bearing 18–22 pairs of evenly spaced, lateral teeth;
- These rostral teeth are slender, with a groove developing along the rear margin of the tooth in adults; and
- The nostrils are broad with large nasal flaps and are located behind the eyes.

Maximum size: Dwarf sawfish pups are born at 65–81cm and reach a maximum length of at least 310 cm (Last & Stevens, 2009) although it is hypothesised they could grow to about five metres (Peverell, 2009).

Growth rates and longevity: The maximum observed age of dwarf sawfish in the Gulf of Carpentaria is 34 years, although it is hypothesised they may live as long as 80 years (Peverell, 2009). The approximate age of maturity of the species is estimated to be between eight to 10 years old (Peverell, 2009). Males mature at approximately 255–260 cm (Last & Stevens, 2009), but the size at maturity of females is unknown.

3.3.3 Life history

Habitat: Dwarf sawfish usually inhabit shallow (two to three metres) coastal waters and estuarine habitats. Unlike the largetooth sawfish, the dwarf sawfish does not utilise any purely freshwater areas (Thorburn et al., 2007b). A study in north-western Western Australia found that estuarine habitats are used as nursery areas, with juveniles remaining in these areas up until three years of age (Thorburn et al., 2007b). Adults are thought to occupy a range within the coastal fringe of only a few square kilometres and show site fidelity (Stevens et al., 2008). It is unclear how far offshore the adults travel.

Thorburn et al. (2004) captured 19 dwarf sawfish in a survey across northern Australia in 2002. All individuals were caught over fine substrates (mainly silt) in sections of the river channels almost completely devoid of in-stream structure. Excluding one specimen caught in the Victoria River (with a salinity of 9.7), all dwarf sawfish were taken from fully marine water at lower estuarine sites with high turbidity (where measured) and low dissolved oxygen. Capture sites ranged in depth from 70 cm to seven metres and water temperatures were between 25 and 32°C. All were captured on silt/sand flats with low algal and macrophyte cover, low detrital levels and minimal large woody debris.

Between 2005 and 2008, Stevens et al. (2008) actively tracked five juvenile dwarf sawfish in shallow coastal waters off Western Australia. All five dwarf sawfish moved the fastest during falling and rising tides with little or no movement at high tide. For approximately 100 minutes on either side of high tide individuals rested in inundated mangrove forests. High tide resting locations for individuals were often less than 100 m from the previous high tide resting site.

Diet and feeding: Little information is available on the diet and feeding behaviour of dwarf sawfish. Generally, pristids feed on a variety of fish and crustaceans (Peverell, 2005; Thorburn et al. 2007b). As with other sawfish species, the rostrum may be used as a rake through the substratum or to stun schooling fish by sideswiping or threshing the snout while swimming through a school (Larson et al., 2006). The main reported prey species in Western Australia is popeye mullet (*Rhinomugil nasutus*) (Thorburn et al., 2007b).

Reproduction: Little is known about the reproductive cycle in dwarf sawfish. Like other pristids, they reproduce by aplacental viviparity, where eggs develop inside the female's body and young are nourished by large amounts of yolk. Also similar to other sawfish species, the number of young produced by mature females is thought to be around 12 pups per year (Pogonoski et al., 2002; Peverell, 2009). Peverell's (2005) observations on reproductive staging and the capture of neonate specimens suggest that pupping occurred through the wet season until the beginning of the dry season in May.

3.3.4 Distribution

Global distribution: Recovery of historical museum records provides verifiable distribution of dwarf sawfish in Papua New Guinea and Indonesian Borneo (Faria et al., 2013). Other museum records include possible distribution to Réunion, Malaysian Borneo and Java, Indonesia (Faria et al., 2013). There are no recent records from outside of Australian waters.

The Australian population of the species is therefore considered likely to comprise the majority or all of the total global population (Thorburn et al., 2004; Stevens et al., 2005).

Australian distribution and abundance: There are no data available on the range and occurrence of dwarf sawfish prior to European settlement in northern Australia. Since European settlement, the species' Australian distribution has been considered to extend north from Cairns around the Cape York Peninsula in Queensland, across northern Australian waters to the Pilbara coast in Western Australia (Last & Stevens, 1994; McAuley et al., 2005; Stevens et al., 2008; Figure 9). A review of specimen records has found no records of the species from the eastern coast of the Cape York Peninsula, although the species has been confirmed from the Pine River on the western coast of Cape York Peninsula (S. Peverell, pers. comm.).

While eastern Queensland populations of dwarf sawfish cannot be confirmed, if the species was historically present in these waters, these populations may now have been extirpated, representing a contraction of range. It is also believed that habitat preference and physical characteristics render it highly likely to undergo future declines (TSSC, 2009).

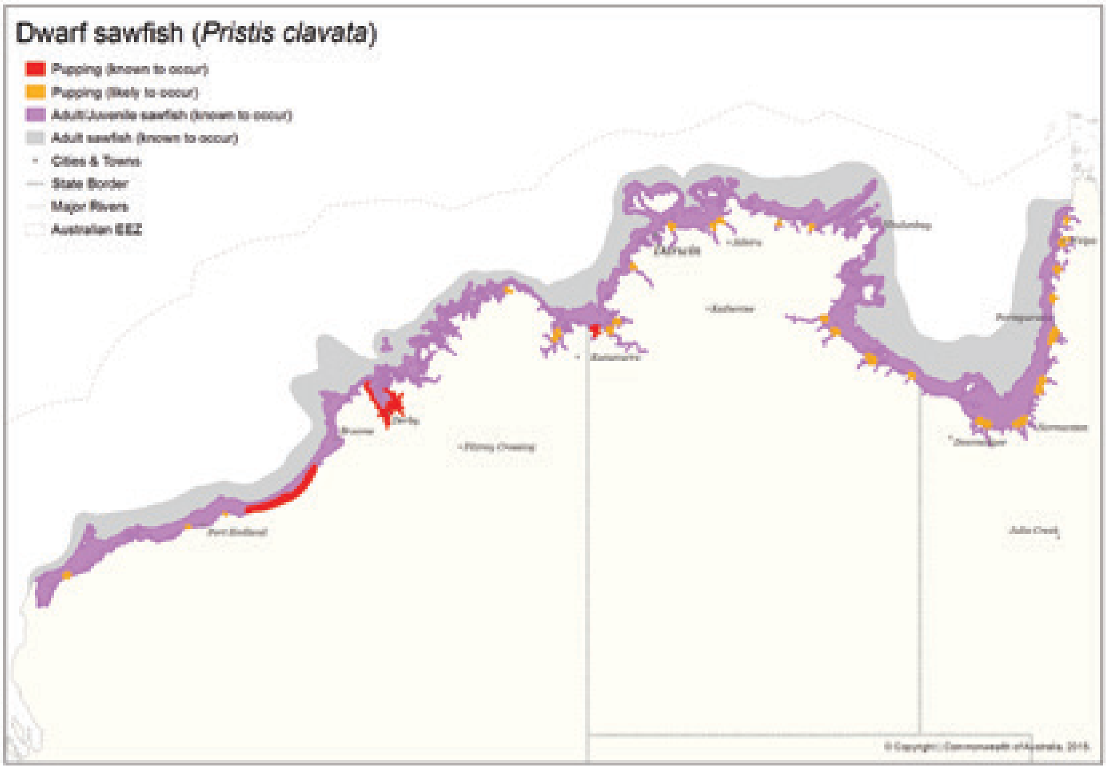

Figure 9. Map showing Australian distribution of dwarf sawfish

Population structure and genetic diversity: An assessment of the population structure of the dwarf sawfish was undertaken based on the analysis of a portion of the control region of the mitochondrial genome and eight microsatellite loci. The results indicate that the dwarf sawfish population is genetically structured in Australian waters, with the populations on the west coast, the north coast and the Gulf of Carpentaria being genetically distinct, although precise population boundaries are unclear (Phillips et al., 2011; Phillips, 2012). Unlike the largetooth sawfish, the genetic results did not find evidence of sex biased dispersal at broad spatial scales in the dwarf sawfish in Australian waters.

The levels of mtDNA and nDNA diversity in dwarf sawfish in Australian waters are low to moderate, and high, respectively, and within the range of values reported for other elasmobranchs including other species of Pristis. However, the levels of mtDNA diversity in dwarf sawfish in the Gulf of Carpentaria are severely reduced compared to those for the west coast and are amongst the lowest reported for elasmobranchs (Phillips et al., 2011).

The pattern of moderate to low levels of mtDNA and high levels of nDNA diversity suggest that the Australian population of dwarf sawfish was founded by small numbers of individuals followed by population expansion and growth. However, the signature of the genetic bottleneck/founder effect is very pronounced in the dwarf sawfish, largetooth sawfish and green sawfish and for all three species is stronger than those reported to date for any other elasmobranchs. For both the green sawfish and dwarf sawfish, this signature is particularly strong in the Gulf of Carpentaria. This suggests that in addition to the founder effect, there may have been contemporary declines in abundance and the continual pressure has prevented any recovery of alleles, especially in the Gulf of Carpentaria where levels of diversity are reduced and the signature of the founder effect/genetic bottleneck is very strong (Phillips, 2012).

Important populations: The genetic analysis suggests that there is negligible maternal or paternal gene flow between regional dwarf sawfish assemblages in Australia. Although the nature and location of the boundaries of these regional populations remain unknown, local population extinctions will not be replenished in the short to medium term by outside migration. This means that the individual assemblages, or regions, should be identified and managed as independent populations.

All populations of dwarf sawfish found in Australian waters should be considered important because the species is endemic and is likely found only in low numbers. However, the Gulf of Carpentaria population perhaps warrants special attention considering the low level of genetic diversity and the generally low numbers found in that region (Peverell, 2005, 2009; Phillips, 2012).

3.4 Speartooth shark (*Glyphis glyphis*)

3.4.1 Taxonomy

Scientific name: *Glyphis glyphis*; Family Carcharhinidae; Order Carcharhiniformes

Common names: Speartooth shark, Bizant river shark, Queensland river shark

Glyphis glyphis (formerly *Glyphis* sp. A) is conventionally accepted and has recently been described by Compagno et al. (2008).

3.4.2 Species description and growth rates

Appearance: Speartooth sharks are medium-sized whaler sharks with the following key characteristics (based on Compagno et al., 2008; Last & Stevens, 2009):

- Precaudal pit a narrow longitudinal or triangular depression (not crescent as in most carcharhinids);
- Second dorsal fin tall, height 67–76% of first dorsal-fin height;
- Snout short, broadly rounded in dorsoventral view, bluntly pointed in lateral view (less flattened than in northern river sharks);
- No interdorsal or predorsal ridges;
- Upper teeth broadly triangular, blade-like teeth;
- Lower teeth narrow, tall, slender with anterior few teeth with cutting edges confined to spear-like (hastate) tips. Small specimens often without hastate teeth;
- Semi-falcate and with a concave posterior margin;
- Short lower labial furrows, length 3.2–5.0 in nostril width (longer in northern river sharks);
- More vertebrae than northern river sharks: total vertebrae 213–222 (vs. 137–151 in *Glyphis garricki*); pre-caudal vertebrae 123–124 (vs. 73–83 in northern river sharks);
- 'B' ratio (length/width of the penultimate monospondylous vertebrae) 51–60 (vs. 91–97 in (northern river sharks);

- Less teeth than northern river sharks: tooth counts in upper jaw 26–29 vs. 31–34 in northern river sharks; lower jaw 27–29 vs. 30–35 in northern river sharks;
- Slate greyish in colour dorsally and abruptly white below; and
- Waterline (line formed by junction of light and dark tonal areas) extending just below eyes and dark tonal area not visible on head in ventral view (vs. extending well below eye and dark areas visible on head in ventral view in northern river sharks).

Maximum size: Based on limited data, speartooth sharks are approximately 50–60 cm at birth and are believed to grow to well over two metres when mature (Stevens et al., 2005; Pillans et al., 2009).

Growth rates and longevity: Estimates of juvenile growth rates based on a single capture (Tanaka, 1991) suggests a growth rate of approximately 19 cm per year (Stevens et al., 2005). There are no estimates of longevity for this species.

The size at maturity is unknown for this species, but is likely to be greater than 157 cm for males based on the largest recorded size for animals with non-calcified claspers and greater than 175 cm for females based on the largest recorded female (Pillans et al., 2009).

3.4.3 Life history

Habitat: Data from over 100 neonate, juvenile and sub-adult individuals indicate that speartooth sharks utilise large tropical river systems as their primary habitat (Stevens et al., 2005). Most captures occur in the tidal and estuarine sections of the rivers, and juveniles up to 175 cm have been captured. Based on physiological and life history similarities with bull sharks (*Carcharhinus leucas*), it is assumed adult speartooth sharks live outside of rivers in the coastal marine environment (Stevens et al., 2005; Pillans et al., 2009).

Speartooth sharks have been recorded in water ranging in salinity from 0.8 to 28 ppm. Given the range of salinity the species has been recorded in, it is a euryhaline elasmobranch capable of living in and moving between freshwater and seawater. Although captured animals have not been recorded in full strength seawater (salinity 35), from a physiological perspective, a salinity of 28 is effectively seawater and animals would need to employ similar physiological mechanisms to bull sharks in order to survive (Pillans & Franklin, 2004; Pillans et al., 2005, 2006, 2009).

The small amount of data collected on the physical properties of river systems where speartooth sharks have been captured indicates a preference for highly turbid, tidally influenced waters with fine muddy substrate. Data on the short term movement patterns of neonate and juvenile speartooth sharks in the Adelaide River (n = 3) and Wenlock River (n = 3) also show that animals have a tidally influenced movement pattern, moving up and downstream with the flood and ebb tides and primarily swim well above the substrate (Pillans et al., 2008, 2009).

Diet and feeding: Juveniles eat a range of estuarine and freshwater benthic and benthopelagic teleosts as well as freshwater crustaceans. Dietary items have included ariid catfish, nurseryfish, bony bream, freshwater gobies and *Macrobrachium spp.* The diet of adults is unknown (Peverell et al., 2006).

Reproduction: As in other carcharhinids, the reproductive mode is most likely placental viviparity with females giving birth to live young. As with other euryhaline elasmobranchs, pupping most likely occurs at river mouths or within estuaries. There are critical gaps in our understanding of fecundity (number of pups, reproductive periodicity) as well as age at maturity for females.

3.4.4 Distribution

Global distribution: Outside of Australia, speartooth sharks are only known to occur in Papua New Guinea from Port Romilly and the Fly River (Compagno et al., 2008).

Global population overview: No data are available on the global population size.

Relationship between the Australian and the global populations: The relationship between the Australian and global populations is poorly understood. It is currently unknown what percentage of the global populations occur in Australia and whether the Australian and Papua New Guinea populations are genetically linked.

Australian distribution and abundance: Based on available data from immature animals, there are three geographically distinct locations in which the species occurs or did occur (Figure 10). These are: 1) Van Diemen Gulf drainage in the Northern Territory, including the Adelaide River, South, East and West Alligator Rivers, and Murganella Creek; 2) Port Musgrave in Queensland, including the Wenlock and Ducie Rivers; and 3) the Princess Charlotte Bay area of eastern Cape York in Queensland.

In Western Australia photographs of one specimen captured in the Ord River resembled this species, however, the specimen was released and this record cannot be verified (R. Pillans, pers. comm.).

Speartooth sharks have been found in all five river systems that flow into the Van Diemen Gulf in the Northern Territory. This region appears to be the centre of abundance for this species and is the only place where speartooth sharks are known to occur in adjacent river systems. Given the proximity of these rivers (less than 115 km apart), it is not unreasonable to assume that, during the wet season, animals would be capable of moving between river systems while remaining in turbid water of reduced salinity.

Speartooth sharks have been confirmed in the Ducie and Wenlock Rivers on the western side of Cape York in Queensland. Speartooth sharks have not been recently recorded in nearby river systems of similar size despite survey effort (Blaber et al., 1989, 1995; S. Blaber, pers. comm., 2005; Peverell et al., 2006).

Speartooth sharks have likely disappeared from river systems in Queensland where they were found previously. Speartooth sharks were previously recorded in the Normanby and Bizant Rivers (Princess Charlotte Bay, Eastern Cape York) and the Hey and Embley Rivers (Western Cape York) (Peverell et al., 2006) but have not been recorded in those systems since 1985 (Pillans et al., 2009). No specimens have been recorded from the east coast of Queensland since 1983.

More data are required to determine whether the remaining populations of speartooth sharks are connected. Additional data on the distribution of speartooth sharks as well as population genetic analyses are needed to determine the degree of fragmentation.

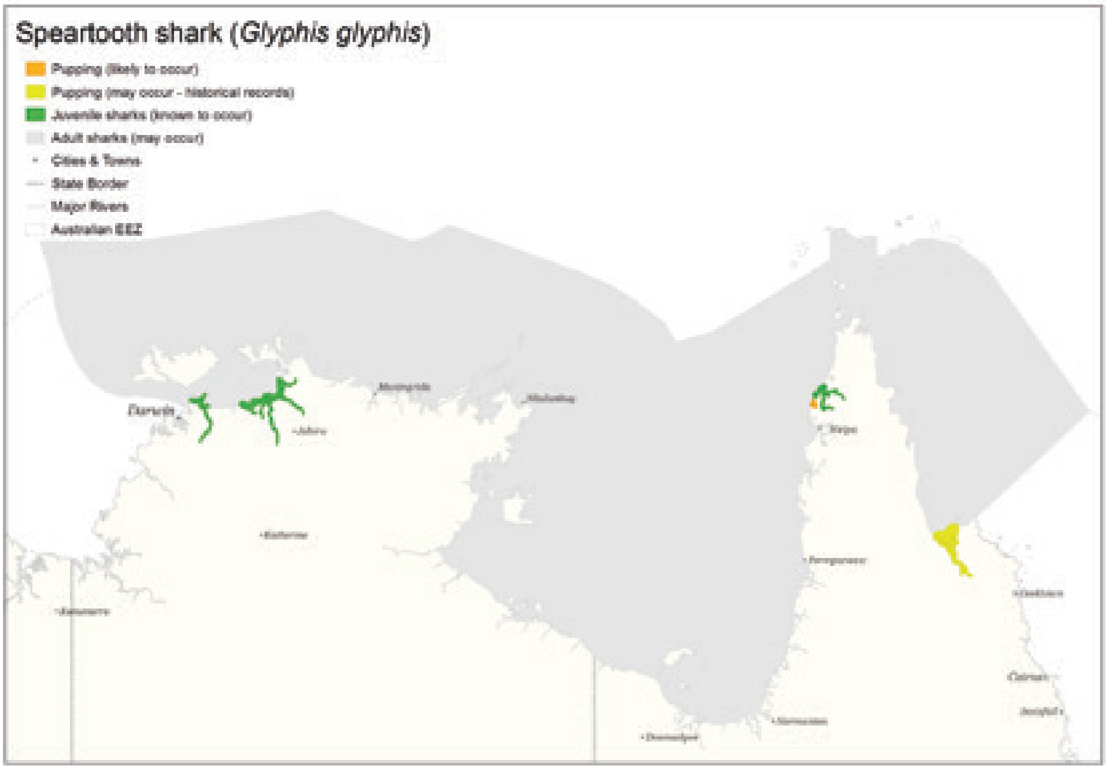

Figure 10. Map showing distribution of speartooth sharks

Population structure and genetic diversity: Analysis on mtDNA was able to discriminate between speartooth sharks and northern river sharks but did not show any population level differences between the separate speartooth shark populations (Wynen et al., 2009).

Important populations: Given the threatened status of this species, all river systems where speartooth sharks have been recorded are important. Populations on the edge of the species' known range include the Wenlock and Ducie Rivers in Queensland and the Adelaide River, Northern Territory. The greatest known concentration of speartooth sharks has been recorded from the Adelaide and South Alligator Rivers which flow into the Van Diemen Gulf; recent surveys have also recorded a significant number of speartooth sharks in the Wenlock River (R. Pillans, pers. comm., 2014).

3.5 Northern river shark (*Glyphis garricki*)

3.5.1 Taxonomy

Scientific name: *Glyphis garricki*; Family Carcharhinidae; Order Carcharhiniformes

Common names: Northern river shark, northern speartooth shark

This species is conventionally accepted and has recently been described by Compagno et al. (2008).
Northern river sharks are morphologically very similar to speartooth sharks but they are clearly separated based on dentition, vertebral counts, coloration and subtle morphological characters.

3.5.2 Species description

Appearance: Northern river sharks are medium-sized whaler sharks with the following key characteristics (based on Compagno et al., 2008; Last & Stevens, 2009):

- Precaudal pit a narrow longitudinal or triangular depression (not crescent as in most carcharhinids);
- Second dorsal fin tall, height 58–66% of first dorsal-fin height;
- Snout elongate, broadly rounded in dorsoventral view, very bluntly pointed, somewhat flattened in lateral view (less flattened but more bluntly pointed than in speartooth sharks);
- No interdorsal or predorsal ridges;
- Upper teeth broadly triangular, blade-like teeth;
- Lower teeth narrow, tall, slender with anterior few teeth with cutting edges confined to spear-like (hastate) tips. Small specimens often without hastate teeth;
- First dorsal fin not falcate and with a nearly straight upper posterior margin;
- Very short lower labial furrows, length 7.1–11.0 in nostril width;
- Fewer vertebrae than speartooth sharks: total vertebrae 137–151 (vs. 213–222 in speartooth sharks); pre-caudal vertebrae 73–83 (vs. 123–124 in speartooth sharks);
- 'B' ratio (length/width of the penultimate monospondylous vertebrae) 91–97 (vs. 51–60 in speartooth sharks);
- More teeth than speartooth sharks: tooth counts in upper jaw 31–34 vs. 26–29 in speartooth sharks; lower jaw 30–35 vs. 27–29 in speartooth sharks;
- Slate greyish in colour dorsally and abruptly white below;
- Eye very small 0.7–1.1% TL, 23–31 times in head length (Compagno et al., 2008); and
- Waterline (line formed by junction of light and dark tonal areas) extending well below eye and dark areas visible on head in ventral view (vs. extending just below eyes and dark tonal area not visible on head in ventral view).

Maximum size: Maximum recorded size is 251 cm for females and 144 cm for males (Pillans et al., 2009).

Growth rates: Size at birth for this species is approximately 55 cm based on the few juveniles that have been recorded. A 131 cm northern river shark captured in the Adelaide River by Tanaka (1991) was estimated to be four years old according to the number of rings on the vertebral centra.

Size at maturity for males is approximately 140 cm (Pillans et al., 2009). During a study in rivers in Western Australia and the Northern Territory, Pillans et al. (2009) recorded two mature males of 142 cm total length and one immature male of 135 cm total length.

Size at maturity for females is approximately 175 cm. A 177 cm female northern river shark was sexually mature and had nine early stage embryos and associated yolk sacs within the uterus (Stevens et al., 2005).

3.5.3 Life history

Habitat: Northern river sharks utilise rivers, tidal sections of large tropical estuarine systems, macrotidal embayments, as well as inshore and offshore marine habitats (Thorburn & Morgan, 2004; Pillans et al., 2009). Adults have been recorded only in marine environments, whereas neonates, juveniles and subadults have been recorded in freshwater, estuarine, and marine environments (Pillans et al., 2009). Data from King Sound show that animals between 91–142 cm occur in the same habitat (with salinities between 20 and 36.8 ppm) (Stevens et al., 2005).

The small amount of data on the physical properties of habitats northern river sharks have been captured in indicates a preference for highly turbid (secchi depth = three to 70 cm), tidally influenced waters with fine muddy substrate (Stevens et al., 2005). However, adults have also been recorded in inshore coastal habitats in Joseph Bonaparte Gulf as well as off the Wessel Islands in 20–25 m of water (Pillans et al., 2009).

This species appears to have a broad salinity tolerance. Given the range of salinity it has been recorded in, it is a euryhaline elasmobranch capable of living in and moving between freshwater and seawater (Stevens et al., 2005). The physiological specialisations that enable it to live in both freshwater and seawater are likely to be similar to those of bull sharks (see Hazon et al., 2003; Pillans & Franklin, 2004; Pillans et al., 2005, 2006, 2009).

Diet and feeding: Northern river sharks feed primarily on bony fish, but may also feed on other things. Stomachs of specimens captured in King Sound contained pieces of king salmon (*Polydactylus macrochir*) and forktailed catfishes (likely *Arius graeffei*) (Thorburn & Morgan, 2004) as well as remains of mud crabs (*Scylla serrata*) (J. Whitty, pers. comm.). Specimens captured in Joseph Bonaparte Gulf have contained barramundi and have had up to 100 small stingray spines imbedded in the musculature and cartilage of the mouth, indicating that stingrays form part of their diet (R. Pillans, pers. comm.).

Reproduction: As in most other carcharhinids, the reproductive mode is placental viviparity with females giving birth to live young. Based on data from one northern river shark, litter size is expected to be around nine. A 251 cm female northern river shark captured during the beginning of the wet season showed evidence of recent pupping, as determined by the distended uteri. This suggests that pupping occurred prior to the wet season (Pillans et al., 2009). The lack of yolky ova in the ovaries of two captured sharks suggests that northern river sharks only breed every second year.

3.5.4 Distribution

Global distribution: Northern river sharks are believed to be endemic to Australia and southern New Guinea. Outside of Australia the species is known from only a few specimens from the Fly River in Papua New Guinea.

Global population overview: The global population size of northern river sharks is unknown (Stevens et al., 2005).

Relationship between the Australian and the global population: The relationship between the Australian and global populations is poorly understood. It is currently unknown what percentage of the global population occurs in Australia and whether the Australian and Papua New Guinea populations are genetically linked.

Australian distribution and abundance: Northern river sharks have been recorded in rivers and estuaries as well as the marine environment within Western Australia and the Northern Territory (Figure 11). In Western Australia, records have come from both the west and east Kimberley, including King Sound, the Ord and King Rivers, the west arm of Cambridge Gulf and also from Joseph Bonaparte Gulf (Thorburn & Morgan, 2004; Stevens et al., 2005; Thorburn, 2006; Field et al., 2008; Whitty et al., 2008; Wynen et al., 2009; Pillans et al., 2009). All locations are macrotidal, with King Sound experiencing tides >11 m, twice daily.

Within the Northern Territory, northern river sharks have been recorded from the highly turbid lower reaches (salinity between two and ten) of the Adelaide River, Daly River and the South and East Alligator Rivers (Larson, 2002; Field et al., 2008.). Northern river sharks have also been recorded off the Wessel Islands in full strength seawater (Pillans et al. 2009).

More data are required to determine whether the distribution of northern river sharks is fragmented. Available data suggest that there are five locations where this species occurs and that there are large distances between the locations. The presence of animals well offshore suggests they undertake movements away from the rivers and estuaries and are therefore likely to move between river systems. The extent to which this occurs, however, and the distances moved are unknown. Additional data on the distribution and movement of northern river sharks as well as population genetic analyses are needed to determine the degree of fragmentation. The high incidence (ca. 50%) of spinal deformities in sharks captured in King Sound may represent a genetic deformity associated with a small gene pool (Thorburn & Morgan, 2004).

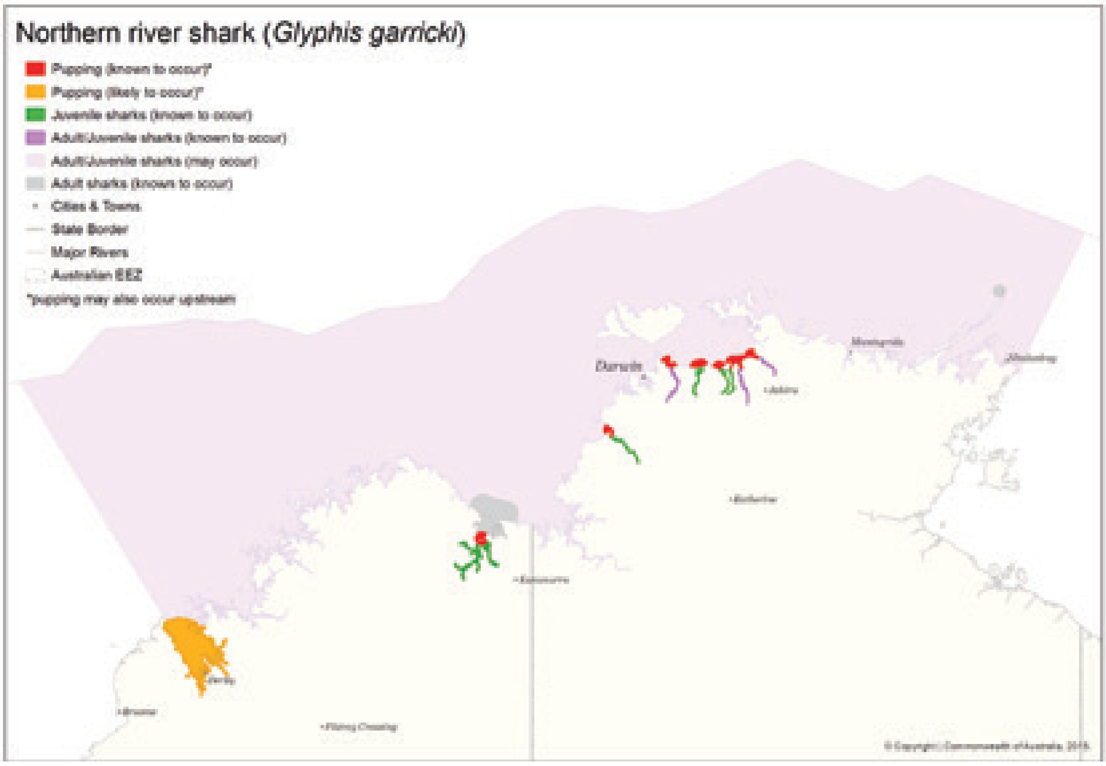

Figure 11. Map showing distribution of northern river sharks

Important populations: Given the threatened status of this species, all river systems where northern river sharks have been recorded are important. Particularly important populations include King Sound, Joseph Bonaparte Gulf and Van Diemen Gulf.

Population structure and genetic diversity: There is insufficient genetic information to determine population structure in northern river sharks.

4 Conservation

4.1 Australian Government

The five species covered by this issues paper are all listed as either Vulnerable, Endangered, or Critically Endangered under the EPBC Act (Table 1) and by respective state and territory legislation (Table 2). They are all listed in the IUCN Red List (Table 3). The three sawfish species are also listed on Appendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and Appendices I and II of the Convention on the Conservation of Migratory Species.

Table 1. Species status under the *Environment Protection and Biodiversity Conservation Act 1999*

Species common name	Scientific name	EPBC Status	Date of listing
*Largetooth sawfish	*Pristis pristis*	Vulnerable	16 July 2000
Green sawfish	*Pristis zijsron*	Vulnerable	7 March 2008
Dwarf sawfish	*Pristis clavata*	Vulnerable	20 October 2009
Speartooth shark	*Glyphis glyphis*	Critically Endangered	16 October 2001
Northern river shark	*Glyphis garricki*	Endangered	16 October 2001

* The freshwater sawfish (*Pristis microdon*) was relisted under its new name, the largetooth sawfish (*Pristis pristis*) on the threatened species list established under the EPBC Act on 3 October 2013.

The largetooth sawfish (then called freshwater sawfish) was transferred from the *Endangered Species Protection Act 1992* to the vulnerable list of the EPBC Act when it came into force in July 2000. For a species to be considered as vulnerable under the *Endangered Species Protection Act 1992*, the Minister must have been satisfied that the species was likely to become endangered within the next 25 years. Recommendations for listing species under the *Endangered Species Protection Act 1992* were made to the Minister by the then Endangered Species Advisory Committee.

The dwarf sawfish was listed as vulnerable under the EPBC Act in 2009. The dwarf sawfish was recommended for listing by the Threatened Species Scientific Committee (TSSC) as it satisfied Criterion 1 (decline in numbers) of the eligibility requirements. Specifically, the TSSC considered that the species may have undergone a range contraction and was highly susceptible to bycatch in inshore gillnet fishing, as well as being subject to other forms of fishing pressure throughout its range. Therefore, the TSSC judged that the species may have undergone a substantial reduction in numbers within the last three generation lengths and was highly susceptible to future declines.

The green sawfish was listed as vulnerable under the EPBC Act in 2008. The green sawfish was recommended for listing by the TSSC as it satisfied Criterion 1 (decline in numbers) of the eligibility requirements. Specifically, the TSSC considered the green sawfish had experienced a decline in numbers and a range reduction of around 30%, with the species becoming extirpated from NSW and southern Queensland, a region where it was once considered common.

Speartooth sharks and northern river sharks were listed as critically endangered and endangered respectively under the EPBC Act in 2001. These species were recommended for listing by the TSSC as they satisfied criterion 2 (geographic distribution), 3 (population size and decline in numbers or distribution) and 4 (population size) of the eligibility criteria. The current listing of these two species of river sharks as critically endangered or endangered is based on their limited geographic distribution and the estimated total number of mature individuals being either very (northern river sharks) or extremely (speartooth sharks) low and likely to continue to decline.

Full details of the listing advice for all of the species covered by this recovery plan can be found at: http://www.environment.gov.au/cgi-bin/sprat/public/sprat.pl

4.2 State and Territory listings

All sawfish and river shark species covered by this issues paper are protected under Australian state and territory legislation. In all state and territory jurisdictions, the taxonomy freshwater sawfish (*Pristis microdon*) is still used. *Pristis microdon* is a synonym for *Pristis pristis*, therefore state protection is still complementary and not in contrast to national legislation.

Table 2. Protected species status in the states and the Northern Territory

Jurisdiction	Species	Status
Northern Territory	Freshwater sawfish Green sawfish Dwarf sawfish Speartooth shark	Vulnerable under NT *Parks and Wildlife Conservation Act 2000* 'no take' species under the NT *Fisheries Act 1988* and Fisheries Regulations
	Northern river shark	Endangered under NT *Parks and Wildlife Conservation Act 2000* 'no take' species under the NT *Fisheries Act 1988* and Fisheries Regulation
Queensland	Freshwater sawfish Green sawfish Dwarf sawfish Speartooth shark (*Northern river sharks not present in Queensland waters*)	Protected ('no take') species under the Queensland *Fisheries Act 1994* and Fisheries Regulation 2008 All species also listed as 'High priority' under Queensland Back on Track species prioritisation framework
Western Australia	Green Sawfish	Totally Protected Fish under the *Fish Resources Management Act 1994* (FRMA) Protected fauna under the *Wildlife Conservation Act 1950* Threatened under the *Wildlife Conservation Act 1950*, and ranked as Vulnerable
	Freshwater Sawfish Dwarf Sawfish Northern River Shark (*Speartooth shark not confirmed in Western Australia waters*)	Totally Protected Fish under the *Fish Resources Management Act 1994* (FRMA) Protected fauna under the *Wildlife Conservation Act 1950*
New South Wales	Green sawfish (*other species not present in New South Wales waters*)	Presumed Extinct under *Fisheries Management Act 1994*

4.3 Non-legislative listing

The species covered under this recovery plan are listed internationally under the International Union for Conservation of Nature (IUCN), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and the Convention on the Conservation of Migratory Species (CMS). *Pristis microdon* is a synonym for *Pristis pristis*, therefore international protection is still complementary and not in contrast to national legislation.

Table 3. International status of sawfish and river shark species as determined by the IUCN, CITES and CMS

Species	Agency	Status
Largetooth sawfish Green sawfish Northern river shark	IUCN	Critically endangered—Red List
Dwarf sawfish Speartooth shark		Endangered—Red List
Green sawfish Dwarf sawfish Largetooth sawfish	CITES	Appendix I
Green sawfish Dwarf sawfish Largetooth sawfish	CMS	Appendix I and II

5 Threats to sawfish and river sharks

The principal threats to the five sawfish and river shark species have been identified as:

- Fishing activities including: being caught as by-catch in the commercial and recreational sectors; through Indigenous fishing; and illegal, unreported and unregulated fishing; and
- Habitat degradation and modification.

Other potential threats to these species include the collection of animals for display in public aquaria and entanglement in, and ingestion of, marine debris.

These factors are discussed in detail below.

5.1 Fisheries bycatch

Fisheries bycatch includes all non-target species caught while fishing. Sawfish and river shark species are known to be caught as bycatch in some fisheries in Australia. The capture of sawfish and river sharks in Australian territorial waters by Australian fishers is not illegal as long as the fishers did not target the species, made efforts to return the animal to the water alive and reported any captures to the relevant state or territory authority or to the Commonwealth, depending on where the capture took place. It should also be noted that fishers have the right to destroy an animal if it is considered removal of fishing gear or disentanglement would be dangerous. The retention of protected species without a permit is, however, an offence in all Australian waters. Considering the high value of sawfish fins and the collector's appeal of the rostra, there remains a risk that these body parts may still be retained illegally.

While the number of sawfish and river sharks that are injured or die as a result of being caught as bycatch has been estimated for some of the fisheries that interact with these species, sufficient data are not available for all fisheries impacting on Australian stocks. Post release survivorship also remains a largely unknown factor in understanding the full impact of fisheries interactions on sawfish and river sharks. Handling sawfish and river sharks correctly (see Kyne & Pillans, 2014) improves the chance of post-release survival from fishing gear. River shark species, however, are thought more likely to suffer mortality from capture. It should also be noted that there is better bycatch information for sawfish species than there is for river shark species. This is probably because sawfish species are more obvious due to their rostra while river shark species are easily misidentified due to their similarities with other whaler species (AFMA, 2009), and because river shark species are restricted to a few geographic locations and less frequently encountered.

Additional domestic fisheries threats come from illegal organised shark finning operations (Putt & Anderson, 2007) and from the deliberate misidentification of river shark species as bull sharks so they can be retained as part of the legitimate shark catch. In addition, fishers may catch sawfish and river shark species using illegal gear types and while fishing in closed or prohibited areas. The extent of the domestic illegal take of sawfish and river shark species is unknown.

5.1.1 Risk assessment of fishing methods

Bycatch by commercial fishing operations has been identified as one of the major pressures on all sawfish and river shark species in Australian waters and historic declines have been attributed to this source (Stevens et al., 2005, 2008; Pillans et al., 2008). The impact of commercial fishing on the five listed species of sawfish and river sharks will vary according to the gear used and how and where it is used. The principal commercial fishing activities that impact on sawfish and river sharks are gillnets and trawl methods, as well as line fishing. It should be noted that sawfish are particularly susceptible to any net fishing methods as their rostra tend to get caught in the nets where they can be injured before they are released or die due to prolonged periods of capture or stress during handling and release. There is also anecdotal evidence that trawl nets primarily capture adults and are more likely to have a higher impact because they are affecting the breeding population.

There have been a number of risk assessments completed on the various fisheries that operate in northern Australia and on the methods used in those fisheries. Lack (2010) provides a good overview of the different risk assessments undertaken and the conclusions drawn from those assessments, with a focus on the fisheries that operate in Commonwealth waters or that are jointly managed by the Commonwealth and the states and territories. The pressure analysis undertaken as part of the marine bioregional planning process also identified bycatch as 'of concern' for both the North-West region and the North region (DSEWPaC, 2012a, b).

Lack (2010) concluded that demersal and semi-demersal trawl methods; set mesh methods; demersal long-line; and pelagic gillnets posed the greatest risk to sawfish populations. However, of the various individual assessments undertaken, only the risk assessment of the Northern Prawn Fishery (NPF), which is predominantly a demersal trawl fishery (AFMA, 2008), identified sawfish as a 'high risk species' based on the rates of capture and the lack of mitigation methods. The risk assessment undertaken for the Gulf of Carpentaria (DPIF, 2004; Lack, 2010) found that semi-demersal trawl methods posed a medium risk and set mesh methods posed a low to moderate risk to sawfish species. The demersal longline and the pelagic gillnet methods were also considered high risk by Lack (2010). Lack considered these methods high risk due largely to the fact that there were no formal assessments of these gear types in northern waters on sawfish populations and hence based her assessment on what was known of bycatch rates from other fisheries that used these methods and by applying the precautionary approach.

When considering these risk assessments there are two important issues. First, the assessments were based on limited information and relatively limited independent observer data, particularly historical information. This lack of high quality data makes it difficult to objectively quantify the risk to sawfish and river shark species by fishing method or by fishery. A consequence of this lack of data is that a conservative assessment is required in order to ensure that populations are not further impacted while reliable and robust data are being obtained.

The second problem when considering risk by fishing method or fishery is that individual assessments may hide the cumulative risk to each species from all of the fisheries operating within their range (Brewer et al., 2007). For example, a species may be assessed as low risk to fishing pressure in several different risk assessments targeting different fisheries but, combined, the total fishing pressure on the species actually represents a high risk of impacting on the population. A cumulative risk assessment was conducted as part of research into the sustainability of target and bycatch species of Northern Australian sharks and rays (Salini et al., 2007) which found sawfish were the least sustainable group, with all species having the highest susceptibility ranks due to the fact that they are captured by prawn and fish trawls, gillnets and long lines. Other species that were least likely to be sustainable included the speartooth and northern river sharks. These species were classified as being least likely to be sustainable due to their high susceptibility in target and bycatch gill net and longline fisheries.

5.1.2 Fisheries that interact with sawfish and river sharks

A number of fisheries have been identified as interacting with sawfish and river shark species. The main fisheries are summarised in Table 4. A brief description of known bycatch rates and related risk will be discussed below for each of these fisheries. The descriptions of bycatch levels in each of the fisheries is mostly limited to publicly available data based on logbook records, observer data and scientific studies. Caution needs to be exercised when assessing these data as: 1) much of it is patchy and incomplete and, as such, generally does not provide a clear picture of the real fishing pressure on these species, and 2) there is little or no baseline information with which to compare the significance of the total numbers in relation to changes in either population rates over time or trends in catch rates. In addition, species identification is an ongoing problem in many commercial fisheries, as the differences between species within families (e.g., the sawfish family) can often be difficult for non-experts to identify. However, the information that is available does provide an indication of what is going on currently. It should also be noted that there are other fisheries which may interact with the five species but these are not discussed as there is limited or no data available.

Northern Prawn Fishery (NPF): The NPF is primarily an otter trawl fishery targeting several prawn species across northern Australian. In 2013, AFMA reported that there were 236 interactions with sawfish, of which 119 were narrow sawfish (*Anoxypristis cuspidate*), 107 were green sawfish, five were dwarf sawfish and five were largetooth sawfish (AFMA 2013). Under co-management arrangements, the Northern Prawn Fishery Industry Pty Ltd produces data summary reports to summarise catch and effort information for the Northern Prawn Fishery, including data relating to interactions with protected species. The data summary reports provide information on observer data, both from crew members and scientific observers and the most recent data summary report in 2012 suggests that the interaction frequency was greater in the scientific observer dataset than the crew member observer or logbook datasets (Bardwick, 2013). This discrepancy between logbook and observer datasets suggests some under-reporting in the fishery.

Gulf of Carpentaria Inshore Finfish Fishery: This fishery is primarily a gillnet fishery that targets a number of inshore fish species, including barramundi, king threadfin and grey mackerel. Largetooth, green and dwarf sawfish are recorded as part of the incidental catch in the gillnet fisheries in the Gulf of Carpentaria. The peak catch rates correspond with the monsoonal wet season, when the salinity levels at the river mouths and along the coastal shoreline are very low (Peverell, 2005). Interactions occur commonly in both the estuarine component of the fishery where both juveniles and adults were recorded, and more rarely in the coastal mackerel/shark components of the fishery (Peverell, 2005). The estuarine component of the fishery catches mostly juvenile individuals up to around 300 cm in length.

The latest fishing year report on the Gulf of Carpentaria Inshore Finfish Fishery is for the 2011 fishing season in which a total of 25 interactions were reported through the Species of Conservation Interest (SOCI) logbooks (DAFF, 2013a). This included 12 largetooth sawfish and three dwarf sawfish of which all but one largetooth sawfish were released alive. There was no observer coverage in 2011. However, in 2009, the last time there was observer coverage, a total of 21 interactions were reported through the SOCI logbooks for this fishery (DEEDI, 2010a). This included 12 largetooth sawfish and two dwarf sawfish. Of these, all but one largetooth sawfish was reported as being released alive. However, the observer program reported a total of 26 interactions with the five listed species of sawfish and river sharks, these included: one dwarf sawfish, 20 largetooth sawfish, one green sawfish and four speartooth sharks. Of those, the sawfish were mostly reported as being returned alive but three of the four speartooth sharks died during capture. There is an obvious discrepancy between the SOCI logbook data and the observer data, which suggests a high degree of under-reporting is taking place in this fishery. The observer data was based on 61 days of observation and included 512 net sets totalling 40.5 km and 3250 fishing hours. This represents less than one percent of total fishing effort in the fishery.

Gulf of Carpentaria Developmental Finfish Trawl: This fishery uses trawl methods in offshore waters to target red snapper species. No SOCI interactions were reported by the operators in the 2009 or 2011 seasons (DEEDI, 2010b; DAFF, 2013b) and four interactions with largetooth sawfish were reported by operators in the 2010 season (DEEDI, 2011a). There were no observer trips in the 2010 or 2011 seasons and on the one observer trip (nine days) in the 2009 season no interactions were observed with any protected species (DEEDI, 2010b; DEEDI, 2011a; DAFF, 2013b). It appears from SOCI logbook reporting that interactions with the five EPBC Act listed species of sawfish and river sharks are likely to be minimal.

East Coast Otter Trawl Fishery: The east coast otter trawl fishery primarily targets prawn species but also takes scallops, bugs, lobsters, crabs and other non-teleost marine species. This fishery is thought to have only a limited impact on sawfish and river shark species. Interactions with one of the five species covered in this document were reported in 2009—one green sawfish was captured and that individual was released alive (DEEDI, 2010c). In later years, only narrow sawfish were captured; three in 2010 (DEEDI, 2012) and one in 2011–12 (DAFF, 2013c), all of which were released alive.

East Coast Inshore Finfish Fishery (ECIFF): The ECIFF is a large fishery targeting a broad range of fish species, including several shark species, along the Queensland east coast. There were seven reported interactions with green sawfish between 2006 and 2009 based on 149 observed trips (Harry et al., 2011), but no reported interactions with sawfish and river shark species in this fishery based on 248 days of observer coverage from 2009 to 2011 (DEEDI, 2011b). It is possible that some interactions might have been recorded between 2009 and 2011 had there been observer coverage north of Cooktown and in the Princess Charlotte Bay region. SOCI logbook records for this fishery for 2009 confirm relatively low rates of interactions with the three protected sawfish and two protected river shark species but there were four records of capture of green sawfish, of which two were released injured and the other two died during capture (DEEDI, 2011b).

Offshore Net and Line Fishery (ONLF): The ONLF primarily targets black-tip sharks (*Carcharhinus tilstoni* and *C. limbatus*), spot-tail sharks (*C. sorrah*) and grey mackerel (*Scomberomorus semifasciatus*) and operates in offshore regions in the Northern Territory, particularly around the Gulf of Carpentaria. This fishery is not thought to pose a significant threat to sawfish and river shark species, although they have been recorded as bycatch. Observer coverage of this fishery over 49 days at sea recorded only one capture each of both the northern river shark and the green sawfish (Field et al., 2008). This low level of observed interactions accords with historical logbook records which indicate 40 green sawfish, two largetooth sawfish and one unspecified river shark species were captured in 2005 and 2006 combined (Field et al., 2008). The number of interactions with sawfish has increased between 2010 and 2012. The 2010 Fishery Status report for the ONLF does not report any interactions with any of the five protected species of sawfish or river shark (DoR, 2011), while the 2011 Fishery Status report on the ONLF reports an interaction with one dwarf sawfish, which was released alive (DPIF, 2012), and the 2012 Fishery Status report on the ONLF reports interactions with three largetooth, and at least 10 green sawfish (DPIF, 2014).

Table 4. The main Australian commercial fisheries that are known to interact with sawfish and river shark species

Fishery	Managed by	Interactions with species	Gear type
Northern Prawn Fishery	Commonwealth	Dwarf sawfish Largetooth sawfish Green sawfish	Trawl
Gulf of Carpentaria Inshore Finfish Fishery	Queensland	Dwarf sawfish Largetooth sawfish Green sawfish River shark spp.	Set mesh nets
Gulf of Carpentaria Developmental Finfish Trawl Fishery	Queensland	Sawfish spp.	Trawl
East Coast Otter Trawl Fishery	Queensland	Green sawfish	Trawl
East Coast Inshore Finfish Fishery	Queensland	Largetooth sawfish Green sawfish River shark spp.	Net
Offshore Net and Line Fishery	Northern Territory	Largetooth sawfish Green sawfish Dwarf sawfish Speartooth shark	Net and line
Northern Barramundi Fishery	Northern Territory	Largetooth sawfish Green sawfish Dwarf sawfish Speartooth shark	Net
Kimberly Gillnet and Barramundi Managed Fishery	Western Australia	Largetooth sawfish Green sawfish Dwarf sawfish Speartooth shark	Net
Pilbara Demersal Trawl Fishery	Western Australia	Green sawfish	Fish trawl

Northern Territory Barramundi Fishery: The Northern Territory Barramundi Fishery is a relatively small mixed fishery. The primary target species are barramundi (*Lates calcarifer*) and king threadfin (*Polydactylus macrochir*). The shark bycatch composition of this fishery is currently poorly understood but this fishery is known to interact with sawfish and river shark species. Observer data from two independent studies (Salini et al., 2007; Field et al., 2008) taken over 52 days at sea recorded captures of 17 speartooth sharks, 20 dwarf sawfish and 12 green sawfish. Of the sawfish caught, about half were dead when retrieved.

The 2010, 2011 and 2012 Fishery Status reports indicates the Northern Barramundi Fishery has minimal interactions with threatened species according to logbooks and their observer program (DoR, 2011; DPIF, 2012, 2014).

Kimberly Gillnet and Barramundi Managed Fishery (KGBMF): The KGBMF extends from the Western Australia/Northern Territory border to the top of Eighty Mile Beach. The fishery operates in inshore and estuarine regions and targets fish by the use of gillnets. As a result of where the fishery operates and the fishing methods it uses it does catch some sawfish and river shark species. The 2012 State of the Fishery Report (Fletcher & Santoro, 2012) indicates that the catch of these protected species is minimal due to generally low effort but does not quantify the level of catch. In 2013, the Western Australian Government purchased and retired the two remaining licenses in this fishery operating out of Roebuck Bay and introduced a closure to commercial netting from North Broome to the top of Eighty Mile Beach, effectively closing the southern extent of the fishery.

Pilbara Demersal Trawl Fishery (PDTF): The PDTF is situated in the Pilbara region in the north west of Australia. The 2011 status report (Fletcher & Santoro, 2011) indicates that green sawfish are caught in this fishery and that, in 2010, there were a total of 19 reported captures, of which all but two were released alive. The 2012 status report (Fletcher & Santoro, 2012) indicates that in 2011, there were a total of six reported green sawfish captures, with all six reported to have been released alive. The 2013 status report (Fletcher & Santoro, 2013) indicated that in 2012, there were 37 reported green sawfish captures, with 17 being reported as released alive.

In the 2012 trial of alternative bycatch mitigation measures in the fishery (Wakefield et al., 2014), interaction rates of 11 green sawfish per 1000 trawls were recorded. However, seasonal trends in sawfish abundance were also detected, so extrapolations of this figure are difficult. Logbook data from the fishery has recorded between six and 27 green sawfish per year, with catch rates variable from year to year and most animals being released alive.

According to vessel logbook records, catch of sawfish is typically higher during the second and third quarters of each year, suggesting there may be a seasonal influence associated with catches (Wakefield et al., 2014).

The Western Australian Department of Fisheries has advised that future trials of excluder grids closer to the mouth of the net may reduce the incidence of dolphins and green sawfish becoming trapped within the trawl nets.

5.2 Recreational fishing

The recreational catch of sawfish and river sharks is banned by legislation in Western Australia, Northern Territory and Queensland. Any sawfish captured must be returned to the water unharmed and as quickly as possible. However, recreational fishing continues to grow in popularity and with a growing population, improvements in technology, larger recreational boats, greater access to the coast and an increase in fishing tour operators, more remote areas of northern Australia are now becoming accessible which will increase the pressure on these species as they will be increasingly caught, whether it be as incidental capture or through deliberate capture for highly prized rostrum trophies.

The total recreational catch of sawfish and river sharks is difficult to quantify although rostra mounted on the walls of fishers' homes and in public establishments are testament to a long history of catch in northern Australia, extending into the fairly recent period of history before fishing licences and gear restrictions were introduced. Recent surveys of recreational fishing in Queensland, the Northern Territory and Western Australia have been undertaken (Taylor et al., 2012; Ryan et al., 2013). While quantifying the general level of take in the recreational sector, the reports do not provide relevant information regarding the take of protected shark species due to the lack of species level data. It is also possible that misidentification (as bull sharks or sawsharks for example) or reporting in 'other shark' categories may result in recreational fishing interactions with protected species going unnoticed.

While catch rates of protected sawfish and river shark species in the recreational sector cannot be quantified, it is considered that the use of lures by recreational fishers targeting barramundi poses less of a threat to sawfish than the use of baited lines or nets, although there are anecdotal reports of sawfish being caught on lures. Regardless of which method is more likely to catch sawfish species, survivability is thought to be higher when the animals are caught on lines rather than in nets as they are likely to be released more quickly. Nevertheless, survival will ultimately depend on a number of factors, including fight time.

Ongoing education campaigns have been implemented in order to help recreational fishers understand the threats to sawfish and river sharks, how to better identify them and ways to avoid capture and/or reduce harm to the animals once captured. The effectiveness of these campaigns has not been assessed.

5.3 Indigenous fishing

The current level of Indigenous fishing of the protected sawfish and river shark species is unknown. However, Indigenous Australians are allowed to take and eat threatened species—including sawfish and river sharks—for personal, domestic or non-commercial communal needs. Sawfish have a significant cultural and spiritual relevance to Indigenous Australians and are also a food source (Truelove, 2003; McDavitt, 2005; Peverell, 2005). The importance of sawfish may vary between Indigenous communities and there also may be cultural restrictions on who can take them, limited to particular times and places. However, considering that these species occur in areas known to be fished by Indigenous Australians, and that they probably occur in low numbers and restricted habitats, they are vulnerable to localised depletion from harvest. This is of particular concern during the dry season, when the habitat of largetooth sawfish will retract into localised pools. Nevertheless, Indigenous take is likely to be localised around communities because of the expense of travelling to fishing areas further afield.

In order to better understand the take of sawfish and river shark species by Indigenous Australians more information needs to be obtained on catch levels and use. A preliminary survey of Indigenous hunters on Groote Eylandt identified that sawfish were occasionally taken, but in small amounts compared to other elasmobranchs (Saunders & Carne, 2010). Another survey of Indigenous fishing in northern Australia (Henry & Lyle, 2003) identified that the Indigenous harvest, while small compared to the general recreational and commercial take, was still significant, particularly in areas with a high proportion of Indigenous people. Neither survey, however, identified animals to species level, so it is difficult to make conclusions about the threat posed by Indigenous fishing on the protected sawfish and river shark species. Further surveys across the range of sawfish and river shark species are required to better understand the magnitude of Indigenous fishing and its potential affect on populations.

The study from Groote Eylandt stresses that working closely with the Indigenous rangers and utilising local community mechanisms to collect information are critical to project success. Ranger programs have been established across northern Australia and are well-placed to collect information relating to harvest and monitoring of these species in Indigenous communities. For example, the I-Tracker program, run through the North Australian Indigenous Land and Sea Management Alliance Limited (NAILSMA), has developed a data collection application using CyberTracker software that Indigenous ranger groups across north Australia use to collect and map information on coastal and marine management activities.

There is also potential to work with Indigenous communities to develop voluntary management arrangements for species of concern. One example of such an arrangement is a Traditional Use of Marine Resource Agreement, a number of which have been developed by Indigenous communities in the Great Barrier Reef Marine Park area in Queensland. Another example is the development of Regional Activity Plans for dugongs and marine turtles through NAILSMA's Dugong and Marine Turtle Project (2005–2009). Through community consultation, the Regional Activity Plans identified Traditional Owners' needs and aspirations, the issues and threats facing dugong and marine turtle management, and the management and research activities that communities wished to undertake. The Dugong and Marine Turtle Knowledge Handbook (2006) brings together scientific and Indigenous knowledge, a copy of which is available at: http://www.nailsma.org.au/sites/default/files/publications/Dugong%20and%20marine%20turtle%20handbook_0.pdf.

5.4 Illegal, unreported and unregulated fishing (IUU)

The deliberate targeting and retention of any of the five species described in the Sawfish and River Sharks Multispecies Recovery Plan is prohibited for any non-Indigenous person in Commonwealth and state waters and in the Northern Territory. Any deliberate targeting of these species therefore, falls into the category of illegal, unreported and unregulated fishing (IUU). Although Australian based vessels can be considered to be part of the IUU trade, the term is usually considered to refer to foreign vessels fishing illegally in Australian waters. The pressure analyses undertaken as part of the bioregional marine planning process identified IUU fishing as 'of concern' for the northern marine bioregion.

The primary IUU threat comes from vessels involved in the shark fin trade illegally fishing in Australian waters. This threat probably relates to sawfish more than river shark species as sawfish fins are amongst the most valuable. Such fishing has been documented (Field et al., 2009) but the magnitude of this threat is unknown. In 2005 it was estimated that the illegal foreign take of sharks in the Gulf of Carpentaria was at least equivalent to the domestic legal catch (Pascoe et al., 2008), although these levels are thought to have since decreased significantly (Lack & Sant, 2008). International vessels fishing on the edge of Australia's Exclusive Economic Zone also pose a threat to Australian populations and there is evidence that such fishing is occurring in the Arafura and Banda Seas (from which two largetooth sawfish specimens were recorded) from boats out of West Papua. Again, the extent of the sawfish take from these operations is unknown.

5.5 Habitat degradation and modification

A wide range of habitat based threats exist for sawfish and river shark species, particularly those species that rely to a greater extent on freshwater and inshore areas, as these are more prone to disturbance. These threats include:

- Coastal development, including canal developments, port expansion and oil and gas related coastal infrastructure, removal of mangroves/sea grass and land clearing;
- Barriers in rivers;
- Reduced water quality and increased sedimentation;
- Interruptions to migration pathways;
- Water extraction;
- Climate change; and
- Bottom trawling, through destruction of benthic habitat.

The impacts of these threats are largely unknown for most species and are likely to be species-specific and localised. It is also likely that the impacts of habitat degradation will be greater on the juveniles of some species because they tend to inhabit fresh water, estuarine and inshore habitats more than the adults. Of the threats mentioned, impacts of water extraction, which affects natural river flow, and impacts of barriers in rivers are of particular concern. It is thought that pupping in sawfish and river shark species is linked to wet season river flows (Peverell, 2005) and that the number of new recruits captured in the dry season is significantly correlated with higher water levels during the late wet (Whitty et al., 2008). The implications of these findings are that changes to the hydrological regimes of the important rivers may impact these species in ways not yet fully understood, but which are likely to be detrimental. Dams, barrages, poorly constructed road crossings and weirs across rivers can impede migration up and down river systems by largetooth sawfish and river shark species and can also cause localised aggregations which may make them more susceptible to natural predation from species such as bull sharks and crocodiles, and also increase their chances of being taken as incidental bycatch, or through deliberate capture, by recreational fishers (Thorburn et al., 2003, 2004, 2007a). The long-term impacts of dams and barrages warrant further investigation.

5.6 Collection for public aquaria

All three sawfish species are listed on Appendix I of CITES which largely prohibits international trade in these species. It does not however preclude collection of sawfish for use in domestic aquaria. The collection of largetooth sawfish for the domestic aquarium trade in Northern Territory waters may only be undertaken by permit from the Director of Fisheries and only for the purpose of supply to public aquariums. Under Western Australian state government legislation, sawfish are a totally protected species that may not be collected or kept for aquarium purposes. Largetooth sawfish are a protected species in Queensland and take of specimens is prohibited without a permit. As of 2013, there are five current general fisheries permits that allow the collecting of sawfish species in Queensland waters. Three of the permits allow the taking of sawfish species for research purposes and the other two allow the taking of sawfish species to supply to aquaria for the purpose of public display or public education. There is no take allowed of any sawfish species in the Great Barrier Reef Marine Park.

There are currently only a small number of sawfish and river shark specimens held in Australian aquariums. The current rate of capture of sawfish for public aquaria is restricted to domestic establishments only, and the current rate of extraction is low. The collection of live sawfish for aquarium trade has the potential to be a significant threat to sawfish populations in Australian waters unless the moratorium is enforced.

5.7 Marine debris

Marine debris (or marine litter) is defined as any persistent, manufactured or processed solid material discarded, disposed of or abandoned in the marine and coastal environment (UNEP, 2005). This includes land-sourced plastic garbage (e.g. bags, bottles, ropes, fibreglass, piping, insulation); derelict fishing gear from recreational and commercial fishing activities and ship-sourced, solid non-biodegradable floating materials lost or disposed of at sea (DEWHA, 2009). These definitions can also be extended to riverine environments.

Northern Australia is especially vulnerable to marine debris given the proximity of intensive fishing operations, difficulties in surveillance and enforcement and ocean circulation patterns that are likely to concentrate floating debris before dumping it on coastlines and beaches (Kiessling, 2003). There are a number of known marine debris sources operating in the region, including major shipping routes, significant numbers of commercial and recreational fishing vessels, as well as land-based sources. Marine debris accumulates in relatively high concentrations along the coasts adjacent to urban centres and remote areas of north-western Cape York, Groote Eylandt, north-east Arnhem Land and the far north Great Barrier Reef (DEWHA 2009). Large amounts of fishing net are discarded or lost from the fisheries of the Gulf of Carpentaria and Arafura Sea and end up beach-washed on Queensland and Northern Territory coastlines (Limpus, 2009).

The likelihood of interaction between debris and sawfish and river shark species in northern Australia is largely unknown. Individuals of small coastal sharks, of the same family (Carcharhinidae) as river shark species, have been found with plastic debris collars (Sazima et al., 2002). Carcharhinid sharks have also been recorded in ghost nets off northern Australia, so morphologically, river shark species would also be vulnerable to capture. Because of their saw-like rostrum, sawfish may be susceptible to entanglement in marine debris, particularly discarded nets (Seitz & Poulakis, 2006). Such entanglement can cause serious or fatal injury. In addition, the occurrence of sawfish and river shark species in popular recreational fishing locations may expose them to discarded or lost fishing line, cast nets or pots, and other debris. For example, Thorburn et al. (2004) reported an interaction between largetooth sawfish and discarded or lost recreational fishing line, causing serious external injury.

Engaging with Indigenous communities is one way of gaining an understanding of the interaction and potential impacts of marine debris on sawfish and river shark species. Indigenous land and sea management groups have been actively engaging in the monitoring of marine debris and associated marine entanglements in partnerships with organisations like GhostNets Australia, Tangaroa Blue and NAILSMA through the I-Tracker program.

6 Summary of issues and future research directions

The primary threats to sawfish and river shark populations are likely from fishing pressure (commercial, recreational, Indigenous and IUU) and habitat disturbance, particularly to river systems and estuaries. Based on scale, it is likely that commercial fishing would result in the most incidental mortalities of sawfish and river shark species. However, to date, no scientific study has clearly identified a trend in catch rates, which would suggest a population decline in any of the regions being fished. Further, most fisheries have, in recent times, implemented a range of measures aimed at reducing interactions with the species in question—including fisheries closures and better release methods—which may already have resulted in reduced capture and mortality rates. Considering the efforts already undertaken by fisheries agencies, the clear requirement to better manage this sector is better information on rates of capture and population trends in the regions being fished. In addition, efforts to reduce interactions, help fishers better identify species and release captured animals in a manner which increases post-release survival, are required.

The current lack of information and detail on capture rates in the recreational sector makes management difficult. As deliberate capture of these species is illegal, it is very difficult to assess its full extent. However, these species are also caught as legitimate bycatch species by the recreational sector. Considering that intentional captures of these species is likely to remain poorly understood, the best way to reduce the capture and mortality rate by this sector is to work with recreational fishers to reduce non-intentional captures by: limiting interactions through avoiding high risk fishing methods; implementing seasonal and area closures; and helping improve identification, handling and release methods.

Indigenous Australians are allowed to take and eat sawfish and river shark species as part of their native title rights. To date, the level of take has not been established, which makes it difficult to manage as the size of the threat is unknown. Establishing the extent of Indigenous take, therefore, should be a priority for future research as would be establishing any population trends in areas that are heavily utilised by Indigenous groups. Once the full extent of Indigenous take is better understood, then measures should be developed in partnership with Indigenous communities to ensure the harvest is sustainable.

Managing the IUU take of sawfish and river sharks is difficult as there is only a very limited understanding of the components of this threat. It is currently unclear who is taking what, whether the threat is primarily local or from international waters and the scale of the threat. Better management of this threat will firstly require an understanding of its scale but also require working closely with the enforcement and compliance sections of government agencies at all levels.

The areas where sawfish and river shark species are mostly found are generally remote and relatively undeveloped. However, in some regions developments such as weirs and barrages in rivers and port development/expansion works associated with population centres, heavy industry or agriculture may result in habitat degradation which may impact on movement and survival rates. There are general knowledge gaps about the impacts of alterations to river flow and these need to be better understood. Other developments may have unforeseen consequences and it is important that appropriate development regulation and oversight occurs, which may include investigations into the specific projects and impacts.

The impact of marine debris also poses a significant problem for many areas in northern Australia. However, the scale that this threat poses to sawfish and river shark species is unknown. Management of this threat will require additional information on mortalities associated with marine debris, which may require the development of better ways to identify animals to a species level so that better monitoring and data collection can occur.

When assessing the threats to sawfish and river shark species, one factor stands out. That is that there is very limited information on any of these species, both in the significance of the threats and in the basic biology and population dynamics of the species involved. The combined issues of minimal data and a limited understanding of population pressures on these species makes it difficult to optimally manage the species in regards to balancing the needs and activities of individuals and communities who interact with these species and ensuring that the individual populations of the species are dynamic and robust. To achieve better outcomes for all stakeholders more targeted research will be required, with a particular focus on establishing programs able to assess population demographics at a regional scale and also better identify the pressures which are limiting growth and recovery.

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8 Appendix

Appendix 1: Outputs of the shark and sawfish species pressure analysis for the North-west and North Marine Region*

Pressure	Source	Source	Species				
		North-west	North				
		Three species sawfish	Dwarf sawfish	Freshwater sawfish	Green sawfish	Northern river shark	Speartooth shark
Sea level rise	Climate change						
Changes in sea temperature	Climate change						
Changes in oceanography	Climate change						
Ocean acidification	Climate change						
Chemical and nutrient pollution	Shipping						
	Vessels						
	Onshore and offshore mining						
	Agricultural activities						
	Urban development						
Changes in turbidity	Dredging spoils						
Marine debris	Land-based activities						
	Fishing vessels						
	Shipping						
	Vessels (other)						
Noise pollution	Seismic exploration vessels (other)						
Physical habitat modification	Dredging/ dredge spoil						
	Urban/coastal development						
	Offshore construction and installation of infrastructure						
	Onshore construction						

Pressure	Source	Source	Species				
		North-west	North				
		Three species sawfish	Dwarf sawfish	Freshwater sawfish	Green sawfish	Northern river shark	Speartooth shark
Human presence at sensitive sites	Tourism						
	Recreation and charter fishing (burleying)						
	Research						
Extraction of living resources	IUU	of less concern	of concern	of concern	of concern	of concern	of concern
	Commercial fishing (non-domestic)						
	Commercial fishing (domestic—harvest for aquaria)		of less concern	of potential concern	of less concern	of less concern	of less concern
	Recreational fishing						
	Indigenous	of less concern	of potential concern	of potential concern	of potential concern	of potential concern	of potential concern
	Commercial fishing (prey depletion)						
Bycatch	Commercial fishing (domestic)	of concern	of concern	of concern	of concern	of concern	of concern
	Recreational fishing	of concern	of concern	of concern	of concern	of concern	of concern
Collision with vessels	Shipping						
	Tourism						
	Fishing						
Invasive species	Shipping						
	Fishing vessels						
	Land-based activities						
Oil Pollution	Shipping		of less concern	of less concern	of less concern	of less concern	of less concern
	Vessels		of less concern	of less concern	of less concern	of less concern	of less concern
	Oil rigs		not of concern	not of concern	not of concern	not of concern	not of concern
Changes in hydrological regimes	Land-based activities	of concern	of concern	of concern	of concern	of concern	of concern
	Climate change		of concern	of concern	of concern	of concern	of concern

Legend: of concern; of potential concern; of less concern; not of concern; data deficient or not assessed

* Appendix 1 is a combination of the pressure analyses undertaken for the North and North-west Marine Regions. Full analysis and explanations for each identified pressure can be found in (DESWPaC, 2012a, b).

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