



Fishers' ecological knowledge of sawfishes in the Sepik and Ramu rivers, northern Papua New Guinea

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ABSTRACT: Papua New Guinea (PNG) is geographically close to northern Australia, a key region for 4 sawfish species. However, detailed data on sawfish presence in PNG are limited, particularly from the north coast. We conducted a short study to assess whether sawfishes are still present in 2 adjacent rivers — the Sepik and Ramu — in northern PNG. Interviews were conducted with fishers from villages along the Sepik River between Chambri Lake and the river mouth, as well as along the Keram River (a tributary of the Sepik) and the Ramu River. Landings by gillnet fishers at the mouth of the Sepik River were observed. At least 2 species, the narrow sawfish *Anoxypristis cuspidata* and the largetooth sawfish *Pristis pristis*, were present at the mouth of the Sepik River and were caught in gillnets used to target sharks and croakers (Sciaenidae). Largetooth sawfish are still captured by fishers in the freshwater reaches of the Sepik, Ramu, and Keram rivers. The fins of sawfishes and other elasmobranchs provide a source of income, and sawfish meat is eaten locally or sold. The Sepik River and surrounding coastline remains important habitat for sawfishes; however, most interviewees reported a decline in sawfish catches over the course of their lifetimes. These findings corroborate existing evidence suggesting that PNG remains a global stronghold for sawfishes. Immediate collaboration with fishing communities and PNG's fisheries and conservation authorities is needed to ensure that any sawfish catches and habitats are appropriately managed so that populations do not decline further.

KEY WORDS: Pristidae · Extinction risk · *Anoxypristis cuspidata* · *Pristis pristis* · Narrow sawfish · Largetooth sawfish · Interview surveys · Bycatch

INTRODUCTION

Sawfishes are considered the most endangered family of elasmobranchs globally (Dulvy et al. 2014, 2016). Of the 5 extant species of sawfish, 4 exist in Australian waters, and northern Australia is considered to be a stronghold for all 4 species (Peverell 2005, White & Kyne 2010, Phillips et al. 2011); however, the distribution and status of sawfishes in the rest of the Indo-Pacific is poorly understood. Despite only a shallow flooded landbridge separating it from

nearby key sawfish habitats in northern Australia, little attention has been focused on assessing sawfish presence in the waters of Papua New Guinea (PNG).

A key objective of the International Union for the Conservation of Nature (IUCN) Shark Specialist Group's Sawfish Conservation Strategy is to survey current and historic distributions and abundance of sawfishes along key river systems and coastal areas, including those in PNG (Harrison & Dulvy 2014). The historical presence of sawfishes in PNG waters has recently been thoroughly documented (White et al.

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2017, this Theme Section). The first published record of sawfish anywhere in PNG waters came from the Crane Pacific Expedition, when the largetooth sawfish *Pristis pristis* (as *P. perotteti*) was recorded in the Sepik River in 1929 (Herre 1936). At that time, Herre (1936) reported sawfish as being common, but by the 1980s, they were considered rare in the Sepik River (Coates 1987). Sawfishes were not recorded in survey catches (the effort of this survey is not known), but rostra were frequently observed in many villages (Coates 1983).

The recent study by White et al. (2017) also documented the continued presence of all 4 species of sawfish known to occur in the Indo-Pacific region—largetooth sawfish, green sawfish *P. zijsron*, dwarf sawfish *P. clavata*, and narrow sawfish *Anoxypristis cuspidata*—at a single site in southern PNG. These findings suggest that PNG may be an important hotspot and potential refuge for sawfishes in the Indo-Pacific. Here, we build on the findings of White et al. (2017) by assessing whether sawfishes persist in historically important habitats on PNG's north coast and determining what threats sawfishes might face in these areas. We focused on interview surveys because they are a rapid means of assessing the his-

torical and current presence of sawfishes in data-poor regions and are a cost- and time-effective means of collecting data on the occurrence of easily recognisable species such as sawfishes in landings (e.g. Poulakis & Seitz 2004, Hossain et al. 2015, Jabado et al. 2017 this Theme Section, Leeney 2017).

MATERIALS AND METHODS

Study area

The Sepik River is over 1100 km long and is the largest river in PNG (Fig. 1). It runs through East Sepik province, entering the Bismarck Sea on PNG's northern coast. The Ramu River flows directly into the Bismarck Sea, while the adjacent Keram River flows northward of the Ramu River into the Sepik River. During the wet season, flood water has been documented to travel between the Keram and Ramu rivers (Yu et al. 1991), although we have no knowledge of whether this still occurs. In the coastal waters, a trial trap-net fishery targeting any fish of value is currently operating at several sites along the northern coast of PNG, including Wewak. Small-scale fish-

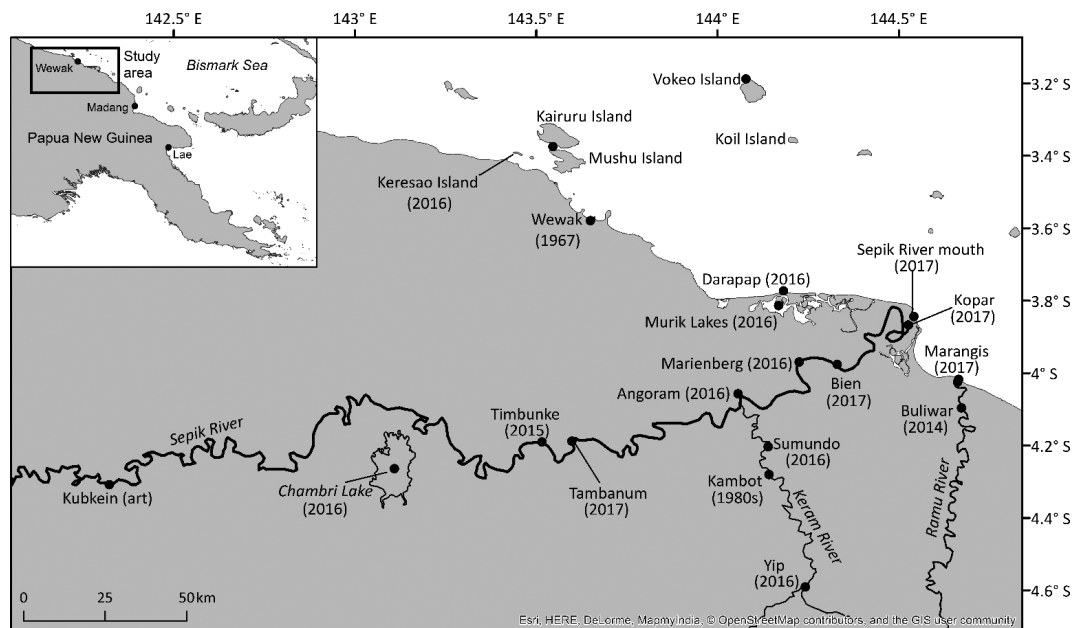


Fig. 1. Papua New Guinea, showing location of Sepik River and the Wewak study area (inset box) and all sites where interviewees stated they had observed sawfishes. Years in parentheses (where present) indicate the most recent reported observation at that site. Kubkein has also been marked for completeness; sawfish art has been collected from this village but no known reports of sawfish catches exist for this site. Observations of sawfishes were also reported from the following places (on the Sepik, SR, or Keram, KR, rivers), for which positions could not be determined as they were not visited by the research team and were not found on maps of the region: Lake Pasol (SR, upriver of Timbunke; 2014); Kangrime Lake (SR, close to Tambanum; 2017); Gambras (SR, between Marienberg & Kopar); Mangan (SR, 2014); Woundac Basis (KR, 'a few km downstream from Kambot'); Niapat Bay (KR, upstream from Sumundo; 1977), and the Awain River mouth (west of Wewak)

ers using wooden canoes (with or without motors) and fibreglass boats with outboard motors, and a longline fishery targeting sharks also operate along this coastline. No trawl fisheries operate in the waters off East Sepik province, but there is a purse seine fleet that targets tuna (composed of 116 industrial vessels in 2006, no more recent statistics available; Kumoru & Koren 2006). Only artisanal fisheries operate within the Sepik, Keram, and Ramu rivers (see 'Results').

In most villages, a contact person was notified of the study and of the research team's wish to conduct interviews several days prior to our arrival, to comply with PNG customs. These contacts were not informed of the study's focus on sawfishes, but rather that the project was investigating different types of fishes in the rivers and along the coast. The interview team travelled by boat to each village visited along the river, and thus, apart from at Kopar and Marienberg, only spent several hours at each site. The short duration of the study and the considerable time required to travel between villages prevented the team from interviewing upriver beyond Timbunke, but fishers from Chambri Lake and the Murik Lakes regularly visit Wewak to conduct business, and thus interviews with individuals who could provide information relating to both these areas were conducted in Wewak.

Interviews

Interviews were carried out with men and women involved in fishing, either currently or in the past. Interviews were conducted in an informal fashion according to the availability of each fisher when approached by an interviewer, and took place throughout the day, either at the interviewee's residence or at other convenient locations in each village. Interviewees were selected at random and were asked whether they had approximately 20 min to speak with the interviewer. Each prospective interviewee was introduced to the interview team and informed that the study was being conducted by the University of PNG, an institution that many would be familiar with. They were told that the interview was for research purposes, would be anonymous, and that they did not have to respond to any question they did not wish to answer. They were also informed that the data collected would be shared with PNG's National Fisheries Authority and that cultural information collected as part of each interview would be archived at the National Research Institute in Port Moresby.

They were then given the opportunity to decline the interview. If permission for the interview to proceed was granted, the interviewer noted the date and unique interview number, and signed to confirm that the interviewee had granted permission for the interview to proceed. Interviews were conducted by the first 2 authors and a local assistant, either in English or Tok Pisin.

Each interviewee was shown a colour photograph of a sawfish and was asked whether s/he recognized the image and knew what type of fish it was. If the interviewee could not identify the sawfish, the interviewer did not proceed any further. If the interviewee could identify the sawfish, the interview was continued. Sawsharks (Pristiophoriformes) may occasionally be confused with sawfishes by interviewees who have only seen one or other group of these saw-bearing elasmobranchs (Leeney 2017). However, sawsharks are not known to be present in PNG waters (Ebert & Fowler 2014) and the majority of interviews took place along river systems rather than coastal areas, so it was considered unlikely that interviewees would mistakenly identify the sawfish image as anything else. Nonetheless, the interviewee was repeatedly shown the sawfish image throughout the interview process, and the interviewers checked periodically throughout each interview that the responses given pertained to sawfishes and not to other species.

Questionnaire

A standard semi-structured questionnaire, containing both open and closed questions, was developed during previous baseline studies on sawfishes in other countries (e.g. Leeney & Downing 2016, Leeney 2017). This questionnaire was slightly modified for the current study (see Questionnaire in the Supplement at www.int-res.com/articles/suppl/n036p015_supp.pdf) and was used as the basis for interviews to collect basic background information from fishers as well as details of historical occurrence, recent sightings and captures, and any cultural or socio-economic importance of sawfishes.

Analysis

Of the 46 individuals interviewed, only 1 had never seen a sawfish, and no one declined to be interviewed. All data presented on interviewee's observations of and knowledge relating to sawfishes

Table 1. Number of women and men interviewed at each village. Murik Lakes and Chambri Lake were not visited by the interview team, but fishers from those areas were interviewed in Wewak and Marienberg

	Village name	Interviewees	
		Female	Male
Sepik River	Kopar	0	6
	Kandok	0	1
	Marienberg	0	3
	Angoram	0	3
	Langasaid	1	1
	Tambanum	2	5
	Timbunke	0	3
	Chambri Lake	2	1
Keram River	Sumundo	1	1
	Kambot	1	3
Ramu River	Marangis/Mangarong	0	5
	Buliwar	0	1
Coast	Wewak	0	1
	Murik Lakes/Darapap	1	4
Total		8	38

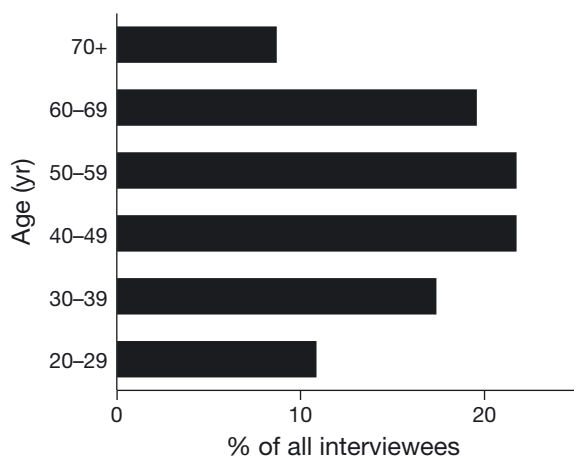


Fig. 2. Age distribution of all interviewees (as % of total, n = 46)

pertains to the responses of the 45 individuals who were familiar with sawfishes, and percentage values were calculated as proportions of these 45 individuals (or as many of those that provided a response to a given question). To investigate whether any perceived changes in sawfish abundance had been observed and what the perceived causes of such changes might have been, responses only from interviewees who had seen a sawfish at least 3 times during their lifetime (42 individuals) were assessed. Due to the small number of interviews conducted, no statistical analyses were conducted on the data.

RESULTS

Between 14 and 21 April 2017, we conducted 46 interviews with 8 women and 38 men from 12 villages along the Sepik, Keram, and Ramu rivers and 2 additional sites along the coastline (Table 1, Fig. 1). The interviewees were between 26 and 87 yr old (Fig. 2), although at least 15% of interviewees were not sure of, or could only estimate their age. Most interviewees used more than 1 type of fishing gear (Table 2). On the rivers, interviewees most commonly reported using hand lines and nets of various mesh sizes. Traditional gears such as basket traps and spears were less common. At the mouths of the Sepik and Ramu rivers and in the bay into which the rivers flow, gillnets were used, as well as longlines, and occasionally, spear guns.

Some individuals, particularly those fishing off the coast, had small outboard motors (39% of all interviewees) and fiberglass boats, but the majority of those fishing in the rivers used traditional canoes—narrow vessels carved from a single tree trunk—with a wooden paddle.

Table 2. Proportions of interviewees (as % of all interviewees, n = 46) using each type of fishing gear, and a description of each gear type. The majority of interviewees used more than 1 type of fishing gear, hence the percentages add to greater than 100%

Gear type	%	Description
Nets (includes gillnets)	89	Includes 'nylon' and 'string' nets of mesh sizes varying from 2.5–35.5 cm, and traditional hand nets woven from tree bark. In the river, nets are anchored in place or used in a form of trawling whereby they are deployed behind the fisher's canoe as it drifts with the river. Scoop nets are often used by women in shallow creeks and swamps to catch juvenile fish
Hook and line	85	
Traps	37	Made from coconut fibre or cane
Spear	37	Traditionally, a popular form of fishing. Traditional wooden spears have now been replaced by iron spears (Quinn 2011)
Longline	9	Used by those fishing on the coast
Spear gun	4	Used in the sea only. Usually an iron spear propelled by surgical rubber (Quinn 2011)

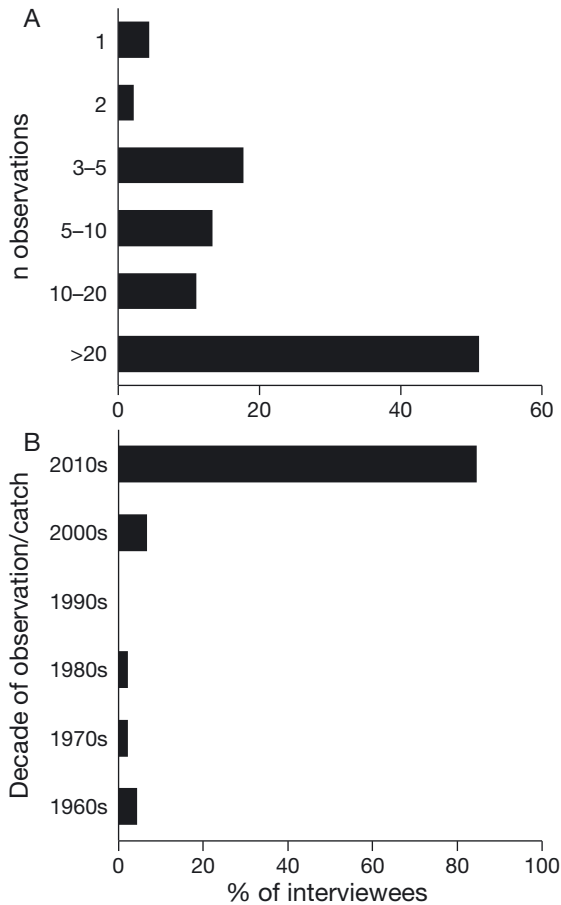


Fig. 3. (A) Number of times interviewees had observed or caught sawfishes over the course of their lifetimes (as % of total, $n = 45$). (B) Decade of most recent sawfish observation or catch for each interviewee (as % of total, $n = 45$). Note that 2010s ends in April 2017

Most recent catches

Only 1 interviewee—a fisher in his mid-20s at Langasaid (adjacent to Angoram)—stated that he had never seen a sawfish. All other interviewees ($n = 45$) readily recognised the sawfish image shown to them. Half (51%) of interviewees stated that they had seen sawfishes (including their own catches) more than 20 times over the course of their lifetime and another 11% had seen sawfishes between 10 and 20 times (Fig. 3A). Most (84%) of these 45 individuals reported seeing a sawfish within the last 7 yr (Fig. 3B). Local names for sawfish are listed in Table S1 in the Supplement.

Distribution

Sawfish catches were reported from all sites along the Sepik River where interviews were conducted,

from the river mouth as far upriver as Chambri Lake (Fig. 1). Interviewees from Chambri Lake reported their most recent sawfish observations in the lake itself, in 2014 and 2016, suggesting that sawfish still occur at least that far upriver. No data were collected from further upriver during this study and thus we were unable to document the upper limit of sawfish occurrence in the Sepik (but see 'Discussion'). All locations reported by interviewees as sites where they had caught sawfishes themselves, or had seen others do so, are mapped in Fig. 1, excluding locations for which no position data could be sourced.

Rostra observed during the study indicated that at least 2 species, the narrow sawfish *Anoxypristis cuspidata* and the largetooth sawfish *Pristis pristis*, were present at the mouth of the Sepik River. The largetooth sawfish appears to be relatively commonly encountered in freshwater habitats along the Sepik River at least as far upstream as Chambri Lake, approximately 200 km from the Sepik River mouth. What we presumed to be largetooth sawfish also occur at least occasionally in the Keram and Ramu rivers; although no rostra were observed in surrounding villages, this species is the only sawfish known to use freshwater habitats. In addition, interviewees suggested that sawfishes are encountered west of the Sepik River mouth in the Murik Lakes and along the coast, around the town of Wewak (Fig. 1). A former shark fisher reported catching sawfishes around a number of the islands off this coastline, including Kairuru, Mushu, and Vokeyo islands (Fig. 1). One interviewee also reported having observed sawfishes at the mouth of the Markham River, at Lae (Fig. 1).

Gear types

Despite the wide variety of gears used by fishers in the Sepik and Ramu rivers, nets were reported to be responsible for the majority (80% of 41 individuals who provided a response) of recently observed sawfish catches. Nets used included gillnets, traditional 'slipper nets', and a variety of other net types with mesh sizes up to 35 cm. In the Sepik River, sawfish were reported to be caught both with hook and line (10%) and with nets. Nets are either set in 1 position, or brought into the centre channel of the river and allowed to drag behind the boat they are attached to—the latter is referred to locally as a 'trawl'. Two fishers working in coastal waters stated that they had caught sawfishes using longlines.

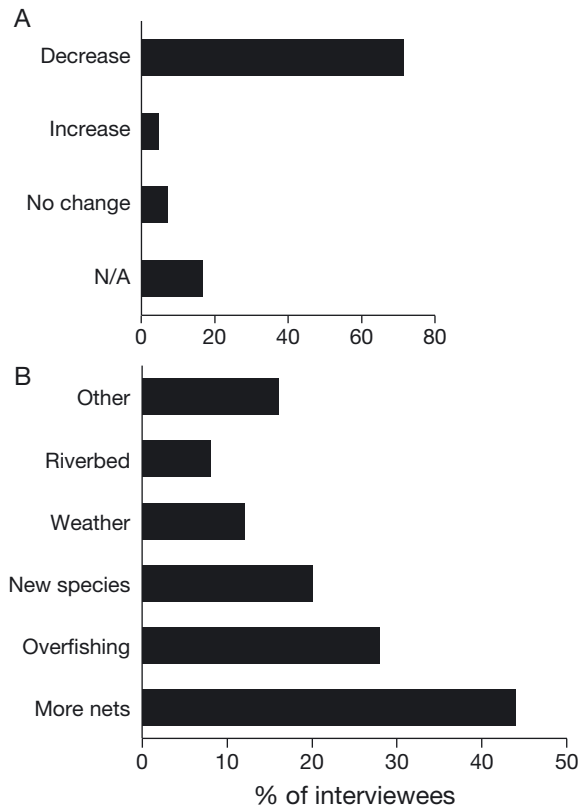


Fig. 4. (A) Perceived changes in abundance of sawfishes over the course of interviewees' lifetimes. Percentage values are proportions of all interviewees who had observed sawfishes at least 3 times during their lifetime ($n = 42$); N/A represents those who did not provide an answer or did not know whether there had been any change. (B) Perceived causes of changed local abundance of sawfish. Percentage values are proportions of all interviewees who had observed sawfishes, perceived a decline, and suggested 1 or more causes ($n = 25$). More nets: greater density of nets (includes those who specified that an abundance of nets scares sawfish away from an area); overfishing: includes mentions of high levels of sawfish catch, and generally higher levels of fishing; new species: introduced fish species and their effects on river habitats; weather: changes to local weather patterns; riverbed: large (possibly logging) vessels making the river channel deeper; other: includes effects of noise from boat motors, capture of juvenile sawfishes, effects of mining upriver, and increases in the human population

Long-term patterns of abundance

Of 45 interviewees who had seen at least 1 sawfish in their lifetime, over half said that they had seen sawfish, including their own catches, more than 20 times. The majority of interviewees who had seen a sawfish at least 3 times ($n = 42$) believed that sawfish abundance in their locale had decreased over the course of their lifetimes (71%; Fig. 4A). An interviewee in Kopar, at the mouth of the Sepik River, stated that when he was a child, he and other children were

not allowed to wash at the river bank — it was considered too dangerous because of the sawfish and crocodiles present in the river. Villagers, including children, washing at the riverbank is now a common sight, indicating that this risk has reduced over time, possibly as populations of these species have declined.

An increase in the number of fishing nets in use was cited by many as a potential reason why sawfish numbers had decreased, as was increased levels of fishing effort (Fig. 4B). A number of fish species have been introduced into the Sepik River in past decades — these include the Java barb *Barbonymus gonionotus*, the Nile tilapia *Tilapia niloticus* (locally known as 'super tilapia') which escaped from aquaculture facilities along the river, and especially the pirapitinga *Piaractus brachypomus* (a piranha species locally known as 'pacu'), which has a reputation for biting people bathing in the river. The presence of such non-native species was clearly a concern for many people along the Sepik River. Introduced fish species were mentioned by 5 individuals as being a possible cause of sawfish decline, either by outcompeting sawfish for their food source, 'eating the eggs of sawfish', or even eating juvenile sawfish. Other interviewees mentioned that there had been changes in weather patterns and more rain in recent years, causing erosion of the river banks. An interviewee in Marangis, on the Ramu River, expressed concern about mining activities upriver, which he stated was affecting the taste of the river water and the fish they caught.

Seasonality and encounter rates

Of the 6 fishers interviewed in Kopar who use gill-nets to target croakers (Sciaenidae, locally known as 'jewfish') and sharks outside the mouth of the Sepik River, 3 indicated that sawfish are present year-round whilst the other 3 suggested that the dry season (the exact stated period varied by individual but fell within the period between June and January) was when most sawfishes were caught (but this coincides with the period when fishers stated that they fished most actively). At other sites along the Sepik, Keram, and Ramu rivers (including Marangis at the mouth of the Ramu), interviewees most often reported that sawfish were present or easier to catch during the dry season (generally June to December; 58% of 33 interviewees) whilst 9% said sawfish could be encountered year-round and 12% stated that the beginning of the rainy season (stated as 'October to February' or some months within that period) was the best time to encounter them.

Interviewees were asked to estimate sawfish catch rates to get a general sense of the frequency with which sawfishes are encountered in the study area. One of the gillnet fishers whom we accompanied to retrieve nets at the mouth of the Sepik River stated that if all 15 of the nets his team fished with (which were stated to be between 100 and 200 m in length) were set daily, they could catch up to 50 or 60 sawfish wk^{-1} . He noted that they catch the greatest numbers of sawfishes in June and July, but that the larger individuals are caught mainly in December and January. According to the village chief in Kopar, most adult men in the village are fishers, and there are at least 5 fibreglass dinghies operating out of the village that set gillnets beyond the estuary mouth. Elsewhere, in Kandok, one interviewee reported a recent catch rate of up to 10 sawfish wk^{-1} during the rainy season. An interviewee in Timbunke stated that there were 'not plenty of sawfish here', and estimated that about 50 sawfish might be caught annually by the fishers in his village.

A former fisher from Murik Lakes, which are salt-water lagoons west of the Sepik River mouth, spent 16 yr (1994 to 2009) fishing for sharks along the coast west of the Sepik River mouth and in the Murik Lakes, using longlines. He stated that when he began shark fishing, his team was the only one targeting sharks in

that area, but they began providing nets and lines to fishers in other areas, including Kopar, and training them in how to catch sharks. He noted that their catch rates dropped as more people became involved in the fishery. They set between 500 and 1000 hooks line^{-1} and he stated that they had caught up to 5 sawfish on a single shark line (year unknown), using tuna as bait.

Socio-economic importance in the Sepik River region

All 45 interviewees who were familiar with sawfish provided information on how their most recent catch, or most recently observed catch, of a sawfish had been used. The most widespread use was as food (82% of interviewees; Fig. 5). The meat was also commonly sold or traded for vegetables and sago, usually at local markets (60% of interviewees). Over one-third of interviewees stated that the fins of sawfishes were sold, but 8 individuals (17.8%) stated that they threw away the fins as they were unaware of any use for them. Whilst 4 and 17.8% of interviewees said that the rostrum was sold or retained, respectively, rostra were generally considered to have no value, and many fishers (37.8%) stated that they discarded them (Fig. 5).

At the mouth of the Sepik River in Kopar, sawfishes and other shark species provide a significant source of income for local fishers, primarily through the sale of their fins. A shark fisher provided a breakdown of recent (April 2017) fin prices according to their grade, which is classified by size. Fins are graded by size as 'super' (the largest), A, B, or C. Super-grade fins can fetch 350 PGK (Papua New Guinean Kina¹) kg^{-1} (110 USD), whilst C-grade fins fetch 100 PGK kg^{-1} (31 USD). Other interviewees stated that prices in 2017 varied from 200 to 350 PGK kg^{-1} (62 to 110 USD). One interviewee stated that he had sold 2 fins for 900 PGK and another, 3 fins for 1200 PGK, both in 2016. Ten interviewees provided information on where or to whom they sold sawfish fins; 3 individuals stated that buyers visited their villages (Kopar and Mangarong) to purchase fins, whilst 7 interviewees stated that they took the fins to the larger towns of Wewak, Madang, or Lae, where large-scale buyers existed.

The meat is used as food, either fresh or dried. Most people who provided current (2016 and 2017) sale prices for sawfish meat stated that a piece of meat

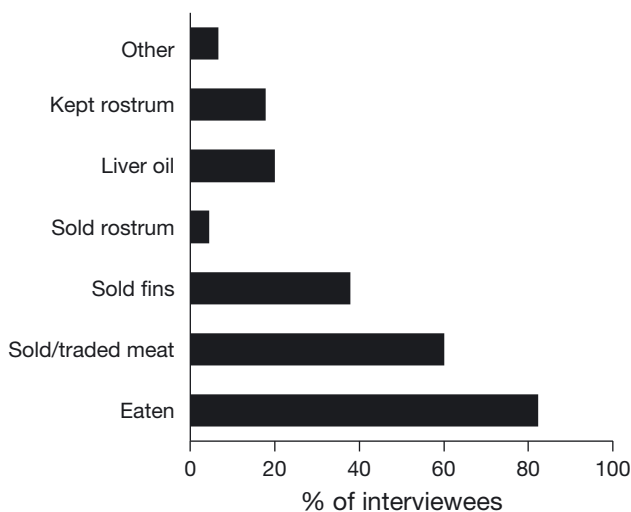


Fig. 5. Ways in which the last sawfish each interviewee caught, or observed being caught, was used. Percentage values are proportions of all interviewees who were familiar with sawfishes ($n = 45$); most individuals provided >1 response. Eaten: meat was consumed; sold/traded meat: meat was sold or exchanged for vegetables or sago; sold fins: fins were sold; sold rostrum: rostrum sold to tourists or to a collector; liver oil: liver oil extracted and used for cooking; kept rostrum: rostrum kept as a decorative item, a weapon, or to use in a traditional 'singsing'; other: used rostral teeth to make a necklace or used fins as food

¹1 USD = 3.18914 PGK, 16 May 2017 (www.xe.com/currencyconverter)

roughly the size of the palm of their hand would sell for 1 or 2 PGK. The meat was usually sold in small local markets in the villages where the fishers lived, or sometimes transported to other villages along the river such as Marienberg. However, some fishers in coastal villages stated that they transported sawfish meat to larger towns such as Wewak and even Madang and Lae. An anthropologist working in the Chambri Lake reported seeing a sawfish of ca. 50 cm total length in the net of a Iatmul woman fishing in the lake in 2013, and noted that any sawfish caught in that area were eaten, but that they were a rare catch and not a preferred source of food (C. Falck pers. comm.). Many individuals also reported extracting oil from sawfish livers and cooking with it. Only 1 interviewee, in Tambanum (a village often visited by tourists wishing to buy traditional carvings), provided a sale price for sawfish rostra. He estimated that rostra could be sold to tourists for between 50 and 150 PGK (15 to 47 USD), depending on the size.



Fig. 6. The (A) fins and (B) rostrum of an adult largetooth sawfish *Pristis pristis* captured at the mouth of the Sepik River on 13 April 2017. Photographs ©Ruth H. Leeney/National Geographic

Observations of catches and rostra

Several groups of fishers based at Kopar targeted sharks just beyond the mouth of the Sepik River. The research team accompanied 1 such group on 13 April 2017, to observe catches of the 5 gillnets (10 and 12 cm mesh sizes) they had set the previous evening. Each net was between 100 and 200 m long and had a depth of approximately 5 m. Two juvenile narrow sawfish (stretched total lengths of 104 and 107 cm) were among the catch; both were released alive. At least 20 juvenile (<50 cm) sharks including wing-heads *Eusphyrna blochii*, scalloped hammerheads *Sphyrna lewini*, and blacktip sharks *Carcharhinus limbatus*, as well as a pregnant blacktip shark were also caught by the same group of fishers. On the same day, another group of fishers landed a largetooth sawfish. By the time the report of the largetooth sawfish capture reached the research team, the fins had been removed and placed in the sun to dry (Fig. 6), and the body of the fish had already been cut into pieces of meat to be dried and sold. The tooth count and overall appearance of the rostrum (as in Whitty et al. 2014: standard rostrum length: 57.4 cm; standard rostrum width: 13.8 cm; tooth counts: 18/16), along with the presence of a caudal fin with a relatively short ventral lobe identified it as a largetooth sawfish.

A total of 7 rostra from 2 species (*A. cuspidata* and *P. pristis*) were observed during the study, in only 2 villages—Kopar and Marienberg (see Table S2 in the Supplement). Most of the interviewed fishers had not kept the rostra from sawfishes they caught. All interviewees were asked whether they or anyone else in their village owned a rostrum, but none were observed in villages on the Keram or Ramu rivers.

DISCUSSION

This is the first study to document contemporary presence of 2 sawfish species, the narrow sawfish *Anoxypristis cuspidata* and the largetooth sawfish *Pristis pristis* in the Sepik and Ramu rivers of northern PNG. The interview dataset, whilst small, clearly indicates that sawfishes are still frequently encountered by fishers in both rivers, and that they are also caught by fishers targeting sharks along the northern coast of PNG.

This study revealed the current distribution of largetooth sawfish in the Sepik River to be at least as far upriver as Chambri Lake, but several additional reports extend that range. Sawfish art has been col-

lected from communities as far upriver as Kubkein, implying that sawfish themselves likely occurred that far upstream, at least historically (M. McDavitt pers. comm.). The sightings and catch rates reported by many interviewees in this study stand in contrast to similar surveys conducted in other countries throughout the world including Guinea-Bissau, The Gambia, Mexico, and Mozambique (Leeney & Poncet 2015, Leeney & Downing 2016, Bonfil et al. 2017, Leeney 2017), where many interviewees have never seen sawfishes or have only encountered them occasionally during their lifetimes.

Threats in northern PNG

Whilst in southern PNG, trawl fisheries pose a significant threat to sawfishes (White et al. 2017), the largest threat to sawfishes in East Sepik province is likely to be the intensive, relatively small-scale² shark fishery operating at the mouths of the Sepik and Ramu rivers, documented during this study. This fishery likely poses a threat, not only to sawfish populations but also to other elasmobranch species. The group of fishers accompanied during this study stated that they can set up to 10 nets each day, and several other groups of gillnet fishers also operate in the same area. The mouth of the Sepik River may be an important nursery or pupping site for juvenile sawfishes and sharks, and if so, the fishery currently operating there has the potential to rapidly deplete these populations unless management actions are taken.

Subsistence and artisanal fishers who fish in the Sepik, Keram, and Ramu rivers, at least in the areas visited during this study, also catch sawfish at least occasionally. There has been a proliferation of fishing nets in this region in recent decades, as many fishers referred to when asked about the possible reasons for sawfish declines. Falck (2016) documented this shift in Timbunmeli, on the shore of Chambri Lake. Previously, women typically owned only 1 or 2 nets, but nets became more widely

available in the 1990s and now most women in this village own more than 10 (up to 24) nets each (Falck 2016). There has also been a shift from the use of traditional fishing gears such as locally made nets, basket traps, and spears to modern nets, which has likely resulted in greater levels of sawfish catch. Traditionally, people made nets out of fibres from tree bark; such nets were strong but biodegradable. Quinn (2011) noted that some of the traditional fishing techniques associated with nets and traps were no longer in use in PNG, because of the considerable time investment to make and set these gears, whilst monofilament nets could be easily purchased in the towns. Although an increase in the number of fishing nets was cited during this study by many as a potential reason why sawfish numbers had decreased, interviewees often described the impact of the nets as 'scaring away' sawfishes, causing them to move to another area, rather than causing population declines through excessive catches.

Less than half of interviewees stated that sawfish fins could be sold — this may be either because they were not aware of the value of the fins, or because they did not have access to buyers. The lack of rostra in villages along the Ramu and most villages along the Sepik, despite the relative frequency of encounters reported during this study, suggests that there is no market for sawfish rostra and people therefore do not place any importance on keeping rostra from sawfish they catch. However, sawfish fins are a high-value commodity with which shark fishers, and other fishers who have access to the market, can vastly increase their income. For this reason, any proposed management of sawfish catches or more broadly of fisheries in this region, including prohibition of trade in sawfish products, is likely to meet with some resistance. The International Trade (Fauna and Flora) (Amendment) Act (Government of PNG 2003) implements CITES Appendix I, thereby theoretically preventing any international trade in sawfish products. However, sawfish fins have been documented in the stocks of shark fin traders in PNG (White et al. 2017). In practice, it is likely that sawfish fins are exported amongst the fins of sharks, and thus, unless customs officers are trained in the identification of fins from sawfishes (and other CITES-listed elasmobranchs), they will go unnoticed in inspections of exports from the main ports. Indeed, several interviewees stated that the fins from the sawfish they catch are sold in Wewak, Madang, and Lae (Fig. 1). Sawfish are also used locally as a food source — both the meat and liver oil are used.

²Artisanal fishing is often defined as small-scale fishing using traditional techniques and equipment (Quinn 2011). However, in the case of non-industrialised shark fisheries documented during this study, small motorised boats and nylon gillnets or steel longlines were in use, in contrast to the non-motorised canoes and often smaller gears in use elsewhere along the rivers. For this reason, the term 'small-scale' has been used here in reference to the shark fishery in this region, to differentiate it from both industrial shark fisheries and from subsistence or artisanal fisheries

In the 1980s and 1990s, 2 programmes to introduce several exotic fish species, with the aim of increasing the protein available to communities along the river, were run by the PNG Government and the Food and Agriculture Organisation (FAO) of the United Nations (Coates 1987, van der Heijden 2002). In the past, local native fish species such as the comb-spined catfish *Cinetodus carinatus* (known locally as 'nilpis') and the Sentani gudgeon *Oxyeleotris heterodon* (known as 'bigmaus') were abundant, but catches of these species are now rare compared with catches of introduced species. The Mozambique tilapia *Oreochromis mossambicus*, the common carp *Cyprinus carpio*, and several other species were introduced into the Sepik River in the 1960s (van der Heijden 2002). A member of the piranha family, *Colossoma bidens*, was introduced to the Sepik in 1994 and the Ramu in 1997 (Coates 1997). During our study, villagers often reported that the piranha species, locally called 'bolkatta pis' or 'pacu', and Java barb feed on the roots of vegetation, thereby prohibiting the growth of waterlilies and water-grass (Falck 2016). Falck (2016, p. 29) reported that people in Timbunmeli had noted changes in their environment for some time:

Whereas in former times people could predict the time of the rainy and dry season, today, people say, the water level can rise at any time.

The primary perceived cause of the degradation of the lake's habitats amongst Timbunmeli villagers was the introduction of fish species, which appear to have had negative impacts on the native fauna of the lake. Not surprisingly, fishers interviewed for this study in other villages along the Sepik similarly reported that pacu now far outnumber the native species that they used to catch. On several days during this study when the Angoram market was visited, pacu also comprised the majority of fish for sale (R. H. Leeney pers. obs.).

Since the turn of the 20th century, the human population of PNG has increased considerably, as have timber exports from commercial forestry operations and oil palm exports from agricultural plantations (Gresham 1982, Filer 1997, Hunt 2002, Shearman et al. 2009). The Sepik region has been heavily logged for decades and the lowlands of East Sepik province have one of the highest levels of deforestation or degradation in the country (Shearman & Bryan 2011). Logging activities were apparent during the study, particularly at Kanduanum where timber was being loaded onto vessels, and at the mouth of the Sepik where these vessels were continuously present during the study (R. H. Leeney pers. obs.). Both logging

and mining activities (e.g. a proposed large-scale copper and gold mine along the Frieda River) in the vicinity of the Sepik and Frieda rivers pose additional threats to these ecosystems if not properly managed.

Conservation prospects in northern PNG

Although the relative remoteness of the Sepik and Ramu rivers may have offered some protection to theargetooth sawfish up to this point, increases in local human population, fishing net density, and awareness of potential markets for sawfish products have likely resulted in a decline in abundance, although the findings of this study suggest that sawfishes remain a relatively common sight in this region. Introduced fish species have clearly had effects on the physical structure and species complement of the Sepik River and Chambri Lake, but it is difficult to assess whether this has negatively affected the sawfish populations. Several decades ago, Coates (1983) reported observing 'many' sawfish rostra in villages along the Sepik, but did not quantify this statement. Few rostra were observed during this study, which may have indicated a waning abundance of sawfish in the river, but may also have been due to fewer tourists visiting the region and thus a lower demand for local curios and art. Insufficient data were collected from the coast to assess the status of narrow sawfish populations, and whether other sawfish species may also be present in coastal habitats in this region.

The communities along the Sepik, Keram, and Ramu rivers visited for this study are mostly composed of subsistence fishers—there are few other livelihood options in the region. The diet of people in these villages consists mainly of sago, which they harvest from the marshy ground along the river, and fish caught locally, occasionally supplemented with locally grown vegetables (R. H. Leeney pers. obs.). Essentially, these communities are entirely reliant on their local resources for survival and do not have a cash economy. As such, they are directly reliant on whatever fish they catch for their daily survival. This poses a distinct challenge for sawfish conservation, and any efforts to encourage communities to release sawfish alive from their fishing nets should take into consideration the loss of a source of food and income, and how that might be appropriately addressed.

Sawfish populations are likely to be affected by fishing activities in this region, but the effects of other anthropogenic activities such as mining, pollution, and species introductions are less clear. A better

understanding of population sizes and critical habitats of each of the 4 species of sawfishes present in PNG waters, and the threats they face, is needed to assess their current statuses and to focus conservation action. We therefore recommend a series of precautionary actions for immediate implementation. These recommendations have been sent to the National Fisheries Authority of PNG.

- Assessment of major threats and possible mitigation approaches in all habitats where sawfishes have recently been confirmed to be present
- Assessment of total catch rates of sawfishes in all fisheries, through continued data collection via existing fisheries observer programmes for commercial fisheries and development of a monitoring programme for artisanal fisheries
- Non-destructive sampling in the Fly and Sepik rivers and nearby coastal areas at the mouth of each river, to assess the species and age classes present
- Development and implementation of a programme to monitor shark fin exports and identify sawfish fins therein, as required of CITES signatories
- Research to assess how to reduce sawfish catch in gillnet fisheries or to increase the survival of bycaught sawfishes, in parallel with community consultation to assess how to motivate fishers to release sawfishes
- Development of an outreach and education programme aimed at fishers operating in sawfish habitats as well as shark fin traders, to highlight the CITES ban on exports of sawfish fins and the repercussions of selling or exporting sawfish fins, and to encourage live release of sawfishes, including training fishers in safe handling and release
- A workshop to develop national legislation to protect PNG's sawfish populations from decline, including the addition of sawfishes to PNG's national protected fauna legislation

CONCLUSIONS

PNG appears to be only the third sawfish stronghold that exists globally, alongside Australia and the southeastern USA, and with international support and collaboration, can act as an important refuge for these threatened species. A recent study suggests that *Pristis* sawfishes in northern Australian waters have experienced population bottlenecks (Phillips et al. 2017, this Theme Section). The preservation of re-

maining genetic diversity should thus be a high conservation priority, and sawfish populations in PNG, if properly managed, may act as another stronghold and source of genetic variability. The findings of this study are intended to serve as a starting point for future research. Thorough surveys to determine relative abundance, patterns of habitat use, and local threats to sawfishes in the Sepik and Ramu rivers and in the coastal waters of East Sepik province will be required. For conservation success in areas where sawfishes and people interact, however, education of communities about the benefits of ecosystem management will be key, alongside collaborative efforts to develop locally relevant and feasible management plans and alternative livelihoods.

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