Protocols for Surveying and Tagging Sawfishes and River Sharks

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December 2014

www.nerpmarine.edu.au

National Library of Australia
Cataloguing-in-Publication entry
National Environmental Research Program (NERP) Marine Biodiversity Hub

Title: Protocols for Surveying and Tagging Sawfishes and River Sharks
Format: PDF
Authors: Peter M. Kyne, and Richard D. Pillans
ISBN: 978-1-4863-0436-3

Citation

Kyne, P.M. and Pillans, R.D. (2014). Protocols for Surveying and Tagging Sawfishes and River Sharks. National Environmental Research Program Marine Biodiversity Hub, Hobart.

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Protocols can be constantly assessed and improved when new and more advanced techniques become available. Readers should therefore ensure that they are abreast of the current literature.

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Acknowledgements

This work was undertaken for the Marine Biodiversity Hub, a collaborative partnership supported through funding from the Australian Government's National Environmental Research Program (NERP). NERP Marine Biodiversity Hub partners include the Institute for Marine and Antarctic Studies, University of Tasmania, CSIRO, Geoscience Australia, Australian Institute of Marine Science, Museum Victoria, Charles Darwin University and the University of Western Australia. Support is also provided by the NERP Northern Australia Hub, Northern Territory Fisheries and Kakadu National Park. We thank Alastair Graham, Annabel Ozimec, Peter Last, John Stevens and Carli Piltz for access to and assistance with maps which were modified from Last and Stevens (2009). Thanks to Nic Bax and Russ Bradford (CSIRO) and to Jillian Grayson, Debbie Rudd and Ashley Leedman (Department of the Environment) for comments on the document. Photos used in this publication are credited to Peter Kyne, Richard Pillans, Grant Johnson, Miguel Clavero and the Australian National Fish Collection, CSIRO (*Anoxypristis cuspidata* and *Pristis zijsron* images).

Introduction

Aim, scope, audience and application

Aim: This document will establish best practice guidelines for safe and ethical research and monitoring of threatened sawfishes and river sharks in Australia. It covers surveying, handling, processing (data collection), tagging and releasing sawfishes and river sharks.

Scope: This manual is designed specifically for threatened euryhaline elasmobranchs - sawfishes (*Pristis* species) and river sharks (*Glyphis* species) - in coastal, estuarine and freshwater systems. However, it also has wider application to elasmobranchs (sharks and rays) in general.

Audience: Environmental consultants (not specifically trained to work on these species; in relation, but not exclusive to, environmental impact assessments), State and Territory agencies that undertake environmental assessments and approvals, research academics and students, Commonwealth, State and Territory fisheries agency staff, national park staff, traditional owners and Indigenous ranger groups, and the Commonwealth Department of the Environment.

Application: For use by consultants when undertaking surveys for threatened sawfishes and river sharks for environmental impact assessments; for researchers and resource management staff undertaking activities related to sawfishes and river sharks; for the Department of the Environment and other Commonwealth, State and Territory Government Departments when assessing research proposals and addressing referred actions.

This document arises from a need to develop a standardised procedure for all aspects of research and monitoring associated with sawfishes and river sharks. It recognises that issues such as excessive handling and prolonged exposure to the sun, incorrect tagging approaches and tag biofouling have previously occurred causing adverse effects on animals (issues not unique to just these species, having occurred more widely with elasmobranchs). This document aims to alleviate these adverse effects through awareness, education and standardised procedures. This document also serves to maximise the amount of data collected from each capture of these species and provide a standard format for the collection of data across Australia. Reducing the risks of research and monitoring and making the most value of any data collected will support the Recovery Plan for these species (DOE 2014).

It is recommended that research or monitoring on other species using fishing/survey gear which may potentially interact with sawfishes and river sharks adhere to these protocols in order to minimise their impact.

While these protocols have been developed specifically for sawfishes and river sharks of northern Australia, they may generally be applicable to research and surveying of these species in other locations, and more broadly to other elasmobranch species. However, local conditions and species-specific factors will need to be considered.

All research including surveys, monitoring and tagging requires valid permits from the relevant State/Territory and/or Commonwealth agencies. Additionally, procedures are required to be approved by an independent Animal Ethics Committee (see research permits section, page 36).

Checklist for the design and execution of surveys for sawfishes and/or river sharks

1. What species are being targeted or likely to be caught in the surveys? (see page 9).

2. What is the appropriate time of year to survey for these species? (see page 13).

3. What is the appropriate fishing gear to survey for these species? (see page 13).

4. Are all team members familiar with safe handling of animals? (see page 16).

5. Are all team members familiar with processing and data collection procedures? (see page 18).

6. Has the appropriate tagging methodology been chosen (if tagging is appropriate)? (see page 25).

7. Are team members undertaking tagging properly trained and proficient in the application of tags (including internal tagging)? (see page 25).

8. Are all team members familiar with the safe release of animals? (see page 35).

9. Are all appropriate permits and animal ethics approvals in place? (see page 36).

10. Has appropriate approval been sought for access to any Indigenous land? (see page 37).

11. Have Indigenous communities been given the opportunity to partner in or participate in survey or research activities? (see page 37).

Species background

Globally, all five sawfish species (family Pristidae; genera *Pristis* and *Anoxypristis*) have undergone considerable decreases in both abundance and distribution in recent decades and are now severely depleted or extinct in many parts of their range (Dulvy *et al.* 2014). Although populations have declined across northern Australia, this area represents one of the few remaining population strongholds for sawfishes anywhere in the world, with four species occurring in northern Australia.

The river sharks (family Carcharhinidae; genus *Glyphis*) are a small group (5 species) of poorly-known habitat and range-restricted species. These species are specialists of highly turbid, tidal rivers and associated estuaries (Pillans *et al.* 2009). Northern Australia is home to two river shark species, each with a limited distribution.

Appendix I provides an identification guide to the sawfishes and river sharks of northern Australia.

Three sawfish species and both river shark species are listed as threatened species on the Commonwealth *Environment Protection and Biodiversity Conservation Act* (EPBC Act) (Table 1). Some species are also listed as threatened on conservation legislation in the Northern Territory or protected under fisheries legislation in Queensland and Western Australia (Table 1). Additionally, the Green Sawfish is listed as Presumed Extinct in New South Wales. A fourth sawfish species, the Narrow Sawfish *Anoxypristis cuspidata*, is not EPBC-listed but is protected in Queensland and Western Australia (Table 1).

In addition to the EPBC-listed species, this manual is also relevant to the Narrow Sawfish as well as the Bull Shark *Carcharhinus leucas* which is commonly encountered in similar estuarine/riverine habitats.

Table 1. Sawfish and river shark species listed on the Commonwealth *Environment Protection and Biodiversity Conservation Act* (EPBC Act) and State/Territory legislation.

Common name	Scientific name	EPBC listing[1]	QLD listing[2]	NT listing[3]	WA listing[4]
Dwarf Sawfish	*Pristis clavata*	Vulnerable	Protected	Vulnerable	Totally Protected
Green Sawfish	*Pristis zijsron*	Vulnerable	Protected	Vulnerable	Totally Protected
Largetooth Sawfish	*Pristis pristis*	Vulnerable	Protected	Vulnerable	Totally Protected
Narrow Sawfish	*Anoxypristis cuspidata*	Not listed	Protected	Not listed	Totally Protected
Northern River Shark	*Glyphis garricki*	Endangered	na	Endangered	Totally Protected
Speartooth Shark	*Glyphis glyphis*	Critically Endangered	Protected	Vulnerable	na

[1]*Environment Protection and Biodiversity Conservation Act* 1999; [2]Queensland (QLD): *Fisheries Act* 1994; [3]Northern Territory (NT): *Territory Parks and Wildlife Conservation Act* 2000; [4]Western Australia (WA): *Fish Resources Management Act* 1994. na, not applicable (i.e. species does not occur in that state).

Surveying

Undertaking field work in northern Australia presents a number of risks. Of particular note are the dangers associated with working in a crocodile environment. Appendix II provides relevant procedures, but it is noted that researchers and consultants will need to meet the risk assessment requirements of their institution/organisation.

All species considered here overlap in their distribution to some degree and share the same broad habitat types (Table 2). However, an understanding of species-specific habitats is essential in planning and executing surveys and monitoring. Readers are urged to consult the literature regarding habitat requirements of each species, in particular: Stevens *et al.* (2005; 2008), Thorburn *et al.* (2003), Whitty *et al.* (2008), Pillans *et al.* (2009) and Kyne (2014).

Table 2. Broad Australian distributions, habitat and depth ranges for sawfishes and river sharks. Sources: Last and Stevens (2009), Pillans *et al.* (2009), Dulvy *et al.* (2014), Kyne (2014).

Species	Australian distribution	Broad habitats	Depth range (m)
Dwarf Sawfish	The Kimberley, WA to Cape York, QLD (unconfirmed QLD east coast)	Rivers (tidal), estuaries, marine	0–at least 20
Green Sawfish	The Pilbara, WA to QLD east coast (extirpated southern QLD and NSW) (vagrant to SA)	Estuaries, marine	0–70
Largetooth Sawfish	The Kimberley, WA to QLD east coast (vagrant to southwest WA)	Rivers (tidal reaches to hundreds of km upstream), floodplain waterholes and dry season pools, estuaries, marine	0–60
Narrow Sawfish	The Pilbara, WA to QLD east coast	Estuaries, marine	0–128
Northern River Shark	The Kimberley, WA to the Wessel Islands, NT	Rivers (tidal), estuaries, marine	0–at least 20
Speartooth Shark	Adelaide and Alligator Rivers region, NT, and Wenlock River, Cape York, QLD	Rivers (tidal), estuaries (adult habitat unknown but most likely marine)	0–at least 20

Australian State/Territory abbreviations: NSW, New South Wales; NT, Northern Territory; QLD, Queensland; SA, South Australia; WA, Western Australia.

It should be noted that catch rates of sawfishes and river sharks in most areas will be extremely low. In large river systems with expansive floodplain waterholes, considerable effort is required to ascertain the presence or absence of sawfish and the lack of catches from a few days fishing effort cannot be used to inform assessments. As an example, Table 3 provides juvenile Largetooth Sawfish catch-per-unit-effort (CPUE) values for a number of northern Australian rivers to demonstrate the low and variable catch rates that can be expected.

Table 3. Juvenile Largetooth Sawfish catch-per-unit-effort (CPUE) (number of sawfish per 100 hours of 20 m gillnet length) in various Northern Territory rivers. Data from National Environmental Research Program sampling from late 2011 to mid-2014.

Location	CPUE (mean)	CPUE (standard deviation)
Adelaide River	0.46	1.07
Daly River	0.12	0.40
East Alligator River	0.00	0.00
South Alligator River	0.13	0.83
Victoria River	0.08	0.22
Wickham River	0.00	0.00

Reporting the results of surveys should include details of the fishing gear used, the fishing effort undertaken, the locations fished and the catch. Fishing effort (standardised as catch-per-unit-effort, and presented with a measure of error such as standard deviation or standard error) should be broken down by factors which may influence catch rates, such as season, location or habitat. Such information can help to inform future survey design and enable spatio-temporal comparisons.

Survey areas

The following species accounts expand on the broad Australian distributions and habitat types provided in Table 2. Knowledge of distribution and habitat can help inform where surveys should be undertaken. Australian State/Territory abbreviations: NSW, New South Wales; NT, Northern Territory; QLD, Queensland; SA, South Australia; WA, Western Australia.

Dwarf Sawfish

The Dwarf Sawfish occurs across northern Australia from the Kimberley region of WA, through the NT, the Gulf of Carpentaria to western Cape York Peninsula, QLD (Figure 1). Reports from the QLD east coast are unsubstantiated. It has been recorded from several large tidal rivers including the Fitzroy, Keep and South Alligator Rivers, but probably occurs in other inadequately surveyed rivers.

Juvenile and adult Dwarf Sawfish occur in estuaries including brackish sections of the mid estuary/rivers as well as isolated tidal sections of some estuaries such as the Fitzroy and Keep Rivers where spring tides allow access to certain areas every few weeks. Adults are primarily recorded on mangrove-lined mud and sand flats adjacent to coastal foreshores and estuaries.

Green Sawfish

The Green Sawfish occurs across northern Australia from the Pilbara region of WA, through the NT, the Gulf of Carpentaria, Cape York Peninsula to the central QLD east coast. Historically, it occurred through southern QLD to central NSW, with a single historic record from off Glenelg, SA (Figure 1).

Juvenile and adult Green Sawfish occur along coastal foreshores over sand and muddy substrates, often on shallow intertidal flats. It has been recorded in lower reaches of estuaries but is not known to venture large distances upstream in rivers.

Largetooth Sawfish

The Largetooth Sawfish occurs across northern Australia from the Kimberley region of WA, through the NT, the Gulf of Carpentaria, Cape York Peninsula to the northern QLD east coast. It has been recorded from numerous river drainages across that range. There is also a single record of a vagrant off southwest WA (Figure 1).

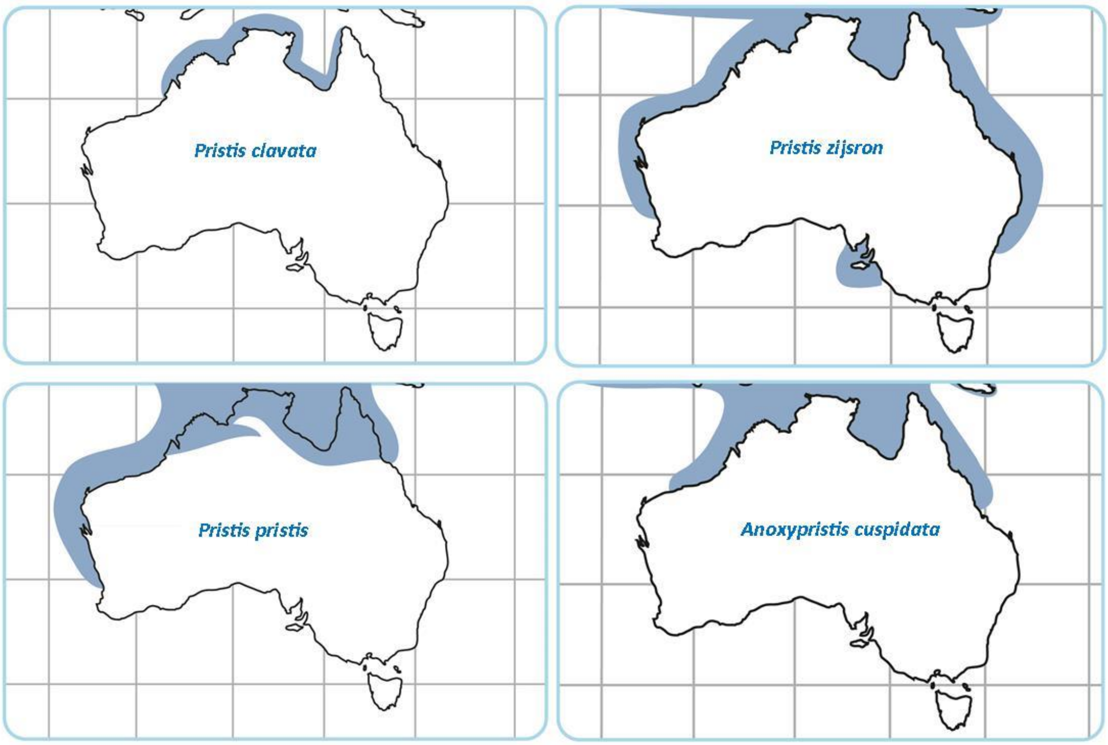
Neonate and juvenile Largetooth Sawfish up to 2.5 m TL can be found from estuaries to hundreds of kilometres inland in rivers and isolated floodplain waterholes. Adults have been primarily recorded offshore in prawn trawls and also in coastal gillnets but also in the lower reaches of rivers and estuaries. It primarily occurs over mud and sandy areas but also over rubble and rocky bottoms although it is rarely encountered in heavily wooded sections of rivers or tree-lined billabongs.

Narrow Sawfish

The Narrow Sawfish occurs across northern Australia from the Pilbara region of WA, through the NT, the Gulf of Carpentaria, Cape York Peninsula to the central QLD east coast (Figure 1).

Juveniles are captured in lower reaches of rivers and estuaries as well as large coastal mud and sand flats often over intertidal areas. Adults are primarily offshore with many records from both prawn trawl and offshore gillnet fisheries. Unlike other sawfish, this species has been captured in mid water gillnets targeting pelagic fish and sharks.

Figure 1. Broad Australian distributions of the four sawfish species: Dwarf Sawfish *Pristis clavata*, Green Sawfish *P. zijsron*, Largetooth Sawfish *P. pristis* and Narrow Sawfish *Anoxypristis cuspidata* (modified from Last and Stevens 2009). All species had broad historical distributions outside of Australia (although the Dwarf Sawfish may now be restricted only to Australia).



Northern River Shark

The Northern River Shark has been recorded in King Sound, Doctors Creek, Ord River, Joseph Bonaparte Gulf, King River, WA, and Daly River, Adelaide River, Sampan Creek, Wildman River, West Alligator River, South Alligator River, East Alligator River and off the Wessel Islands, NT (Figure 2).

Neonate, juvenile and adult Northern River Sharks have been recorded in tidal reaches of rivers with adults also in offshore areas such as Joseph Bonaparte Gulf and the Wessel Islands.

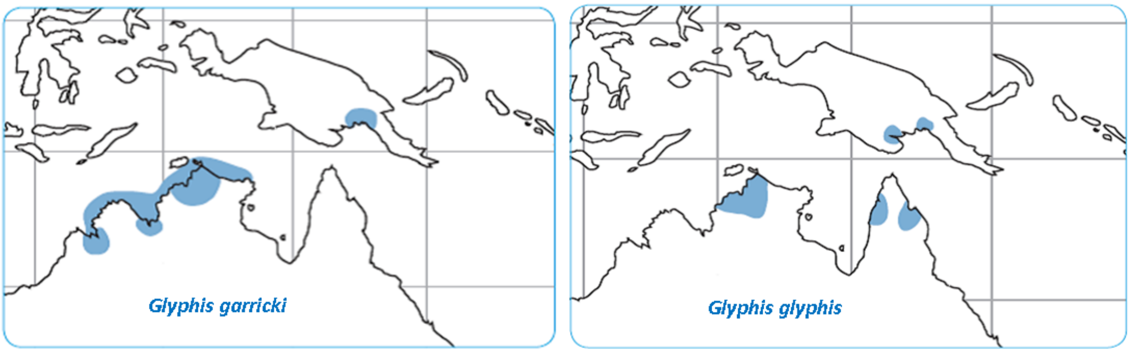
Recent surveys in tidal drainages and rivers of the Van Diemen Gulf (NT) have expanded the previously known range of this species (Kyne and Pillans, unpublished data) and additional surveys in other areas of the NT and WA where this species has not yet been recorded may increase the known distribution. All tidal rivers and drainages within the known range should be sampled before presence/absence can be concluded.

Speartooth Shark

The Speartooth Shark has been recorded in the Adelaide River, Wildman River, West Alligator River, South Alligator River, East Alligator River and Murganella Creek, NT as well as the Wenlock River, Ducie River and Port Musgrave in QLD (Figure 2). There have been no records from the Bizant River, QLD since the early 1980’s.

Neonate and juvenile Speartooth Shark occur in tidal reaches of these rivers. No adults of this species have ever been recorded; presumably adults occur offshore although their distribution may not overlap with commercial fisheries given the lack of records.

Figure 2. Broad global distribution of the two river shark species: Northern River Shark *Glyphis garricki* and Speartooth Shark *G. glyphis* (modified from Last and Stevens 2009). In addition to their Australian distributions, both species have been recorded in southern Papua New Guinea.



Survey timing

Surveys for sawfishes and river sharks can be conducted all year, however seasonal movements related to the wet/dry season cycle should be considered when planning surveys.

For Largetooth Sawfish, sampling for neonates and juveniles can be productive if timed to coincide with wet season flows when animals are more likely to be moving upstream to access habitat that is normally not available. This is particularly relevant if animals are congregating below a barrier during rising water levels. However, high water velocity makes fishing with gillnets impractical unless nets are set in large eddies or areas of low flow. Furthermore, access to rivers and particularly floodplain waterholes is often limited during the wet season precluding sampling during these times. For this reason, more available habitat can generally be sampled during the dry season when access and water levels are more conducive to fishing. Very few adults have been captured in research operations with the majority of records from scientific observers on board commercial prawn trawl and inshore gillnet vessels. Targeted sampling and capture of adult Largetooth Sawfish is generally impractical due to low abundance and the difficulty in handling large animals from small vessels.

Little is known about the seasonal movements of Dwarf, Green and Narrow Sawfish, however sampling in rivers and around coastal foreshores and river mouths during the wet season should consider the influence of salinity as these species are unlikely to be found where freshwater flood plumes are adjacent to the coast during wet season flooding.

For river sharks, there is a downstream seasonal movement associated with increased freshwater flow and reduced salinity which can result in animals occupying downstream reaches of rivers and estuaries during the wet season. Therefore sampling undertaken at the same location during the wet and dry seasons may not be comparable (depending on the scientific questions being asked). The timing and distance moved during annual cycles is probably linked to flow regimes in individual river systems as well as the timing and magnitude of wet season rainfall.

Survey techniques

Due to the different morphology of sawfish and river sharks, different fishing methods need to be employed for surveys of these species. Gillnets are the most effective method for sampling all sawfish species, whereas baited hooks are the most effective method for sampling river sharks.

Sawfishes

Bottom set gillnets are the most effective methods for capturing sawfish. In general, in coastal, estuarine and riverine areas where the majority of sampling is likely to occur, Dwarf, Green and Largetooth Sawfish swim close to the shoreline. As such, nets should be set from the shoreline out, rather than in deep water away from the shoreline.

Net length

The length of the net should be determined according to the habitat being sampled. For expansive shallow areas such as large rivers, mudflats and sandy foreshores, nets in excess of 60 m can easily be deployed and retrieved from small to medium-sized vessels. In confined river channel and floodplain waterholes, shorter nets (10–30 m) may be more appropriate and easier to deploy and retrieve. Longer nets will be subject to increased drag and may require additional anchors and floats than shorter nets. Also be aware of tidal flow which can sink floats, drag nets and make net retrieval difficult.

Net drop

The drop of the net depends on the depth of water being sampled; however, as sawfish generally swim on or near the substrate, bottom set nets with a drop of 2–3 m will be effective. To ensure that gillnets are on the substrate, large anchors need to be placed on each end of the net and in areas of strong current, additional weights may need to be placed along the lead line of the net to ensure it doesn't lift off the substrate.

Mesh and line size

Mesh size refers to the stretched length of a mesh. Line size refers to the thickness of the monofilament line used to construct the net. As an example, a line size of 40 is equivalent to 40 pound breaking strain.

The two most important factors to consider when choosing mesh size are bycatch and the desired size class of the target species. Generally, bycatch of abundant teleosts (e.g. catfish, mullet, barramundi etc.) will increase with decreasing mesh and line size. For Green and Largetooth Sawfish, 6 inch mesh of line size 40–60 will be equally effective at capturing neonates, subadults and adults. For Dwarf and Narrow Sawfish, 6 inch mesh will be effective at capturing subadults and adults but a mesh size of 4 inches and line size of 20–30 will be more effective at capturing neonates due to their smaller size at birth. When targeting subadult and adult sawfish, mesh size of 10–20 inches and line size of 100 and greater can be used to reduce bycatch without reducing the chances of capturing the target species.

Monitoring the net

Although sawfish handle capture in gillnets relatively well, once entangled they are susceptible to predation by sharks and crocodiles. As such, nets should be monitored continuously and animals removed from the nets as soon as they are entangled. In remote areas it is common for Estuarine Crocodiles to wait near gillnets and attempt to eat animals that become entangled.

Key considerations in relation to gillnetting and crocodiles are:

- Inspect potential netting areas for the presence of crocodiles. Do not set nets near observed crocodiles.
- Nets should never be left unattended.
- Nets should be constantly monitored for catches which should be removed immediately (allowing minimal opportunities for crocodiles to be attracted to the net).
- The area surrounding the net should be constantly monitored for the presence of crocodiles.
- If a crocodile is noted showing interest in the net (i.e. moving towards it) an attempt should be made to scare off the crocodile by driving the boat towards it (but not over it as to avoid the chance of boat strike).
- If a crocodile is persistent, netting should cease immediately and the net retrieved.

River sharks

Although both species of river shark can be captured in gillnets, the large range of sizes encountered in rivers and estuaries (~50–190 cm TL) results in gillnets only having a limited selectivity depending on the mesh size used. In addition to issues around not being able to capture a range of sizes, river sharks captured in gillnets can be difficult to revive if they are not removed from nets immediately after becoming entangled. Furthermore, the majority of river sharks occur in tidal rivers, estuaries and bays where gillnets can only be effectively used around slack periods of neap tides due to large tidal flows. In these areas it is more practical to use baited hooks.

As such, it is recommended that surveys for river sharks be conducted using baited hooks. These can take the form of either 5–10 hook longlines or rod and line. As longlines need to be anchored to the substrate, heavy line is required to prevent breakage when large sharks are hooked, as a result of this longlines are more effective at capturing sharks greater than 120 cm TL and as such do not provide a completely representative catch composition. As with gillnets, due to the presence of large predators in tropical areas, any baited lines should be continuously monitored. Longlines should be anchored at both ends with the baits lying on the substrate. A float at each anchor is required to retrieve the line. Wire trace is required to prevent hooked sharks biting through the line; around 200 cm of 150–400 pound plastic coated wire is recommended. Circle hooks are the only hook that should be used with longlines. Size 14/0–20/0 circle hooks will catch a wide range of sizes but as noted previously, the heavy wire and large hook size will select for larger animals. Wire should be attached to a shark clip which is attached directly to the main line.

In areas of relatively high density, rod and line is an effective method for capturing river sharks. The advantage of using rod and line is that this method captures the full range of sizes encountered in the habitat being fished and once individuals are hooked, they can be quickly brought alongside the boat minimising capture time and therefore stress and predation risk. Rod and reels capable of holding 200 m of 50 pound braided fishing line are recommended. A 200 cm length of 60–100 pound monofilament fishing line should be attached to the end of the braided line to minimise abrasion and act as a shock absorber. Small size circle hooks (4/0–7/0) will capture the full range of shark sizes encountered. It is recommended that 50 cm of 40–90 pound plastic coated wire is used between the hook and strong swivel that is attached to the monofilament. The weight of sinkers should be varied depending on tidal flow, but should ensure that the bait is on or near the bottom.

The best bait is any teleost species naturally occurring in the system being fished. This can include mullet, bony bream, blue salmon, queenfish and barramundi. Catfish are generally not the most effective bait. A small mesh gillnet or a cast net is an effective method of capturing bait, however, ensure that research permits allow the capture of fish for the purpose of using them for bait. Although frozen baits will catch sharks, freshly captured bait results in higher catch rates.

Handling

Paramount to handling sawfish and sharks is ensuring the welfare of the animal and the safety of the field crew.

As a general rule, sawfish are more robust to capture than the more sensitive river sharks and therefore different consideration needs to be given to the different species groups. However, the central rule is to minimise handling and processing times.

Exposure to excessive sunlight can damage exposed skin and under no circumstances should fish be left out of the water unnecessarily.

General handling rules:

- Consider both the welfare of the animal and the safety of the field crew.
- Minimise handling time as much as possible.
- Do not lift animals only by their tail or one fin. Always use two hands.
- Animals >1.5 m length will require two people for handling.
- Do not gaff sawfish or sharks.
- Use a large landing net to lift river sharks on board for processing.
- Do not handle or drag sharks by inserting hands in the gill slits.
- Minimise exposure to the sun.
- Hold animals in a large tub with frequent water changes (every 1-2 minutes) or continuous irrigation.

Safety issues

Both sawfish and river sharks are potentially dangerous animals and considerable care must be taken to avoid personal injury. Be aware of the toothed rostrum of sawfishes and the mouth of sharks. Depending on the size of sawfish, the rostrum should be secured by hand (wearing sturdy gloves) at its base on small individuals brought onto the vessel, or with a rope around its base for larger individuals processed alongside the vessel (see below). For sharks, avoid the mouth area at all times.

Removal from fishing gear

Removal of sawfish and sharks from fishing gear should be undertaken as rapidly as possible.

When an individual is captured by gillnet an initial visual assessment is undertaken to determine the extent of entanglement. If lightly entangled, individuals may be removed by hand. If entanglement is more severe, net snips should be used to cut meshes away from the animal to allow fast removal. For sharks, this will likely be meshes around the body/gills and the pectoral fins. For sawfish, this is usually meshes around the rostral teeth. It is far easier to cut meshes from the rostral teeth than to labour away trying to disentangle meshes by hand. Cut net meshes can be easily repaired later.

For both sawfish and sharks, a firm grip is required on the animal as it is removed from fishing gear to ensure it is not a danger when it is freed. Special care needs to be given to the rostrum of sawfish to ensure it is not bent and broken while removing from a net.

When an individual is captured by hook (longline or rod and line), it should be secured as efficiently as possible and the hook removed when safe to do so. Do not attempt to remove hooks by hand but instead use a dehooking device or heavy duty long-handled pliers.

Depending on the size of the fish, individuals are either brought on board the vessel or secured alongside it.

Handling on board vessel

Individuals <2 m in length can usually be brought on board the vessel for processing (depending on vessel size, number of field crew etc.). Processing on board is easier than processing alongside the vessel (and safer due to the crocodile risk).

When caught on rod and line, small animals should be landed with the aid of a landing net (as sharks in particular can easily damage nylon landing nets, a PVC Environet is recommended). Larger animals may need to be secured and landed by hand. All animals >1.5 m in length should be secured by two people. Larger animals should only be brought on board when well secured. Use gloves to handle fish in order to improve grip and provide protection from abrasive skin.

Secure small sharks with one hand around the caudal peduncle, and one on the body or by holding a pectoral fin. If holding the body, be sure not to hold around the gills as these are sensitive, and pressure on this area can cause bleeding. Secure large sharks with one person holding the tail (gripping around the caudal peduncle) and another securing the front end. That person should have one hand on each of the pectoral fins and can hold the animal body against theirs to offer additional support, while at all times keeping the snout/mouth directed away from them.

Secure small sawfish with one hand at the base of the rostrum and the other around the body of the fish.

Fish should initially be placed in a large tub with water taken from the source of capture. This tub can hold animals during any preparation required prior to processing and tagging and returned to the tub for pre-release recovery. Frequent water changes should be undertaken (every 1-2 minutes).

Handling alongside vessel

Larger individuals may need to be secured alongside the vessel for processing. The use of an in-water stretcher is recommended. The stretcher is placed alongside the vessel and the animal positioned into it. Ropes are used to secure the animal and maintain its position which is also supported by the stretcher.

For both sawfish and sharks, secure a rope around the caudal peduncle using a simple loop; do not tighten excessively. For sawfish, a second rope is tied around the base of the rostrum. For sharks, a second rope is tied around the body at the pectoral fin insertions (the rear margins of the pectoral fins where they attach to the body). Use quick release knots to assist in rapid release of the animal after processing. For sawfish, placing a hessian sack (or similar) around the rostrum will prevent the rostral teeth from being broken off against the side of the boat.

Processing

Once landed, the general sequence of processing (and tagging) a sawfish or river shark is as follows:

- Remove hook (if line caught; see page 16).
- Take measurements (see below).
- Assess sex and maturity and take clasper measurements (see page 20).
- Take tissue sample (see page 22).
- Take photographs (see page 23).
- Insert PIT (or conventional) tag (if required; see page 26).
- Insert coded acoustic tag into peritoneal cavity (if required; see page 29).
- Attach continuous acoustic tag to first dorsal fin (if required; see page 29).
- Release (see page 35).

Measurements

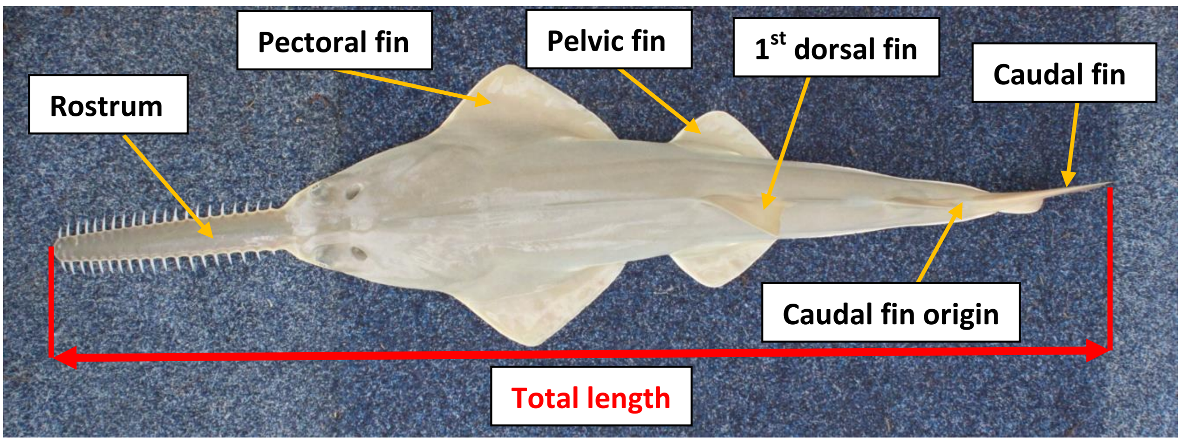
For both sawfish and river sharks, the standard measurement to record is total length (TL). A suite of other measurements can also be recorded if appropriate; these are outlined below.

Where possible, place sawfish and sharks on top of a tape measure or measuring board and record measurements as straight lines. That is, avoid curving the tape measure over the body of the animal. This may however be the only way to obtain measurements from larger individuals.

Sawfishes

Figure 3 shows the measurement of total length on a sawfish, together with key features of sawfish morphology (including those relevant to additional measurements and to species identification; see Appendix I).

Figure 3. Total length measurement and key morphological features of a sawfish.



Description of measurements:

Total length (TL): the distance from the anterior tip of the rostrum to the posterior tip of the caudal fin.

Precaudal length (PCL): the distance from the anterior tip of the rostrum to the caudal fin origin.

Disc width (DW): the distance between the extremities of the pectoral fins.

Disc length (DL): the distance from the anterior tip of the rostrum to the posterior tip of a pectoral fin.

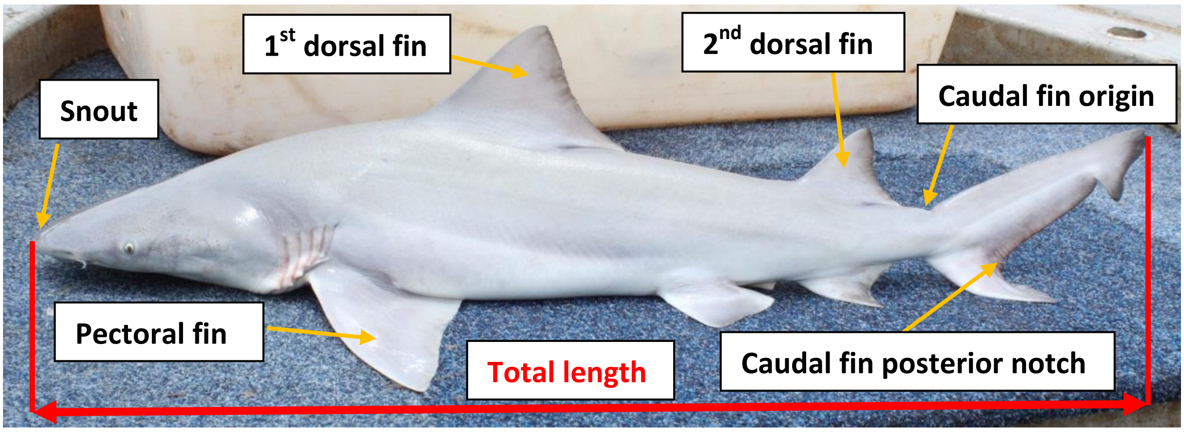
Standard rostrum length (SRL): the distance from the anterior tip of the rostrum to the posterior edge of the basal-most rostral tooth.

Total rostrum length (TRL): the distance from the anterior tip of the rostrum to the posterior extent of the rostrum (i.e. where it joins the head).

River sharks

Figure 4 shows the measurement of total length on a river shark, together with key features of river shark morphology (including those relevant to additional measurements and to species identification; see Appendix I).

Figure 4. Total length measurement and key morphological features of a river shark.



Description of measurements:

Total length (TL): the distance from the anterior tip of the snout to the posterior tip of the caudal fin.

Fork length (FL): the distance from the anterior tip of the snout to the posterior notch of the caudal fin.

Precaudal length (PCL): the distance from the anterior tip of the snout to the caudal fin origin.

Sexing and maturity

The sex of each individual caught should be recorded. It is possible to determine sex externally as males have two appendages on the inside of their pelvic fins called claspers (Figure 5). These are small but still obvious in juvenile sawfish and sharks. Females do not have claspers.

Figure 5. Claspers (red circles) of a juvenile male sawfish. Claspers are absent from females.

For males, sexual maturity can be determined externally by assessing the degree of calcification of the claspers:

- Juvenile: claspers short, uncalcified, flexible.
- Subadult: claspers extended, beginning to become calcified but still somewhat flexible.
- Adult: claspers extended, fully calcified, rigid and inflexible.

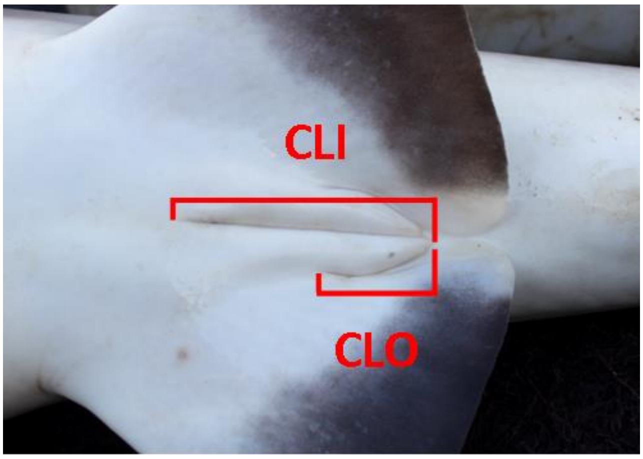
See Conrath (2004) for further details of determining sexual maturity in elasmobranchs. Sexual maturity cannot be determined externally for females. The size at sexual maturity remains unknown for some species of northern Australian sawfishes and river sharks (Table 4).

Table 4. Size at sexual maturity for Australian sawfishes and river sharks. Sources: Pillans *et al.* (2009); Dulvy *et al.* (2014) and references therein. TL, total length.

Species	Size at maturity (cm TL) ♀	Size at maturity (cm TL) ♂
Dwarf Sawfish	unknown	255–260
Green Sawfish	unknown (<380)	unknown
Largetooth Sawfish	300	280–300
Narrow Sawfish	225	200
Northern River Shark	~175	~140
Speartooth Shark	unknown (>175)	unknown (>157)

For males, clasper length should be measured as shown in Figure 6.

Figure 6. Clasper length measurements in male sawfish and sharks. CLI, clasper length inner; CLO, clasper length outer.



Description of measurements:

Clasper length inner (CLI): the distance from the posterior tip of the clasper to the medial insertion of the pelvic fin.

Clasper length outer (CLO): the distance from the posterior tip of the clasper to the lateral insertion of the pelvic fin.

Claspers are best measured with vernier calipers.

If the two claspers on an individual are of unequal length, measure the longest.

Tissue sampling

Tissue samples are a valuable resource for molecular research and should be collected from each individual captured even if their immediate use is not planned. Correct collection and storage can ensure that these are available for future DNA extraction and analysis.

Prior to field work, prepare sample vials (2.0 ml free standing, ribbed screw tubes are best) with 95–100% ethanol. Each sample vial should be uniquely-numbered. Ensure that each vial is close to full with liquid. Do not use formaldehyde as this destroys genetic material.

Upon capture of an individual, cut a fingernail-sized piece of tissue from the free rear tip of one pectoral fin (Figure 7) with clean sterilised scissors and place in a uniquely-numbered sample vial. Use clean sterilised forceps to place the sample in the vial; avoid touching the sample with fingers as this could cause cross-contamination. Ensure that only one sample is placed in each vial. The size of the tissue should be roughly the size of this triangle:

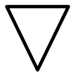


Figure 7. Location of tissue sampling on a sawfish (free rear tip of a pectoral fin).

Scissors and forceps should be cleaned immediately after each sample is taken to avoid cross-contamination. Have vials/containers of clean water, household bleach and >70% ethanol prepared and rinse instruments in the water (be sure to remove any tissue on the instruments at this stage), followed by the bleach and finally the ethanol.

The correct long-term storage of tissue samples is critical. Upon return from the field, samples should be stored in a -80°C freezer. Samples can be stored at -20°C for the short-term if a -80°C freezer is not immediately available. Before placing in any freezer, ensure that ethanol has not evaporated from the vial and that the vial lid is well sealed.

It is good practice to sub-sample the original tissue sample to create a replicate back-up sample, storing these separately. As extracted DNA preserves long-term better than tissue, extracting DNA from one sub-sample is a good approach.

Photography

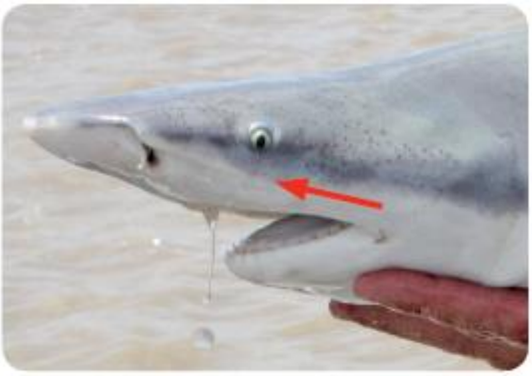
Each individual captured should be photographed to allow later confirmation of identification if required. Photographs should be filed under a unique capture record number. Two simple photographs of key features for each individual will suffice for identification records (see Appendix I). The utility of taking these photographs may depend on the size of the individual and field conditions, but every effort should be made to do so. Additionally, whole animal photographs may be useful.

Sawfishes

For sawfishes, take one photograph of the entire rostrum from directly above and one photograph of the position of the first dorsal fin relative to the pelvic fins:

River sharks

For river sharks, take one photograph of the lateral view of the head to show the waterline mark relative to the eye and one photograph of the undersides of the pectoral fins:



Environmental data

Key environmental data should be collected for each fishing set at each survey site, regardless of the capture of target species. The collection of such data can help build a picture of the habitat preferences and tolerances of sawfishes and river sharks.

For each fishing set and sawfish/shark capture, record location (latitude, longitude) and depth.

Environmental parameters can be collected in the field using water quality measurement instruments. Salinity and turbidity are particularly relevant to describing the environmental preferences of sawfishes and river sharks. Water quality instruments require calibration before use and it is good practice to calibrate prior to each field trip/survey. The following parameters should be collected:

- Salinity (specific conductivity can also be recorded).
- Turbidity.
- Temperature.
- Dissolved oxygen (DO) (%DO can also be recorded).
- Substrate type (mud, sand etc.).

Data management

Standardised datasheets should be prepared ahead of field work and contain all necessary fields to prompt field researchers to collect all data (examples are provided in Appendix III).

A well-designed project database is an essential pre-requisite of any research. It is recommended that a relational database such as Microsoft Access is used. In their simplest form, such a database is likely to consist of a 'set_data' Table and a 'catch_data' Table. In order to enable catch-per-unit-effort to be compared between studies, it is imperative that the time fished (recording start and finish times), as well as the gear used, be recorded systematically. If using a gillnet, record mesh size, net length, line size, net drop and depth of water fished. If using line, record hook size, bait and depth of water fished. For species that are infrequently captured, these data are very important for assessing trends in catch rates over time and unless sufficient detail is provided with each deployment of fishing gear it is difficult to make comparisons. Each fishing set should be recorded with a unique identifier for each time fishing gear is deployed.

It is good practice to enter data as soon as possible following field work, and to scan datasheets to create an electronic copy of the raw datasheet files.

Tagging

Readers are referred to the *CSIRO Marine and Atmospheric Research Code of Practice for Tagging Marine Animals* (Bradford *et al.* 2009).

Training in all tagging practices is required for any inexperienced staff. Training for the relevant tagging method should follow that outlined in Bradford *et al.* (2009).

Any tagging study requires valid justification of the tagging method to be employed. Consideration needs to be given to how tagging will address research questions and what is the most appropriate tagging methodology.

Note that radio telemetry is not suitable for research on sawfishes and river sharks given their euryhaline nature (radio waves do not transmit effectively through saltwater).

General rules of tagging

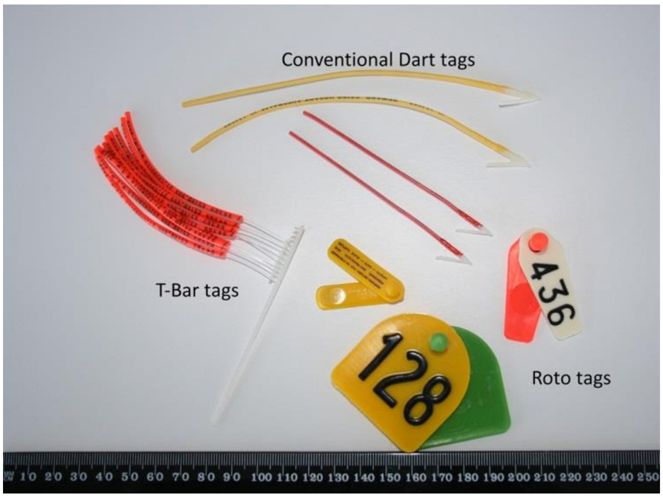
The following is taken directly from Bradford *et al.* (2009):

- **Be trained:** never attempt to tag an animal without prior adequate training.
- **Be prepared:** have all of your equipment set-up, ready to use, and at hand before any animals are captured.
- **Be clean:** all equipment must be cleaned between the tagging of each animal and dipped in antiseptic to avoid transfer of zoonoses, disease and viruses; if using a cloth to cover the eyes or head of an animal, use a fresh cloth on each animal.
- **Be careful and quick:** aim for all handling and tagging operations to take the minimum amount of time without compromising the care taken in handling the animal.
- **Be gentle:** use the minimum amount of force required when handling animals, always wear gloves and in the case of fish ensure your gloves are damp.
- **Be focused:** capture and tagging of animals often involves moving and noisy platforms, multiple people and elevated levels of adrenalin. Remain calm, take extra care and remain totally focused.
- **Know your role:** if you are part of a team of people required for the capture and tagging of an animal know your role and stick to it unless directed otherwise.

Conventional tagging

Conventional tagging includes T-bar, dart and rototags which are applied externally to an animal (Figure 8).

Figure 8. Examples of T-bar, dart and rototags, each individual tag showing a unique number code.



External tags can cause significant biofouling and abrasion issues, the latter of which can lead to infection. The use of external tags needs to be reconsidered on threatened sawfishes and river sharks due to these issues. Unless a study is using mark-recapture to estimate population parameters, where a large sample size is required and the study anticipates tag returns from outside sources (e.g. recreational fishers, commercial fishers, Indigenous fishers), the need for external conventional tagging is not warranted.

Key recommendations in relation to conventional tagging of threatened sawfishes and river sharks are:

- Rototags should never be used.
- Conventional external tags should only be used for mark-recapture studies relying on tag returns from outside sources (fisheries etc.).
- If conventional external tagging is warranted, then dart tags are preferable.
- Internal PIT tags are recommended in place of external conventional tags (see below).

Dart tags are applied using a stainless steel needle. The needle and tag head should be soaked in a mixture of 50% Betadine™/50% distilled water prior to application.

In both sawfish and river sharks, dart tags should be applied in the dorsal body musculature at the base of the first dorsal fin.

PIT tagging

Passive integrated transponder (PIT) tags are the preferred tag type to individually identify sawfish and river sharks. These tags have been successfully applied to a large number of individuals of these species under the National Environmental Research Program (NERP).

PIT tags are applied internally (in the body musculature, just under the skin) via a stainless steel needle attached to an applicator gun (Figure 9). After application, tags sit in the musculature of an animal with no external parts. The disadvantage over conventional tag types outlined above is that outside parties (e.g. recreational fishers, commercial fishers, Indigenous fishers) are not aware of the tag and can therefore not report recaptures. PIT tags can only be read with the use of a PIT tag scanner. However, PIT tagging circumvents the biofouling and abrasion issues of external conventional tagging. They are particularly appropriate for mark-recapture studies in remote areas (where outside tag return rates are expected to be low) or where repeated sampling is likely to capture the same individuals and as such there is a need to identify individuals.

Figure 9. PIT tag applicator and polymer PIT tag. The tag is 12.8 mm long.

PIT tags have traditionally been constructed with glass casings. These present a risk when ingested, acknowledging that Indigenous people can harvest sawfish and rivers sharks. Therefore, only food-safe polymer PIT tags should be used. These PIT tags are very small (12.8 mm in length) and suitable for all sizes of sawfishes and river sharks (Figure 9).

PIT tags are applied at a shallow angle to the skin, so that the needle enters the musculature close to parallel to the skin. The applicator needle should not be forced into the skin and muscle at a perpendicular angle.

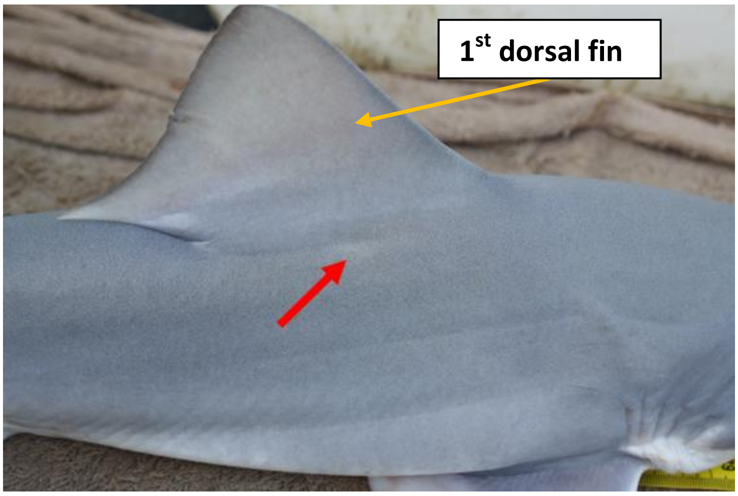
As standard practice, all sawfish and river sharks under NERP have been tagged on the right side of the body, at the base of the first dorsal fin, meaning that only a small area of the body surface needs to be scanned to check for PIT tags. Any activities using PIT tagging should apply this as standard practice.

Key recommendations in relation to PIT tagging are:

- Use only food-safe polymer PIT tags.
- Soak PIT tags in a 50% Betadine™/50% distilled water solution prior to deployment.
- Rinse applicator needle in 50% Betadine™/50% distilled water solution after each tag application.
- Deploy PIT tag on the right side of the animal, at the base of the first dorsal fin (Figure 10).
- Replace applicator needle regularly as frequent use on elasmobranchs will blunt them.

Spare applicator guns and needles should be carried on each field trip. A PIT tag scanner is also required.

Figure 10. Location of insertion of a PIT tag (red arrow; base of 1st dorsal fin, right side of body). The red arrow points to a healed PIT tag insertion scar on a Northern River Shark.



Acoustic tagging

Acoustic tagging is a specialised tagging approach and its use needs to be well justified in terms of the research questions it is attempting to answer. In particular it should be used to address specific questions relevant to objectives set out in the Recovery Plan for sawfishes and river sharks (DOE 2014). There are two types of acoustic tracking (telemetry) used to understand fish movements and habitat use: active telemetry (for short-term studies) and passive telemetry (for long-term studies).

Active telemetry

Active telemetry uses a 'continuous' tag to track fish in real-time. The tag transmits at a fixed rate (usually between 1 and 3 seconds) continuously from activation until battery expiry. Individual fish are tracked manually from a boat using a tracking receiver and hydrophone with the researcher recording fish position using a GPS device. Continuous tags have a relatively short battery life and this approach provides detailed data on short-term movements and habitat use. It has been used with success on both sawfishes (Peverell and Pillans 2004; Stevens *et al.* 2008; and under NERP) and river sharks (Pillans *et al.* 2010). Only one individual fish can be tracked at a time and this method is labour-intensive given the need to manually track the fish.

External attachment of these tags is appropriate since their lifespan is short. However, consideration needs to be given to their attachment method. Dissolving sutures are recommended as once these dissolve and the used tag falls off, no material will remain attached to the animal. The attachment of a continuous tag should not be via a rototag, bolts or cable ties which will remain on the animal and cause biofouling and abrasion issues. Monosyn 3/0 CC absorbable sutures with a cutting needle have been used successfully to attach continuous tags to both sawfish and river sharks. The best attachment site for continuous acoustic tags is in the musculature below the first dorsal fin for both sawfish and sharks.

Passive telemetry

Passive telemetry uses 'coded' tags in conjunction with an array of positioned acoustic receivers (Figure 11). Each tag transmits a unique code which is logged by moored receivers when within the detection range of the receiver. Receivers are downloaded periodically by researchers to obtain data on fish positions. Coded tags allow multiple fish to be tracked at one time over long-time scales. Tags come in a variety of sizes, power outputs, battery life and sensor options and consideration needs to be given to the most appropriate combination to answer the desired research questions.

Figure 11. An example of an acoustic receiver (VEMCO VR2W), which has been coated with antifouling paint for an estuarine deployment.

Passive telemetry requires the appropriate acoustic receiver array to address specific questions. The deployment of such an array requires significant planning and readers are urged to consult Heupel *et al.* (2006) for receiver array design and application, and Kessel *et al.* (2014) for advice on detection range testing.

The large tidal ranges of northern Australia, together with shifting sediment, high wet season flows, floating woody debris, and crocodiles, mean that careful consideration is needed for the design of receiver moorings. Crocodiles have a tendency to bite floats (Figure 12) and large crocodiles are capable of dragging moorings away from the deployment site. As such, surface floats may not be suitable (submerged floats attract less attention from both crocodiles and humans).

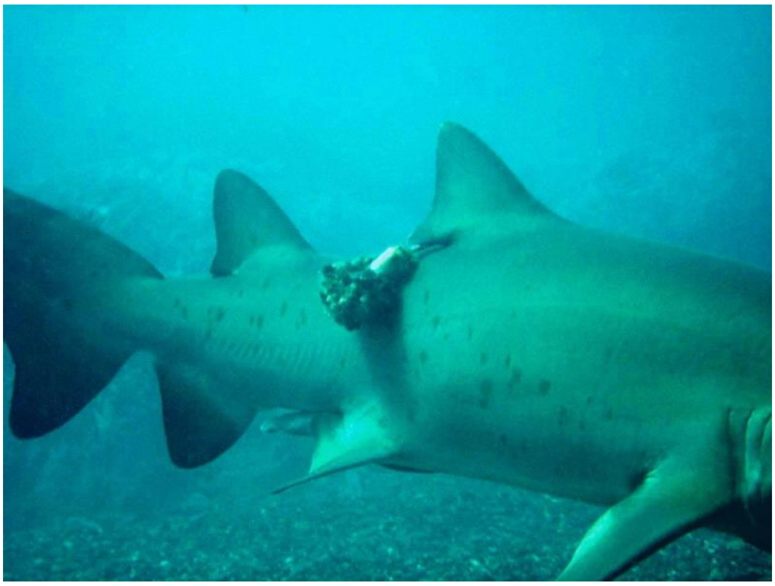
Figure 12. Float types tested in a northern Australian billabong. All floats shown here have been bitten by crocodiles, following which, hollow plastic floats (brown float on left) fill with water and sink, polystyrene foam floats (white float in centre) shatter, while solid ethylene vinyl acetate (E.V.A) floats (yellow float on right) maintain their functionality.

Due to the presence of crocodiles, receivers cannot be retrieved by diving or snorkel and therefore require surface retrieval. Riparian vegetation and mangroves can serve as attachment sites for stainless wire rope leading to a mooring. Alternatively, grapple lines can be secured to the mooring and a grapple anchor towed by a vessel to 'hook-up' on the receiver/mooring (noting, as mentioned above, surface floats are generally unsuitable).

Moored acoustic receivers can be affected by biofouling and consideration should be given to applying anti-fouling paint to receivers (see Heupel *et al.* 2008). Regular maintenance may be needed to remove barnacles and other growth, plus to ensure moorings are not being covered by sediment which can make retrieval difficult.

Coded tag models used on large fish can have a battery life of up to 10 years. External tag attachment results in tags detaching before the end of the tag life and can cause irritation and damage to the animals over long periods of attachment. Therefore, external tag attachment is not recommended due to biofouling (Figure 13) and abrasion/infection issues outlined previously.

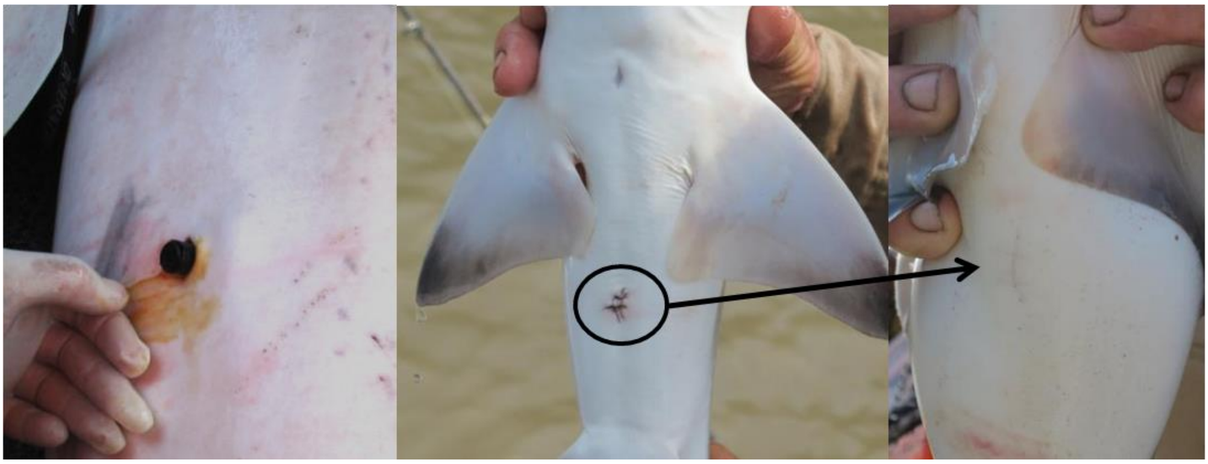
Figure 13. Considerable biofouling on an external tag deployed on a Grey Nurse Shark.



For animal welfare and attachment lifespan reasons, coded tags should be surgically implanted (Figure 14). Surgical implantation of tags has been successfully applied to an increasing number of elasmobranch species. However, surgical implantation is a specialist skill and should only to be conducted by experienced researchers. New staff are required to undergo significant training prior to supervised surgery. This includes perfecting suturing techniques on practice materials, practicing incisions and suturing on surrogate fish (such as dead sharks obtained from a fisheries agency), considerable observation of live surgery by experienced practitioners, and finally supervised surgery in the field. Training should follow the levels outlined in Bradford *et al.* (2009).

As with all tagging, implantation of acoustic tags should be rapid. Instruments and gear should be well prepared ahead of fishing.

Figure 14. Photographic sequence showing (left to right) an acoustic tag being inserted, sutures used to close the wound and a fully healed incision.



Key recommendations in relation to acoustic tagging are:

- Coded (long-term) acoustic tags should be surgically implanted only (no external attachment via rototag or similar).
- Only experienced staff are to undertake this procedure.
- New staff are to undergo significant training prior to supervised surgery (following training levels outlined in Bradford *et al.* 2009).
- Tags, instruments and sutures are to be sterilised before use.
- The use of drugs, including anaesthetics, is unnecessary and not recommended; anaesthetics can cause long recovery times, increase predation risk upon release (a real consideration in the predator-dense environments of sawfishes and river sharks); instead surgery should be done as quickly as possible (less than 3-4 minutes) and the animal released as soon as possible.

Protocol for the surgical implantation of acoustic tags:

- Check the condition of the fish; only healthy fish should be tagged. Fish that have been hooked in the gut or gills should be released without tagging. Fish that are lethargic or unhealthy should also not be tagged and should be released immediately.
- Check function of tag with a tracking receiver (such as a VEMCO VR100 unit) prior to use.
- Adhere to the accepted 2% maximum tag to body mass ratio for tagging fish (Bridger and Booth 2003); although some studies have actually demonstrated that a higher ratio is also non-detrimental to tagged fish (Brown *et al.* 1999; Childs *et al.* 2011), it is good practice to ensure that this tag to body mass ratio is not exceeded. Furthermore, consider the available space within the peritoneal cavity as a neonate shark may not have the space within the peritoneal cavity to hold a large tag despite the tag weighing less than 2% of the body mass.
- Soak tags in 50% Betadine™/50% distilled water solution prior to surgery.

- Surgeon should wear sterile surgical gloves; assistants should also wear laboratory gloves (non-sterile is acceptable).

- Soak surgical instruments and sutures in an appropriate veterinary disinfectant and adhere to product instructions with regards to preoperative skin preparation, instrument and surface disinfection.

- Use high-quality medical grade instruments and sutures.

- Surgery requires animal to be ventral side up. Small individuals can be tagged in the holding tub so that they remain mostly underwater (with the animal held so that the belly is out of the water but the mouth and gills remain underwater). Larger individuals are placed on a foam surgery mat placed on a flat surface. Many elasmobranchs demonstrate tonic immobility where individuals remain in a relaxed and immobile state when inverted (Henningsen 1994). Placing large animals on their dorsal surface can result in the dorsal fin being twisted under the animal; therefore it is recommended that large animals be tagged on their dorso-ventral surface to prevent the dorsal fin from being unnaturally folded.

- During surgery, sawfish and sharks should be continuously irrigated with water from the site of capture. A portable bilge pump with adjustable nozzle to control water flow is a necessity.

- The incision area is beside the ventral midline; in sawfish, in the area adjacent to the pectoral fin insertion; in sharks, in the area approximately one third to two thirds the distance between the cloaca and the pectoral fin insertion. This should correspond to where the combined skin, musculature and peritoneal wall are thinnest.

- Apply Betadine™ to the incision area prior to incision.

- Use either a scalpel (No. 22 blade or above) for small animals or a surgical knife for larger animals to cut through the skin and outer muscle layers. Extreme care needs to be exercised when cutting through the muscle layers into the peritoneal cavity. It is recommended that rounded scissors are used to tease apart the muscle layers immediately above the peritoneal cavity. This eliminates the possibility of rupturing internal organs.

- Incision length is ~10-30 mm, depending on tag size. The incision should be as small as reasonable but not too small that the tag needs to be excessively forced in (which may result in tearing of the skin).

- Use rat-tooth forceps to gently lift up the skin when making the incision. Extra care is needed not to cut any internal organs when piercing the peritoneal wall (see above).

- Use only dissolving sutures. Monosyn 3/0 CC absorbable sutures with a cutting needle are suitable for small to medium-sized sawfish and river sharks. For large animals, thicker suture material and a larger needle (size 1) are more appropriate. Having a coloured suture makes it easier to see and it is recommended that violet sutures are used. The ½ circle needles are easier to use and there is less chance of nicking internal organs with a ½ circle due to the greater re-curve. Regardless of the needle type, extreme care should be taken when doing the sutures as the stomach wall can be pierced if not careful. Only 2 sutures are generally needed and either interrupted or running sutures can be applied depending on preference.

- Once suturing is complete, roll the animal back onto its ventral side (returning it to the holding tub if it was tagged on a tagging mat).

- Follow release procedures outlined in the next section (see page 35). Be aware of the presence of the incision/sutures and avoid this area when handling/releasing the animal.

- In circumstances where it is expected that multiple animals may be caught at one time (and multiple animals are to be tagged), medical grade oxygen should be available and bubbled through a holding tub where animals are held prior to surgery (ensuring that the holding tub is large enough to accommodate the animals). Alternatively, regular water changes should be made.

Archival tagging

Archival tags are user-programmable tags capable of storing data on internal and external environmental parameters, typically water and body temperature, depth and ambient light levels (Bradford *et al.* 2009). These are attached externally or surgically implanted. The tagged animal must be recaptured to obtain the tag and the archived data, limiting its utility in rare species such as sawfishes and river sharks (which are protected and so cannot be sacrificed to recover implanted tags).

Satellite tagging

Satellite transmitting tags (SAT) and Pop-up satellite archival tags (PSAT) (Figure 15) are user-programmable tags capable of storing data on external environmental parameters, typically water temperature, depth and ambient light levels (Bradford *et al.* 2009). SAT tags transmit data to satellites when the tag is exposed to air (i.e. when the study animal breaks the water surface) while PSAT tags detach from the study animal (at a user-programmed time) and float to the surface where they transmit archived data to satellites. These tags are attached externally.

Figure 15. Pop-up satellite archival tag on an applicator pole.

The utility of these tag types is particularly problematic in tropical waters due to the restricted coverage of the tropics by polar-orbiting Argos satellites (Hoenner *et al.* 2012) and biofouling issues (Hays *et al.* 2007). Furthermore, since transmission of SAT tag location requires animals to come to the surface, the infrequent surfacing behaviour of sawfishes and river sharks generally render those tags unsuitable for application to these species. Satellite tags have been deployed on Dwarf Sawfish (Stevens *et al.* 2008), Narrow Sawfish (CSIRO unpublished data), Largetooth Sawfish and Northern River Sharks (Whitty *et al.* 2008) however, the data obtained from these tags has not been useful in determining movement and habitat use. However, developments in tagging technology should be monitored for future advancements.

As with all tagging, clear thought needs to be given to how particular tag types will answer research questions and researchers should contact tag manufacturers to keep abreast of advances in this technology. Refer to the *CSIRO Marine and Atmospheric Research Code of Practice for Tagging Marine Animals* (Bradford *et al.* 2009) for further information on archival and satellite tagging.

Releasing

Upon completion of measuring, sampling and tagging, the animal should be returned to the site of capture as quickly as possible. Consideration first needs to be given to the state of the animal through a post-recovery inspection. Small individuals can be allowed to recover on board the vessel in the holding tub. For sharks, these can be manually "swum" in the tub to ensure water flow over the gills. This is not necessary for sawfishes, which like all batoids, can draw water in through their spiracles. Ensure regular water changes (every 1-2 minutes) if recovery is required on the vessel.

Larger individuals may need to be "swum" in the water by gently moving them back and forth to ensure water flow over the gills. Prior to release, an animal should be capable of vigorously swimming. The recovery time of sawfish and sharks of all sizes is greatly reduced by constantly irrigating the gills with water from the site of capture.

Prior to release, a team member should inspect the area surrounding the vessel for the presence of any crocodiles. Post-release predation is a risk when handled/tagged animals are returned to the water. If crocodiles which are behaving curiously towards the vessel are noted, then the vessel should be driven a short distance away before the captured animal is released.

Releases should be 'gentle', providing support for the animal when releasing; do not throw the animal back into the water.

Research permits

Researchers need to be in possession of valid permits relevant to their proposed location of activity, as well as Animal Ethics Committee approval for any activities related to surveying or sampling for sawfishes and river sharks. For the State/Territory of operation, a valid fisheries permit is required for research fishing activities, and additional permits will be required if research falls within the boundaries of a national park or other reserve.

Commonwealth

Animal research permits are generally the mandate of State/Territory agencies. However, specialist permits are required for activities in Commonwealth reserves (e.g. Kakadu National Park or the Great Barrier Reef Marine Park) or for the export of material (e.g. sending tissue samples overseas).

Kakadu National Park: http://www.environment.gov.au/resource/researchers

Great Barrier Reef Marine Park: http://www.gbrmpa.gov.au/zoning-permits-and-plans/permits

Wildlife export: http://www.environment.gov.au/topics/biodiversity/wildlife-trade/wildlife-trade-permits-and-forms

Queensland (QLD)

QLD Fisheries: http://www.business.qld.gov.au/industry/fisheries/commercial-fishing/licences-and-fees/commercial-fishing-licences/fishing-permits

QLD Marine Parks: http://www.nprsr.qld.gov.au/licences-permits/marine-parks/research_permits.html

Northern Territory (NT)

NT Fisheries:
http://www.nt.gov.au/d/Fisheries/index.cfm?Header=Special%20Permits%20and%20Permits

NT Parks and Wildlife Commission: http://parksandwildlife.nt.gov.au/permits/permits#.U0y5lnfiHq4

Western Australia (WA)

WA Fisheries: http://www.fisheries.wa.gov.au/Pages/Home.aspx

WA Parks and Wildlife: http://www.dpaw.wa.gov.au/plants-and-animals/licences-and-permits

Animal Ethics Committees

Approval from an Animal Ethics Committee (AEC) is required for any research on vertebrate animals. Approval must be sought for all proposed activities, including (but not exclusive to), each type of fishing gear (e.g. gillnet, longline, rod and line…), each type of tagging (e.g. PIT tagging, acoustic tagging...) and the collection of tissue samples. Consideration also needs to be given to the safe release of bycatch. Readers are first referred to the Australian code for the care and use of animals for scientific purposes (NHMRC 2013): https://www.nhmrc.gov.au/guidelines/publications/ea28

Each Australian university has an AEC from which approval can be sought. As an example, information on the Charles Darwin University AEC can be found at: http://www.cdu.edu.au/research/ori/animal-ethics

Indigenous land access and engagement

It is imperative that any activities have the explicit approval of landowners, including Indigenous Traditional Owners and private landowners. Much of the sawfish and river shark habitat of northern Australia is on Indigenous country. When working on Indigenous land there should always be prior informed consent obtained from the community which includes providing a clear explanation of the research prior to commencement. Access and research on Indigenous land requires a permit, usually applied for through the relevant land council, for example:

Northern Land Council: http://www.nlc.org.au/articles/info/research-permit/

Kimberley Land Council: http://klc.org.au/research-and-access/research-requests/

Guidelines and protocols for research conduct on Indigenous lands (NAILSMA 2007) are available at: http://www.nailsma.org.au/sites/default/files/publications/NAILSMA_Guidelines_Jun07.pdf

Proposed research or survey activities on Indigenous lands provide an opportunity to engage with and benefit local Indigenous communities. Indigenous custodians also have a unique connection to their land and sea country and can be an informative source on the distribution and occurrence of fauna, and this is particularly the case in relation to sawfishes of northern Australia. Wherever possible, research activities should also assist communities to record, collate and store Indigenous knowledge.

Many areas of northern Australia have Indigenous ranger groups which work to manage land and sea resources on traditional lands. Local ranger groups should be approached when planning research activities.

Guidelines for the engagement of Indigenous communities are available from:

http://www.nerpnorthern.edu.au/sites/default/files/managed/files/nerp_indigenous_engagement_strategy_updated_14_march_2014.pdf

Broadly, Indigenous engagement should seek to (modified from the above document):

1. Ensure research is relevant and can benefit Indigenous peoples and organisations including meeting identified Indigenous research and management priorities.

2. Ensure research is conducted according to the highest ethical standards and respects Indigenous priorities and values.

3. Provide opportunities for Indigenous employment, and transfer skills, share knowledge and increase cultural awareness amongst all parties.

4. Effectively communicate research results and share knowledge with Indigenous people.

5. Ensure effective Indigenous participation in project governance.

Following research or survey activities, it is particularly important to communicate results and knowledge to Indigenous communities (point 4 above). This can be facilitated by follow-up visits to communities and reporting findings directly to communities.

References

Bradford, R.W., Hobday, A.J., Evans, K. and Lansdell, M. (2009). CMAR code of practice for tagging marine animals. CSIRO Marine and Atmospheric Research Paper 028. CSIRO, Hobart.

Bridger, C.J. and Booth, R.K. (2003). The effects of biotelemetry transmitter presence and attachment procedures on fish physiology and behaviour. *Reviews in Fisheries Science* 11:13–34.

Brown, R.S., Cooke, S.J., Anderson, W.G. and McKinley, R.S. (1999). Evidence to challenge the "2% Rule" for biotelemetry. *North American Journal of Fisheries Manage*ment 19:867–871.

Childs, A.R., Næsje, T.F. and Cowley, P.D. (2011). Long-term effects of different-sized surgically implanted acoustic transmitters on the sciaenid *Arygyrosomus japonicus*: breaking the 2% tag-to-body mass rule. *Marine and Freshwater Research* 62:432–438.

Conrath, C. (2004). Reproductive biology. Pp. 133–164 In: Musick, J.A. and Bonfil, R. (eds). *Elasmobranch Fisheries Management Techniques*. APEC Secretariat, Singapore.

Department of the Environment (DOE) (2014). Draft recovery plan for sawfish and river sharks: Largetooth Sawfish (*Pristis pristis*), Green Sawfish (*Pristis zijsron*), Dwarf Sawfish (*Pristis clavata*), Speartooth Shark (*Glyphis glyphis*), Northern River Shark (*Glyphis garricki*). Australian Government Department of the Environment, Canberra.

Dulvy, N.K., Davidson, L.N.K., Kyne, P.M., Simpfendorfer, C.A., Harrison, L.R., Carlson, J.K. and Fordham, S.V. (2014). Ghosts of the coast: global extinction risk and conservation of sawfishes. *Aquatic Conservation: Marine and Freshwater Ecosystems* Early View DOI: 10.1002/aqc.2525

Hays, G.C., Bradshaw, C.J.A., James, M.C., Lovell, P. and Sims, D.W. (2007). Why do Argos satellite tags deployed on marine animals stop transmitting? J*ournal of Experimental Marine Biology and Ecology* 349:52–60.

Henningsen, A.D. (1994). Tonic immobility in 12 elasmobranchs: use as an aid in captive husbandry. *Zoo Biology* 13:325–332.

Heupel, M.R., Semmens, J.M. and Hobday, A.J. (2006). Automated acoustic tracking of aquatic animals: scales, design and deployment of listening station arrays. *Marine and Freshwater Research* 57:1–13.

Heupel, M.R., Reiss, K.L., Yeiser, B.G. and Simpfendorfer, C.A. (2008). Effects of biofouling on performance of moored data logging acoustic receivers. *Limnology and Oceanography: Methods* 6:327–335.

Hoenner, X., Whiting, S.D., Hindell, M.A. and McMahon, C.R. (2012). Enhancing the use of Argos satellite data for home range and long distance migration studies of marine animals. *PLOS One* 7:e40713.

Kessel, S.T., Cooke, S.J., Heupel, M.R., Hussey, N.E., Simpfendorfer, C.A., Vagle, S. and Fisk, A.T. (2014). A review of detection range testing in aquatic passive acoustic telemetry studies. *Reviews in Fish Biology and Fisheries* 24:199–218.

Kyne, P.M. (2014). Threatened fishes and marine turtles of Kakadu National Park (with notes on marine mammals). Pp. 58–74. In: Winderlich, S. and Woinarski, J. (eds). Kakadu National Park Landscape Symposia Series. Symposium 7: Conservation of Threatened Species, 26-27 March 2013, Bowali Visitor Centre, Kakadu National Park. Internal Report 623, Supervising Scientist, Darwin.

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

National Health and Medical Research Council (NHMRC). (2013). Australian code for the care and use of animals for scientific purposes, 8th edition. National Health and Medical Research Council, Canberra.

North Australian Indigenous Land and Sea Management Alliance (NAILSMA). (2007). Guidelines and protocols for the conduct of research. North Australian Indigenous Land and Sea Management Alliance, Darwin.

Peverell, S. and Pillans, R.D. (2004). Determining feasibility of acoustic tag attachment and documenting short-term movements in *Pristis zijsron* Bleeker, 1851. A report for the National Oceans Office.

Pillans, R.D., Stevens, J.D., Kyne, P.M. and Salini, J. (2009). Observations on the distribution, biology, short-term movements and habitat requirements of river sharks *Glyphis* spp. in northern Australia. *Endangered Species Research* 10:321–332.

Stevens, J.D., Pillans, R.D. and Salini, J. (2005). Conservation assessment of *Glyphis* sp. A (speartooth shark), *Glyphis* sp. C (northern river shark), *Pristis microdon* (freshwater sawfish) and *Pristis zijsron* (green sawfish). Final Report to the Department of the Environment and Heritage.

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

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

Whitty, J.M., Phillips, N.M., Morgan, D.L., Chaplin, J.A., Thorburn, D.C. and Peverell, S.C. (2008). Habitat associations of Freshwater Sawfish (*Pristis microdon*) and Northern River Sharks (*Glyphis* sp. C): including genetic analysis of *P. microdon* across northern Australia. Report to the Department of Environment, Water, Heritage and the Arts.

Appendix I: Identification guide to northern Australian sawfishes and river sharks

See Last and Stevens (2009) for additional details on species identification.

Sawfishes

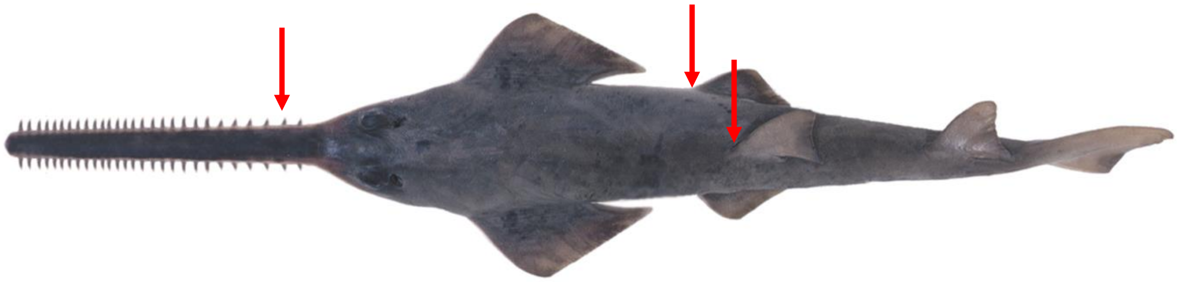
The toothed rostrum of sawfishes easily separates them from all other elasmobranchs occurring in northern Australia. Identification between the four species occurring in Australia is based upon the spacing of teeth on the rostrum and the position of the first dorsal fin relative to the pelvic fins.

Narrow Sawfish (*Anoxypristis cuspidata*)

No rostral teeth on the basal quarter of the rostrum; relatively enlarged lower lobe of the caudal fin.

Green Sawfish (*Pristis zijsron*)

Rostral teeth start at base of rostrum; rostral teeth ***unevenly*** spaced (teeth becoming closer to each other towards the tip of the rostrum); first dorsal fin origin ***behind*** the pelvic fin origin.

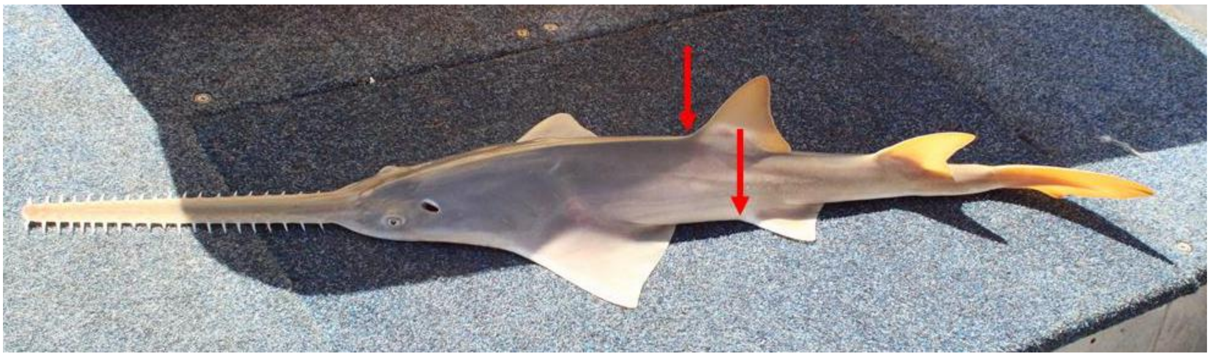


Dwarf Sawfish (*Pristis clavata*)

Rostral teeth start at base of rostrum; rostral teeth ***evenly*** spaced; first dorsal fin origin ***over or slightly behind*** the pelvic fin origin.

Largetooth Sawfish (*Pristis pristis*)

Rostral teeth start at base of rostrum; rostral teeth ***evenly*** spaced; first dorsal fin origin ***well forward*** of the pelvic fin origin.

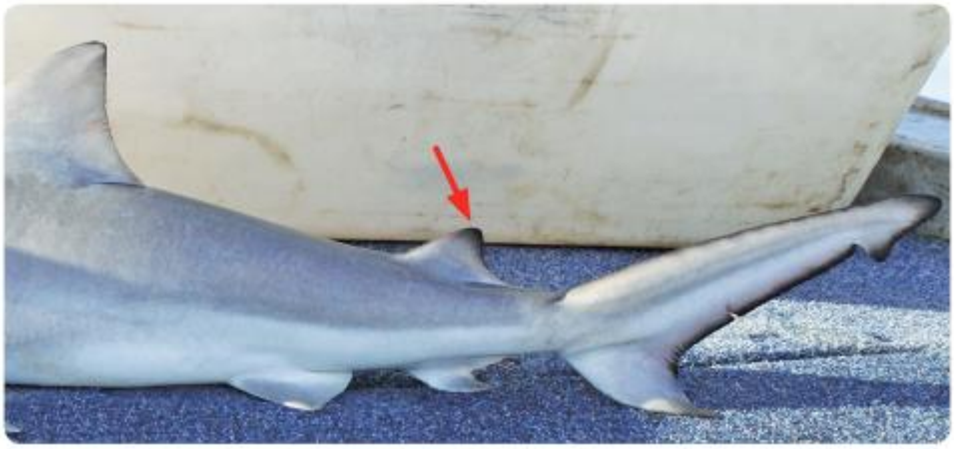


River sharks

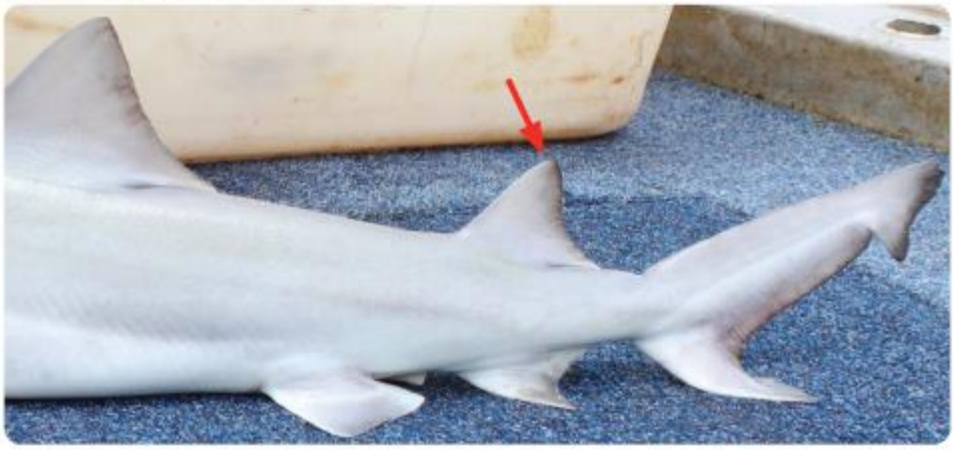
Separating river sharks from Bull Sharks

Bull Sharks are regularly encountered in the habitat of river sharks (*Glyphis* species). The large second dorsal fin of river sharks (the height is about three quarters of the height of the first dorsal fin) distinguishes river sharks from the Bull Shark.

BULL SHARK second dorsal fin

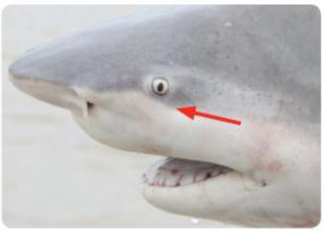


RIVER SHARK second dorsal fin



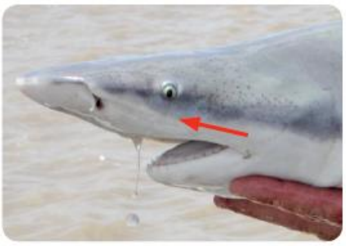
Speartooth Shark (*Glyphis glyphis*)

The large second dorsal fin easily separates Speartooth Shark from Bull Shark. The waterline mark just below the eye, prominent dark blotches on undersides of the pectoral fins (although not always as dark as shown here) and the short snout separates Speartooth Shark from Northern River Shark. The position of the waterline mark is the key identification feature.



Northern River Shark (*Glyphis garricki*)

The large second dorsal fin easily separates Northern River Shark from Bull Shark. The waterline mark more than an eye diameter below the eye, often pale undersides of the pectoral fins (although can be dark in some individuals) and the elongate snout separates Northern River Shark from Speartooth Shark. The position of the waterline mark is the key identification feature.



Appendix II: Procedures for working in a crocodile environment

These procedures are based on similar procedures in use by Charles Darwin University and NT Fisheries.

- Not less than two staff for field trips, one to act as a lookout and to watch out for dangers.
- Keep out of the water. This is the safest avenue to take.
- Treat all water ways as if they are inhabited by crocodiles. Carry out visual inspection of the area you intend to work in looking for crocodile tracks or slides and talk to locals to determine if there are any problem crocodiles in the area.
- If there is a report of a problem crocodile in the work area, or staff deems there is a danger of an attack, staff are to leave the area immediately and report the incident to the appropriate authority. All dangerous interactions with crocodiles must be reported by the staff member completing an incident report and notifying their supervisor of the incident as soon as possible.
- If a crocodile displays curious behaviour towards fishing gear (particularly gillnets), the gear should be immediately retrieved and relocated away from the area.
- Net poles are to be used to retrieve nets and equipment. Keep hands and limbs out of the water at all times.
- Vessels should be deployed and retrieved at boat ramps/water access points by driving the vessel on and off the trailer, so as to alleviate the need for any staff member to enter the water.
- Vessels are to be a minimum of 3 m in length and have adequate lighting for any work at night.
- Report any crocodiles hanging around public boat ramps to appropriate authorities.
- If it is necessary to camp at the worksite, staff are to ensure that the sleeping area is made as safe as possible, at least 100 m from the water's edge and where able, move the camp regularly if staying for a number of nights.
- Staff in the field must carry a satellite phone and EPIRB.
- Staff in the field must be able to communicate with other field workers at all times.
- At least two staff attending any field trip should hold a senior first aid certificate.
- First aid kits must be taken on all field trips and should be stocked appropriately with adequate bandages to be able to deal with a crocodile attack.
- Staff should never feed crocodiles, clean fish or dump rubbish into waterways and should always leave their campsites clean.

Appendix III: Datasheet examples

Gillnet set datasheet (can be modified for other fishing gear types)

Gillnet Set Data															
Set_ID	Date	Location	Latitude	Longitude	GPS Mark	Gear type	Mesh size_Inch	Net length	Net drop	Time in	Time out	Soak time	Depth min	Depth max	Tide
Env Data	Time	Depth	Temp	spC	pH	DO	DO%	Sal	Turb	Cloud cover	Comments				
Set_ID	Date	Location	Latitude	Longitude	GPS Mark	Gear type	Mesh size_Inch	Net length	Net drop	Time in	Time out	Soak time	Depth min	Depth max	Tide
Env Data	Time	Depth	Temp	spC	pH	DO	DO%	Sal	Turb	Cloud cover	Comments				
Set_ID	Date	Location	Latitude	Longitude	GPS Mark	Gear type	Mesh size_Inch	Net length	Net drop	Time in	Time out	Soak time	Depth min	Depth max	Tide
Env Data	Time	Depth	Temp	spC	pH	DO	DO%	Sal	Turb	Cloud cover	Comments				
Set_ID	Date	Location	Latitude	Longitude	GPS Mark	Gear type	Mesh size_Inch	Net length	Net drop	Time in	Time out	Soak time	Depth min	Depth max	Tide
Env Data	Time	Depth	Temp	spC	pH	DO	DO%	Sal	Turb	Cloud cover	Comments				
Set_ID	Date	Location	Latitude	Longitude	GPS Mark	Gear type	Mesh size_Inch	Net length	Net drop	Time in	Time out	Soak time	Depth min	Depth max	Tide
Env Data	Time	Depth	Temp	spC	pH	DO	DO%	Sal	Turb	Cloud cover	Comments				
Set_ID	Date	Location	Latitude	Longitude	GPS Mark	Gear type	Mesh size_Inch	Net length	Net drop	Time in	Time out	Soak time	Depth min	Depth max	Tide
Env Data	Time	Depth	Temp	spC	pH	DO	DO%	Sal	Turb	Cloud cover	Comments				
Set_ID	Date	Location	Latitude	Longitude	GPS Mark	Gear type	Mesh size_Inch	Net length	Net drop	Time in	Time out	Soak time	Depth min	Depth max	Tide
Env Data	Time	Depth	Temp	spC	pH	DO	DO%	Sal	Turb	Cloud cover	Comments				
Set_ID	Date	Location	Latitude	Longitude	GPS Mark	Gear type	Mesh size_Inch	Net length	Net drop	Time in	Time out	Soak time	Depth min	Depth max	Tide
Env Data	Time	Depth	Temp	spC	pH	DO	DO%	Sal	Turb	Cloud cover	Comments				

Sawfish catch datasheet

Sawfish Catch Data

Date	Time	Set_ID	Fish_ID	PIT Tag #	Sex	SRL	TRL	DL	PCL	FL	TL	DW	CLI/CLO	Tide	Depth	Notes

Shark catch datasheet

Shark Catch Data

Date	Time	Set_ID	Fish_ID	PIT Tag #	Sex	PCL	FL	TL	CLI/CLO	Tide	Depth	Notes

Acoustic tagging datasheet

Acoustic Tagging Data									
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes
Fish_ID	Set_ID	Date	Time	Tag type (V9, V13)	Tag serial	Tag code	Surgeon	Health	Notes

Datasheets notes

- These datasheets are examples designed for a specific project, and can be modified as necessary.
- Environmental data (Env Data) on gillnet set datasheet: Temp, temperature; spC, specific conductivity; DO, dissolved oxygen; DO%, percentage dissolved oxygen; Sal, salinity; Turb, turbidity.
- See text for definition of sawfish measurements on sawfish catch datasheet: SRL; standard rostral length; TRL, total rostral length; DL, disc length; PCL, precaudal length; FL, fork length; TL, total length; DW; disc width; CLI, clasper length inner; CLO, clasper length outer.
- See text for definition of shark measurements on shark catch datasheet: PCL, precaudal length; FL, fork length; TL, total length; CLI, clasper length inner; CLO, clasper length outer.
- ‘Set_ID’ on the sawfish catch, shark catch and acoustic tagging datasheets corresponds to a unique ‘Set_ID’ number recorded on the set datasheet.
- ‘Health’ on the acoustic tagging datasheet refers to the condition of an animal following surgical implantation of an acoustic tag (on a scale such as ‘poor, good, excellent’).
- Note that ‘species’ is not included as a field (although it can be). Species is encompassed in the ‘Fish_ID’ field, this being a unique code for an individual fish. The NERP project uses a two letter code for species, a one letter code for river/drainage and a three digit code for fish number. For example, GGA001 is a *Glyphis garricki* caught in the Alligator Rivers region; PPV005 is a *Pristis pristis* caught in the Victoria River.

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