Local knowledge surveys with small-scale fishers indicate challenges to sawfish conservation in southern Papua New Guinea

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Abstract

1.Sawfish (Pristidae) are considered to be among the most threatened families of elasmobranch (sharks and rays). There is presently a need to gather information on the status of poorly-known sawfish populations to assist in global recovery initiatives.

2.This study used interviews with local fishers to investigate the presence of sawfish in southern Papua New Guinea (PNG) and their interactions, uses, and values with small-scale fishers.

3. A range of sawfish size classes are still encountered throughout southern PNG, while juvenile largetooth sawfish *Pristis pristis* were additionally reported in the freshwater reaches of all rivers surveyed. Reports of large size classes in estuarine and marine environments provides an optimistic outlook that sawfish populations persist throughout southern PNG.

4.Most fishers that catch sawfish retain them for various uses including consumption, and for sale of meat, fins, and occasionally rostra. Negative population trends including decreases in catch frequency and/or size classes were reported by 66% of interviewees, with the largest declines being reported in the Kikori River. The increasing technical capacity of small-scale fishers, their preference for gillnetting, and the emerging market for teleost swim bladder (a high value fishery product), present a major ongoing threat to sawfish in southern PNG. Furthermore, the tendency of fishers to kill or remove rostra from entangled sawfish results in high fishing mortality regardless of any use by the fisher.

5.This study indicates considerable community engagement will be necessary to manifest any legislative actions or increased enforcement on international trade regulations for sawfishes in PNG. This is due to traditional land and waterway ownership values throughout PNG, and the local perception of sawfish as a traditional food resource, rather than an animal of intrinsic biodiversity value as perceived by global conservationists. Future research should consider exploring culturally appropriate conservation initiatives that are likely to achieve engagement and participation from local fishers.

Keywords

Conservation, estuarine, fresh water, interviews, marine, Papua New Guinea, Pristidae, surveys, threatened species

1. Introduction

Drawing on knowledge of local resource users is an effective approach to gathering information on threatened species. This approach can be particularly useful in conservation and management in remote regions lacking historical time-series data (e.g. Dulvy & Polunin, 2004). The knowledge held by local resource users can complement contemporary quantitative scientific data in numerous ways, including: i) to better understand local population trends over time, including relative abundance, and current and historical distributions (e.g. Valerio-Vargas & Espinoza, 2019); ii) infer historical population baselines from which perceived changes can be measured (e.g. Pauly, 1995; Eckert et al., 2018); iii) inform timing, impact, and duration of environmental or anthropogenic disturbances that may have resulted in changes to the population over time (e.g. McDavitt, 2002); and iv) provide insights on biological characteristics of how the population interacts with the local environment (e.g. spawning seasons, migrations, or nursery areas), which may have been previously unknown, or undocumented (Ames, 2004). Furthermore, engaging with local resource users allows for an understanding of how threatened species exist within local culture, with respect to uses and values. In remote regions with limited commercial harvest activities, understanding the historical or contemporary cultural uses and value that a threatened species has, helps to inform how culturally appropriate conservation initiatives can be best developed and implemented to achieve high levels of engagement and participation from local resource users (McDavitt, 2014; Booth, Squires & Milner-Gulland, 2019).

Sawfishes (family Pristidae) are among the most recognizable and charismatic ray species, due to their long-toothed rostrum. Historically, they were commonly distributed throughout the tropics in shallow coastal and estuarine environments, while the largetooth sawfish *Pristis pristis* was additionally common throughout tropical riverine environments (Thorson, Cowan & Watson, 1966; Dulvy et al., 2016). Consequently, cultural beliefs, symbols, and connotations of sawfish are found within many historical and current cultures and societies within Central and South America, Africa, Asia, and northern Australia (McDavitt, 2014). High human interaction has led to widespread declines in sawfish populations globally (Dulvy et al., 2016). The green sawfish *Pristis zijsron*, largetooth sawfish *P. pristis*, and smalltooth sawfish *Pristis pectinata*, have been assessed as Critically Endangered on the IUCN Red List of Threatened

93 Species (hereafter 'IUCN Red List'), while the dwarf sawfish *Pristis clavata* and narrow
94 sawfish *Anoxypristis cuspidata*, are Endangered (IUCN 2020).

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96 The imperiled conservation status of sawfish is primarily due to incidental capture and
97 exploitation in tropical fisheries. Fishing activities (including commercial, small-scale, and
98 cultural) are concentrated in shallow coastal and riverine environments, particularly in
99 developing tropical nations where sawfish occur (Compagno & Cook, 1995; Blaber, 2009),
100 and the toothed rostra of sawfish increases their susceptibility to net fisheries (Dulvy et al.,
101 2016). Degradation of coastal and riverine environments has also likely been a prominent factor
102 in sawfish population declines, mainly through coastal development and river engineering
103 (Hossain et al., 2015; Brame et al., 2019). Presently, northern Australia and the south-east
104 United States are regarded as potentially the last remaining significant refuges for sawfish
105 populations within the Indo–Pacific and Atlantic, respectively (Dulvy et al., 2016). Both of
106 these regions have national and state legislative protection measures, and also maintain active
107 research, monitoring, and community-based sawfish conservation efforts (Morgan et al., 2011;
108 Brame et al., 2019). However, the rebuilding of global sawfish populations cannot rely on these
109 refuge regions alone. There is a need to document sawfish distribution, abundance, threats, and
110 how they interact with local culture in other nations where remnant populations may persist so
111 that effective local conservation measures can be developed and implemented (Dulvy et al.,
112 2016). Within the Indo-Pacific, there may be remote locations where relatively intact
113 populations persist, as has been found with other riverine elasmobranchs (e.g. White et al.,
114 2015). This will assist in the rebuilding of global populations and may provide alternative
115 locations to study aspects of sawfish life history, ecology, and habitat use requirements, which
116 will ultimately lead to more informed conservation initiatives globally.

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118 Recently, there has been increased interest in Papua New Guinea (PNG) as a possible refuge
119 for the four Indo–Pacific sawfish species (*A. cuspidata*, *P. clavata*, *P. pristis*, and *P. zijsron*)(
120 White et al., 2017; Leeney, Mana & Dulvy, 2018; White et al., 2019). Recent observations
121 from a shark fin trader at Daru, Western Province, provided evidence that all four Indo–Pacific
122 sawfish species still occur within southern PNG. *Anoxypristis cuspidata* and *P. pristis* were
123 additionally observed in the bycatch of the Gulf of Papua Prawn Trawl Fishery (the only
124 commercial fishery in southern PNG likely to catch sawfish) (White et al., 2019). On the

northern coast of PNG, Leeney et al. (2018) noted populations of *A. cuspidata* at the mouth of the Sepik and Ramu Rivers, while *P. pristis* was additionally found upstream in freshwaters of the Sepik River. Compared to northern PNG however, the southern coastline of PNG provides a higher abundance of suitable shallow habitat, with several large adjacent river basins (Fly River, Bamu/Aramia River, Turama River, Kikori River, and Purari River) draining into the Gulf of Papua. The southern coastline of PNG has very low human population density, and most of its land, rivers, and coastline remain undeveloped and largely inaccessible to commercialized activities, with communities generally living by traditional means.

While there is great potential for southern PNG to provide a refuge for Indo–Pacific sawfish species, there is still a lot of information required to assist conservation initiatives. Specifically, a greater understanding is needed on: i) distribution, abundance, and population trends of sawfishes in the region; ii) the cultural use and value of sawfish to local people; and, iii) insights into threats sawfish may be facing in southern PNG, with particular reference to sawfish interactions with small-scale fisheries. Gathering information on sawfish and relevant small-scale fisheries in southern PNG however presents many logistical challenges and knowledge gaps. The remoteness and inaccessibility of southern PNG has impeded the amount of research that has been conducted, particularly on elasmobranch species (White & Ko'ou, 2018), while studies documenting small-scale fishery characteristics are restricted to the South Fly Coast (e.g. Busilacchi et al., 2014; Busilacchi et al., 2021). This lack of recent information also impedes development of conservation initiatives for threatened species such as sawfish within PNG, as present levels of threat from small-scale fisheries are unclear, and there is no historical time-series information available to determine the extent and duration of any population declines.

The purpose of this study was to provide information on sawfish in southern PNG including exploitation in small-scale fisheries, for use in development of fisheries management and conservation initiatives. Following recent studies that focused on local knowledge of sawfish in other data-limited regions e.g. Brazil (Giglio et al., 2016; Feitosa, Martins & Nunes, 2017), Costa Rica (Valerio-Vargas & Espinoza, 2019), and northern PNG (Leeney, Mana & Dulvy, 2018), this study used interviews with experienced fishers across remote communities in

southern PNG to collect data on sawfish occurrence, values, and interactions with small-scale fishers to fill knowledge gaps resulting from a lack of historical baseline data.

2. Methods

2.1 Study location

This study was conducted in coastal and riverine communities in the Western and Gulf Provinces of Papua New Guinea (PNG) during 2018–2019. Within these Provinces, interviews were conducted in six broad regions; South Fly Coast, Aramia River, and Bamu River in the Western Province, and Turama River, Kikori River, and Tiamura River in the Gulf Province (Figure 1). The environment along the South Fly Coast is predominately marine and estuarine, with substantial outflow from the Fly River. The Oriomo and Mia Kussa Rivers also provide smaller outflow volumes and estuarine environments in their lower reaches and adjacent coastline, although their influence is significantly less than the Fly River. The Aramia River is a freshwater system flowing into the Bamu River, and is freshwater all year round, occasionally receiving saltwater inflow during spring tides in the dry season. The Bamu, Turama, and Kikori Rivers are all large high flow systems with delta areas around their respective river mouths. The environment around these deltas and adjacent coastline is estuarine, while upstream of deltas is freshwater. The Tiamura River is significantly smaller than these other rivers. Its mouth forms a large estuarine bay (Kerema Bay) with significant marine tidal influence, while its head waters provide freshwater inflow year-round.

2.2 Interview process and questionnaire

Before arrival in any region, village Councillors or Chiefs were made aware of the research parties intent to visit and enquire about fishing activities by local project collaborators from either the Western Provincial Fisheries (South Fly Coast), Gulf Provincial Fisheries (Tiamura River), or the Piku Biodiversity Network (Aramia, Bamu, Turama, and Kikori Rivers). Where prior engagement was not always possible in particularly remote regions (e.g. Aramia, Bamu, and Turama Rivers, or upstream of the Tiamura River), discussions about the study were undertaken with village Councillors or Chiefs upon arrival.

In each region, the selection of village communities or fishing camps to visit aimed to cover a range of coastal, estuarine, and freshwater environments. Most of the regions visited were very remote, with low population densities, and highly dispersed village communities. This study aimed to conduct at least one interview per village or fishing camp visited, with two or three villages usually visited each day. Interviews could not be conducted around the mouth (coast or estuary) of the Turama River, and freshwater reaches of the Bamu, Oriomo, and Mia Kussa Rivers due to logistical issues.

Upon arrival at villages or fishing camps, identification of a suitable interviewee with prolonged fishing experience in the local area was discussed with the local Councillor, Chief, or community elders. Prospective interviewees were firstly informed about the types of questions they were going to be asked (i.e. about sawfishes and fishing activities), and that the study was being conducted through James Cook University (mediation provided by either YA, DI, or DJ). It was made clear to interviewees that answers provided would be used in a study on local knowledge of sawfishes and fishing activities throughout southern PNG, and that upon completion, this study may be published and made publicly available for use by fisheries managers or conservation practitioners. Interviewees were also informed that they would not be personally identifiable as a result of participating, and that their answers would be collated with other fishers in the region, to provide a general understanding for that region. Interviewees were asked to answer questions with respect to fishing activities in the given region the interview was being conducted in, and to not take into account fishing activities of former residence elsewhere (e.g. in the South Fly Coast it was common that fishers grew up in the Fly River). However, responses on cultural significance of sawfishes were considered from places of former residence. Following this explanation, all interviewees were asked if they wished to proceed with the interview. Due to literacy differences between interviewees, questions were asked verbally, and answers documented by MIG, YA, or DI. All answers given by interviewees were reconfirmed verbally before documenting on the questionnaire.

The questionnaire used in the present study was structured into four sections, with both open and closed questions (Appendix). The first section was designed to ensure positive identification of sawfishes and seek information on biological aspects of sawfish in the local environment. Interviewees were shown a picture of a sawfish (and additionally a rostrum when

on hand) to firstly establish a positive identification and familiarity of sawfish. The second section addressed characteristics of the fishery and interactions of sawfishes over time. The third section addressed social and cultural uses of sawfish. The fourth section addressed the cultural significance of sawfish to local people. For interviews in the Aramia, Bamu, Turama, and Kikori Rivers, an additional question was added to the survey which asked interviewees whether they would be supportive of sawfish conservation, and the reasons for their answer. This was to extract information more directly applicable to formulation and implementation of future conservation initiatives, which we felt was not sufficiently addressed in the initial survey trip to South Fly Coast and Tiamura River.

While this study aimed to interview one individual fisher each location it was not always possible due to variety of reasons attributed to local culture: 1) village Councillors or Chiefs appointed a group (who fish collectively) or family of fishers for the interview; 2) equality among individuals in land and waterway ownership or fishing resources (e.g. gear, boat, engine) meant fishing activities are group or family based, and entitlement to participate in the interview was shared (and time restrictions precluded the possibility of multiple interviews being conducted); and 3) due to the extremely remote nature of many villages visited, the intrinsic factor of having visitors meant that community interest and willingness to help was exceptionally high. In the occurrence of any of these scenarios, it was deemed to be inappropriate to enforce our desire for a single interviewee. Furthermore, in most instances interviews with fishers were conducted in the presence of important village personnel (Councillors, Chiefs, elders, etc.). Where a group (>3) of interviewees contributed, their ages were not recorded as it would hinder the interpretation of any age-knowledge relationship. Where more than one interviewee contributed, consensus among interviewees in answers given was confirmed before documenting. Because the aim of the interview was to gather local knowledge on sawfishes and information on fishery characteristics from a range of environments in different regions, we did not consider that interviews conducted on small groups of collective fishers violated this aim in any instance, and thus responses from these interviews were included in analysis.

2.3 Data analysis

Answers received from interviewees were pooled into six regions for analysis. Only one interview (in the Aramia River) was terminated early due to an incoming tidal bore and answers from section one and two only were included in the analysis. Quantitative data were entered into Excel which was used to produce descriptive statistics. Responses to open ended questions were coded into categorical responses. Small sample sizes made statistical comparisons between regions inappropriate. Results were presented in terms of 'number of interviewees' and 'proportion of interviewees', and ranges, means, and medians were presented where appropriate. All questions in each interview were not always answered or were not applicable based on previous answers given by the interviewee. For this reason, number of interviewees (*n*) is presented for each aspect of the analysis.

3. Results

In total, 49 interviews were conducted across 42 villages or fishing camps over six regions (Table 1, Figure 1) with 36/49 conducted with a single fisher, 5/49 conducted with 2–3 fishers, and 8/49 conducted on a small group (>3 fishers). The age of interviewees ranged from 17–85 (mean 42). Most interviewees were male (92%), with only four females (8%) participating (1 in Tiamura River, 3 in Kikori River). This disparity in gender of interviewees was not reflective of gender participation in fisheries, but rather culture in remote communities in regions visited. For example, village Councillors or Chiefs generally recommended male fishers during the discussion process, while in some regions it is not customary that females engage with visitors, or in some instances unmarried men.

3.1 Identification of sawfishes

All interviewees (100%) could readily identify sawfish from a photograph, and sawfish were reported to be caught in all habitat types accessible from villages and fishing camps where interviews were conducted (Table 2). A majority of interviewees (61%) reported that only one type of sawfish was caught, which included all interviewees from villages with access to only freshwater environments. Of the 19 (39%) interviewees that reported two types being caught (none reported more than two), distinction between types was on the basis of size (9), colour (4), rostrum (2), size and colour (1), colour and shape (1), or other (2). Size distinction was always based on 'small sizes' or 'large sizes' with some language names reflecting that division

(e.g. Kikori River; Table 2), while colour distinction between the 'two types' was either light or dark coloured, and yellow/green/orange or dark brown. Two interviewees commented that the two types caught have either narrow or wide 'saws', or teeth spaced close together or wider apart. Meanwhile, two interviewees reported "some with saw, some without" and "some have white spots". It was assumed that these were in reference to other shark-like rays (e.g. the wedgefish family Rhinidae and the giant guitarfish family Glaucostegidae) rather than sawfish with amputated rostra, as amputee sawfish are not expected to survive (see Discussion). Furthermore, these reports came from coastal environments where these other shark-like rays occur. To avoid confusion, it was made clear to these interviewees that the remainder of the survey was only in reference to types with a 'saw' (this was repeatedly clarified during interviews).

3.2 Small-scale fishery characteristics

In total, seven gear types were reported to be used by interviewees across regions (Table 3). The largest diversity of gear types encountered came from South Fly Coast interviewees, although this is likely influenced by small sample sizes in other regions. Gillnets were the most common fishing gear with 92% of interviewees reporting use. Hook & line was the second most common, with 55% reporting use, although only 4% of interviewees reported exclusive use of hook & line. Only 4% of interviewees reported that their primary fishing gears were not gillnet or hook & line, instead they primarily use basket and drag nets (to target prawns and small fish), and spear (targeting fish in headwater pools during the dry season). While no data were explicitly collected on vessel type used by fishers, most fishing activities are conducted using large wooden paddle-powered canoes. In coastal environments fishers tend to use fibreglass 'banana boats' with outboard engines in place of wooden canoes, or wade out at low tide to set nets. Fishers that access offshore reef habitat on the South Fly Coast use fibreglass banana boats exclusively, while fishers in the Kikori and Tiamura Rivers paddle offshore occasionally when trolling baited hooks.

A wide range of answers were given when interviewees were asked how many gillnets are set each day (or fishing activity) (Table 3). Answers ranged from 1–115 (second highest was 55), with most interviewees reporting a range, stating that it depends on how many gillnets are available at the time. However, interviewees may fish individually, or in small or large groups,

depending on equity share in land and waterway or fishing resources, and many interviewees did not themselves outright own a specified number of gillnets (e.g. the interviewee that reported 115 gillnets stated that when they fish, the village has 115 gillnets to set). The questionnaire used in the present study did not specifically address the number of fishers each interviewee conducted fishing activities with, or how many other fishers they shared land, waterway, or fishing resources with, and so this result should not be interpreted as an estimate of the number of gillnets used per fisher in each region.

Gillnet mesh sizes ranged 1.5–9″, with the largest median mesh sizes occurring in the South Fly Coast, Aramia River, and Kikori River (Figure 2). Large mesh sizes were more frequent in coastal villages, and particularly around the South Fly Coast and Kikori River where fishers target barramundi *Lates calcarifer*, scaly croaker *Nibea squamosa* (locally referred to as 'stone fish'), and king threadfin salmon *Polydactylus macrochir* which are sold to commercial buyers in Daru and Kikori Town, respectively. In the Aramia River, 5/6 interviewees reported use of mesh sizes ≥ 5", although were not explicitly targeting certain species. In the Tiamura River, target species included snappers (Lutjanidae) and mackerels (Scombridae), which are sold in local markets. In Bamu and Turama Rivers, smaller mesh sizes were reported, and interviewees generally did not report a target species. When target species were reported in Aramia, Bamu, and Turama Rivers, it was based on species with higher preference for eating, or species with cultural value as 'food fish', rather than those with higher economic value.

3.3 Fishery trends in sawfish catch frequency, size classes, and fate

The frequency of sawfish catch varied across interviewees in each region (Figure 3). Interviewees in the Turama River reported weekly catch frequency in villages well upriver. Within the Aramia River, sawfish were reported to be caught monthly at villages close to the confluence with the Bamu River, while upstream in the Aramia River, sawfish were reported to be caught less than yearly. One interviewee in each of the South Fly Coast and Tiamura River, reported that sawfish are caught weekly, though on a seasonal basis (April-August in South Fly Coast, April-July in Tiamura River) coinciding with 'stone fish season' (*N. squamosa*). Most interviewees (55%) reported no seasonality in sawfish catch. Of those reporting a 'sawfish season', 33% reported sawfish being more common in the dry season (generally ranging from June-December), with 13/16 of these reports coming from riverine

communities (villages with access to fresh water and/or estuary only). Other reports of seasonality (12%) again highlighted that sawfish are caught when fishers target *N. squamosa* (April-July on South Fly Coast, October-March in Kikori River).

Fishing effort, measured as mean number of gillnets reported per interviewee, was compared between each categorical variable of sawfish catch frequency for all regions combined. Average fishing effort was: Weekly (n = 9), 8.3 gillnets; Monthly (n = 10), 6.2 gillnets; Every couple of months (n = 7), 22.0 gillnets; Couple per year (n = 7), 4.4 gillnets; and less than one per year (n = 10), 2.6 gillnets. Total average effort (n = 46) was 8.1 gillnets. However, some averages were skewed by two outlying results including the report of 115 gillnets from an interviewee in the South Fly Coast, and a report of 50–60 gillnets also from the South Fly Coast (Table 3). These outlying results were reported from two interviewees in the same village. With the removal of these data, average fishing effort for Weekly (n = 8) fell to 2.4 gillnets, and Every couple of months (n = 6) fell to 6.5 gillnets, while the total average effort (n = 44) fell to 4.4 gillnets.

Size classes of sawfish reported to be caught by interviewees ranged from <1 m to >4 m (Figure 3). All size classes were reported from the South Fly Coast, Turama River, and Kikori River, while only smaller size classes were reported in other regions. Generally, coastal villages reported higher incidence of larger sawfish being caught, while villages with access to only freshwater habitats (e.g. Aramia River) reported size classes <2 m. Only one interviewee in freshwaters of the Turama River reported sizes up to 4 m.

Across all regions, 44% of interviewees reported that they had seen a sawfish >4 m. Excluding interviews conducted in upper freshwater reaches of rivers (where large sawfish are unlikely to occur), 60% of interviewees had seen a sawfish >4 m (these data were not included in Figure 3, unless the interviewee had caught a sawfish >4 m themselves within the last 10 years). In the South Fly Coast, 64% of interviewees reported sawfish >4 m (two within a few months, one within 6 months, two within a year, one within 5 years, and one more than 10 years ago). The Kikori River, however, had the highest proportion (80%) of interviewees reporting having seen a sawfish >4 m (one within a month, two within a few months, four within a year, two

within five years, and three more than 10 years). In the Turama River, only one interviewee reported seeing a sawfish >4 m about one year ago. In the Aramia River, one interviewee reported seeing a sawfish >4 m in 1975. Sawfish >4 m were not reported to have ever been seen by interviewees in the Bamu and Tiamura Rivers.

In most instances (72%), interviewees reported that sawfish are always retained when caught (Figure 3). The Turama River was the only region where sawfish are generally released when caught. This is due to the practising obligations of communities that identify with the Seventh Day Adventist denomination of Christianity, whereby non-scaly fish cannot be consumed, and the remoteness of the Turama River precludes the possibility of travelling to Kikori Town to sell elasmobranch catch. Of the 13 interviewees who did not always retain sawfish (categories 'usually, 'sometimes', and 'never' in Figure 3), only three reported that sawfish are always untangled and released, while four reported that large sawfish are killed or 'saw removed' and that only small sawfish are untangled and released. The other six interviewees (five from Turama River, where retention was lowest) reported that sawfish are always either killed or 'saw removed' before releasing. Reasons cited were safety or to reduce damage to gillnets from sawfish thrashing their rostrum. Interviewees that reported sawfish being either usually or sometimes retained, generally reported that sawfish are secondary to other fish in terms of eating quality, and they are retained only if needed.

3.4 Trends in sawfish catch over time

Of the interviewees that provided responses about trends in sawfish catch over time (n = 44), 34% reported no noticeable change in frequency of catch or size classes caught, 25% reported decreases in catch frequency, though not in size classes caught, 11% reported decreases in size classes caught, though not catch frequency, and 30% reported decreases in both catch frequency and size classes (Figure 3). Only one interviewee (on the South Fly Coast) reported that sawfish are caught more commonly now, though this interviewee also reported size classes caught are smaller than caught previously. Reports of decreases in sawfish catch frequency and/or size classes were proportionately lowest in Bamu River (33%, one interviewee did not answer) and Turama River (37%), while highest (92%) in the Kikori River.

Of interviewees that provided an answer on changes in sawfish catch frequency or size classes (four interviewees did not provide an answer), 20% (9/44) reported decreases in catch frequency of other sharks also (inclusive of all other shark species). Four of these reports came from the Kikori River, while one report came from the South Fly Coast and Bamu, Turama, and Tiamura Rivers each. Two fishers in Kikori River and one on the South Fly Coast (7%) reported increases in other sharks, while all other (73%) interviewees reported no notable changes. However, this result should be interpreted carefully as fishers in freshwater or estuaries have access to fewer shark species occurring in these environments compared to coastal fishers (Grant et al., 2019).

From the 29 interviewees that reported declines in either catch frequency or size classes of sawfish across regions, a variety of different reasons were suggested to have attributed to declines (Table 4). Six of these interviewees (21%) did not provide an answer as they were unsure, or reluctant to speak openly. Overall, increased fishing activity was the most commonly provided reason (34%), with seven accounts coming from the Kikori River. The second most common response were those related to changes in environment or climate (24%), three of which came from the South Fly Coast. Five (17%) interviewees offered several reasons for observed declines, which generally encompassed a list of any commercial activities in the region (e.g. logging, Gulf of Papua Prawn Trawl Fishery, or mining operations).

3.5 Contemporary use of sawfish

The main direct uses of sawfish body parts were consumption of meat (92%), sale of meat (50%), sale of fin (50%), decoration in village houses (65%), weapons (15%), and cultural uses (23%) (Figure 4). Cultural uses included here are only those presently practised that involve a physical body part from sawfishes including use as ceremonial prop, medicine, or in rituals (for indirect and historical cultural uses see '*Historical use and cultural significance of sawfish*' below). Additionally, one interviewee on the South Fly Coast reported that rostra are occasionally sold to fin buyers, and two interviewees in Kikori River reported that they occasionally make necklaces from rostral teeth. Only one interviewee in the Turama River stated no use of sawfish.

Interviewees reported that the sale of meat or fin, prices and market information varied across and within regions (Table 5). Sawfish meat was mostly sold in local markets (non-commercial) and usually in pieces, rather than whole animals, with price depending on portion size. The only exception was in Kikori River, where the local fish plant (commercial) buys whole sharks (including sawfish and other shark-like rays) at $3 Papua New Guinean Kina (PGK) kg^{-1} (1 PGK = ~ $0.28 USD, 04/04/2021), with fins attached. The value of fins usually varied depending on region and reflected shark fin prices in general, rather than sawfish specifically. One interviewee in the South Fly Coast reported that fins from a single sawfish are worth ~$7 PGK, while two interviewees in the Kikori River reported $15–25 PGK per fin, and $60–300 PGK per fin set, respectively for sawfish, although it was not clear if these prices were higher than fin from other sharks of comparable size.

Overall, most interviewees stated that elasmobranch resources were not an important part of their food (77%) or economic security (77%). Interviewees in the South Fly Coast reported the highest reliance on elasmobranchs as a resource (55% reported important to both food and economic security; 18% important to food security; 9% important to economic security; 18% none). In the Kikori River, 6% of interviewees reported that elasmobranchs are important to both their food and economic security, while in the Tiamura River, 13% reported importance to both; 13% reported importance to food security only; and, 25% reported importance to economic security only. No interviewees explicitly stated that sawfish have a disproportionate price for either their meat or fins, relative to other sharks.

3.6 Historical use and cultural significance of sawfish

Sawfish were reported to be used either historically or culturally by 52% of interviewees (inclusive of direct cultural uses in Figure 4), with various stories and rituals involving sawfish either directly or indirectly being reported (Table 6). Most cultural stories and rituals about sawfish came from interviewees in Kikori River (which also had the largest sample size), while no historical use or cultural significance of sawfish was reported from the Turama River.

Nine interviewees (from all regions except Bamu River) reported that sawfish rostra were historically used to make weapons or tools, with only one of these reports coming from an interviewee who also reported current use of rostra in weapons from the Tiamura River. Two interviewees in the Tiamura River, and one in each of the Aramia and Kikori River, reported a connotation of sawfish being a totem animal, or representative of a clan, or group of people that identify with it. Four interviewees (three South Fly Coast, one Tiamura River) reported that sharks (including sawfish), are used for medicinal purposes involving the consumption of shark meat broth. One interviewee in the Bamu River reported that shark (including sawfish) cannot be eaten with sago (starch made from palm *Metroxylon* spp.) or cassava or it will 'make them sick', while another interviewee from Bamu River reported sawfish as a traditional food source from the river. In the Kikori River, three interviewees reported that sawfish have a tendency to make babies and young children sick, and that fishers must wash their hands after catching sawfish before touching their children.

3.7 Community perspective on sawfish conservation

Across the four regions where interviewees (n = 32) were additionally asked about their perspective on sawfish conservation efforts (Aramia, Bamu, Turama, and Kikori Rivers), 88% were supportive, 9% were open to the idea, though not outright supportive, while 3% chose not to provide an answer. No interviewees were opposed to the idea of sawfish conservation effort within their region.

Reasons for why interviewees gave their respective answers about sawfish conservation were grouped into four broad categories encompassing conservation for: i) future generations; ii) cultural resource or food source; iii) environment health or intrinsic value of environment; and, iv) other (Table 7). Responses categorized as 'other' included those that did not specifically outline a reason. Some interviewees stated that while they would support conservation, they mentioned that sawfish have very little relevance to everyday life and that they were indifferent as to why sawfish mattered. However, these same interviewees recognized increased values and uses sawfish may have to other people, hence their support, or openness to support. On the Turama River, four interviewees gave reasons that concerned the implementation of conservation effort, largely stating that it would be a collective decision to be made within the village, or among village Councillors throughout the river. While in the Kikori River, two

interviewees stated that they are already doing environmental conservation in their local environment. One interviewee in each of the Araima and Turama Rivers stated that they would require a benefit (e.g. financial) to participate in sawfish conservation.

4. Discussion

4.1 Sawfish catch frequency and size classes

This study has provided information to suggest that sawfish are still widely encountered throughout southern PNG, building upon preliminary observations in the Western Province (White et al., 2017) and Gulf of Papua Prawn Trawl Fishery (White et al., 2019). A wide range of size classes were reported throughout coastal regions, and while species-specific information was not sought from interviewees, these may include any of the four Indo–Pacific species. In all freshwater systems surveyed, interviewees reported only smaller sawfish size classes present, which can be attributed to juvenile *P. pristis* with a reasonable degree of confidence given their ecological life history (e.g. Lear et al., 2019). Thus, data obtained in the present study support suggestions of White et al. (2017) that the South Fly Coast and delta areas of the Gulf of Papua have sustained sawfish populations. However, development of domestic legislative protection measures and strategic community driven conservation initiatives are needed to ensure future sustainability of populations.

Differences in sawfish catch frequency and size classes caught were apparent between regions. The highest sawfish catch frequencies came from the Turama River where most interviewees reported weekly capture, while the lowest catch frequencies were reported from the Aramia and Tiamura Rivers. Many factors may potentially influence this variation including habitat availability, site fidelity, the accessibility of habitats to fishers, the spatial extent of fishing (i.e. how far they operate from home), and fishing gear used. For example, in the Turama River two villages only a few kilometres apart reported sawfish catch frequencies of ‘weekly’ and ‘every couple of months’, respectively, which may reflect characteristics of high site fidelity which have been noted for juvenile *P. pristis* (e.g. Whitty et al., 2009; Whitty et al., 2017), *P. clavata* (Stevens et al., 2008; Thorburn et al., 2008), and *P. zijsron* (Morgan et al., 2017).

Large size classes of sawfish were not commonly reported, with interviewees in only the South Fly Coast, Kikori River, and one in the Turama River reporting sawfish of >3 m in their catches. However, it would not necessarily be expected that large sawfish would be encountered by interviewees living in upper freshwater reaches of rivers. Meanwhile, the Tiamura River is a considerably smaller system compared to other regions surveyed, and the relatively clear water bay at the river's mouth is possibly unsuitable habitat for large sawfish, or may be more favoured by *A. cuspidata* or *P. clavata* which are not known to attain sizes > 4m (Last et al., 2016). Conversely, the Bamu River is a large high-flow turbid system with a significant delta at its mouth, and fishers use similar gillnets to those observed in the South Fly Coast, and Turama, and Kikori Rivers where large size classes were reported. Thus, it is unclear why large size classes were not reported between the four experienced fishers surveyed. Furthermore, no interviewees in the Bamu River noted ever seeing a sawfish >4 m. The highest instances of interviewees reporting to have caught or seen a sawfish >4 m came from the South Fly Coast and Kikori River. The Fly River has at least historically supported a rich *P. pristis* population (White et al., 2017), and it is likely that large sawfish encountered by South Fly Coast interviewees included *P. pristis* associated with the Fly River, possibly following its southern outflow. In addition, *P. zijsron*, which can attain sizes up to 7 m occurs along the South Fly Coast also (White et al., 2017), although this species does not appear to associate as commonly with low salinity waters. Meanwhile, the Kikori-Purari Delta system forms an enormous expanse of estuarine mangrove habitat, and reports of large sawfish from Kikori River can likely be attributed to both ideal habitat and large portions of the delta having not been historically accessible to fishing.

4.2 Sawfish population trends

While the widely reported occurrence of sawfish throughout southern PNG and its rivers is a positive indication for the species' conservation potential, it was also clear that declines have occurred in all regions except possibly the Turama River, with 80% of interviewees in other regions reporting declines in either catch frequency and/or size classes. Comparatively, only 20% of interviewees reported declines in other 'sharks' (all species as a general grouping) which may indicate disproportionate declines in sawfish. There is a wide diversity of sharks in PNG (White et al., 2018) and differences in resilience between shark

562 species (Cortés, 2002) may mask species-specific declines within this broader 'shark'
563 grouping.

564

565 The scale and timing of sawfish declines is difficult to gauge due to a lack of historic baselines
566 in most areas. Therefore, it is hard to distinguish whether the 'shifting baseline syndrome'
567 (Pauly, 1995) is apparent with some interviewees. Quantitative evidence of declines in sawfish
568 in southern PNG is limited to the Fly River where substantial declines have occurred since the
569 1970–80s, likely due to a combination of fisheries pressure and pollution associated with the
570 Ok Tedi copper mine (Burton, 1995; Storey et al., 2009). Sawfish have been noted historically
571 on the South Fly Coast from the Oriomo River and Daru Island within the range of the present
572 study (Tanaka, 1991). While further westward to the Indonesian border, *P. clavata* were
573 'common' in the Morehead and Bensback Rivers during the 1970s, and *P. pristis* was also
574 noted (White et al., 2017). Most South Fly Coast interviewees in the present study reported
575 either declines in catch frequency or size classes, though none reported declines in both. Most
576 interviewees residing around Daru and east to the Fly River reported that sawfish can still be
577 caught on offshore rocky reefs. While it was apparent that sawfish are not commonly caught
578 in gillnets set along the beach; improved accessibility to motorized vessels (see '*Shifting trends*
579 *in the small-scale fishery'* below) mean that fishers now have greater access to offshore fishing
580 grounds, including the northern Torres Strait (Busilacchi et al., 2014). The lack of sawfish
581 declines reported on the South Fly Coast in this study could therefore reflect continued
582 expansion of fishing effort into areas that historically were not accessible to fishers, and where
583 sawfish may have persisted.

584

585 Surveys of the Purari Delta (eastern part of Kikori-Purari Delta) in the 1970–80s indicate that
586 sawfish were common (Haines, 1977; Haines, 1979). During this period, Haines (1978/79)
587 reported that while gillnets could be observed in villages, traditional gears (e.g. spears, traps,
588 bow and arrow) were often used in their place. Therefore, significant sawfish catch may not
589 have been occurring at this time. In the present study gillnets were the primary, and often only,
590 fishing gear used by interviewees throughout the Kikori River Delta. Interviewees in Kikori
591 River reported the highest sawfish declines, with more than half reporting declines in both
592 sawfish catch frequency and size classes. Many interviewees (some as young as ~40 years old)
593 recalled seeing 'plenty' of sawfish in the sandbanks in front of their villages during the

evenings as little as 15–20 years ago. It is possible that sawfish declines in the Kikori River have been more recent than declines in other survey areas, and thus less of a 'shifting baseline syndrome' has occurred. Most interviewees in the Kikori River attributed declines to overfishing, with many remarking on the amount of nets in the water 'today'.

There is very little historical literature of sawfish in the Aramia, Bamu, Turama, and Tiamura Rivers (White et al., 2017), therefore data from the present survey can offer insight into historical baselines. Little change in sawfish populations were reported by interviewees in the Turama River, suggesting that only minor declines (if any) have occurred in this system. Juvenile *P. pristis* are still reported to occur in freshwater pools upstream of the Tiamura River, while larger sawfish appear to have declined around the river mouth. Some interviewees suggested that the absence of large size classes is possibly due to the Gulf of Papua Prawn Trawl Fishery, which typically has the highest concentration of effort in the north-east Gulf of Papua and is known to capture *A. cuspidata* and *P. pristis* incidentally (White et al., 2019). Within the Aramia and Bamu River basin, sawfish (almost certainly *P. pristis*) were reported to be more common downstream in the Aramia River at its junction with the Bamu River, compared to the floodplain environment upstream. Interviewees in this upstream environment reported that sawfish were once common, although now they are seldom caught once per year. However, this may reflect population declines in the Fly River Basin (Storey et al., 2009), as interviewees reported wet season connectivity with the Fly River basin (through both Fly and Strickland River floodplains), and that sawfish migrate into the Aramia River floodplain from these systems.

4.3 Uses of sawfish by small-scale fishing communities

The main reason for retaining sawfish catch across regions was consumption (92%) followed by sale of meat (50%) or fin (50%). While 65% of interviewees reported use of sawfish rostra for decoration, this was a secondary use, with no interviewees reporting sawfish capture for this purpose alone. Similarly, use of rostra or rostral teeth in weapons was never explicitly mentioned as a reason for retaining sawfish. The higher instance of consumption compared to sale of sawfish products was due to three main reasons: i) interviewees had limited access to markets to sell products (i.e. Aramaia, Bamu, and Turama Rivers); ii) interviewees reported a tendency to consume elasmobranchs and sell teleost fish, as fish meat is considered

626 easier to sell and more valuable; and, iii) elasmobranchs are not frequently caught limiting
627 marketability (mainly freshwater environments). These reasons also contributed to the high
628 number of interviewees reporting that elasmobranchs were not important to their food security,
629 and that they are consumed secondarily to fish. Interviewees who sold meat or fin from
630 elasmobranchs and did not consider it important to their economic security, usually stated
631 similar reasons and that opportunistic sale complimented their primary income. Secondary uses
632 of incidentally captured sawfish have also been noted in South America for rostra (McDavitt
633 & Charvet-Almeida, 2004), and likely represents the opportunistic use of resources by local
634 fishers in developing nations.

635

636 PNG is a signatory to the Convention on International Trade in Endangered Species of Wild
637 Fauna and Flora (CITES). In coastal regions from South Fly Coast to Kikori River,
638 interviewees mentioned buyers travelling from Indonesia to purchase shark fin ('shark fin'
639 refers to any species, inclusive of sawfish) and swim bladder. Illegal trade routes stemming
640 from Merauke, Indonesia, into the South Fly Coast were noted by Busilacchi et al. (2021), and
641 the present study indicates that this network extends east to at least Kikori River Delta. PNG-
642 based buyers (presumably licensed) travelling from Port Moresby were also mentioned by
643 interviewees from Kikori River to Tiamura River. Additionally, sale of shark fin to licensed
644 buyers in Daru and Kikori Town was reported by interviewees in the South Fly Coast and
645 Kikori River, respectively. The issue for PNG's national fisheries and conservation authorities
646 is that Indonesian-based buyers purchasing sawfish fin (within 'shark fin') from PNG's small-
647 scale fishers contravenes the CITES Appendix I listing of sawfishes. Furthermore, the
648 subsequent market chains for trade of shark fin by licensed PNG-based buyers appears to result
649 in export to three central nodes in Asia (Hong Kong, Singapore, and Kuala Lumpur; Busilacchi
650 et al., 2021). Therefore, PNG has a responsibility to the international community to enforce
651 CITES trade restricted species within its export markets, and this study indicates a need for
652 greater enforcement capacity.

653

654 From the few interviewees that felt comfortable discussing sale of shark fin, it was mentioned
655 that sale to PNG-based buyers (those from Port Moresby, Daru, and Kikori Town) fetch
656 significantly lower prices compared to non-licensed buyers. Interviewees who gave a larger
657 range in prices they may expect for shark fin were likely those who sold to non-licensed buyers

as their responses did not reflect fixed rates for shark fin, such as those offered at Kikori Fish Plant ($3 PGK kg^{-1} of whole animal weight). Prices of shark fin reported were generally significantly less than prices given by Leeney et al. (2018) of $100–350 PGK kg^{-1} in northern PNG, and interviewees did not mention any 'grades of fin quality', or variability in price for particular species. This suggests an overall less structured shark fin market in PNG's south, probably due to high market infiltration of non-licensed buyers. Unfortunately, the questionnaire used did not specifically address attitudes or incentives driving an interviewees participation in either legal or illegal shark fin markets. On the South Fly Coast, Busilacchi et al. (2021) found that engagement with illegal markets (including sale of shark fin) was driven mainly by: i) a need to improve living standard; ii) they are the only markets available; and, iii) non-licenced buyers provide additional goods (e.g. flour, rice, and batteries). It is unclear if these drivers are also present in regions other than the South Fly Coast, and this remains an important area for future research. For example, fishers in Kikori River consistently indicated that much higher shark fin prices were offered by non-licensed buyers compared to Kikori Fish Plant, while Busilacchi et al. (2021) found that higher prices were offered by licensed PNG-based buyers on the South Fly Coast. This likely due to a lack of commercial competition in the Kikori River (only Kikori Fish Plant), whereas multiple licensed buyers exist in Daru, and they may compete for supply from local fishers on the South Fly Coast. Further information on social aspects of the shark fin trade in the wider Gulf of Papua would complement information provided by Busilacchi et al. (2021) for the South Fly Coast, and ultimately be useful to inform more strategic management approaches within PNG's shark fin trade markets. A more transparent shark fin trade in PNG would assist in enforcement of CITES restricted species and help to disincentivise retention and sale of sawfish parts, ultimately helping to facilitate conservation of sawfishes in PNG.

4.4 Cultural significance of sawfishes

Sawfish specifically, were generally not prominent within culture across regions visited in the present study, with the exception of the Kikori River. Many cultural stories, particularly medicinal or food source related, referenced sharks in general and were inclusive of sawfishes rather than specific to sawfishes. There was no mention of sawfish art for example, which differs from Sepik River communities who possibly share a richer cultural connection with sawfish specifically (McDavitt, 2014; White et al., 2017). Regardless, this study suggests that

690 sawfish do have importance to at least some communities in all regions except Turama River,
691 and this should be considered and integrated in the formulation of both community-based and
692 legislative conservation initiatives of sawfish in southern PNG.

693

694 Aspects of the interview approach may have limited the sharing of cultural information. It is
695 likely that intimate aspects of culture were not shared by interviewees in some cases due to the
696 short nature of many of the village visits. Surveys in the Turama and Aramia Rivers appeared
697 to be a very novel experience for communities, and for this reason, it is likely that the
698 interviewees in these regions shared a reluctance to divulge aspects of their culture. This
699 contrasted with the Kikori River where there is a longstanding relationship with the Piku
700 Biodiversity Network, and regular contact with researchers. Sawfish appeared to have the
701 highest cultural value in the Kikori River, but these cultural factors mean that interpretations
702 of the cultural significance of sawfish to communities from this study should be considered
703 with caution and may in fact only reflect a glimpse of cultural values and connections.

704

705 *4.5 Shifting trends in the small-scale fishery*

706

707 Gillnets were the primary fishing gear used by interviewees across all regions surveyed.
708 Only one interviewee in the headwaters of the Tiamura River reported a traditional gear (spear)
709 as their main fishing method. All other interviewees reported that they now use either gillnet
710 (92%), hook and line (4%), or basket and drag nets (2%) predominantly, or a combination of
711 these gears. A shift to 'westernised' fishing techniques has previously been noted in PNG's
712 better studied Island Provinces and northern coast (Quinn, 2011; Leeney et al., 2018) and is
713 largely attributed to the time-consuming nature of constructing traditional gears, when nylon-
714 based nets are now relatively cheap, effective, and easily repairable or replaceable. Within our
715 study regions, gillnets were noted to be readily available in general stores, and these nets were
716 routinely observed set along rivers or within delta areas in all regions visited.

717

718 Throughout southern PNG, fishing effort is becoming increasingly sophisticated and targeted
719 to high value products (mainly swim bladder also known as fish maw, from *L. calcarifer* and

720 *N. squamosa*, and to a lesser extent shark fin), while management or monitoring of fisheries
721 remains scarce to non-existent. Large mesh-size gillnets were most common along the South
722 Fly Coast and delta environments of Kikori River. In both of these regions commercial fish
723 buyers are present (Daru and Kikori Town, respectively) and fishers reportedly use leased high
724 quality gillnets (and even fiberglass boats and outboard engines) from these buyers under the
725 arrangement that high value fish and fish products are sold back to the leaser. This practice has
726 historically occurred in the Kikori-Purari Delta through commercial fish buyers, defined as
727 'village level commercial fishing', as opposed to 'subsistence fishing' where catch is only
728 consumed or sold in local markets (Haines & Stevens, 1983). In the South Fly Coast, village
729 level commercial fishing falls under the Western Provinces Barramundi Management Plan
730 (National Fisheries Authority, 2003). Between village level commercial fisheries in the South
731 Fly Coast and Kikori River, there is no management of allowable fishing effort and there is no
732 management of non-target species (mainly elasmobranchs), which are either consumed, sold
733 locally at Daru or Kikori Town market, respectively, or are traded with non-licensed buyers
734 (shark fin only). Management initiatives around the Kikori Fish Plant (within Gulf Province)
735 remain less clear than for commercial fish buyers in Daru, and it is not presently understood if
736 there are particular target species that Kikori Fish Plant is licensed to buy from local fishers
737 (although a clear preference for *L. calcarifer*, *N. squamosa* and *P. macrochir* was noted) or if
738 any restrictions are in place on total allowable catch. Presently, Kikori Fish Plant purchases
739 sawfish from small-scale fishers at \$3 PGK kg^{-1} (with fins attached). This is concerning as any
740 economic incentive to retain sawfishes will present a challenge to future conservation effort.

741

742 *4.6 Considerations for the conservation of sawfish*

743 Presently, small-scale fishers throughout southern PNG sell sawfish parts (i.e. fin) to
744 domestic and international buyers. Given their CITES Appendix I listing, greater enforcement
745 from PNG to cease international trade (either directly to Indonesian-based buyers, or in
746 subsequent market chains for licensed PNG-based buyers) will result in less economic
747 opportunity for small-scale fishers. While it is hard to determine what the effects of this will
748 be for small-scale fisher communities, most interviewees in the present study stated they have
749 little economic reliance on the sale of elasmobranchs (including fin). The exception was South
750 Fly Coast where many interviewees stated that elasmobranchs were important to their
751 economic security, as also noted in previous studies (e.g. Busilacchi et al., 2014; Busilacchi et

752 al., 2021). Given the low catch rate of sawfish, coupled with an absence of responses indicating
753 that sawfish fins have a disproportionately higher value relative to other elasmobranchs, it is
754 unlikely that eradication of sawfish trade in PNG would have a substantial long-term economic
755 effect on small-scale fishers. National fisheries and conservation authorities in PNG need to
756 consider the nation's role as a CITES signatory and seek to ensure that efforts are made to
757 cease international trade of sawfish.

758

759 At the community level, engagement and awareness will still be needed to manifest any
760 conservation actions reflective of legislation or greater international trade enforcement from
761 national authorities. Congruently, receptiveness by interviewees to supporting the conservation
762 for sawfish was overwhelmingly positive. Although, responses as to why interviewees were
763 receptive, and the reasons why they valued sawfish, revealed the complexity of considerations
764 needed in both the formulation and implementation of any conservation initiative. Broadly
765 speaking, the local perspective of sawfish differs to that of the wider 'global conservation
766 community'. Sawfish were mainly perceived by interviewees as a traditional food source,
767 rather than an animal of intrinsic biodiversity value, as perceived by global conservationists.
768 These differences in global and local values towards sawfish can result in poor community
769 engagement and participation in conservation initiatives that are formulated from a global
770 conservationist perspective (e.g. Foale & Manele, 2004). A further consideration is that
771 interviewees in some communities expressed the view that any conservation initiative toward
772 sawfish would be a decision to be made within the village, or among local village Councillors,
773 or that conservation was already being practised locally. This suggests that a lack of
774 receptiveness to 'outside' conservation initiatives may be encountered in some areas
775 throughout southern PNG. Any prospective conservation initiatives should be mindful of the
776 'customary management' framework within PNG's small-scale fisheries, which is governed
777 by traditional land and waterway ownership rights held by family groups, or clans and tribes
778 (Cinner & Aswani, 2007). Working with Traditional Owners in the development of
779 conservation initiatives will be important to achieving engagement and participation from the
780 broader community.

781

782 Effective community engagement for development of sawfish conservation initiatives can
783 likely be informed from experiences of the threatened pig-nose turtle (*Carettochelys insculpta*)

784 in the Kikori River. *Carettochelys insculpta* conservation initiatives have recognized that while
785 complete elimination of harvest is unlikely, a more 'sustainable fishery' type approach to the
786 life stages targeted, volume of harvest, and spatial pattern of harvest activities, may be realistic
787 (Eisemberg et al., 2011; Eisemberg et al., 2015). The perception of sawfish being primarily
788 valued as a food source aligns closely with local perceptions of *C. insculpta* and formulation
789 of sawfish conservation initiatives should follow a similar fishery approach, although there is
790 a subtle difference to consider. Within local perceptions of these food sources, *C. insculpta* is
791 valued as a traditionally important species for consumption and trade, and is actively targeted
792 by locals through cultural harvest activities on a seasonal basis (e.g. harvest of nesting females
793 and eggs in the dry season) (Eisemberg et al., 2011). Sawfish differ in this regard as they do
794 not appear to be actively targeted, but rather are incidentally caught while fishers target more
795 favoured or economically valued teleost species. This is reflected by the high proportion of
796 interviewees stating that sawfish are not important to their food or economic security, and that
797 many interviewees prefer to consume and sell more palatable teleost species when concurrently
798 caught with sawfish. Conversely, a high proportion of interviewees also cited the value of
799 sawfish as a food item or as a resource for future generations when questioned as to why they
800 were supportive toward sawfish conservation. While it appears sawfish are more often
801 consumed opportunistically rather than relied upon, they still have value as a traditional, albeit
802 irregular food source, to those communities that do consume them. However, the prominent
803 issue for sawfish was the tendency for interviewees to kill or amputate rostra from entangled
804 sawfish, regardless of any intended or required use (e.g. Turama River fishers who do not
805 consume sawfish but kill to untangle them). While consumption and trade of sawfish may be
806 low, fisheries-imposed mortality of captured individuals is high. Therefore, while it is unlikely
807 that complete elimination of sawfish consumption throughout southern PNG could be
808 achieved, conservation initiatives aiming to minimize retention for non-essential consumption
809 and trade, coupled with awareness and education for better sawfish release practices, may have
810 potential.

811

812 The issue of killing or amputating rostra from sawfish was mentioned by interviewees to be
813 primarily for preservation of fishing gear and fisher safety. Available evidence of sawfish with
814 amputated rostra suggests an impeded ability to forage, and that it likely results in eventual
815 death (Morgan et al., 2016). Release guides for sawfish in gillnets are widely available,
816 although they are generally orientated to western fisheries with high technical capacity and

817 may recommend inflicting damage to the gillnet on the premise that repair tools and spare
818 mono-filament line is readily available (e.g. NOAA safe release guide
819 https://www.fisheries.noaa.gov/resource/educational-materials/endangered-sawfish-handling-
820 release-and-reporting-procedures). For small-scale fishers in southern PNG, a gillnet may
821 represent a significant investment, or a leased asset requiring payments to local commercial
822 fish buyers. Therefore, it is unlikely that fishers would, or should be expected to, damage their
823 fishing gear for the safe release of an individual sawfish. Furthermore, resource materials to
824 repair gillnets are seldom available in fishing camps. However, this mainly applies to capture
825 of large sizes >150 cm, as juvenile sawfish can generally be restrained by hand and untangled
826 from nets with appropriate technique (e.g. QLD DAF safe release guide
827 https://www.daf.qld.gov.au/__data/assets/pdf_file/0005/49109/Sawfish-Guide-Final-Nov-
828 2010.pdf).

829

830 There is potential to engage with freshwater communities about better sawfish release practices
831 in particular, as only small size classes were reported from these environments. Development
832 of a sawfish safe release guide appropriate to local fishing methods and gear in PNG would
833 likely be more favourably received than presently available guides for high capacity
834 commercial fisheries in other nations. The safe release of larger sawfish sizes from gillnets in
835 coastal regions is more challenging, and concerns minimizing gear damage as well as injury to
836 the fisher(s). Engaging with local fishers to establish feasible solutions to encourage live and
837 unharmed release of sawfish should be considered in future work as this will maximise local
838 participation. Education and awareness materials outlining sawfish status and importance to
839 some local cultures may help increase broader community engagement and participation in
840 sawfish conservation, and these materials could effectively be distributed through local schools
841 and markets where people from different communities regularly transit.

842

843 *Conclusion*

844 Overall, there remains a considerable amount of work to secure conservation of
845 sawfishes in southern PNG. Future actions should consider a combination of legislative
846 fisheries management that includes threatened non-target species and greater enforcement of
847 international trade obligations (i.e. Appendix I CITES listing), coupled with community-driven
848 conservation initiatives that minimize unnecessary fisheries mortality. The present survey has

849 indicated that a shift from traditional fishing gears to gillnets over recent decades has likely
850 resulted in declines of sawfish throughout southern PNG. Historical collapses of sawfish due
851 to net-based fishing activities in other nations (e.g. Giglio et al., 2016), indicate that the present
852 unregulated use of gillnets in small-scale fisheries, coupled with the current practice of killing
853 or amputating rostra from entangled animals, is the most immediate threat to PNG's sawfish.

854

855 This study has indicated that conservation initiatives for sawfish will need to consider their use
856 as a resource to local fishers. Further research on community engagement should focus on
857 social aspects of cultural appropriateness to various conservation initiatives (e.g. development
858 of safe release guides and de-incentivising sale of sawfish products in local and commercial
859 markets) that would be likely to achieve high levels of engagement and participation across a
860 range of communities with different values and uses of sawfish. General research on small-
861 scale fisheries in southern PNG that would help further inform conservation include: i)
862 quantifying elasmobranch catch in village level commercial fishing operations and their uses
863 and values as a resource; ii) sustainability assessment of species that support high value fish
864 products (primarily swim bladder, but also shark fin) currently driving small-scale fishing
865 effort in southern PNG; iii) more detailed study on the livelihoods of small-scale fishers
866 throughout southern PNG to complement existing information on the South Fly Coast (e.g.
867 Busilacchi et al., 2021), and their reliance on fisheries with respect to alternative livelihood
868 options; iv) building a greater understanding of the traditional fisheries management structure
869 through mapping traditionally owned land and waterway boundaries held by different clan and
870 tribe groups; and, v) improved capacity building for local, provincial, and national government
871 and non-government institutions and organisations to assist in monitoring and enforcement.
872 Collectively, this information will help guide more strategic and culturally appropriate
873 conservation effort for sawfishes.

874

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Tables

Table 1. Total number of villages visited, number of interviews conducted, and mean age and age range of interviewees in each region. Ages from a group of interviewees (>3 fishers) are not included

Region	No. villages (No. interviews)	Mean age of interviewees (range)
South Fly Coast	8 (11)	47 (23–72)
Aramia River	6 (6)	39 (27–54)
Bamu River	4 (4)	43 (25–63)
Turama River	8 (8)	35 (17–50)
Kikori River	11 (15)	37 (24–49)
Tiamura River	5 (5)	56 (39–85)

Table 2. Local names for sawfish and types of environment sawfish were reported to be caught in across regions.

Region	Local names for sawfish	Environment type(s) sawfish reported from
South Fly Coast	Gabara, Badiam	Offshore, coastal, estuary
Aramia River	Dibini, Tibini, Walikapi, Poke	Freshwater
Bamu River	Napora, Sawamutu, Baidamo, Suamutu	Coastal, estuary, freshwater
Turama River	Gabora, Sorowaro, Shark (no name), Shargi	Freshwater
Kikori River	Maiwo/Mai'ivo/Mivo (small), Gabora/Gabara (large)	Offshore, coastal, estuary, freshwater
Tiamura River	Love (luv-ay), Poser, Mehere	Offshore, coastal, estuary, freshwater

Table 3. Gear types used by interviewees in each region and number of gillnets reported to be used by fishers. Fishing activity was categorised as targeted (fishing effort applied toward capture of particular species) or non-targeted (fishing effort applied to catch any type of fish). Number of interviewees that provided an answer in each region are shown in parenthesis (*n*). Gear types included in 'Other' were lure (South Fly Coast) and cast net (Kikori River).

Region	Gear types and number of interviewees reporting use						Fishing activity		Range (mean) of gillnets used each day/fishing activity
	Gillnet	Hook & line	Drag net	Basket net	Spear	Other	Targeted	Non-targeted	
South Fly Coast (*n* = 11)	10	6	2	1	1	1	11	0	2–115 (14.5)
Aramia River (*n* = 6)	6	4	0	0	0	0	1	5	1–2 (1.2)
Bamu River (*n* = 4)	4	4	0	1	1	0	1	3	1–5 (2.3)
Turama River (*n* = 8))	7	8	0	0	0	0	1	7	1–9 (3.3)
Kikori River (*n* = 15)	15	4	0	0	1	1	13	2	1–12 (3.9)
Tiamura River (*n* = 5)	3	1	0	0	1	0	5	0	2–10 (6.8)

Table 4. Reasons that interviewees attribute declines in sawfish catch frequency or sizes classes in each region. Increased fishing activity; includes direct reports of overfishing and reports of increased fishing effort due to modern gears replacing traditional gears over time. Change in environment or climate; includes any report related to habitat degradation, such as erosion, sedimentation, increased debris and runoff, increased suspended sediments, and rising sea level. Pollution; mining operation related pollutants. Disturbance; human activities including motorised boats now used to fish and travel, tug boats from logging camps, and oil pipelines. Introduced species; presence of non-native species. Other; reasons which did not fit into any category included responses such as, the fisher used to live elsewhere, fisher now uses a smaller net or less effective gear for sawfish, or referred to sawfish behaviour such as 'they keep to themselves' or stay in deeper water. Number of interviewees that provided an answer in each region are shown in parenthesis (*n*). Some interviewees indicated multiple reasons.

Reasons for decline	South Fly Coast (*n* = 7)	Aramia River (*n* = 3)	Bamu River (*n* = 1)	Turama River (*n* = 3)	Kikori River (*n* = 12)	Tiamura River (*n* = 3)	Total (*n* = 29)
None provided	3			1	2		6 (21%)
Increased fishing activity	1	1			7	1	10 (34%)
Change in environment or climate	3		1		1	2	7 (24%)
Pollution	1	1	1				3 (10%)
Disturbance	1		1		2	2	6 (21%)
Introduced species		1			1		2 (7%)
Other	1			2	1		4 (14%)

Table 5. Prices of meat and fin and the nature of the market products are sold to in each region. Number of interviewees who provided an answer on meat and fin, respectively, in each region are also included. No interviewees in the Turama River reported sale of meat or fin. PGK, Papua New Guinean Kina (1 PGK = ~$0.28 USD, 04/04/2021)

Region	n	Price of meat (PGK) (unit)	Market	n	Price of fins PGK (unit)	Market
South Fly Coast	5	1–10 (piece)	Local	6	1–70 (kg)	Buyer
Aramia River	1	5 (piece)	Local		Not reported to be sold	
Bamu River	1	15–25 (whole)	Local	1	15–25 (kg)	Buyer, logging camp
Kikori River	12	1–15 (piece), 3 (kg), 60–70 (whole)	Local, Fish plant	8	15–20 (per fin), 60–300 (single set), 400–500 (kg), 3 (kg)	Buyer, Fish plant
Tiamura River	5	1–6 (piece)	Local	1	2 (kg)	Buyer

Table 6. Cultural stories and rituals involving sawfish in each region. Number of interviewees that provided an answer in each region are shown in parenthesis (*n*). No interviewees in the Turama River reported cultural stories or rituals involving sawfish.

Region	Cultural story or ritual practice
South Fly Coast (*n* = 11)	1. Historically, large sawfish were perceived as monsters, not so much today though. Today they are considered bad luck to catch, as they may disturb other catch in the net. We generally relocate net if caught. 2. Rostral teeth were used in a gardening ritual whereby a small watermelon or pumpkins were poked with a rostral tooth around the base of the fruit to leave a small mark. This was to enrich the fruit. (From a time a few decades prior when the interviewee lived on the Fly River as a boy). 3. Shark (including sawfish) can be boiled and broth drunk when sick (reported by three separate interviewees).
Araima River (*n* = 5)	1. Men crush up sawfish rostra and perform a dance, which allows them to select any girl they like.
Bamu River (*n* = 4)	1. People will not eat sawfish (or shark in general) with sago or cassava as it would make them sick. 2. Valued as a traditional food source from the river.
Kikori River (*n* = 15)	1. The first time a young man catches and kills a sawfish there is a big celebration with dancing and a big feast. Large sawfish (locally called 'Gabora' or 'Gabara') are consumed in the longhouse†, and only men can eat these large sawfish. 2. The sawfish lives in deep parts of the river and travels upstream at night (light connotation of being 'the giant of the river'). 3. If a fisher catches a sawfish while his wife is pregnant or has a small baby, the baby will regard the sawfish as a friend and will not be able to hunt it. If the fisher catches one in his net and has children, after he touches the sawfish, he must wash his hands before he touches children, or they will get sores on their body or be sick. 4. If a man dreams of a sawfish, it is a sign giving him notice that his wife will have a child, so she will follow custom of not eating sawfish. When the baby is born, the father must catch a sawfish and wash the baby with its fat. Following this, the mother can eat sawfish again, and the child will not develop sores or become sick. 5. Historically, they only wore sawfish rostra to dance in ceremony sometimes. Pregnant women and young children were not allowed to eat sawfish or the baby when born, or as young child, would become sick. 6. Sharks and sawfish when called, used to help boats and canoes move faster and quicker through the water. If men needed to go and fight and travel quickly, they would get into one canoe and call on sharks and sawfish to help them move faster.
Tiamura River (*n* = 5)	1. Rostra are used as a prop in ceremony, where they are held when dancing. 2. Sharks (including sawfish) are boiled with lemongrass and vegetables when sick.

† A longhouse is a large, often elaborately decorated dwelling within a village that females are not permitted to enter. Males would sleep in the longhouse while females slept in smaller family village houses with children. Longhouses were often used as places of ritualistic importance to male culture in PNG. In some regions within PNG, longhouses are still used for these traditional values.

Table.7 Responses on why interviewees would support or be open to supporting conservation of sawfish in their region. Number of interviewees who provided an answer in each region are shown in parenthesis (*n*).

	Aramia River (*n* = 5)	**Bamu River (*n* = 3)**	**Turama River (*n* = 8)**	**Kikori River (*n* = 15)**	**Totals (*n* = 31)**
Future generations	1	0	2	6	9 (29%)
Resource (cultural, food, economic)	2	1	1	4	8 (26%)
Ecosystem health and intrinsic value	1	0	1	8	10 (32%)
Other	2	2	4	3	11 (35%)

Figure captions

Figure 1. Location of villages and fishing camps visited throughout southern Papua New Guinea**.** **South Fly Coast:** 1. Sibidiri Village, 2. Old Mawata, 3. Tureture Village, 4. Oriomo River mouth fishing camp (Kadawa Village), 5–8. Daru (capital of Western Province), 9. Kadawa Village, 10–11. Katatai Village. **Aramia River:** 12. Garu Village, 13. Madila Village, 14. Kewa Village, 15. Kawito Village, 16. Makapa Village, 17. Ali-Bogola Village. **Bamu River:** 18. Bina Village, 19. Wariho Village, 20. Sisiaimi Village, 21. Sasairi Village. **Turama River:** 22. Meagio Village, 23. Masusu Village, 24. Sorobo Village, 25. Sagari Village, 26. Moka 2 Village, 27. Moka 1 Village, 28. Kuri Village, 29. Haivaro Village. **Kikori River:** 30. Kemei Village, 31. Aiedio Village, 32–34. Goare Village, 35. Ivibirri fishing camp (Apeawa Village), 36. Kampo fishing camp (Apeawa Village), 37. Kotoiia-Bari fishing camp (Apeawa Village), 38. Veraibari Village, 39. Evamu Village, 40. Babai Village, 41. Ero Village, 42. Samoa Village, 43. Veiru Village, 44. Omo Village, ○Kikori town. **Tiamura River:** 45. Uaripi 1 Village, 46. Uaripi 2 Village, 47. Kerema (capital of Gulf Province), 48. Sicari fishing camp, 49. Murua Village.

Figure 2. Frequency of gillnet mesh sizes reported to be used by interviewees in each region. Asterisks show the median mesh size, within the range of mesh sizes reported in each region. Number of interviewees who provided an answer in each region are shown in parenthesis (*n*).

Figure 3. A) Frequency of the size class (length) of sawfish reported in each region by interviewees. B) Reported frequency of sawfish catch (any size) in each region. C) Reported retention of sawfishes in each region. D) Reported changes in sawfish catch over time. Number of interviewees who provided an answer in each region for each aspect of data analysis are shown in parenthesis (*n*).

Figure 4. Reported uses of sawfish by interviewees in each region. Number of interviewees who provided an answer in each region are shown in parenthesis (*n*).