

Characterization of the trade in manta and devil ray gill plates in China and South-east Asia through trader surveys

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ABSTRACT

1. Dried gill plates from manta and devil rays, some of the world's most biologically vulnerable fishes, have become a valued commodity in Asian dried-seafood and traditional Chinese medicine markets. This trade is a primary driver of fisheries, which have led to declines in many mobulid populations.

2. With no reliable trade statistics and scarce data on mobulid fisheries, this study estimates the number and species of mobulids required to supply this trade, and investigates the consumers and suppliers involved and drivers of demand. Following preliminary market research, 525 trader surveys were conducted in Hong Kong, Singapore, Macau, Taiwan, and southern China.

3. Guangzhou, China was identified as the centre of the trade accounting for 99% of total estimated market volume of 60.5 tons of dried gill plates in 2011, increasing to 120.5 tons by 2013. The estimated number of mobulids converted from tons of gill plates more than doubled over the period to 130 000, comprising 96% devil rays, *Mobula japonica*, *Mobula thurstoni*, and *Mobula tarapacana*, and 4% *Manta* spp. By 2015 the Guangzhou market had declined sharply, reportedly due to conservation campaigns and government policies. However Hong Kong's gill plate sales increased dramatically between 2011 and 2015.

4. China, Indonesia, Vietnam, Sri Lanka, and India were reported most frequently as gill plate sources.

5. Vendors recommend gill plates (trade name *pengyusai*) for ailments ranging from acne to cancer and as a general health tonic. While *pengyusai* is a new addition to traditional Chinese medicine literature and is rarely prescribed by traditional medicine practitioners, it is readily available over the counter and aggressively marketed by vendors.

6. Working in concert with consumer demand reduction efforts, increased measures to restrict mobulid fisheries and trade are recommended to prevent further population declines of these highly vulnerable species.

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INTRODUCTION

Manta and devil rays (collectively mobulids) have been increasingly targeted over the past two decades to supply a growing market for their gills, which are sold in traditional Chinese medicine (TCM) and Asian dried-seafood markets (White *et al.*, 2006b; Camhi *et al.*, 2009; Couturier *et al.*, 2012). These planktivorous elasmobranchs possess gill plates, also referred to commonly as gill rakers, which are rigid sieving pads used to filter zooplankton from sea water (Cortes *et al.*, 2008; Paig-Tran *et al.*, 2013). While mobulid meat is generally not highly valued for human consumption, the dried gill plates from these species have recently become a valued commodity in Chinese and South-east Asian markets (White *et al.*, 2006b; Rajapackiam *et al.*, 2007; Anderson *et al.*, 2010; Heinrichs *et al.*, 2011). Similar to the trades in shark fin, rhino horn, and saiga antelope horn, these specific body parts are worth substantially more than the rest of the animal (Cheung, 1995; Milner-Gulland *et al.*, 2003; Clarke *et al.*, 2007). The gill plates are marketed under the trade name *pengyusai*, a remedy purported to treat a variety of health issues ranging from acne to cancer (Heinrichs *et al.*, 2011).

Manta and devil rays belong to the Mobulidae family, which comprises the two species of the genus *Manta* and nine species of the genus *Mobula* (Couturier *et al.*, 2012). Behavioural characteristics, such as surface-feeding and aggregating in large numbers (Bizarro *et al.*, 2006, Valenti and Kyne, 2009; Marshall *et al.*, 2011a, b; Couturier *et al.*, 2012), combined with overlap of mobulids' habitat and migratory paths with artisanal and large-scale commercial fisheries (Ward-Paige *et al.*, 2013; Germanov and Marshall, 2014; Thorrold *et al.*, 2014; Croll *et al.*, 2015), make these species easily accessible to fishers. These characteristics, in addition to extremely low reproductive rates (Couturier *et al.*, 2012), leave mobulid populations exceptionally vulnerable to mortality from directed fisheries and bycatch with limited capacity to recover from overfishing (Couturier *et al.*, 2012; Dulvy *et al.*, 2014). Fisheries supplying the Asian dried gill plate market have been documented in India, Sri Lanka, Indonesia, Malaysia, the Philippines, Mozambique,

Palestine, and China, and have heavily impacted many mobulid subpopulations (Alava *et al.*, 2002; Rajapackiam *et al.*, 2007; Fernando and Stevens, 2011; Heinrichs *et al.*, 2011; Abudaya *et al.*, 2014; Dent and Clarke, 2015; Lewis *et al.*, 2015). This escalating threat has led to IUCN Red List classification of *Manta alfredi* and *Manta birostris* as globally vulnerable to extinction (Marshall *et al.*, 2011a, b), and *Mobula tarapacana*, *Mobula japonica*, and *Mobula thurstoni* as vulnerable in South-east Asia (Clark *et al.*, 2006a, b; White *et al.*, 2006a).

With growing concerns about the stability of many regional mobulid subpopulations from increased targeted fishing, combined with scarce reporting of fisheries data and no tracking of trade data (FAO, 2015), there is a need for better information about the market for gill plates to aid in conservation and management efforts. This study is the first assessment of the mobulid gill plate trade in southern China and South-east Asia, and estimates the scale of the trade, determines market trends and factors driving demand, and explores the potential implications of current levels of trade on the conservation of mobulid species.

METHODS

Data collection

Data collection to assess the *pengyusai* market's distribution, volume, species composition, and trends comprised field research in dried seafood and TCM markets over four survey periods in 2009–2010, 2011, 2013, and 2015 and research of web-based traders in 2014 and 2016. In addition, a TCM literature review via Internet search and the Hong Kong University library and interviews with TCM practitioners in Guangzhou, China, Singapore, Hong Kong, and Macau were conducted with assistance from native Mandarin and Cantonese speakers.

Determination of areas to investigate was made based on reports and observations from prior investigations of the shark fin trade in China and South-east Asia, review of previously conducted wildlife TCM market studies (Vincent, 1997; Cheung and Dudgeon, 2006; Li *et al.*, 2007), an Indonesian mobulid fishery study (White *et al.*,

2006b), and interviews with traders at mobulid fishery landing sites in Sri Lanka and Indonesia. In 2009–2010, prior to initiating the first market investigations, a preliminary assessment was conducted in southern China to identify the key cities and market districts in which to focus more extensive surveys. This assessment entailed eight field visits to dried seafood and TCM market areas in Guangdong (primary market centres in Guangzhou and Shenzhen and secondary markets including the border area between Guangdong and Fujian), Hunan, and Hainan Provinces.

In April/May 2011, 283 dried seafood and TCM businesses were surveyed across Hong Kong, Singapore, Macau, Taiwan, and Guangzhou, China. Authors (PH, SH), accompanied by residents fluent in the local dialect and familiar with the markets in each area, spent several days surveying the dried seafood and TCM business districts within each of these locations. The Guangzhou survey focused on the two key market areas identified – the Qingping Market in the north of Shamian Island, Liwan District and the Yide Dry Seafood Market in the Yuexiu District. Sixty-five stores were selected in these two areas, including 32 sellers that were previously observed or reported to be large specialist *pengyusai* sellers or dried seafood/TCM sellers with large quantities of gills on hand. As the bulk of the remaining stores in the key market areas appeared to either not have gills available or were small retail shops displaying only small quantities, a random sample of 33 additional stores was chosen to survey in the areas (buildings/street market sections) with the highest concentration of *pengyusai* sellers. In Singapore and Hong Kong a similar methodology was applied to select vendors to survey, while the Macau and Taiwan interviews were conducted randomly in the districts where dried seafood and TCM products are sold.

Based on the results of the 2011 surveys, a second survey was conducted in December 2013 (PH) solely focused on key market districts in Guangzhou. In December 2015 follow-up surveys were conducted in Guangzhou (MO) and Hong Kong (PH). In 2013 and 2015, following market-wide visual surveys of key districts for presence/absence of *pengyusai*, the vendors

previously identified as major sellers from earlier surveys were revisited in addition to vendors observed to be displaying large quantities of gills during visual surveys, and random samples of smaller sellers (Table 1).

Research of Internet-based sellers was conducted via Google searches using the Chinese characters for *pengyusai* (膨鱼腮). Details including species offered for sale, prices, reported stock quantities, business location, reported source region(s), and recommended uses advertised by each seller were recorded. In December 2014 a native Mandarin speaker then contacted the major *pengyusai* traders, with 'major' defined as those reporting a physical store or warehouse location and/or direct importation of gill plates and advertising available stock of 25 kg or more.

In all surveys, each business was asked a series of questions, including: 'Do you carry *pengyusai*?', 'Can we see it?', 'How much supply do you have?', 'How much does it cost', 'How much do you sell per year?', 'Where do you source it?', 'What do your customers purchase *pengyusai* for?', 'What trends are you seeing in supply and demand', and 'Can we take a photo?'. During the 2014 phone interviews, additional questions were asked to sellers reporting China as a source location in order to gather information on potential mobulid landing sites in China. As reliability of vendor-supplied data was a primary concern, researchers posed as potential buyers to improve responsiveness (Li *et al.*, 2007; Chow *et al.*, 2014). To account for potential exaggeration of available stock, estimates included only visual counts or quantities that vendors reported to be able to supply immediately (Li *et al.*, 2007). Interview responses and observations of visible dried gill plate stock, including quantities, species, and prices were recorded.

Data on dried gill plate yields per animal were obtained from interviews with the manager of a shark and mobulid processing plant in Puqi, Zhejiang Province, the city known as the shark processing centre of southern China (Li *et al.*, 2012b), investigation of a directed mobulid fishery in Lamakera, East Flores, Indonesia (Lewis *et al.*, 2015), and review of the Fernando and Stevens (2011) report on Sri Lanka's mobulid fisheries and

Table 1. Market districts surveyed (including percentage of stores visually surveyed that had pengyusai for sale)

Survey	Districts	Total estimated stores ¹	Visual presence/absence	Had PYS	Vendors surveyed ³
Guangzhou 2011 ²	Qingping	650	265	30	37
	Yuexiu	400	250	30	28
Total (12%)		1050	515	60	65
Hong Kong 2011	Sheung Wan	300	180	17	46
	Central	30	10	2	22
	Cheung Chau	15	5	1	1
Total (10%)		345	195	20	69
Macau 2011 (32%)	Central Business District	60	50	16	26
Singapore 2011	Albert Centre	50	50	6	12
	Chinatown	40	30	10	30
	Victoria Street Wholesale	20	20	2	8
	Bencoolen	10	10	2	6
	Other	20	10	4	12
Total (20%)		140	120	24	68
Taiwan 2011	Taipei (Di Hwa St.)		11	0	11
	Taichung (Wu Chi)		11	0	11
	Kaoshiung (San Feng St.)		33	0	33
Total (0%)			55	0	55
Guangzhou 2013	Qingping	653	466	69	43
	Yuexiu	433	286	20	17
Total (12%)		1086	752	89	60
Online Sellers 2014	Taobao.com	56	56	56	18
Guangzhou 2015	Qingping	1,611	1,611	59	59
	Yuexiu	561	561	18	18
Total (4%)		2172	2172	87	87
Hong Kong 2015	Sheung Wan	300	NA	14	52
	Central	30	NA	8	25
Total				22	77

¹Total number of stores in each district refers to estimated number of stores of the type potentially selling pengyusai (dried seafood, TCM).

²Presence/absence survey was conducted in 2010.

³In Guangzhou 2015 surveys, stock counts were done at 87 stores and interviews conducted at 30 stores. PYS - pengyusai

trade. Consultation with these researchers provided further confirmation of average dried gill plate yields. Lamakera fishermen reported typical dried gill plate yields of 5 kg per *M. birostris* (and up to 7 kg from very large mantas) and 2 to 3 kg for *M. tarapacana* (Lewis *et al.*, 2015). The Puqi plant manager reported yields of 2.5 kg dried gills per 500 kg of whole animals. As the Puqi manager reported dried gill plate yields for *M. japanica* by weight rather than number of animals, typical total weight (TW) per *M. japanica* was estimated using the Notarbartolo di Sciara (1988) DW (disc width) to TW conversion formula as follows: *M. japanica* ($TW = 4.29 \times 10^{-10}(DW)^{3.4}$), with typical DW approximated at 2188 mm, the average of male and female sizes at maturity for this species (Notarbartolo di Sciara, 1987). Dried gill plate yield estimates were then used to convert the annual sales of dried gill plates in kg for each species to the estimated total number of animals

required to supply the dried gill plate trade annually.

Data analysis

Using vendor survey responses and visual stock counts, low, medium, and high estimates were calculated for the total volume (in kg) of dried gill plates sold annually in each survey city. Visual stock estimates entailed recording the number and estimated weight of gill plate containers in each surveyed store by gill plate type. Container weights were estimated based upon responses from traders and researchers' observations, and by weighing several bags to test the accuracy of estimates (Figure 1). To calculate annual sales volume estimates for sellers that did not divulge their sales figures, the median stock quantity to annual sales volume ratios from sellers who reported both inventory and annual sales figures

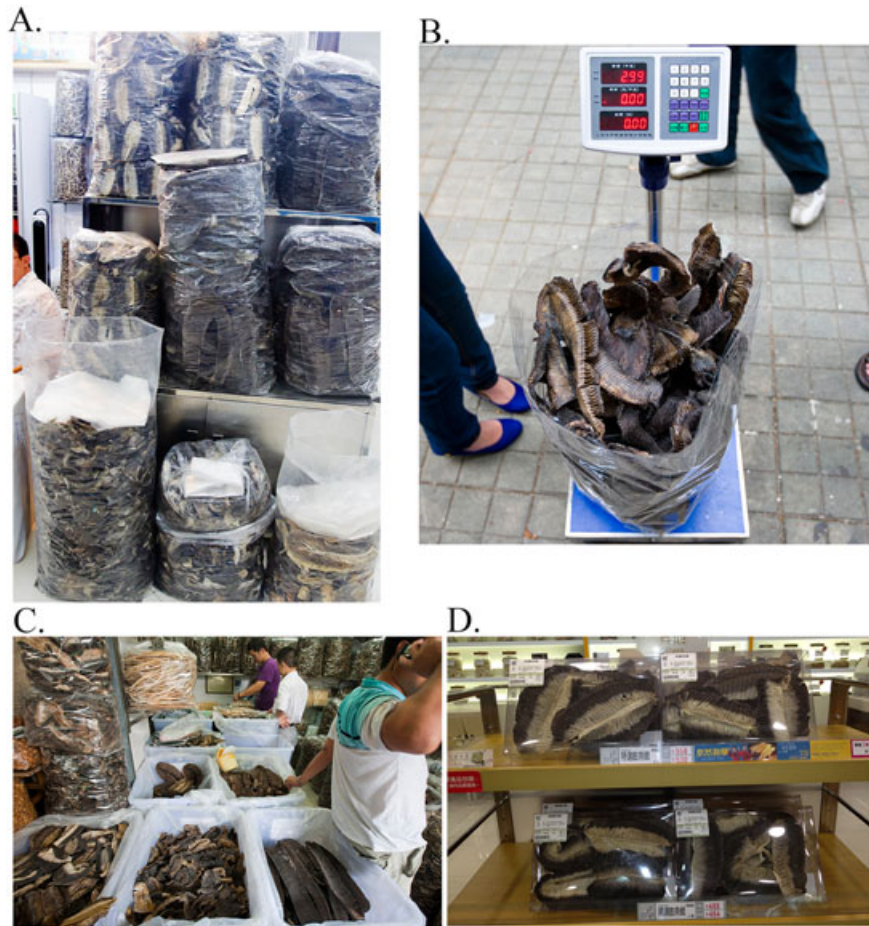


Figure 1. Stock estimates. Bags/containers of various sizes were weighed and the number of each type per species were counted to estimate stock amounts. (A) Large bags of *Manta* spp., *M. tarapacana* and *M. japanica*/other gill plates; (B) weighing a small bag of *Manta* spp. gill plates; (C) bins with the three different gill plate types; (D) plastic packages of *M. tarapacana* gill plates. Photos by Paul Hilton (A, B, C), Mary O'Malley (D).

were applied to the stock numbers for the sellers that did not report annual sales. To estimate total market volume, annual sales estimates for each seller were organized by type of seller, and the percentage of survey coverage by volume was estimated for each seller type. These market coverage estimates were then applied to the total annual volumes from the stores surveyed to generate overall estimates for the gill plate trade in each market. Trade volume in Chinese yuan (CNY) was calculated by multiplying the average price per kg for each gill type by the estimated annual sales in kg for each gill type. Historical exchange rates from April 2011, December 2013, and December 2015 (www.xe.com) were used to convert CNY sales to USD. To assess market trends, vendor-reported trends in supply and

demand were compared across all markets and years. Estimates of gill plate stock, annual sales volume, species composition, and prices were compared across the three Guangzhou surveys. Analysis of Variance (ANOVA) was used to identify significant differences in prices across survey years and among species (IBM Corp., 2010). Both Species and Year were considered to be fixed effects and an interaction term was included between these effects, with the model equation: Response Variable ~ Species * Year. A non-parametric Kruskal–Wallis test was used to identify differences in stocks and sales of gill plates between years for each species, as these data were non-normally distributed. All statistical analyses were conducted in R. As the 2015 Hong Kong price levels were reported from one large

distributor interviewed, and price data were not collected from all vendors, analysis of variance could not be conducted for Hong Kong prices.

Dried gill plates were identified by species using visual identification characteristics from the Stevens (2011, 2013) mobulid identification field guides. The species composition of stock and sales volume was estimated through visual stock counts and seller interviews. For further confirmation of species identification, photographs of dried mobulid gill plates of different types and sizes were later compared with dried gill plate photographs from the Lamakera fishery, Puqi processing plant, and diagrams provided in Paig-Tran *et al.* (2013), in consultation with the Sri Lanka researchers (G. Stevens, D. Fernando).

RESULTS

Market volume and trends

The 2011 surveys revealed that Guangzhou, China traded by far the largest volume of gill plates of all the market cities surveyed, with 99.5% of the estimated total annual market volume of 60.15 t, representing CNY 83 million (USD 10.7 million) in sales. Taiwan was apparently not involved in the trade, with most businesses surveyed having never heard of gill plates or *pengyusai*. Annual gill plate sales per vendor did not change significantly between years for the two main types of *Mobula* gill plates identified, *M. japonica/other* ($P = 0.97$) or *M. tarapacana* ($P = 0.29$), but gill plate sales per vendor dropped significantly between 2011 and 2013 for *Manta* spp. ($P = 0.009$). However, the total estimated market volume from the December 2013 Guangzhou survey was 120.45 t (CNY 176.3 million; USD 29 million), double the 2011 estimate, with large increases in estimated total annual sales of the two types of *Mobula* spp. gill plates and a slight increase for *Manta* spp. (Table 2(a)). In 2015 it was not possible to estimate annual sales for the Guangzhou market, since most of the large suppliers from previous surveys were either no longer selling *pengyusai* or reported plans to exit the trade after selling off remaining stock. Total gill plate stocks in 2015 (2.7 t) were down to roughly a third (37%) of 2013

levels (8.1 t) and a little over half (55%) of 2011 levels (5.6 t) (Table 2(b)). However, three of the vendors interviewed in 2015 still reported selling large quantities of gill plates, including one that reported to be selling 6 t per year, with the majority exported to two large traders in Hong Kong and one in Macau.

The Hong Kong survey revealed there are two major traders supplying gill plates to this market. One located in Sheung Wan (Hong Kong Island) reported selling between 1 and 2 t per year with a steady supply of gills primarily from Indonesia and Sri Lanka, and smaller amounts from the

Table 2. Gill plate market volume estimates

a. Estimated annual gill plate sales volume (KG)

	<i>Manta</i>	<i>M. tarapacana</i>	<i>M. japonica/other</i>	Total
Apr 2011 Surveys				
Guangzhou	21 876	20 324	17 952	60 152
Singapore	92	64	27	183
Hong Kong	90	9	26	125
Macau	11	7	10	28
Dec 2013				
Guangzhou	23 811	42 165	54 493	120469
Dec 2015 Surveys				
Guangzhou	NA	NA	NA	NA
Hong Kong	1925	875	700	3500
Guangzhou Apr 2011 to Dec 2013 Change %	+9%	+107%	+204%	+100%
Hong Kong Dec 2011 to Dec 2015 Change %	+2039%	+9622%	+2592%	+2700%

b. Estimated gill plate stocks (KG)

	<i>Manta</i>	<i>M. tarapacana</i>	<i>M. japonica/other</i>	Total
Apr 2011 Surveys				
Guangzhou	1837	1836	1376	5049
Singapore	49	34	15	98
Hong Kong	60	6	17	83
Macau	7	5	6	18
Dec 2013				
Guangzhou	1399	3439	2630	7468
Dec 2015 Surveys				
Guangzhou	916	799	1,038	2764
Hong Kong	NA	NA	NA	NA
Guangzhou Apr 2011 to Dec 2013 Change %	-24%	+87%	+91%	+48%
Guangzhou Dec 2013 to Dec 2015 Change %	-35%	-77%	-61%	-63%

Philippines. The Guangzhou trader reported selling gill plates to both the major traders in Hong Kong, and reported that the larger customer, located in Kowloon, purchases 2 t of gill plates per year from her business. From these reports, 2015 annual market volume for Hong Kong was roughly estimated at 3–4 t per year, an increase of 28 times the 2011 market estimate of 125 kg per year. None of the gill plate vendors had *pengyusai* stock on display, but would retrieve a bag of about 0.6 kg when asked if they carried the product. The Guangzhou trader reported sourcing gill plates mainly from Mauritius and Vietnam. This trader and the large Hong Kong trader reported a strong preference for large manta gill plates among Hong Kong and Macau consumers with mainland Chinese customers generally preferring the less expensive small devil ray gill plates.

In Guangzhou, there were approximately 1100 shops in the key market areas in 2011 and 2013, and 12% had gill plates visibly displayed for sale in both years. In 2015 researchers counted over 2100 stores in these market areas and 3.4% with gill plates for sale (Table 1). There were three main types of gill plate sellers: (1) large suppliers specializing in gill plates, fish bladders, seahorses, and puffer fish with very large stock levels; (2) larger dried seafood/TCM shops with a large inventory of a range of products; and (3) small dried seafood/TCM retailers and apothecaries with limited gill plate stock. The large suppliers and shops reported importing gills directly from overseas or purchasing from Chinese ports or processors and selling to retail shops, restaurants, and individuals. Small retailers were generally reluctant to reveal their suppliers, but reported selling almost exclusively to individuals for personal use. The large stores kept gill plates in large bags (approximately 15 kg), while the small shops displayed stock in various bags, bins, jars, and plastic packages. In 2011, Guangzhou stores stocked considerably higher quantities (mean 124 kg $SD \pm 59$) compared with the other cities (mean 2.9 kg ± 4.2), and reported faster stock turnover (median of 12 \times per year). Stock turnover rates reported by Guangzhou sellers in 2013 were similar to 2011 (median of 12 \times to 15 \times). In

contrast, most stores in Singapore, the next largest market in 2011, stocked 1–3 kg, while in Hong Kong and Macau, all but a few stores carried only about 0.6 kg, with these inventory levels reported to last for 6 months to a year. Mean stock quantities were substantially higher in 2013 (170 kg $SD \pm 384$), with two sellers reporting 1.5 and 2 t of gill plate stock. In 2015 mean stock levels were down to 36 kg ($SD \pm 52$), considerably below even 2011 stock levels. Stocks of gill plates in Guangzhou were statistically different between years ($P < 0.0001$ for all species).

Market coverage estimates used to calculate total annual sales estimates were 81% in 2011 and 91% in 2013 for Guangzhou surveys, assuming 100% coverage of the large specialist sellers, 75% coverage of large non-specialized sellers, and excluding small retail shops to avoid double-counting of retail and wholesale volumes. Coverage for the other markets in 2011 was estimated at 66% for Hong Kong, 64% for Singapore, and 83% for Macau¹.

The 2014 Internet search revealed 56 sellers advertising mobulid gill plates via the Chinese online commerce site, Taobao.com. Most of the sellers were based in Guangdong Province (Zhanjiang, Yangjiang, Jiangmen, Foshan, Maoming, and Guangzhou) with a few from Guangxi Zhuang Autonomous Region (Beihai and Nanning) and Hong Kong. Eighteen were identified as 'major' sellers, and the others appeared to be exclusively online resellers of a wide range of products. Interviews confirmed that 11 of the 'major' sellers were direct importers or purchased gill plates from Chinese ports, and 10 of these were located outside of Guangzhou (and thus not covered in previous field surveys). Total annual *pengyusai* sales volume from these 10 sellers was estimated at 1.6 t of dried gill plates. Sellers reported that only a small percentage of their business came from Internet sales, since the primary *pengyusai* purchasers are middle-aged housewives, who are reportedly not accustomed to making online purchases. The 2016

¹Hong Kong and Singapore estimates assumed 75% coverage of large sellers and 50% of remaining sellers. Macau coverage was estimated as the percentage of stores checked out of the estimated total, since volumes from all sellers were similar.

Internet search identified only four sellers on Taobao, all advertising China as the product source.

In 2011 *pengyusai* sellers in all markets consistently reported difficulty in sourcing gill plates, especially manta ray gills, with large manta gills especially scarce. All sellers responding in Singapore, Hong Kong, and Macau commented that *pengyusai* was not a popular product, with several adding that only elderly clients purchased it or that it was too expensive. In contrast, most Guangzhou sellers (82%) reported increasing demand despite rising prices, with peak sales in summer to early autumn (5 months). In 2013 only 55% of Guangzhou sellers reported decreasing supply of gill plates, and 75% reported continued increasing demand. In 2014, 64% of the online sellers interviewed reported decreasing supply, with difficulty sourcing manta gills especially, while 36% reported stable supply from Indonesia and Sri Lanka. All of those responding to the question on demand trends reported decreasing demand, with two commenting that the *pengyusai* business 'has no future'. In 2015 the Guangzhou sellers willing to discuss market trends reported lower demand, especially for the more expensive *Manta* and *M. tarapacana* gill plates, owing to conservation awareness among consumers, the Chinese government crackdown on corruption affecting purchase of expensive gifts, and concerns about an imminent government ban of the gill plate trade. One large trader with more than 100 kg stock of all three types of gill plates said the local

government had given *pengyusai* traders an unspecified amount of time to sell off remaining stock and that sales had become very difficult. Hong Kong traders reported steady supply from Indonesia, Sri Lanka, and lower quantities from the Philippines (Table 3).

Mean gill plate prices were higher in 2013 than 2011 for all gill plates, with larger price increases for both types of *Mobula* gill plates (Table 4). Prices in 2015 were again higher relative to 2013, with larger increases for *M. tarapacana* and *Manta* gills. The ANOVA confirmed that Guangzhou gill plate prices were significantly different between years ($P < 0.001$) and species ($P < 0.001$). According to the large distributor interviewed, Hong Kong prices for both types of *Mobula* gills were slightly higher in 2015 relative to 2011 and slightly lower for *Manta* gills.

Species composition

In all surveys, the gill plate market comprised three main types: (1) *Manta* spp.; (2) *M. tarapacana*; and (3) small gill plates from *M. japanica*, *M. thurstoni*, and possibly other *Mobula* spp. As *M. japanica* and *M. thurstoni* gill plates are very similar in size and appearance and are mixed together in the same containers, it was not possible to determine the proportion of each species in stock estimates. A small amount of whale shark gills marketed as *pengyusai* was also observed in all three years. In

Table 3. Vendor-reported market trends in supply and demand

Survey	Supply trends				Demand trends			
	Number of reports	Stable	Up	Down	Number of reports	Stable	Up	Down
2011 Guangzhou	11	0	0	11	22	1	18	3
2011 Singapore	21	0	0	21	15	0	0	15
2011 Hong Kong	10	0	0	10	7	0	0	7
2011 Macau	6	0	0	6	8	0	0	8
2011 Total	48	0	0	48	52	1	18	33
Percentage of 2011 Total		0%	0%	100%		2%	35%	63%
Guangzhou % of total		0%	0%	100%		5%	82%	14%
2013 Guangzhou	11	6	2	3	24	3	18	3
Percentage of 2013 Total		55%	18%	27%		13%	75%	13%
2014 Taobao	8	3	0	5	4	0	0	4
Percentage of 2014 Total		38%	0%	63%		0%	0%	100%
2015 Guangzhou	11	3	8	0	7	0	0	7
Percentage of 2015 Total		27%	73%	0%		0%	0%	100%

Table 4. Average dried gill plate prices per kg; local currency and USD*

Market city	Apr 2011 surveys		Dec 2013 survey		Dec 2015 surveys	
	Local Curr	USD	Local Curr	USD	Local Curr	USD
Guangzhou	CNY		CNY		CNY	
<i>Manta</i> spp.	¥1813	\$277	¥1970	\$325	¥2127	\$329
<i>M. tarapacana</i>	¥1269	\$194	¥1553	\$256	¥1850	\$286
<i>M. japonica</i> /other	¥923	\$141	¥1173	\$193	¥1218	\$189
Hong Kong	HKD				HKD	USD
<i>Manta</i> spp.	3670\$	\$472			3250\$	\$419
<i>M. tarapacana</i>	1790\$	\$230			1875\$	\$242
<i>M. japonica</i> /other	1450\$	\$187			1550\$	\$200
Macau	HKD					
<i>Manta</i> spp.	2670\$	\$343				
<i>M. tarapacana</i>	1870\$	\$241				
<i>M. japonica</i> /other	1200\$	\$154				
Singapore	SGD					
<i>Manta</i> spp.	507\$	\$408				
<i>M. tarapacana</i>	446\$	\$359				
<i>M. japonica</i> /other	360\$	\$290				
% Changes (local curr.)	Apr 2011 to Dec. 2013	Dec 2013 to Dec. 2015	Apr 2011 to Dec. 2015			
Guangzhou						
<i>Manta</i> spp.	9%	8%	17%			
<i>M. tarapacana</i>	22%	19%	46%			
<i>M. japonica</i> /other	27%	4%	32%			
Hong Kong						
<i>Manta</i> spp.			-11%			
<i>M. tarapacana</i>			5%			
<i>M. japonica</i> /other			7%			

*Local currency prices converted to USD using historical exchange rate tables from www.xe.com.

2011 the proportion of stock by dried gill plate volume from Guangzhou surveys was 36% *Manta* spp. gill plates, 34% *M. tarapacana* gill plates, and 30% small gill plates from other *Mobula* spp. The proportion of *Manta* gill plates dropped in 2013 (20%) and increased in 2015 (33%) (Figure 2). Traders consistently referred to *M. tarapacana* gill plates as *flower gill*, but a large variety of trade names was used for gills from other species, often referring to source location, size, and/or coloration, such as *Beihai penyusai*, *Vietnam soft speckled gills*, *Myanmar speckled gills*, *South American giant white penyusai*, or *Vietnamese black gills*.

Number of mobulids

Figure 3 illustrates the configuration of gill plates in whole mobulids. Based on these reported yields, the number of mobulids represented in the Guangzhou market's annual gill plate sales was estimated at 48 400 in 2011 and 120 500 in 2013 (Table 5). Owing to the smaller size and much lower dried

gill plate yield per animal for devil rays, these species represented the bulk of the estimated number of mobulids required to produce the dried gill plate stocks observed in the Guangzhou market surveys (90% in 2011, 96% in 2013, and 93% in 2015).

Source locations

Twenty-two different locations were reported as the source of dried gill plates from all surveys, including 14 countries, plus Hong Kong and Taiwan, and six continents or ocean regions (Table 6). The most frequently reported source locations were China, followed by China Seas (especially the northern part of the South China Sea), Indonesia, Vietnam, Sri Lanka, and India. Vendors reporting China as source identified Yangjiang (Shapa Bay, Zhapo, and Dongping Harbor), Zhangjiang (Naozhou Island), and Maoming (Bohe) as the primary ports for sourcing domestic gill plates. The countries participating in the mobulid gill plate trade and

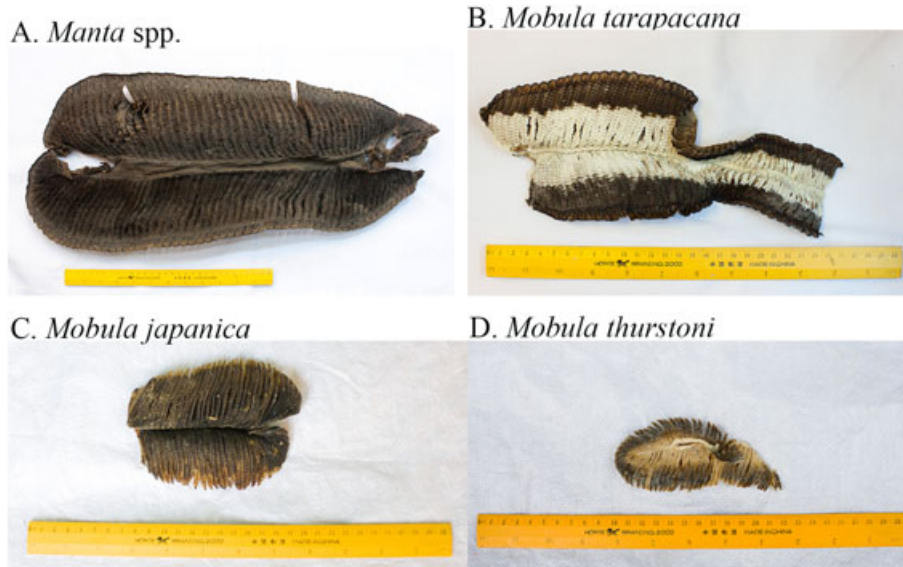


Figure 2. Gill plates from each species identified in this study. A = *Manta* spp., B = *M. tarapacana*, C = *M. japonica*, D = *M. thurstoni*; scale =30 cm. Photos by Paul Hilton.

the roles played by each, based on vendor responses across all surveys, are summarized in Table 7.

Reported medicinal uses

The *pengyusai* tonic is prepared as a soup with dried gill plate pieces boiled together with other ingredients, such as dried seahorses, pipefish or scallops, pork or beef, and various medicinal plants, with accompanying ingredients differing according to the ailment to be treated. Seller interviews and online research revealed that *pengyusai* is recommended to treat a wide range of ailments and for general health maintenance (Table 8). In 2011, the most common health claims included treatment for cough/phlegm, fever, and chicken pox. By 2013, the list of medicinal claims had expanded to include lactation aid, health support especially for heavy drinkers and smokers, lung, liver, and eyesight support, and reducing inflammation, irritability, and hyperactivity (particularly for babies). In 2015 the five vendors responding to this question during Guangzhou surveys claimed it was for clearing the lungs and promoting respiratory health, while Taobao web-based sellers and Hong Kong sellers continued to promote the same range of uses as in previous surveys.

Of the four TCM interviews conducted in 2011, two doctors (Macau, Hong Kong) were trained as TCM doctors, but had stopped practising medicine to open dried seafood stores. Both touted the effectiveness of *pengyusai* for several health issues, including cough/sore throat and chicken pox/measles, and one (Hong Kong) explained that it is effective for all thyroid and lymph node related diseases including cancer. The TCM practitioner interviewed at a Guangzhou TCM Centre agreed when asked if *pengyusai* would be an effective treatment for a child with chicken pox, and added that it eliminates heat and is good for the skin. However, when she realized there were no gill plates in stock at the Centre, she said that they were getting more difficult to source, were not very effective, and many alternatives were available. The other two TCM doctors interviewed (Guangzhou and Singapore) stated that *pengyusai* had no health benefits and many alternatives were available. One (Guangzhou) further asserted that *pengyusai* is not a part of standard, medically recognized, and practised TCM, and that vendors promote the misconception that *pengyusai* is prescribed as TCM.

There is no information on *pengyusai* in the *Compendium of Materia Medica* by Dr. Li Shi-zhen (*c.* 1578), which is still considered the

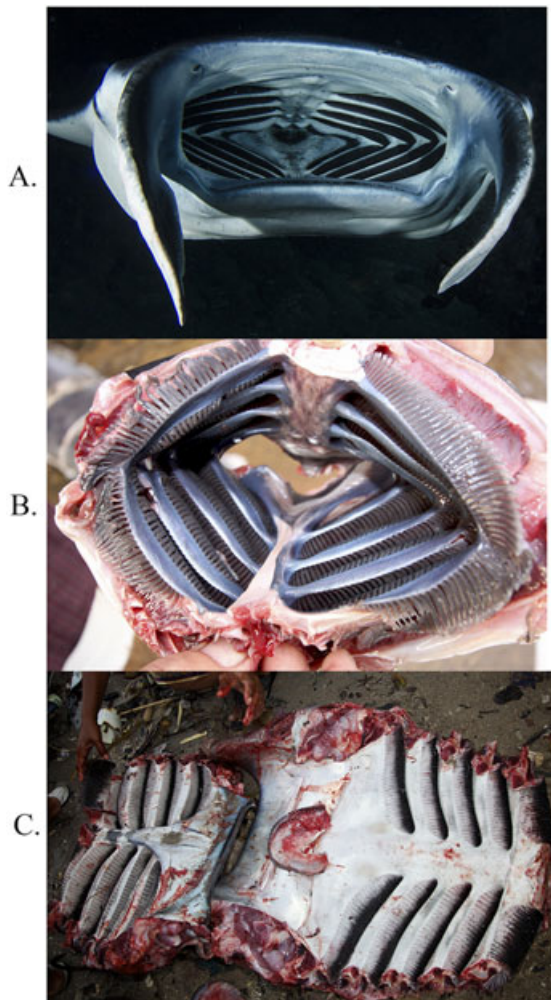


Figure 3. Gill plates per whole animal. A . *Manta* spp. gill plate structure shown in live feeding manta, B . *M. japonica* gill plates front view, C . *M. tarapacana* cut open to expose gill plates. Photos by Mary O'Malley (A), Gisele Kaufman (B) and Shawn Heinrichs (C).

premier reference tool for TCM (Mainka and Mills, 1995; Library of Congress, 2014). However, an extensive literature review located several recent references to *pengyusai* in TCM textbooks (Lin, 1976; Anon, 1977; Peigen, 1988; Guan and Wang, 2009). Its first appearance in TCM literature was in 1976 in *Guangxi Medicinal Animals*, by Lin, Yu He (Shen *et al.*, 2001), in which *pengyusai* was described as the dried gills from *Mobula 'japonica'* (sic) (Lin, 1976). *Manta birostris* first appeared in *China Pharmaceuticals of Marine Biological Origin* (Anon, 1977), with *Mobula 'japonica'* noted as a sister species, and medicinal benefits described as detoxification,

clearing heat, and promoting eruption, for treatment of measles and skin issues (ulcer and boils). The most recent TCM reference found was *Chinese Marine Materia Medica* (Guan and Wang, 2009), which describes *pengyusai* as the gill from five types of 'Manta' species, *Manta birostris*, *Mobula diabolus*², *Mobula 'japonica'*, *Aetobatus flagellum*³, and *Aetobatus narinari*, with medicinal uses including detoxification, exposing exanthema (viral disease accompanied by a skin rash), measles, pertussis (whooping cough), dysentery, funculus (boil), and furunculosis (recurring boils). This reference also cites large population declines for manta and devil ray species due to overfishing and endangered status according to the IUCN and China's species red list.

DISCUSSION

Market surveys in 2011 clearly identified Guangzhou as the centre of gill plate consumption and trade, while estimates from the December 2013 Guangzhou survey demonstrated a worrying trend of increased market volume, prices, and demand. The volume of gill plates increased most dramatically for the small *Mobula* spp. gill plates, which tripled over the period. Results from 2015 surveys suggest that Guangzhou government efforts to phase out the gill plate trade in cooperation with an NGO demand reduction campaign are showing signs of success in reducing gill plate demand, but may also indicate a shift to Hong Kong as the new centre of the trade, possibly due in part to lax enforcement of import control in this free trade port (Cheung and Dudgeon, 2006).

Species found in gill plate markets, primarily *Mobula japonica*, *M. thurstoni*, *M. tarapacana*, and *Manta* spp., correspond to those reported most frequently in fisheries supplying the gill plate trade (White *et al.*, 2006b; Fernando and Stevens,

²*Mobula diabolus* is not a recognized species. The sketch in the book appears to refer to *Mobula tarapacana* (Stevens, 2011; G. Stevens, pers. comm.).

³Eagle ray species

Table 5. Conversion of dried gills to estimated number of mobulids*

Estimated number of mobulids represented in Guangzhou annual sales 2011 and 2013

Species	Dried gills (kg)/ animal	Apr 2011 survey			Dec 2013 survey			Change Apr. 2011 to Dec. 2013	
		Dried gill plate volume (kg)	Number of mobulids	% per species	Dried gill plate volume (kg)	Number of mobulids	% per species	Number of Mobulids	%
<i>Manta</i> spp.	5	21 876	4375	9%	23 811	4762	4%	+387	+9%
<i>M. tarapacana</i>	2.5	20 324	8130	17%	42 165	16 866	13%	+8736	+107%
<i>M. japonica</i> / other	0.5	17 952	35 904	74%	54 493	108 986	83%	+73 082	+204%
Totals		60 152	48 409	100%	120 469	130 614	100%	+82 206	+170%

* Calculated by dividing the total estimated volume (kg) of gill plates per species by average dried gill weight (kg) per animal.

Table 6. Reported gill plate sources from vendor interviews

Reported source	Total	%	2015		2014		2013		2011	
				%		%		%		%
Vendors reporting sources	181		33		50		30		68	
China	73	40.3%	10	30%	40	80%	11	37%	12	18%
China Seas	26	14.4%	0	0%	1	2%	13	43%	12	18%
Indonesia	25	13.8%	5	15%	1	2%	4	13%	15	22%
Vietnam	13	7.2%	2	6%	1	2%	5	17%	5	7%
Sri Lanka	10	5.5%	4	12%	3	6%	1	3%	2	3%
India	9	5.0%	1	3%	0	0%	1	3%	7	10%
South America ¹	8	4.4%	0	0%	1	2%	4	13%	3	4%
Malaysia	8	4.4%	3	9%	3	6%	1	3%	1	1%
South Africa	6	3.3%	2	6%	0	0%	1	3%	3	4%
Hong Kong	6	3.3%	0	0%	1	2%	1	3%	4	6%
Australia	5	2.8%	1	3%	0	0%	1	3%	3	4%
Brazil	4	2.2%	3	9%	0	0%	1	3%	0	0%
Europe	4	2.2%	0	0%	1	2%	1	3%	2	3%
Philippines	4	2.2%	3	9%	0	0%	0	0%	1	1%
Africa	3	1.7%	0	0%	0	0%	0	0%	3	4%
Taiwan	3	1.7%	0	0%	1	2%	0	0%	2	3%
Thailand	3	1.7%	1	3%	0	0%	0	0%	2	3%
Japan	2	1.1%	0	0%	0	0%	2	7%	0	0%
Middle East	2	1.1%	0	0%	0	0%	1	3%	1	1%
Myanmar	1	0.6%	0	0%	0	0%	0	0%	1	1%
Pacific Ocean	1	0.6%	0	0%	0	0%	0	0%	1	1%
Mauritius	1	0.6%	1	3%	0	0%	0	0%	0	0%

¹One seller specified Brazil.²Six specified South Africa.

Sources reported by sellers in Macau were Hong Kong, Taiwan and China.

Sources reported by sellers in Hong Kong were Indonesia, Sri Lanka, India, Malaysia, Australia, Thailand and Philippines.

Sources reported by sellers in Singapore were Indonesia, India, Africa, Australia and Middle East.

2011; Acebes, 2013). Recently reported evidence of the export of gill plates from *Mobula mobular*, IUCN Red List classified as Endangered (Notarbartolo di Sciara *et al.*, 2006), from Gaza, Palestine (Abudaya *et al.*, 2014) suggests that more devil ray species may be affected by the gill plate trade than those identified in this study. The large number of devil rays represented in market

estimates is concerning as limited biological information is available for these species and the risk of unsustainable harvesting relatively high (Couturier *et al.*, 2012). Also concerning is the strong preference for large manta ray gill plates in the expanding Hong Kong market, which could drive increased fishing effort for these species.

Table 7. Participants in the mobulid gill plate trade and roles played by each according to vendor interviews

Producer ¹	Importer/consumer ²	Exporter
China	China	China
Vietnam	Hong Kong	Hong Kong
Indonesia	Macau	Vietnam
S America	Singapore	Indonesia
Sri Lanka		S America
Africa		Sri Lanka
Malaysia		Africa
Europe		Malaysia
Myanmar		Europe
Australia		Myanmar
Japan		Australia
India		Japan
Taiwan		India
Middle East		Taiwan
Thailand		Middle East
Philippines		Thailand
Mauritius		Philippines
		Mauritius

Producer = reported as a gill plate source

Importer/consumer = reported sourcing gill plates from other regions and selling locally

Exporter = reported by other markets as source of gill plates

¹Hong Kong was reported as a source location by some vendors in China and Macau, but does not catch mobulids, and therefore is not listed as a Producer. Hong Kong distributors reported that Hong Kong imports gill plates and re-exports 70–80% to China.

²Malaysia and Canada were also identified as consumers from other sources (Dulvy *et al.*, 2014; Manta Trust, 2014).

Source countries for gill plates reported from this study were comparable with mobulid fishery locations listed in the Couturier *et al.* (2012) and Croll *et al.* (2015) mobulid conservation reviews. However, several locations were highlighted through the interview process that had not been previously identified as having fisheries supplying the gill plate trade, including Vietnam, Mauritius, Myanmar, Thailand, Japan, Australia, South Africa, Europe, Middle East, and South America (including Brazil specifically). Gill plate exports from these locations, however, have yet to be verified and some may refer to illegal catches within the waters of these countries. For example, Indonesian fishers from Tanjung Luar, Lombok have admitted to illegally targeting mobulids in northern Australian waters (Lewis *et al.*, 2015), a Hong Kong trader reported in 2015 to be receiving manta ray gills that were illegally transhipped from Indonesia (P. Hilton, pers. comm.), and illegal catch of manta rays and export of manta gill plates have been documented in the Philippines (Rayos *et al.*, 2012; Acebes,

2013; Asis *et al.*, 2014). In addition Indonesia, Australia, Brazil, and the Philippines were still reported as sources in 2015 despite laws prohibiting take and trade of some or all mobulid species in these countries.

The very high proportion of reports of China as a source of gill plate supply is questionable. The manager of the mobulid processing plant in Puqi stated the mobulids processed in his facility were landed in Chinese ports, but were caught in international waters. In addition, seller reports of gill plates from regions where the gill plate trade has not been observed, but in which Chinese distant water fishing fleets have been reported (Pauly *et al.*, 2014; D. Fernando, pers. comm.), could indicate unreported take of mobulids by Chinese vessels in other regions. However, documentation of the year-round presence of whale sharks primarily off China's southern provinces in the South China Sea, with an estimated 1000 landed per year (Li *et al.*, 2012b), suggests a substantial local mobulid fishery could also exist. As large filter-feeding elasmobranchs living mainly in tropical and subtropical waters, manta and devil rays often share habitat and aggregation areas with whale sharks (Sleeman *et al.*, 2007; Anderson *et al.*, 2011; de la Parra *et al.*, 2011; Rohner *et al.*, 2013; Berumen *et al.*, 2014) and have been targeted by the same fisheries (Alava *et al.*, 2002; Barnes, 2005; White and Cavanaugh, 2007). In addition, the South China Sea has been identified as home range to seven of the world's 11 mobulid species (Last and Compagno, 2002; Marshall *et al.*, 2009).

Traditional Chinese medicine (TCM) is believed to have originated over 5000 years ago (Mainka and Mills, 1995; Liddick, 2011) and is one of the most popular forms of alternative and complementary medicines in East Asia (Leung *et al.*, 2003). Gill plates as a remedy first appeared in Chinese medicine literature in 1976 (Lin, 1976) and the earliest reports of fisheries supplying gill plates to China came from the Philippines in the 1960s, when a buyer from Mindanao introduced the trade (Acebes, 2013). The expansion of the gill plate trade in the late 1990s (Dewar, 2002; Acebes, 2013) may be explained, at least in part, by the broader trend of increased use of wildlife for

Table 8. Vendor-recommended uses of gill plates

Recommended use	2015 surveys		2013–2014 surveys		2011 surveys	
	Number of vendors	Percentage of vendors reporting	Number of vendors	Percentage of vendors reporting	Number of vendors	Percentage of vendors reporting
	13		71		31	
General health*	0	0%	41	58%	11	35%
Removes toxins	1	8%	41	58%	2	6%
Chicken Pox/Small Pox/Measles	2	15%	35	49%	4	13%
Lactation aid	5	38%	33	46%	0	0%
Cough /Sore Throat /Phlegm/Tonsil inflammation (Children)	0	0%	29	41%	6	19%
Reduce internal heat	0	0%	27	38%	7	23%
Lung support	0	0%	17	24%	0	0%
Liver support	1	8%	14	20%	0	0%
Eyesight support	5	38%	13	18%	0	0%
Skin Complaints/Acne/Boils	0	0%	13	18%	5	16%
Cancer	0	0%	9	13%	1	3%
Fever	1	8%	9	13%	6	19%
Reduce inflammation	6	46%	8	11%	0	0%
Aids digestion /good for stomach	1	8%	8	11%	1	3%
Overuse of alcohol-tobacco-stay up all night	5	38%	7	10%	0	0%
Aids blood circulation	1	8%	7	10%	1	3%
Kidney support	4	31%	4	6%	5	16%
Irritability	3	23%	3	4%	0	0%
Not TCM	1	8%	3	4%	1	3%
Mumps	0	0%	1	1%	2	6%
Fertility aid	1	8%	1	1%	1	3%
Hyperactivity (babies)	1	8%	1	1%	0	0%
Thyroid gland support	3	23%	0	0%	1	3%

*'General Health' also includes: Nourish Yin, Adjust Qi, Enhance physical fitness, Avoid hospital/medical injections, Boosts immunity

medicinal purposes, which has 'escalated alarmingly in the past decade' (WWF /Dalberg, 2012). Increasing wealth in China and the prestige associated with being able to procure rare and expensive remedies and foods have contributed to this trend (Clarke *et al.*, 2007; Fabinyi, 2011; Graham-Rowe, 2012; Zhang and Yin, 2014). Other factors driving demand include concerns about toxicity and dangerous side effects from pharmaceutical drugs (Pang, 2012) and the common beliefs in powerful medicinal properties associated with certain foods (Yiming and Dianmo, 1998; Qifeng *et al.*, 2012) and in wild-sourced ingredients being more potent and free of impurities than cultivated ones (Fabinyi, 2011). Internet advertisements for gill plates frequently focus on the purity of *pengyusai*, claiming it has been harvested from pristine ocean areas, and promoting its efficacy in improving respiratory health. Thus China's air pollution crisis and associated respiratory illnesses (Lelieveld *et al.*,

2015) may well be another driver of *pengyusai* demand. Ironically, consumption of unregulated animal products from unknown sources carries a number of potential health risks from heavy metal accumulation, toxic chemicals used in processing, and zoonotic transmission of infectious diseases (Still, 2003; Clarke *et al.*, 2007; Alves *et al.*, 2013). Mobulid gill plates and tissues tested have been found to contain potentially unsafe levels of heavy metals, including arsenic, cadmium, and mercury (Essumuang, 2009; Whitcraft *et al.*, 2014; Oi *et al.*, 2015), with some gill plate samples tested exceeding the Pharmacopoeia of China recommended limit for arsenic by as much as 20 times (Li *et al.*, 2012a; Whitcraft *et al.*, 2014).

In general, prescription of remedies from endangered animals is no longer common (Graham-Rowe, 2012), and in fact, top TCM doctors and companies have publicly renounced the use of products containing endangered species (TRAFFIC, 2014). In this study apothecaries and

TCM doctors interviewed confirmed that prescriptions for *pengyusai* are rare. However, 92% of consumers surveyed in Guangzhou in 2014 reported learning of *pengyusai* through word of mouth from friends or relatives (Whitcraft *et al.*, 2014), and it is readily available over the counter. In addition, vendors drive demand for animal-derived TCM remedies with claims of medicinal benefits which are often more expansive than those recorded in TCM texts (Graham-Rowe, 2012). For example, rhino horn, which has been used in Chinese medicine for thousands of years, was originally described as a heat-clearing and detoxifying remedy, similar to mobulid gill plates (Nowell, 2012). However, it is now marketed by some as a cure for cancer and to ease hangover symptoms in Vietnam and China (Nowell, 2012). Similarly *pengyusai* is marketed for a wide range of uses that are not documented in TCM literature. The greater percentage of sellers promoting regular *pengyusai* use for general health maintenance and the expanded list of reported health benefits in 2013 relative to 2011, suggests trader marketing aimed at broadening the consumer base over this period of rapid market growth. In particular, none of the sellers or TCM practitioners interviewed in 2011 reported lactation aid as a benefit, nor does this application appear in any of the TCM references reviewed. Yet this use, which clearly targets a new and younger consumer group, was reported by 47% of sellers in the 2013 Guangzhou survey and 2014 survey of Chinese web-based sellers.

The findings of this study together with reported declines in mobulid landings of 75 to 95% in Indonesian fisheries supplying the gill plate trade over the past 10 to 15 years, despite increased targeted effort (Lewis *et al.*, 2015), suggest that the gill plate trade may already have had a serious negative impact on regional mobulid populations. In addition a recent vulnerability analysis indicates these species can only withstand very low levels of fishing mortality (Dulvy *et al.*, 2014). Consequently, the levels of trade identified by this study are unlikely to be sustainable and could lead to further population declines and local extinctions.

In order to develop informed conservation strategies for manta and devil rays, the extreme

deficiency of data on mobulid fisheries and trade must be addressed as an urgent priority. The latest available trade data from the Food and Agriculture Organization (FAO) do not distinguish trade in rays from other elasmobranchs (FAO, 2015), and there are no uniform customs codes to enable tracking of trade in mobulids (Mundy-Taylor and Crook, 2013). The FAO has two categories in which countries can report capture production of manta and devil rays (*Mantas*, *devil rays*, *nei* and *Giant manta*), but only four countries have reported in these categories (FAO, 2015). Indonesia is the only country to have reported mobulid landings consistently since 2005 (FAO, 2015), but even these data may not be reliable (Fahmi and Dharmadi, 2015). To address these data deficiencies, establishment of uniform import/export codes for manta and devil ray gill plates and other mobulid products, and training and capacity building to assist countries with reporting landings at the species level will be required. RFMOs can play an important role in this respect. For example, in 2015 the Inter-American Tropical Tuna Commission (IATTC) passed a resolution that prohibits retention or sale of mobulid rays, requires prompt release of live animals using safe release protocols and recording of data on discards and live releases, and includes provisions for technical assistance and capacity building (IATTC, 2015).

Investigations of fishery landings and exports in countries frequently cited as gill plate sources, but for which no data on fisheries or trade have been reported, are also needed in order to prioritize conservation efforts. Vietnam, for example, was the third most frequently cited source country, but the authors were unable to locate any data on mobulid fisheries or trade in this country. Similarly in China, cited as source country in more than half of all interviews over the study period, the only fishery data identified were from the manager of the Puqi shark and ray processing plant in 2011. Further surveys in southern China's coastal cities outside of Guangzhou may also be warranted, particularly Zhanjiang, Yangjiang, Jiangmen, and Zhuhai in Guangdong Province and Beihai in Guangxi Zhuang Autonomous Region, as vendors commented that the Chinese ports reported as

mobulid landing sites were formerly small fishing communities, but had recently transformed into major seafood markets.

A number of vendors expressed frustration with supply difficulties and increasing prices, and most sell a range of products and therefore are not heavily reliant on income from gill plate sales. Therefore efforts by gill plate source and consuming countries to restrict the supply of gill plates through implementation and enforcement of CITES trade restrictions, CMS protection commitments, and domestic fisheries management measures could be highly effective in reducing the gill plate trade. The Indonesian government announced full protection of manta rays in January 2014 (Anon., 2014) and has been proactive in arresting and prosecuting traders who illegally purchase and export manta gills (Bell, 2014; Gannon, 2014). However, source locations reported by sellers indicate that a substantial proportion of the mobulid gill plate trade may violate provisions of both CITES and CMS treaties, and few have national laws to manage mobulid populations. Six of the 14 reported source countries plus the European Union are parties to CMS (Australia, India, Mauritius, Philippines, South Africa, Sri Lanka) (CMS, 2014), which requires parties to prohibit take of these Appendix I listed species with very limited scope for exceptions (CMS, 2003), though to date only Australia and the European Union have passed such regulations. All the reported source countries for gill plates from Appendix II listed *Manta* spp. are parties to CITES (CITES, 2014). As of the September 2014 implementation deadline, this binding international treaty requires exporting countries to produce non-detriment findings (NDFs), which certify exports are from legal and sustainable fisheries that are not detrimental to *Manta* spp. populations (Vincent *et al.*, 2013). To date, no country has produced an NDF with scientific support for a sustainable level of trade for *Manta* spp. (CITES, 2016). The possibly widespread misreporting of China as the country of origin could frustrate implementation of CITES regulations, since domestic manta ray gill plates would not be subject to CITES restrictions (Vincent *et al.*, 2013). However, landing mantas caught outside of China's EEZ in Chinese ports, as

reported by the Puqi processing plant manager, would be subject to Appendix II requirements under the Introduction from the Sea provision (Vincent *et al.*, 2013). Extending CITES Appendix II restrictions to include devil rays would provide the legal basis for strictly regulating trade in all mobulid gill plates and facilitate trade enforcement, while ensuring comparable conservation measures for devil rays, which share similar biological vulnerabilities with manta rays and face similar threats.

Of the reported source countries, Australia (2015) and Brazil (2013) recently prohibited take and trade of all mobulids, and Indonesia and the Philippines prohibit capture and trade of one or both *Manta* species, but have no management measures for *Mobula* spp. (Lawson *et al.*, 2016). Though China does not have management measures specifically applying to mobulids, China's Protection of Wildlife Law specifies that hunting of all CITES Appendix II listed species is illegal without a special permit from the Chinese government (Wenjun *et al.*, 1996; Li *et al.*, 2012b; China.org.cn, 2014). However, there are no measures in place to monitor or manage mobulid fisheries or trade in any of the other reported source countries, including the four most frequently reported after China and Indonesia (i.e. Vietnam, Sri Lanka, India, and Malaysia) (Lawson *et al.*, 2016). Programmes to assist fishing communities with sustainable management of marine resources will be critical to the implementation of effective conservation measures in these countries. In Indonesia a collaborative NGO programme is underway in Lamakera (Solor), the country's largest directed mobulid fishery, to help the community transition to more sustainable sources of income, including sustainable fisheries and practices (i.e. hand-line yellowfin tuna), marine megafauna ecotourism, production of finely woven cloth, and part-time work as marine megafauna scientific research staff (Lewis *et al.*, 2015). These programmes show a great deal of promise, and could be mirrored in other countries supplying the market for manta and devil ray gill plates as well as other threatened wildlife species.

Finally, campaigns to address demand in China, as well as Hong Kong and Macau, are a critical component of a mobulid conservation strategy (Lawson *et al.*, 2016). The growing number of consumers who can now afford *pengyusai* and other expensive remedies from threatened species are largely unaware of the conservation and legal implications of buying these products (Zhang *et al.*, 2008; Whitcraft *et al.*, 2014). However, a large percentage of consumers surveyed expressed a willingness to stop consuming *pengyusai* for protection of threatened wildlife (91%) or due to the presence of heavy metals or other toxins (97%) (Whitcraft *et al.*, 2014), indicating that targeted communication campaigns currently underway in Guangzhou since May 2014 (IUCN – SOS Marine, 2014), could be effective in reducing *pengyusai* demand and have likely contributed to the market decline observed since the 2011 and 2013 surveys.

Continued measures contributing to a comprehensive strategy integrating international and local measures to address both the demand for and supply of manta and devil ray gill plates should be pursued with urgency to prevent the continued unsustainable exploitation of these biologically vulnerable species.

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