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PERSPECTIVE

Maw money, maw problems: A lucrative fish maw fishery in Papua New Guinea highlights a global conservation issue driven by Chinese cultural demand

Yolarnie Amepou[1] | **Andrew Chin**[2,3] | **Simon Foale**[4] | **Glenn Sant**[5,6] | **Olivia Smailes**[2] | **Michael I. Grant**[1,2,3]

[1]Piku Biodiversity Network, National Research Institute, Port Moresby, National Capital District, Papua, New Guinea

[2]Centre for Sustainable Tropical Fisheries and Aquaculture and College of Science and Engineering, James Cook University, Townsville, Queensland, Australia

[3]Faculty of Marine Science and Fisheries, Hasanuddin University, Makassar, Indonesia

[4]College of Arts, Society, and Education, James Cook University, Townsville, Australia

[5]TRAFFIC International, Cambridge, UK

[6]Australian National Centre for Ocean Resources and Security, University of Wollongong, New South Wales, Australia

Correspondence
Yolarnie Amepou, Piku Biodiversity Network, National Research Institute, PO Box 804, Vision City Post Office, Waigani Dr. Port Moresby, National Capital District. Papua, New Guinea. Email: yamepou@pikubionet.org.pg

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Abstract

Fish maw (teleost swim bladder) is a dried seafood product valued highly by Chinese cultures in East Asia, though global supply chains are poorly understood. Here, we describe the rapid development of a fish maw fishery in a low-income nation to illustrate how globalization can affect sustainability. In Papua New Guinea (PNG), fish maw developed into a fishery valued at ~$831,000 USD annually between 2014–2018. Its development has been driven by Asian expatriates, who provide market access and fishing gear to local communities. The highest valued local species, scaly croaker *Nibea squamosa*, has a maximum value of $15,615 USD kg^{-1} (dried) at first-point-of-sale, potentially the highest first-point-of-sale fish maw product globally. Its value has led to high incidental catch rates of threatened species in an area that is a globally significant conservation stronghold. International trade databases need to recognize fish maw as a high value and globally traded product and consider a specific fish maw commodity code to assist nations in identifying emerging fish maw fisheries. Additionally, the Convention on the International Trade of Endangered Species of Flora and Fauna (CITES) could assist in protecting vulnerable fish maw species and facilitate management practices for incidentally caught threatened species.

KEYWORDS
Asian markets, dried seafood products, fish maw, international trade, sustainability, swim bladder

1 | INTRODUCTION

China's Belt and Road Initiative development strategy has led to increased maritime investments and establishment of trade infrastructure in low-income nations (Song & Fabinyi, 2022). This has led to increased exploitation and import of fisheries resources to Chinese markets, although the fisheries sustainability and local livelihood impacts in source nations are poorly understood (Barclay et al., 2019; Song et al., 2022). One increasingly traded product is "fish maw" (teleost swim bladder), a fibrous organ used by fishes for buoyancy control and communication. Dried fish maw is a product mainly valued in East Asia, particularly within Chinese cultures who are the main consumers, and China itself is the largest consumer (Sadovy de Mitcheson et al., 2019). Fish maw is comparable to other luxury seafood items such as sea cucumber and shark fin in the volume, value, and number of countries contributing to global trade (Sadovy de Mitcheson et al., 2019). The value of high-end maw products can range from thousands to tens-of-thousands USD kg^{-1}, while reports exist of exceptional prices; $475,000 USD for a single large Chinese bahaba *Bahaba taipingensis* (Moore, 2012). End uses of fish maw are diverse, but are mostly consumptive, mainly culinary or traditional Chinese medicines (Ben-Hasan et al., 2021; Sadovy de Mitcheson et al., 2019). Among Chinese cultures, fish maw is believed to reflect status, wealth, prestige, and honor and it is comparable to "shark fin" with respect to these same values (Ho & Shea 2015; 2021).

Chinese cultural demand for fish maw has led to development of high value global supply chains, with Hong Kong Special Administration Region (hereafter "Hong Kong SAR") being the main importer and re exporter. Sadovy de Mitcheson et al. (2019) found that 3144–3882 ton (t) of dried fish maw were imported annually to Hong Kong from 2015–2018, from 110 source nations with a value of $264–394 million USD. Croaker (Sciaenidae) maws are the most abundant and generally highest valued, while other common taxa includes Lates perches (Latidae), pufferfish (Tetraodontidae), catfishes (Siluriformes), and pike conger (Muraenesocidae). Certain species possess particularly desirable maw traits (e.g., size, thickness, shape), leading to the development of targeted "fish maw fisheries" (Sadovy de Mitcheson et al., 2019). Owing to the exceptional prices and high demand, fish maw fisheries can be characterized by high and rapidly increasing fishing effort and unsustainability. These fisheries are increasingly linked to impacts on threatened species and negative social impacts for fishers (Ben-Hasan et al., 2021; Constant et al., 2021). For example, the impending extinction of the vaquita *Phocoena sinus* due to targeted illegal fishing in Mexico for totoaba *Totoaba macdonaldi* (Taylor et al., 2017) is a widely known negative consequence of a fish maw fishery.

Most studies have focused on source, trade, and consumption of fish maw, although there is paucity of information on the development and characteristics of fish maw fisheries in low-income nations (Constant et al., 2021). Here, first, we describe the rapid development and characteristics of a fish maw fishery in southern Papua New Guinea (PNG) by drawing on recent literature and anecdotal observations made by the Piku Biodiversity Network (a PNG non-government organization). Second, we examine trade data from the Fisheries and Agriculture Organization (FAO), Hong Kong's Census and Statistics Database (Hong Kong CSD), and United Nations International Comtrade database (UN Comtrade) to contextualize PNG's contribution to the global fish maw trade. Third, we highlight the conservation implications that PNG's fish maw fishery is having on an Indo-Pacific threatened species stronghold. Lastly, we discuss how this PNG case study illustrates a global pattern of emergent unsustainable fish maw fishery impacts. We argue the need for FAO and UN Comtrade to include a fish maw specific category to improve national level trade data, and we discuss the potential role that international agreements such as the Convention on the International Trade of Endangered Species of Wild Flora and Fauna (CITES) could have on achieving sustainable fish maw fisheries with flow on benefits to threatened bycatch.

2 | CASE STUDY: DEVELOPMENT OF THE GULF PROVINCE FISH MAW FISHERY

The Piku Biodiversity Network has been conducting and facilitating research on fisheries and cultural activities in the Gulf Province, PNG, for over a decade. In 2012, various fish species were being sold whole in small-scale markets for mean prices of $0.3–5.8 USD (1 Papua New Guinea Kina = $0.29 USD) (Eisemberg & Berra, 2016). In 2014–2015, two commercial seafood buyers, owned by Chinese expatriates, commenced operations in the Kikori District, coinciding with the emergence of a fish maw fishery. Companies made arrangements with local fishing communities whereby gillnets, boats, outboard engines, and side (insulated cooler boxes) were provided to fishers on the condition that fishery products were sold back to them (this practice continues presently) (Grant et al., 2022; Grant et al., 2021b). No knowledge of prices for commercial fish products exists for this early period. In 2018–2019, the concerted targeting of stone fish *Nibea squamosa* and barramundi *Lates calcarifer* for fish maw was first documented (Grant et al., 2021a; Grant et al., 2021b). Maximum dried maw prices (first-point-of-sale) at this time were

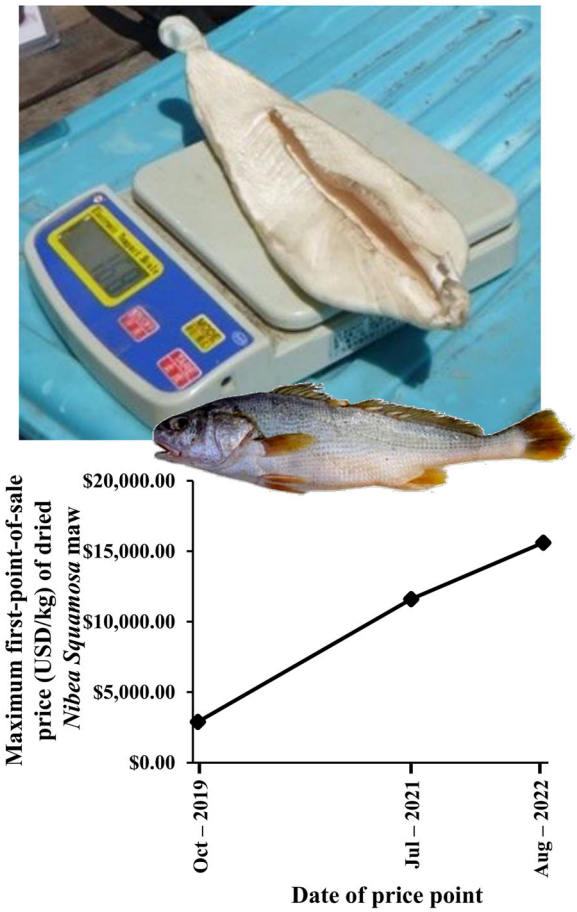

FIGURE 1 (Top) harvested scaly croaker "stone fish" *Nibea squamosa* maw with wet weight of 168 grams. Reportedly, dried maw weight is about half wet weight. (Bottom) Maximum local value of dried *N. squamosa* maw from 2019 to 2022 in the Gulf Province.

$2900 USD kg^{-1} for *N. squamosa*. Owing to COVID-19, field activities were restricted from 2019 to 2021. By July 2021, the maximum *N. squamosa* maw price had reached $11,600 USD kg^{-1} (Figure 1).

In September 2021, the National Fisheries Authority announced a closure to new license applications for fish maw, citing the occurrence of illegal, unregulated, and unreported activities pertaining to this fishery (https://www.fisheries.gov.pg/_files/ugd/2c6676_269e9667735a4a08b73e5342a8c05943.pdf). This closure is in place until a fish maw management plan is developed and to protect presently operating businesses. At the time of the closure, six companies in the Gulf Province were associated with fish maw, and collectively there were 15 active buyer licenses (Figure 2). Each of the companies are owned by Asian expatriates. Licensed buyers associated with each company include at least one expatriate, while other licensees are local community members. Most of the companies presently engaging in fish maw trading were licensed in 2017–2019. This included the opportunistic adaptations of several companies that trade in other products or services (e.g., groceries and accommodation) to also engage in fish maw trade.

In August 2022, product price lists were obtained from public notice boards at two companies. The maximum *N. squamosa* dried maw price was $15,615 USD kg^{-1} at KW Veraibari Seafood (maw > 130 g), while maximum price of *N. squamosa* maw at Kikori Seafood LTD was $8120 USD kg^{-1} (maw up to 100 g). Black jewfish *Prontonibea dicanthus* maw had a maximum value of $1547 USD kg^{-1} (maw > 300 g) at Kikori Seafood LTD (Supplementary Information). Meanwhile, fish meat was $1.5 USD kg^{-1} for *L. calcarifer*, and $0.6 USD kg^{-1} for *N. squamosa*. Of the two species with meat and maw prices provided, the maximum ratio of meat:maw price was 1:26,025 for *N. squamosa*, and 1:1718 for *P. dicanthus*.

3 | VOLUME AND VALUE OF PNG'S FISH MAW TRADE

PNG fish maw export data were taken from the FAO (available data 2014–2020), while data on fish maw imports from PNG were taken from UN Comtrade (China, Hong Kong SAR and Singapore only) and Hong Kong CSD for 2014–2021. In both the FAO and UN Comtrade databases, fish maw is listed within an amalgamated commodity, hereafter "amalgamated fish maw commodity," while Hong Kong CSD has a fish maw specific commodity (Supplementary Information).

PNG's reported exports of the amalgamated fish maw commodity to FAO increased from 0 in 2013, to 13.61 metric tonnes (mt) in 2019, and declined to 3.83 mt during the height of the COVID-19 pandemic (Figure 3). The largest increase in volume (600%) occurred between 2017 (2.0 mt) and 2018 (12.0 mt), with export value peaking at $831,000 USD in 2018 (Figure 3). In 2019 and 2020, FAO trade partner countries indicated that China Hong Kong SAR (primary) and Singapore (secondary) were the largest importers of PNG's amalgamated fish maw commodity (Supplementary material).

Hong Kong CSD and UN Comtrade import data had variable correspondence with PNG's FAO exports (Figure 3). The reported import values corresponded to PNG's reported exports values for 2014–2017, and 2019. This indicates that most of the amalgamated fish maw commodity in these years was imported by China, Hong Kong SAR. In other years import and export data did not correspond, highlighting issues in the transparency of traded products within the amalgamated fish maw commodity. For example, in 2015 17.7 mt of the amalgamated fish maw product was imported by China, Hong Kong SAR, though the lower import value ($267,689 USD) indi-

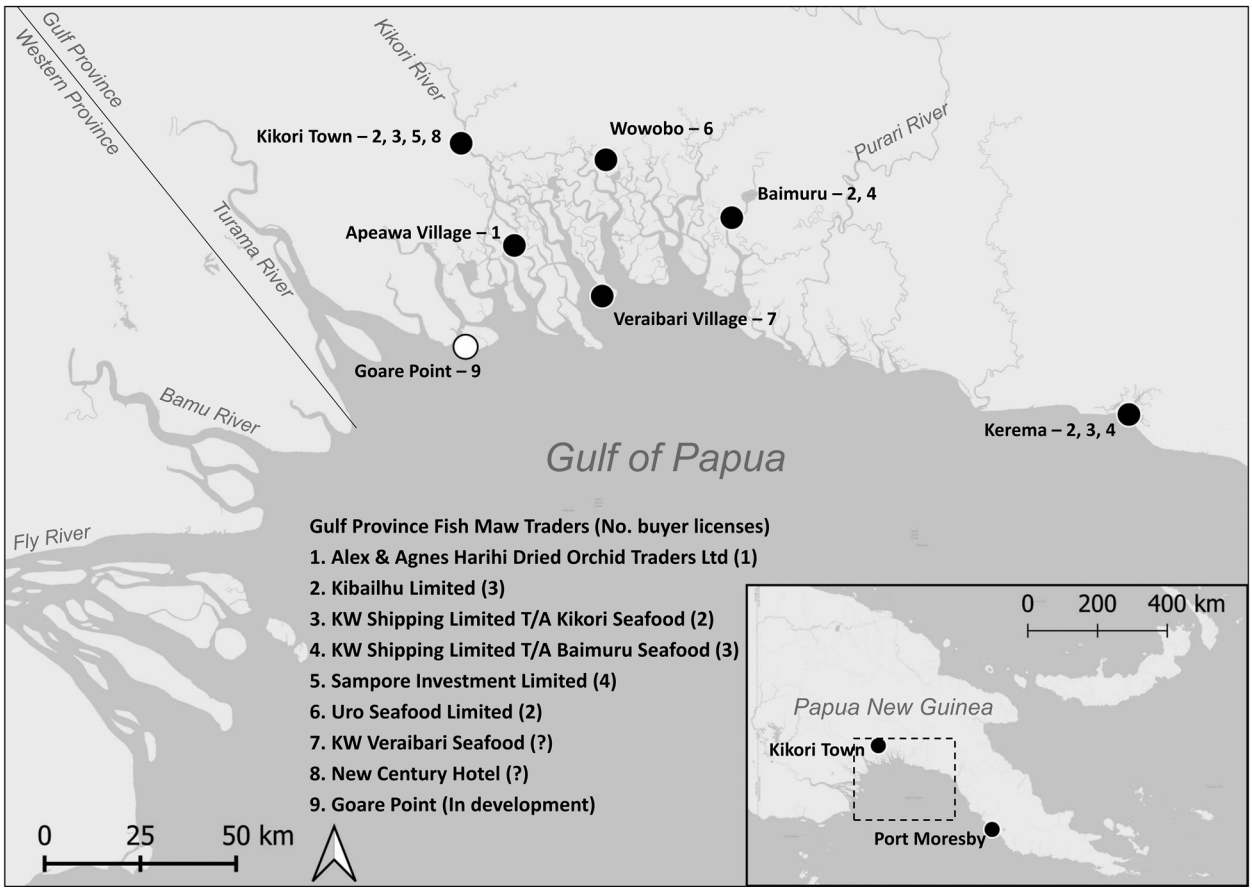

FIGURE 2 Location of commercial fish maw buyers in Gulf Province. Companies engaged in the fish maw trade are listed and the sites of their business operations are given in parenthesis. Number of buyer licenses associated with each company are also given.

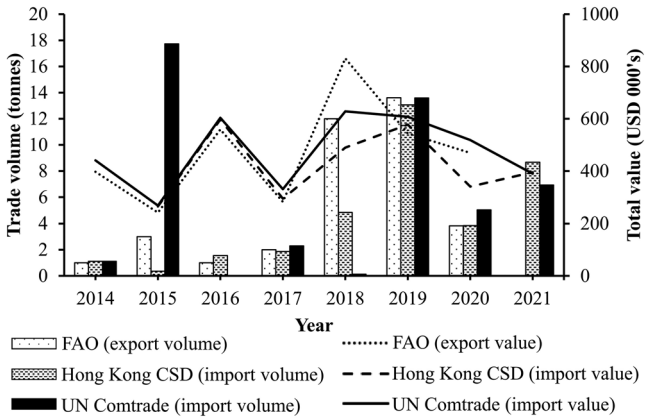

FIGURE 3 Fish maw volume and value statistics for PNG exports (FAO, FishStatJ database; 2014–2020), China, Hong Kong SAR imports (Hong Kong Census and Statistics Database; 2014–2021), and UN Comtrade imports for China, Hong Kong SAR and Singapore (United Nations International Trade Statistics Database; 2014–2021).

cated this only included fish maw in part. This volume is not represented in FAO export data, which in theory should show equal or higher volumes and values to amounts reported on Hong Kong CSD and UN Comtrade.

In the context of the global fish maw imports by China, Hong Kong SAR, PNG's contribution ranged from 0.01% to 0.40% during 2015–2021, with the greatest contribution occurring in 2019. PNG's contribution by measure of value ranged from 0.1% to 0.22%, with the greatest contribution occurring in 2016. Reported values for price kg^{-1} varied considerably with respect to the global average. In 2015, the import price kg^{-1} from PNG was 862% higher than the global average, while in 2019 the import price from PNG was 54% lower than the global average (Table 1). However, we suggest these values reported to the FAO are an underestimate, as reported values do not appear to reflect prices being reported by fishers on the ground (Supplementary Information).

4 | CONSERVATION IMPLICATIONS OF FISH MAW FISHERIES IN PNG

The rapid development of PNG's fish maw fishery is having large impacts on its populations of threatened

TABLE 1 Volume and value of fish maw imports for all countries (global) and Papua New Guinea as reported on the Hong Kong Census and Statistics Database.

	2015	2016	2017	2018	2019	2020	2021
Global							
Volume (mt)	3144.06	3319.77	3272.05	3882.08	3294.18	3175.71	3460.91
Value (USD 000′s)	$264,159	$266,861	$262,202	$391,521	$316,804	$279,881	$261,377
Price kg^{-1}	$84.02	$80.39	$80.13	$100.85	$96.17	$88.13	$75.52
Papua New Guinea							
Volume (mt)	0.37	1.56	1.87	4.83	13.07	3.85	8.67
Value (USD)	$264,346	$596,975	$294,284	$489,326	$577,484	$340,273	$395,308
Price kg^{-1}	$724.23	$383.91	$157.04	$101.25	$44.20	$88.50	$45.62

Note: Only data for the commodity 03057210, fish maws, dried, was included (available range was 2015–2021). Metric tonnes, mt; kilogram, kg.

marine megafauna. Southern PNG has been identified as a stronghold for threatened Indo-Pacific sawfishes (Pristidae) and river sharks *Glyphis* sp. (Fordham et al., 2018; Grant et al., 2021a). Other incidentally caught elasmobranchs in elevated extinction risk categories (Endangered or Critically Endangered) include three hammerhead sharks (winghead *Eusphrya blochii*, scalloped hammerhead *Syphyrna lewini*, and great hammerhead *Syphyrna mokarran*), giant guitarfish *Glaucostegus typus*, and bottlenose wedgefish *Rhynchobatus australiae* (Grant et al., 2021a). It is likely that the Gulf of Papua region and associated rivers would qualify for several recently produced Important Shark and Ray Area criteria (Hyde et al., 2022). Additionally, southern PNG hosts an IUCN Important Marine Mammal Area, with two vulnerable inshore dolphin species, Australian snubfin dolphin *Orcaella heinsohni*, and Australian humpback dolphin, *Sousa sahulensis*, known from the area (Parra et al., 2017a; Parra et al., 2017b). Southern PNG is an important part of the Endangered pig-nosed turtle *Carettochelys inscuplta* range (Eisemberg et al., 2018), while leatherback turtles *Dermochelys coriacea* and dugong *Dugong dugong*, both listed as vulnerable, are also present.

The emergence of the fish maw fishery has rapidly increased pressure on these species, and now threatens PNG's regional biodiversity heritage value. Sawfishes are already locally depleted (Grant et al., 2021b), while river sharks and *E. blochii* are currently being caught in large volumes (Grant et al., 2022; Grant et al., 2021a). Grant et al. (2022) recently observed the two main target fish maw species (*N. squamosa* and *L. calcarifer*) to constitute 22% of landings, while elasmobranchs constituted 49% of landings. In the Western Kikori River Delta, a single fish maw fishing community landed 1112 elasmobranchs over four months, 97.1% of which were from species listed as threatened on the IUCN Red List. These sharks and shark-like-rays are usually finned, though meat is not commonly used for consumption or sale (Figure 4). Owing to significant increases in fishing effort due to fish maw, shark and ray landings and the volume of harvested fin have increased from pre-fish maw fishery levels. This includes CITES Appendix I (Pristidae) and II (e.g., Carcharhinidae, Rhinidae, Sphyrnidae) listed species. Furthermore, 69 inshore dolphin mortalities in the fish maw fishery were recorded from November 2021–May 2022 (I. Beasley, Unpubl Data). These species occur in small, localized populations, indicating that the present fisheries mortality presents a significant local extinction risk. The fish maw fishery also threatens turtles, with the first observations of entangled *D. coriacea* observed in 2022, while capture in gillnets is an ongoing issue for *C. inscuplta* (Eisemberg et al., 2015).

5 | GLOBAL INSIGHTS FROM PNG'S FISH MAW FISHERY

The present case study highlights the rapid development of a high value fish maw fishery, driven by Chinese cultural demand. In five years, fish maw developed into a national commodity worth over $800 000 USD annually (FAO value). The Gulf Province fish maw fishery is being driven by Asian expatriates facilitating steep increases in on-the-ground fisheries pressure and controlling value and export networks. Of concern is their supply of high-capacity fishing gears to local communities under leasing arrangements, and financial incentives for fishers to target the largest length classes. The engagement of locals in the fish maw fishery is further driven by prevalent issues with poverty, education standards, and general lack of alterna-

FIGURE 4 On February 3, 2020, 51 discarded carcasses were observed on the beach of a single fishing village community. Among these carcasses were five endangered narrow sawfish *Anoxypristis cuspidata*. All sharks and shark-like-rays had been finned. A large king threadfin salmon with only its swim bladder harvested (for fish maw trade) was also observed among the carcasses.

tive livelihood options (e.g., Allen et al., 2005; Wiltshire et al., 2020; Magury, 2022).

Much of the globe's fish maw product is sourced from low-income nations with limited fisheries management (Ben-Hasan et al., 2021; Constant et al., 2021). This is the case in PNG's Gulf Province. There is presently no management of PNG's fish maw fisheries, and consequently there is a lack of data on volume, trade, spatial scale, the economic and social impacts of fisher communities, and there are no population status indicators for target and incidentally caught species (Grant et al., 2021a). The absence of a fisheries management plan means there is no impetus for companies or associated fish maw buyers to record transaction data (purchase volumes and value) or abide to any other information lodging requirements that would ordinarily assist managers. As such, along with threatened species issues, there are serious concerns for the sustainability of target species, which lack information to inform sustainable harvest strategies (Grant et al., 2022; Grant et al., 2021a). It is known that croakers (*N. squamosa* and *P. diacanthus* in the present study region) are generally slow growing and vulnerable to over exploitation (Cheung et al., 2005; Kinch, 2006). The increasing global value of fish maw has driven the rapid expansion of croaker fisheries in neighboring Queensland, Australia, causing fisheries managers to enact a regulation that whole fish (with swim bladder naturally attached) must be landed and a Total Allowable Catch of 26 mt has been imposed, which is typically reached within the first few months of the year (following commencement of annual fishery allotment). The absence of similar fisheries management regulations in PNG risks creating a scenario whereby companies purchasing fish maw can exploit the fishery resources in the highest capacity possible, before requisite information becomes available for managers to enact controls. The decision of the National Fisheries Authority to close new fish maw trading license applications in response to a clearly unsustainable fishery is a positive step, while it deliberates on management options.

Given the exceptional prices of fish maw on the global market, it is possible that fish maw traders are intentionally targeting high value maw species in low-income nations with limited fisheries management such as PNG, as rapid and unregulated exploitation is possible. The present case study has illustrated the need for the international community to recognize the sustainability, conservation, and social risks of fish maw fisheries, and develop systems for the early detection of detrimental exploitation in low-income nations that lack management resources and capacity. This will also facilitate international assistance for low-income nations in developing national level policy and providing resources and capacity to effectively manage and monitor their fish maw fisheries.

6 | MANAGEMENT PRIORITIES FOR THE GLOBAL FISH MAW TRADE

The collection of catch data for species entering the fish maw trade is limited, but given fish maw is primarily traded internationally, international trade databases offer a good indicator and monitoring point to infer catch. Historically, in the development of data categories for monitoring fisheries trade there appears to have been priority given to high value products that drive fishery production, such as meat in the case of teleosts. Therefore, lower value by-products were amalgamated into single categories, such as the case with fish maws in FAO and UN Comtrade categories. Owing to changing demand in global markets, this amalgamation is inappropriate for fish maws, which are increasingly driving fishery effort, such as in the present case study. The present ambiguity of global fish maw export and import statistics limits our ability to understand trends in global trade and value, inhibiting our

ability to globally manage fish maw and its associated fisheries. Presently, the most reliable data source of fish maw trade is Hong Kong CSD (the only database with a specific fish maw commodity code), although this potentially means that contributions of other fish maw market hubs (e.g., Vietnam, Singapore) are being overlooked. There is now sufficient evidence that concerted high value fish maw fisheries exist, and that they are generally poorly understood and managed (Ben-Hasan et al., 2021; Sadovy de Mitcheson et al., 2019). There is an opportunity for international trade databases to collate fish maw data as a single product category, preferably at a species level. This will assist in (1) identification of emerging fish maw fisheries; (2) add much needed transparency to the global trade and implicit species; and (3) facilitate management actions at the appropriate national, regional, or international scales.

Benefits may also be achievable from international trade agreements such as CITES. Species listed within Appendix II of CITES can be traded when accompanied with export permits issued by the exporting country that indicate legal acquisition (Legal Acquisition Finding) and non-detrimental harvest to the population (Non-Detriment Finding). Given the extinction risk for a number of species harvested for international trade of their fish maws (Ben-Hasan et al., 2021; Sadovy de Mitcheson et al., 2019), additional species may meet the listing criteria for CITES Appendix II. This could be an effective policy tool to facilitate improved national management and monitoring of targeted fish maw fisheries, and would likely have positive flow on effects for incidentally caught threatened species. Further, as we have observed in our case study in PNG, fish maw trade may be facilitating the capture and trade of species already listed on CITES Appendices I and II. We acknowledge that such listings would require a concerted effort from the international community to assist implicated low-income nations to meet CITES obligations and supplement affected fisher livelihoods.

Ultimately, the global fish maw trade represents a complex challenge, but without skilled assessment and management, the risk of negative impacts could be significant. Chinese cultural demand for luxury dried seafood products is a sustainability and conservation challenge that has arisen many times before (Fabinyi, 2012; Fabinyi & Liu, 2014). It is likely that lessons can be learnt from the international trade management of other products, to set in motion policy and management actions that will facilitate targeted sustainable harvest of fish maw and conserve species that are incidentally caught in these fisheries.

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DATA AVAILABILITY STATEMENT

The data that supports the findings of this study are available in the supplementary material of this article

ORCID

Michael I. Grant https://orcid.org/0000-0002-6127-8968

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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