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CONTRIBUTED PAPER

Internet trade of a previously unknown wildlife product from a critically endangered marine fish

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Abstract

Online research methods are increasingly used in conservation science to monitor and collect data on online wildlife trade. Shark-like rays (Rhinopristiformes) are among the most threatened vertebrates, prized for their high-value fins while other uses for their derivatives are largely unrecognized in the literature. The bowmouth guitarfish (*Rhina ancylostomus*) is characterized by ridges of enlarged thorns, sometimes sold as amulets. Listed on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Appendix II, the thorn-market has been ignored and undocumented. Using systematic, retrospective online searches, we recorded 977 bowmouth-derivatives for sale. In our global and multi-lingual scope, 97% of products were offered from Thailand, despite prohibited trade. 98% of all products were thorns (USD3-300) and sold alongside high-profile CITES-listed taxa (e.g., tiger claws). Consistent advertisements from 2012 revealed a previously unquantified trade of an often-neglected marketplace in elasmobranch research. Our findings offer insight into the drivers of the thorn trade, potentially rooted in cultural beliefs. Our accessible research methods can be applied internationally and across species, providing quantitative and qualitative insights on aspects of the wildlife trade of a critically endangered fish. Continued monitoring of online markets, like this study, is necessary to fill critical gaps for informed policy and species-specific management.

KEYWORDS

bowmouth guitarfish, CITES, elasmobranch, policy, shark, social media, Southeast Asia, wedgefish

1 | INTRODUCTION

The legal wildlife trade is worth an estimated USD 323 billion (Berec et al., 2018) and includes trade for subsistence, luxury items, traditional medicine, cultural symbols (e.g., amulets), and curios (Warchol, 2004). Sustainable wildlife trade, or trade that does not lead to the long-term decline of biodiversity (CITES, 2020a) can

support communities through capital gain and as nourishment, but unregulated trade has led to increased global extinction risks for many taxa of plants and animals. Unsustainable exploitation has led to drastic species declines (e.g., sharks for their fins; Fields et al., 2017) and fisheries collapse (e.g., sea cucumbers; Louw & Búrgener, 2020). The Convention on International Trade in Endangered Species of Flora and Fauna (CITES) is a

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legally binding international agreement with 183 Parties that regulates the trade of over 38,700 species, listed on one of three appendices (CITES, 1973). Over 90% of species are listed on Appendix II, permitting sustainable international trade, whereas an Appendix I listing prohibits trade (other than in specific circumstances, e.g., scientific research). Despite national and international laws and regulations, protected species continue to be traded at unsustainable levels (Ferrette et al., 2019).

1.1 | Online illegal wildlife trade and research

The illegal wildlife trade ranks among the top five transnational crimes (Esmail et al., 2020). Monetarily valued at > USD 20 billion annually (Alexander & Sanderson, 2017), international illegal trade is increasingly facilitated by globalization and the growing online marketplace (D'Cruze & Macdonald, 2016; Lavorgna, 2014). The global reach of online marketplaces was revealed in a 2008 survey of publicly available websites from over 7000 listed auctions and advertisements (IFAW, 2012). Ivory was the dominant product (73%), prompting the auction site eBay to ban ivory trade on its platform in the same year (IFAW, 2012). In 2018, the Coalition to End Wildlife Trafficking Online was launched, including 34 of the biggest online marketplace and technology companies (e.g., eBay, Facebook, Alibaba) accounting for nine billion global users (Coalition to End Wildlife Trafficking Online, 2020). Wildlife trade is easily and increasingly facilitated by social networking sites (SNSs, e.g., Facebook), where users can easily set up profiles free of charge, and both live animals and their derivatives are easily searchable (Yeo et al., 2017). Despite commitments to monitoring and enforcement, illegal online trade is openly available across platforms and is a serious conservation threat (Yeo et al., 2017).

Online research methods are increasingly applied to conservation science to study the illegal wildlife trade and provide data for neglected markets, countries, and species. Recognizing the necessity to study online trade markets, researchers have gathered quantitative and qualitative data, spanning taxa from orchids to live wild animals, and wildlife derivatives such as bear claws and ivory (Di Minin et al., 2019; Hinsley et al., 2016; Nijman et al., 2019). Marine fishes have long been regarded as commodities rather than wildlife and are overlooked in wildlife trade research (Aylesworth et al., 2020; Vincent et al., 2014). While buying and selling terrestrial wildlife products online is quite well established, the extent of online trade in marine fishes, to our knowledge, remains largely unquantified and under-researched. With only one study

on ornamental freshwater and marine fish conducted in Brazil (Borges et al., 2021), and a single gray literature study on sawfish (Pristidae) rostra (McDavitt, 2004), elasmobranchs (sharks and rays) are especially poorly represented in online trade research. A notable exception to this is a recent study that used social media postings to delineate the distribution of a critically endangered, poorly known ray species, the clown wedgefish (*Rhynchobatus cooki*) (McDavitt & Kyne, 2020).

1.2 | Elasmobranch trade

Elasmobranchs face much higher extinction risks than most other vertebrates and are undergoing drastic declines, largely as a result of overfishing, bycatch, and habitat loss (Dulvy et al., 2021).

The shark-fin trade is associated with global declines (Fields et al., 2017) and trade in some of the most valuable elasmobranch species is now regulated by CITES, however, unreported trade of listed species remains common (Cardenosa et al., 2018). Traceability of products is complicated by the potential of multiple supply chains owing to the range of tradeable products potentially derived from one individual, from luxury items (e.g., fins), subsistence (e.g., meat), curios (e.g., jaws), and amulets (e.g., vertebrae) (Dulvy et al., 2017; Haque & Spaet, 2021). Once processed or removed from the carcass, some parts may require additional expertise or tools to reveal the species (e.g., DNA testing of shark fin; Wainwright et al., 2018). The ability to use morphological identification, for example through a guidebook, provides a low cost and accessible method of monitoring and enforcement of wildlife trade regulations (Barone et al., 2022) but this approach is obviously restricted to products that are visually distinctive, where the animal part product resembles the species form.

1.3 | Bowmouth guitarfish (*Rhina ancylostomus*)

The bowmouth guitarfish, is a highly distinctive species of wedgefish (Rhinidae), morphologically unique from most other wedgefishes by its broadly rounded head and characterized by ridges of pyramidal-shaped, enlarged denticles [thorns, (Figure 1)]. Wedgefishes are shark-like rays in the order Rhinopristiformes and are one of the most endangered vertebrates (Kyne et al., 2020; Moore, 2017). In 2018, nine of the 10 evaluated species of wedgefishes were listed as critically endangered by the International Union for the Conservation of Nature (IUCN). Coastal batoid fins in trade are often from wedgefishes (Fields et al., 2017) and in 2019, all wedgefishes were added to CITES



FIGURE 1 Distinctive medial (foreground) and orbital thorns from a bowmouth guitarfish (*Rhina ancylostomus*). Image credit: J. Giles (Fin Forensics, LLC).

Appendix II (CITES, 2020b). Bowmouth are the wedgefish with the widest geographic distribution, found across the Indo-West Pacific from South Africa to Japan, and have undergone drastic declines of >80% in the past few decades (Kyne et al., 2019). Bowmouth reach a maximum total length (TL) of 270 cm and give live birth to 2–11 pups, 46–50 cm in TL (Last et al., 2016) but very little is known of their life history traits, or indeed their basic ecology. For example, this is a species often associated with the seabed and coral reefs, and generally occurring at depths up to 70 m (Kyne et al., 2019). The 2018 capture of one individual in the open ocean with a school of tuna (Forget & Muir, 2021), however, indicates how little understood these rare and endangered fish are. Species-specific trade data is also limited, with inferences from elasmobranch landings data and elasmobranch fin market surveys given their exceptionally high value fins (Moore, 2017), which can fetch up to USD 964/kilogram (Jabado, 2018, 2019). The protein-rich meat of the bowmouth is consumed by some communities when landed in the coastal states of its range, as well as being exported dried (Nasir & Afsar, 2020).

1.4 | Thailand and the wildlife trade

Southeast Asia is at the epicenter of wildlife trade (Krishnasamy & Zavagli, 2020) and illegal online trade is spreading throughout the region. Considered the hub of the illegal wildlife trade, the increase in online trade is especially high in Thailand, evident by arrests of sellers conducting business on platforms like Facebook (Phassaraudomsak & Krishnasamy, 2018). Thailand is also the world's largest exporter of fins (FAO, 2018) and the sixth largest wildlife trader (Andersson et al., 2021).

As a range state to bowmouth, Thailand has enacted national legislation to protect it. The Wild Animal Preservation and Protection Act (WARPA) is Thailand's main wildlife legislation, introduced in part to provide implementation and enforcement for CITES-listings (Phassaraudomsak et al., 2019), legislation that covers both physical and online trade. Possession of a WARPA species without a license is punishable by a fine of over USD 30,000 and a maximum prison sentence of 10 years (Phassaraudomsak et al., 2019). Reported as increasingly rare in Thai waters 20 years ago, the bowmouth's distinctive thorns are processed into jewelry (BOBLME, 2012) offered for sale in markets and associated with protective powers. In 2018, the bowmouth became a protected species, prohibiting landings and requiring all persons in possession of bowmouth products to register them by November 30, 2018. Past that date, manufacturing of bowmouth products is prohibited and trade is only possible for products with proof of registration. Aside from anecdotal mentions to the decorative use of their thorns in jewelry (BOBLME, 2015; Fowler et al., 2002; Moore, 2017), which are associated with protective powers (S. Arunrugstichai, e-mail, June 18, 2020) the trade in bowmouth thorns (and most bowmouth derivatives) is unquantified (Moore, 2017). The scale and scope of the thorn market is unknown, representing a critical knowledge gap on an insufficiently understood and critically endangered species.

1.5 | Study focus and objectives

Monitoring online trade captures a critical element of trade which would otherwise be unaccounted for with physical studies alone. Here, we expand upon a rapid assessment online search methodology (Phassaraudomsak & Krishnasamy, 2018) to perform a multi-platform search approach to quantify the economic value and online trade of bowmouth guitarfish, with a focus on the characteristic enlarged thorns. Specifically, our study objectives were to (1) characterize the online trade of bowmouth products by assessing product types, (2) quantify the volume of trade, and (3) identify spatial and temporal trends of sellers and online platforms. Understanding the nature of the online sale in bowmouth thorns, and characterizing the derived products from this data poor, critically endangered fish, will improve estimates of the volume of bowmouth involved in trade and lay the groundwork to inform strategies on sustainable trade. Using unobtrusive and accessible research methods, results here have uncovered a previously ignored component of the market for a fish that is data poor and likely on the verge of extinction.

2 | METHODS

2.1 | Ethics statement

The study design was approved by Bangor University Ethics Committee (approval code: COESE2020JP01A). As this research involved collection of data on potentially illegal activity, the conditions of the approval did not permit active involvement with buyers or sellers. As a result, we did not request to join private groups, post comments, or attempt to purchase items listed for sale. Personal information was not collected during sampling, but user-names (which are non-confidential online pseudonyms) of buyers and sellers were collected to prevent data duplication and to distinguish between unique sellers.

2.2 | Pilot study

To establish the presence and extent of the online trade in bowmouth products, we first ran a pilot search to refine both the online search protocol, the study scope, and develop a standard approach to identifying and classifying bowmouth products. We applied the protocol to different search engines (Google Chrome, Mozilla Firefox, DuckDuckGo, Microsoft Edge) using the “All” function and separately with the “Image” function. Searches were run using “*Rhina ancylostoma*” and on a list of 64 common names of *R. ancylostomus* from 27 countries in 29 different languages and dialects obtained from sources such as Fishbase (2013). This revealed that product advertisements were predominately in Thai, as well as English and Simplified-Chinese. The full study search protocol was performed using *Rhina ancylostoma* and the common names for *R. ancylostomus* in those languages (Table 1). Although searches were performed using the

widely used synonym of *Rhina ancylostoma* (Kyne et al., 2019; Last et al., 2016), we recognize that the accepted name is *R. ancylostomus* (Eschmeyer, 1998; Fricke et al., 2022; R. Fricke, e-mail, November 22, 2022).

2.3 | Identification of bowmouth parts

While intact bowmouth (and their enlarged thorn rows in situ) are highly distinctive, we acknowledged the possibility of misidentification or misreporting by traders. Before undertaking the full search protocol, we reviewed how identifiable bowmouth thorns were in relation to other taxa by consulting with global authorities on elasmobranch taxonomy and the curator of fishes for the Natural History Museum, London (P. Last, W. White, O. Crimmen, pers. comms.), and considered images including scutes of sturgeon (Acipenseridae), and thorns of skates (Rajidae) and stingrays (Dasyatidae). From this, we concluded the morphology and size of bowmouth thorns is highly distinctive with minimal potential for misidentification with other animal parts. To estimate the average number of thorns on an individual bowmouth, we enumerated enlarged thorns from images of 52 individual bowmouth (Figure 2).

2.4 | Online search protocol for traded bowmouth products

Searches were conducted over a 21-day sampling period in June and July 2020. Time spent collecting data was limited to 3.5 h per day. All listings, regardless of date posted, were recorded and the cumulative number of records tracked (Table S1).

Site selection of SNSs (Facebook, Twitter, and Instagram) was based on their global popularity. Online advertisements

TABLE 1 Search terms for bowmouth guitarfish (*Rhina ancylostomus*) used to search online for bowmouth products, June–July 2020 (advertisements dated 2012–2020).

Search term	Language	Approximate English	Reference
<i>Rhina ancylostoma</i>	Latin. Widely used synonym of accepted name		Last et al., 2016; Kyne et al., 2019
กระเบนท้องน้ำ	Thai	Stingray	M. McDavitt, e-mail, March 11, 2020
แหวนเงิน หัวกระเบนท้องน้ำ	Thai	Stingray with belly ring	Google suggestion
โรนิน, กระเบน ท้อง น้ำ	Thai	Ronin, stingray water belly	BOBLME, 2015
Ronin	Thai	Stingray	Fishbase, 2013
圓犁頭鱈	Simplified Chinese	Bowmouth/round pike	Wikimedia, 2019
波口鰲頭鱈	Simplified Chinese	Horseshoe crab	Lack & Sant, 2012
Bowmouth guitarfish	English	-	Fishbase, 2013

Note: The search terms were selected following a pilot study conducted using *Rhina ancylostoma* and 64 common names in 29 languages.



FIGURE 2 Bowmouth guitarfish (*Rhina ancylostomus*) at a small fishing village in Sarawak, Malaysia on display at a fishing stall. The numbers indicate the enlarged denticles (thorns), very prominent on this specimen, surrounded by smaller tubercles. Numbered thorns represent what would be desirable thorn quality in the bowmouth thorn trade. Image credit: Nick Jansen/Global Gibbon.

were identified by entering pre-identified search terms (as per Phassaraudomsak & Krishnasamy, 2018; Table 1). The Facebook searches were restricted to Facebook Marketplace (a buy/sell forum) and general Facebook searches (accessed through the main page); Facebook group searches returned private groups only and not pursued further (as per Ethics Approval). No advertisements were found during searches on Instagram or Twitter.

The image search function of the Google search engine returned the most accurate results in the pilot study, so we applied the same approach as above with the SNSs to search Google images. Bowmouth-relevant search image hits were systematically selected and used to navigate to the original webpage containing the image, at which point the weblink was saved with screenshots. If an image led to a site with multiple items for sale, we recorded the site and searched within it until listings appeared to be exhausted; this process was then repeated. Of note, Google searches did not yield any SNS results, which reduced issues regarding duplication. Nevertheless, at the end of each day, all records were checked for duplicates and removed as necessary. Only those advertisements that included an image of the product were extracted and only minimum counts of items were recorded (see Krishnasamy & Stoner, 2016); where an advertisement presented multiple items, only those which included a description in the heading were recorded. For the purposes of analysis, individual products are referred to rather than advertisements.

Search results were categorized by online platform type: (1) Electronic commerce (E-commerce, e.g., Lazada, Shopee) which refers to sites that support the activity of buying or selling products, including online malls; (2) auction sites including general (e.g., eBay) and amulet-specific sites (e.g., Uamulet); and (3) SNSs or social media.

2.5 | Data extraction

Each bowmouth product found was assigned a unique product code and cross-referenced with a web-clip to retain a still image and link to the original advertisement. Where available, data recorded from each search hit included: site type; country of buyer; country of seller; province or state of seller; product type; size of thorn; price in local currency; year first posted; sale date. Qualitative data were also extracted from the listing, such as mentions of cultural relevance, legality of trade (both regional and international), and conspicuous reference to other potentially illegal wildlife items, like tiger and elephant ivory related products. Product prices were converted to US dollars (USD) using Oanda (<https://www1.oanda.com/currency/converter/>) on July 8, 2020.

2.6 | Product classification

The type of product for sale was recorded during data extraction as “raw” (no added materials) or “worked” (e.g., mounted on a jewelry base). When the products (whether raw or worked) included bowmouth thorn, these were further classified. Bowmouth thorns occur in distinct strips on the dorsal surface, above the orbit (“orbital”), on the dorsal midline (“medial”), and on each shoulder (“scapular”). Only orbital and medial thorns provide enlarged, saleable thorns, with the latter generally providing a higher number of these. Saleable (i.e. trade quality) thorns occur on both the orbital and medial strips and these strips are easily distinguishable from each other, with a higher number of enlarged thorns generally being present on the medial strips (Table S2). Based on a visual assessment of the thorn type in the product, strip type origin was recorded, thorns were coded as either medial, orbital or in cases of uncertainty, medial/orbital.

2.7 | Size and price of thorns

To establish the relationship between the size of bowmouth thorns and the price fetched, Spearman's Rank correlations were performed for single raw thorns and

single worked thorns separately. Thorn size (cm) as measured by the length of the basal plate, was extracted from the product listing. Single worked thorns were without exception mounted as jewelry rings. The value of mounted material was not considered in this analysis and any rings containing more than one thorn were excluded.

For the dominant seller location (Thailand), we determined whether online trade changed in relation to the possession ban under WARPA. We did this by comparing the mean thorn price estimates *pre-registration* (before November 30, 2018) and *post-registration* (November 30, 2018 onwards) using a Wilcoxon Signed Rank test. Dates used were the most recent date posted on the listing, or date of sale when available. All data summaries, visualizations, and analyses were performed in R Version 4.0.2 (R Core Team, 2021).

2.8 | Evidence of de-thorning

To better understand and provide qualitative context on the extent of bowmouth thorn removal, we contacted several researchers throughout the bowmouth's range and requested anecdotal and photographic evidence of bowmouth landing and thorn removal, and information relating to consumptive and non-consumptive trade. We also searched online for video and photographic evidence demonstrating thorn removal.

3 | RESULTS

3.1 | Bowmouth product summary

A total of 977 confirmed bowmouth products were found. Advertised products were almost exclusively thorns (98%, $n = 962$), most ($n = 864$) of which were single, either raw or mounted on rings. Other products comprised of strips of thorns ($n = 99$) sometimes formed into bracelets ($n = 33$), jaws ($n = 12$) and taxidermized whole specimens ($n = 2$) (Figure 3). Nine items that could not be confirmed as originating from bowmouth were omitted from the analysis (teeth, $n = 7$, UK seller; "tongue" and jaw cartilage, $n = 2$, USA seller). The mean number of enlarged saleable thorns (of trade quality) on an individual bowmouth was 11 (SD 3.8, range 3–18; Table S1).

3.2 | Geographic patterns of advertisements and product origin

Nearly all (97%, $n = 947$) products were advertised by sellers based in Thailand. The remainder were from

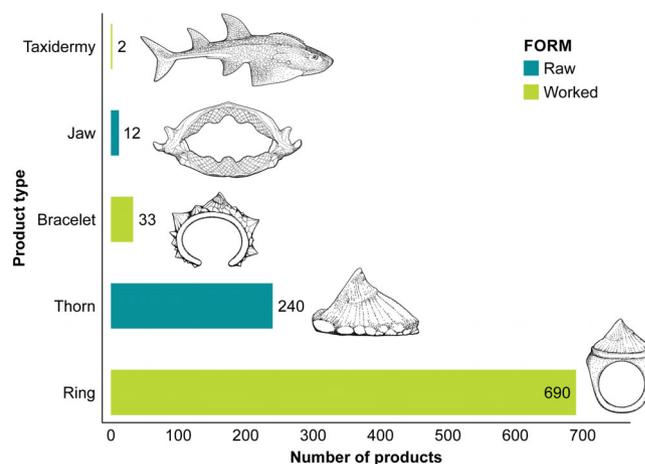


FIGURE 3 Number of advertised bowmouth guitarfish (*Rhina ancylostomus*) product types recorded during online searches conducted June–July 2020 (advertisements dated 2012–2020).

bowmouth range states Taiwan, ($n = 4$) and Australia ($n = 3$) and non-range states USA ($n = 15$), Italy ($n = 6$), UK ($n = 1$), Canada ($n = 1$) (Figure 4). Most (735 of 947) Thai-based posts included the seller's location at a provincial level: over two-thirds ($n = 512$) were based in Bangkok and 15% ($n = 111$) in Satun, a southern Province on the coast of the Andaman Sea. All products from Satun occurred in 2020, contributing to over half of advertised products from January 2020 to July 2020.

Most (94%) products did not indicate the geographic origin of the bowmouth. Of those that did ($n = 55$) 60% were from Indonesia ($n = 33$), 18% ($n = 10$) from the Philippines, 9% Madagascar ($n = 5$), and the remainder listed as "Malaysia/Thailand" ($n = 3$), Indian Ocean ($n = 2$), Andaman Sea ($n = 1$), and India ($n = 1$), all of which are coastal states that fall within the range of the species.

3.3 | Online sales platforms

Nearly all products were advertised on E-commerce sites (65%, $n = 638$) or Facebook (30%, $n = 296$), and less than 5% ($n = 45$) from auction sites (Figure 5). Products were recorded from 48 unique sellers across 21 sites. A minimum of 4 sellers (8%) (Thailand = 3; USA = 1) advertised their bowmouth products on more than one site, encouraging buyers to "visit their [other] site." A shift away from auction sites (such as amulet sites, e.g., Uamulet.com) toward e-commerce sites and Facebook was apparent after 2016. Products advertised on Facebook represented over 50% of products in 2017, 2018, and 2020 (Figure 5).

FIGURE 4 Map detailing: (1) the global range of the bowmouth guitarfish (*Rhina ancylostomus*); (2) anecdotal evidence of dethorning collected from personal communications and photographic and video evidence; (3) location of sellers offering bowmouth-derived products for sale captured during online searches conducted June–July 2020 (advertisements dated 2012–2020) and; (4) the stated origin of products, when indicated by seller, providing evidence of international trade. Shape Files for map: IUCN SSC Shark Specialist Group 2018. *Rhina ancylostoma*. The IUCN Red List of Threatened Species. Version 2022-1.

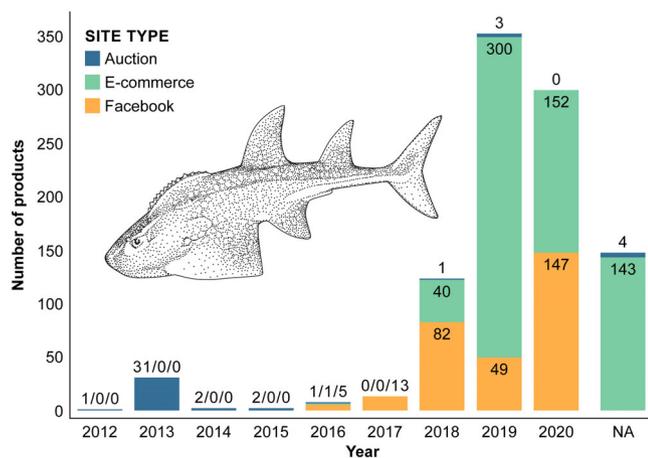
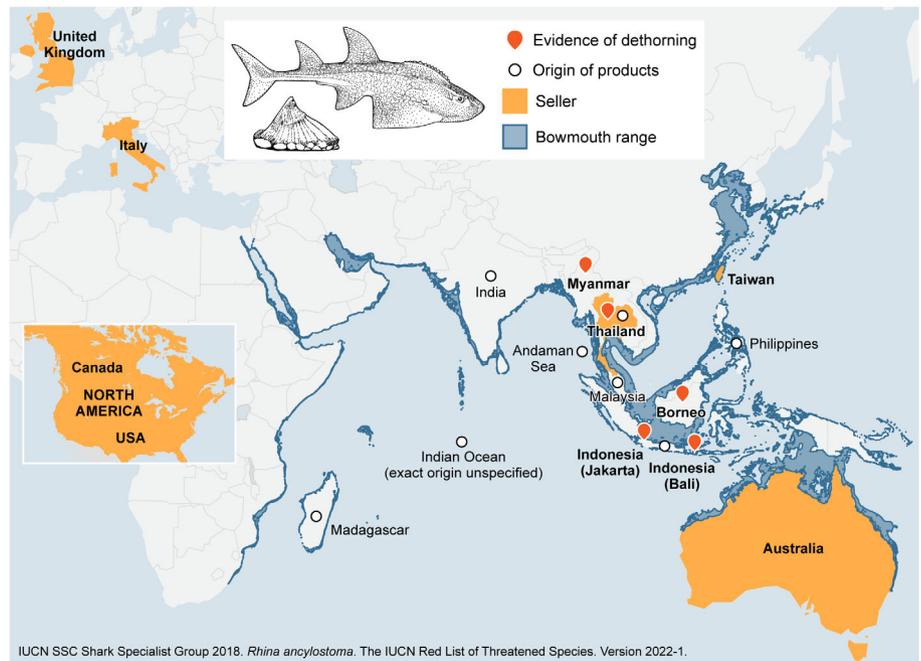


FIGURE 5 Number of advertised bowmouth guitarfish (*Rhina ancylostomus*) products by platform type, recorded during online searches conducted June–July 2020 (advertisements dated 2012–2020). NA, no date provided.

3.4 | Trade documents and legality

While a majority (66%, $n = 644$) of Thai advertisements were dated after the November 2018 Thai Department of Fisheries bowmouth trade registration requirement was introduced, only around a third (36%, $n = 231$) of products explicitly stated that the product was registered, with the majority remainder stating the product was “not registered/registration not available” (27%, $n = 172$), or had no reference to registration (37%, $n = 241$). One listing stated that the product had “a commercial license from the Department of Fisheries” (translated from Thai). No mentions to CITES were recorded.

Thirteen sellers (all Thai-based) also offered products from high-profile CITES-listed taxa such as bears (*Ursidae* spp., CITES I/II), tigers (*Panthera tigris*, CITES I), elephants (*Elephantidae* spp., CITES I), seahorses (*Hippocampus* spp., CITES II) and rosewood (*Dalbergia* spp., CITES I/II) (UNEP, 2020). Listings of these items were recorded from Facebook and Alibaba-owned e-commerce sites (e.g., Lazada), members of the aforementioned Coalition To End Wildlife Trafficking Online.

One percent ($n = 10$) of all advertisements mentioned the product was sustainably sourced, with claims only coming from non-range states (UK $n = 1$, USA $n = 9$) posting on auction sites (Catawiki and eBay). The unverified claim stated advertised products were from legal fisheries.

3.5 | Cultural dimensions

Twenty eight percent ($n = 269$) of all thorn product records explicitly referred to the item as an amulet (i.e., ‘an object worn because it is believed to protect against evil, disease, or unhappiness’ [Cambridge, 2021]). Of the advertisements for rings, over one-third ($n = 247/690$) featured a representation of the Garuda on the ring itself, a symbol in Buddhist mythology and a common feature on Thai amulets, representative of protection (Srichampa, 2014). A minimum of 61% ($n = 424$) of the advertised rings made reference in the accompanying text to the protective properties or magical powers of bowmouth thorns as sources of protection from the water and other dangers.

	<i>n</i>	Size (cm)		Price (USD)	
		Mean (SD)	Min/Max	Mean (SD)	Min/Max
Raw					
Thorns					
Orbital strip	17	17.3 (4.8)	8.0/30.0	50.0 (69.2)	15.7/303.7
Medial strip	60	14.0 (4.8)	7.5/35.0	58.8 (48.0)	17.3/284.5
Single thorn	162	2.5 (1.1)	0.9/5.0	24.0 (15.9)	4.8/79.9
Other					
Jaws	12	-	-	99.3 (41.1)	61.0/175.8
Taxidermy	2	-	-	35.1	
Worked					
Rings	690	2.3 (0.9)	0.5/4.5	47.3 (21.1)	3.2/252.6
Bracelets	33	13.7 (3.6)	2.5/21.0	56.5 (52.4)	27.2/303.7
All	977	4.2 (9.5)	0.5/200	44.1 (27.1)	3.2/303.7

TABLE 2 Sizes (cm) and prices (USD) of all advertised bowmouth guitarfish (*Rhina ancylostomus*) products recorded from online platforms, June–July 2020 (advertisements dated 2012–2020).

3.6 | Size and price of thorns

The majority ($n = 726$ of 977) of advertised products were in a worked form and nearly all (95%, $n = 690$) worked products were rings. Thorns for sale in their raw form included single enlarged thorns ($n = 116$) and strips of thorns ($n = 66$). Where reported in product descriptions, strips ranged in size from 3 to 55 cm ($n = 62$) (Table 2). Eighty-four percent ($n = 827$) of products included a product price, ranging from a minimum of USD 3 to a maximum of 300 (Table 2). Prices of thorn strips ranged from USD ~15 to USD 300 while single raw thorns ranged from USD 5 to 80 (Table 2). The size of raw single thorns ranged from 0.9 to 5.5 cm (Table 2), with price tending to increase with size ($r_3 = 0.75$, $n = 105$, $p < 0.001$), ranging from USD 9.60 for the smallest to a maximum of USD 80. Similarly, ring-mounted thorn price tended to increase with size ($r_3 = 0.51$, $n = 431$, $p < 0.001$), ranging from 0.5 to 4.5 cm in size, and USD 3 to 250 in price (Table 2). Bowmouth products were recorded for sale every year from 2012 to 2020, with 156 of 977 products undated. Price of rings in Thailand were statistically significantly higher in the period before the registration requirement (Mean [SD] = 51.5[18.5]) compared to after (47.2[22.2]), $W = 18,843$, $p = 0.002$).

3.7 | Evidence of de-thorning

De-thorning was apparent in photographic and anecdotal information from landing sites in Thailand, Malaysia, and Indonesia, dating back to at least 2002. Video evidence was found of bowmouth being de-thorned at fisheries

landings sites in Borneo (June 2002), and photographic evidence from Angke Market, Jakarta, Indonesia (January 2003, July 2004, July 2005), Samut Sakhorn, Gulf Coast of Thailand (November 2008) and Kuala Ropin, Malaysia (September 2015) (W. White, e-mail, November 29, 2020, Dharmadi, e-mail, December 1, 2020, J. Giles, e-mail, February 2, 2021) (Figure 6). Raw strips were found in Kedonganan Fish Market, Bali Indonesia in 2005 (Figure 6). In addition, we recorded anecdotal evidence of detached thorns: as single thorn rings worn by people involved in the shark and ray trade in the Indo-West Pacific; for sale as bracelets at Chatuchak Market, Bangkok in November 2008 (J. Giles, e-mail, February 2, 2021); in markets in the Tanintharyi region of Myanmar, where thorns are likely purchased by mainly Thais and at lower prices than in Thailand, “a couple hundred [thai] baht” (S. Arunrugstichai, e-mail, June 18, 2020) and; outside of the Indo-West Pacific (unspecified location).

4 | DISCUSSION

Our novel approach of a multilingual and cross platform search of internet-based sales data revealed ~1000 products derived from a critically endangered, CITES Appendix II-listed marine species. We gathered baseline data that establishes the consistent presence of bowmouth guitarfish in online trade from 2012 to 2020. Additionally, we identified and documented a geographically specific market, unique to Thailand, for bowmouth thorn-based amulets, and provide evidence of de-thorning in other countries. Our findings clearly reveal a new dimension of the online wildlife trade that includes CITES-listed

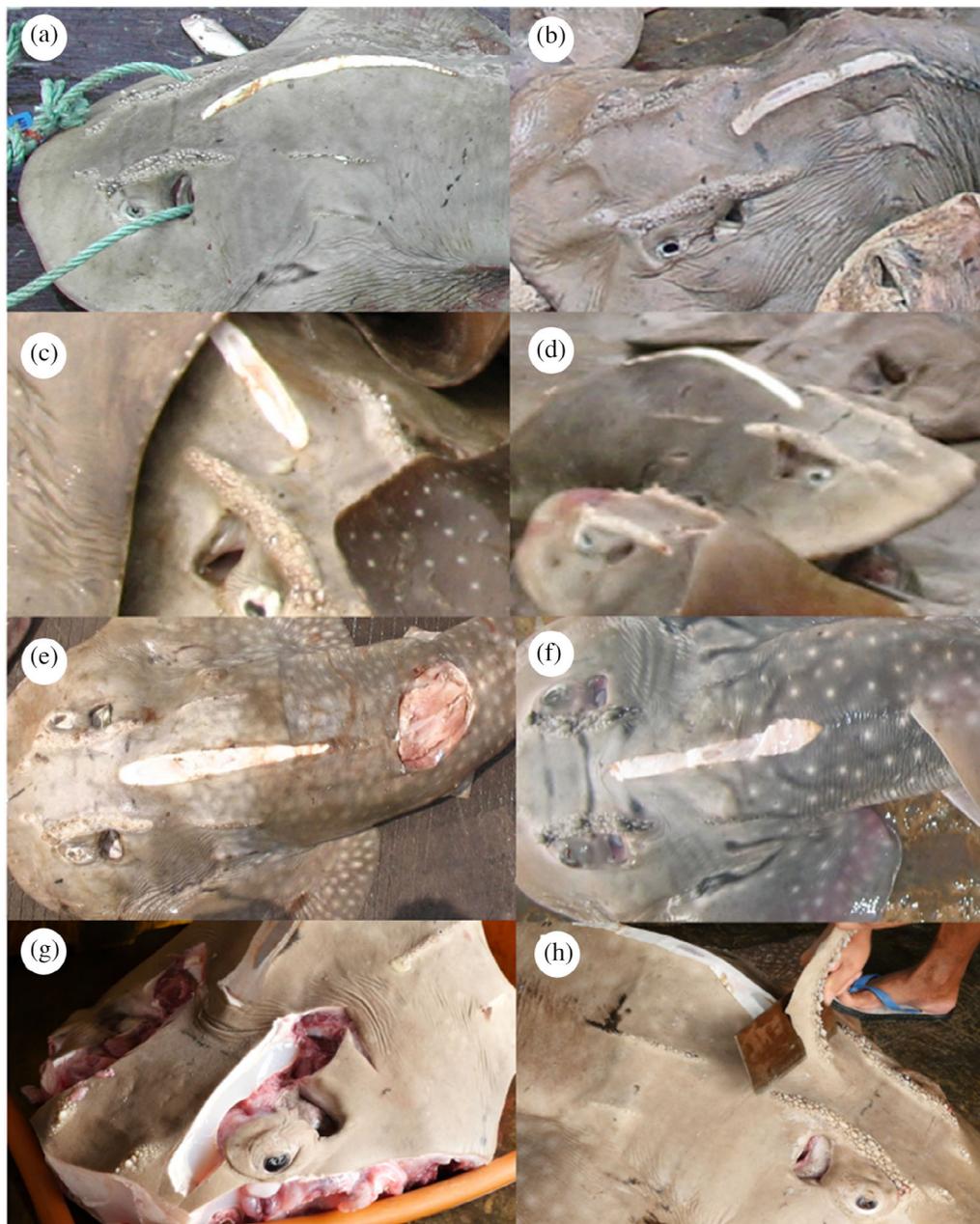


FIGURE 6 Photographic evidence of medial and/or orbital thorn removal from dead bowmouth guitarfish (*Rhina ancylostomus*) at fisheries landing sites and markets in Southeast Asia. (a) Borneo, June 2002; (b–d) Muara Angke Market, Jakarta, Indonesia (b) January 2003, (c and d) July 2004; (e) mature male, ~2600 cm TL at Muara Angke Landing Site, Jakarta, Indonesia, July 16, 2005, (f) immature male, 910 cm TL at Samut Sakhorn, Gulf Coast of Thailand, November 6, 2008; (g) and (h) Kuala Rompin, Malaysia, September 2015. Image credit: (a) Will White (CSIRO National Fish Collection); (b) Gordon Yearsley (CSIRO National Fish Collection); (c and d) Dharmadi (Ministry of Affairs and Fisheries, Indonesia); (e) J. Giles (Fin Forensics, LLC), Dharmadi, Fahmi; (f) J. Giles (Fin Forensics, LLC); (g and h) www.scubazoo.com, with permission.

elasmobranchs and marine fish. We discuss the implications of our results in relation to (1) CITES challenges, (2) identifying and quantifying [by-]products, (3) the utility of internet derived data as a low cost and accessible research method to monitor and enforce trade restriction and trace products, especially in visually distinctive derivative products.

4.1 | Non-detriment findings

The ready availability of bowmouth related products suggests restrictions are not effectively implemented for this species in Thailand. A key control measure to regulate cross-border trade, online or otherwise, in any CITES Appendix I or II-listed species is the requirement for an

export permit. These are only granted when the appropriate authority of the exporting state has advised that the export will not be detrimental to the survival of the species, a determination known as a “non-detriment finding” or NDF. The NDF process thus requires collection of valuable data on the conservation status of a species in a given country, and volumes of trade. However, an NDF is not applicable where the specimen was obtained illegally or in contravention of domestic legislation (Mundy-Taylor et al., 2014). Given that a minimum of one-quarter of the Thai-based products we recorded online were offered for sale without national registration and thus illegal under Thai wildlife laws, estimation and regulation of trade—and whether it is detrimental to the species’ survival—is, therefore, extremely challenging. This is further complicated by the fact that we found evidence that bowmouth products sold online in Thailand may have already crossed international borders from the place of capture (e.g., Indonesia). Elasmobranchs are not a target fishery in Thailand but, when permitted, are required to be landed whole and fully utilized, and management and species-level data are sparse (Arunrugstichai et al., 2018; Krajangdara, 2019). The FAO recently recognized the increasing prevalence of internet-based trade for CITES-listed species and recommended the use of online markets as complementary datasets in trade assessments (Pavitt et al., 2021). Our online research on traded items, volumes, markets, and routes thus provides an alternative to formal regulation and could provide a focus for appropriate intervention by relevant agencies and supplement national datasets.

4.2 | By-products

The fins of shark-like rays (including bowmouth) are the most desirable and expensive in the fin trade (known as *Qun chi*) (Fields et al., 2017; Hau et al., 2018; Moore, 2017). The value of their fins and high protein meat leads to their retention when caught as bycatch. Perhaps the relatively low commercial value of bowmouth thorns (mean USD 47 for a worked thorn) could suggest that thorn removal is opportunistic and justified and could be indicative as a means of eliminating waste from an already dead individual. The approach of utilizing the whole animal can, however, have unintended consequences such as creating a market and increased demand. Requirements to land sharks whole aimed at eliminating finning (i.e., slicing off fins and discarding the carcass at sea) may be responsible for a 20% increase in shark meat exports since 2000 (Clarke et al., 2014). Off-cuts from whole animals or their larger products can make products more difficult to identify (Magnussen et al., 2007; Morcatty et al., 2020) and can create alternate

markets: fin-trimmings from processing creates a market for inexpensive shark fin soup (Cardeñosa et al., 2020; Fields et al., 2017); beads made from rhino horn off-cuts are easier to smuggle because of their reduced size and recognisability (Moneron et al., 2017); powdered rhinoceros horn sold as a health tonic is a “by product” that is a driver of the rhinoceros trade (Gao et al., 2016). In contrast to many other lower value derivatives, we have demonstrated that trade in bowmouth thorn related products ought to be less challenging to monitor and enforce, due to the visually distinctive nature of their horns.

4.3 | Quantifying volume and value

While there are no estimates of bowmouth population status, inferences from historical and contemporary data suggest an 80% reduction over the last 45 years (Kyne et al., 2019). Here we recorded nearly 1000 bowmouth products and this finding is significant given the short sampling period of our study and the rarity of the species. Based on a rudimentary thorn frequency calculation using average enlarged thorns per individual (see Methods and Results), we conservatively estimate that there are 11 saleable thorns on an individual bowmouth, giving a minimum estimate of 77 individuals captured to provide the thorn products recorded here. While the rarity and threatened status of the bowmouth alone make this a significant finding, it is also likely an underestimate of product availability overall and on Facebook specifically, due to the ethics permissions we did not search private groups or engage with sellers. Additionally, increasing the precision of the thorn frequency analysis could serve as a beneficial complement to long term trade monitoring and volume estimates. Though thorns may be traded in quantities that are minimal compared to other shark commodities like fins and meat, they nevertheless provide an accessible traceability method, particularly in the absence of other data.

Comparisons with other wildlife products in terms of volume is not straightforward, to put the quantity into context we can look to similar studies of Thai-based online trade. For example, in a six-month survey of public and private Thai Facebook groups, Phassaraudomsak et al. (2019) recorded 546 hornbill (Family: Bucerotidae) products from nine species offered for sale with posts dated from 2014 to June 2019; in that same time frame, we recorded 149 bowmouth products from public Facebook groups, 296 if 2020 is included. Like this study, the majority of hornbill products were worked (70%), rings representing the most popular worked item. The hornbill species recorded are listed on CITES Appendix I or II, are native to Thailand and protected under WARPA, like the

bowmouth. The demand for hornbill products, unlike bowmouth thorns, is described in the literature (Phassaraudomsak et al., 2019). Considering the similar price comparisons (Table S4) and more conservative search practices in our study, recorded volumes between the two studies are roughly similar. Given the dearth of studies characterizing elasmobranch products (Choo et al., 2021), our results highlight an unrecognized market which, with continued monitoring, can offer additional insights into trade routes as well as regulatory impacts.

4.4 | Enforcement

Thailand has some of the most severe penalties for illegal wildlife trafficking in Asia (Phassaraudomsak et al., 2019), however enforcement of management measures in marine fisheries by the Thai Department of Fisheries is limited (Aylesworth et al., 2020). While we do not know the origin of the bowmouth from which these products were derived and where or when they were landed, we do know that bowmouth parts are readily available for purchase online from predominantly Thai based sellers. This ready availability is indicative of a potential enforcement gap of the Thai Wild Animal Preservation and Protection Act under which bowmouth is listed as a protected species. Because the majority of bowmouth products found were thorns, mostly mounted on rings, and often with symbols commonly displayed on amulets in Buddhist mythology, this highlights the need to understand the underlying motivations of both buyers (Gao & Clark, 2014), as well as sellers. We estimate the commercial value of all enlarged thorns from an individual bowmouth (using the mean value of raw thorns per individual) as USD 264 (or USD 520 for rings). The fine for trading one unregistered bowmouth-derived product in Thailand is >USD30,000; Supporting Information for product comparison, yet the relatively low value of bowmouth thorns in relation to the fine, and the volume and open availability of thorns we reported strongly suggest enforcement gaps in Thailand for this species, as a minimum. The Royal Thai Police and Department of National Parks, Wildlife and Plant Conservation have established cyber taskforces to target illicit online trade (Siriwat & Nijman, 2018). In fact, from 2000 to 2019, Thai authorities reported five seizures of hornbill products from online sellers (from 19 total seizures; Phassaraudomsak et al., 2019). While a positive initiative, sting operations may lead to increased privacy settings from sellers (Siriwat & Nijman, 2018), creating further monitoring, control and surveillance challenges and requiring greater resources. Nevertheless, our characterization of the online marketplace could be used to direct enforcement assets to focus search efforts in order to identify flagrant violators (Sutinen & Kuperan, 1999), or to

underpin an awareness raising campaign that encourages voluntary compliance with regulations.

4.5 | Online trade

The application of social media to detect trade and facilitate enforcement is gaining recognition (D'Cruze & Macdonald, 2015; Pavitt et al., 2021). Advertisements for wildlife products trending away from auction sites toward SNSs has been reported in the literature (e.g., Di Minin et al., 2019) and agrees with our findings. Online retailers and social media companies have the means and ability to effectively monitor transactions and leading internet technology companies have committed to prohibiting the trade of endangered species and detrimental trade on their platforms (Coalition to End Wildlife Trafficking Online, 2020; Phassaraudomsak et al., 2019; Siriwat & Nijman, 2018). A minimum of one-quarter of the Thai-based products we recorded were offered for sale without registration, illegal under Thailand's wildlife laws. Alongside bowmouth curios, we found high profile CITES Appendix I/II taxa such as ivory and tiger claws openly advertised on popular e-commerce sites and Facebook, in contravention to the platforms' prohibited products list (see <https://www.endwildlifetraffickingonline.org/coalition-prohibited-wildlife-policy>). Other studies of online wildlife trade have found illicit sales of live reptiles alongside orchid sales (Hinsley et al., 2016) and tiger teeth, Asiatic Black Bear (*Ursus thibetanus*) paws, pangolin scales, and corals offered by groups selling ivory (Indraswari et al., 2020). In contrast, systematic searches looking for high profile illegal taxa on the dark web revealed very little trade (Harrison et al., 2016) which suggests that sellers of illegal products recognize that surface monitoring is weak. The scale of online markets calls for large scale monitoring to aid enforcement and automated tools can help (Hinsley et al., 2016). The use of machine learning has been successfully applied to monitor the illicit trade of ivory on eBay (Hernandez-Castro & Roberts, 2015), and on Twitter to monitor rhinoceros horns (Di Minin et al., 2018), ivory, and pangolin sales (Xu et al., 2019). Unlike other products that are difficult to identify after processing (Morcatty et al., 2020), the unique and readily identifiable nature of bowmouth thorns presents a viable candidate for automated online monitoring methods. Our study, and others of the same nature, provides tangible examples of where online enforcement efforts can be directed by demonstrating platform category and specific sites responsible for the greatest volume of (potentially illegal) trade (Figure 5 and Supporting Information). This information can in turn be used by site hosts and help legal and enforcement officials prioritize limited resources.

4.6 | Putting the data to work

Domestic and international markets for elasmobranch-derived products are poorly understood (Dent & Clarke, 2015). As a first step to combatting unsustainable and illegal trade, knowledge of the species and products traded is a first step (Scheffers et al., 2019). The intended scope of this study was global but systematic searches found Thailand was the center of the trade, an important finding toward product traceability. Long-term monitoring of online and physical sites will provide further details on drivers of trade, where animals are caught, and impacts of management and policy.

Our online study clearly identified that further research is needed on the bowmouth thorn trade: specifically, the geographic extent of de-thorning, the supply chain, physical markets, and cultural, socio-economic and regulatory aspects. Before confronting the often-ignored human side of elasmobranch fisheries and conservation, however, the most basic requirement is to understand the scale of the issue. Herein we have identified a neglected trade in a data-poor species and highlighted the benefits and practicality of implementing low-cost and accessible methods which can be adapted to inform management of fisheries and terrestrial species, including those in countries where the need for effective and efficient conservation is too often neglected.

AUTHOR CONTRIBUTIONS

Conceptualization: Alec Moore. *Methodology:* Adel Heenan, Alec Moore, Jennifer Pytka. *Data curation:* Jennifer Pytka. *Formal analysis and visualization:* Jennifer Pytka. *Writing-Original draft:* Jennifer Pytka. *Writing-Reviewing and editing:* Adel Heenan, Alec Moore, Jennifer Pytka. *Supervision:* Adel Heenan, Alec Moore.

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ETHICS STATEMENT

The study design was approved by Bangor University Ethics Committee (approval code: COESE2020JP01A).

Internet trade of a previously unknown wildlife product from a critically endangered marine fish.

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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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