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Consumer characteristics and preferences for mobulid gill plates in China

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Article impact statement: Preferences of gill plate consumers are heterogeneous and prioritizing their education in mobulid conservation will greatly benefit the taxon.

Abstract

Mobulid species are endangered globally, and the market trade for gill plates is believed to be a major threat. Successful conservation and the sustainable use of mobulids therefore requires an objective understanding of consumer characteristics and preferences for gill plates. Previous studies focused on qualitative descriptions, and reliable quantitative analyses are currently lacking. We used a latent class choice experiment method and a semi-structured questionnaire to provide important new quantitative information about gill plate consumer characteristics and the heterogeneous nature of demand for gill plates. During May to July 2019, we conducted a field study in Guangzhou, the primary consumption hub for mobulid gill plates in mainland China. Utilizing a simple random sampling method, we engaged in face-to-face interviews with 428 consumers of gill plates within the major trading markets in Guangzhou. Our results show that 59.8% of consumers of gill plates were over 40 years old, 62.6% were female, 80.7% had annual household incomes of <200,000 yuan, and 84.5% recognized the medical and health value of gill plates and purchased them. 72.3% of consumers preferred to purchase imported and less expensive gill plates from unprotected species, but they had a strong preference for large gill plates from protected species, such as *Mobula birostris*. This contradiction arose from consumers' lack of knowledge of mobulids and their conservation status. We found, for example, female consumers over 40 years old had the least understanding of conservation status of mobulid species and the link between size of gill plates and rarity of mobulids. This suggests there may be opportunities to promote mobulid conservation through education and marketing targeted at this demographic. 10.0% of

consumers may be harder to influence because they had a positive preference for gill plates from protected species (regardless of price). Overall, we believe education alone is not enough and that the conservation of mobulids would benefit from an integrated approach that involves conservation education and strengthened trade regulations, such as the introduction of traceability systems and a stiffer legal framework for consumption of protected species.

中国蝠鲼鳃耙消费者的消费特征及偏好研究

摘要：蝠鲼在全球范围内受到威胁，而蝠鲼鳃耙贸易被认为是导致种群数量下降的主要致危因素。蝠鲼保护与可持续利用应基于对鳃耙消费者特征及偏好的客观了解。然而以往研究多集中于对鳃耙消费者的定性描述，可靠的定量分析仍旧缺乏。本研究通过使用选择实验方法结合半结构化问卷调查法，提供关于鳃耙消费者特征和异质性需求的重要定量信息。本研究于 2019 年 5-7 月在中国内地蝠鲼鳃耙的主要消费地——广州，展开实地研究。通过利用简单随机抽样法，我们共对 428 位广州蝠鲼鳃耙主要贸易市场中的鳃耙消费者展开了面对面访谈。结果表明，59.8%的鳃耙消费者年龄在 40 岁以上，62.6%的消费者为女性，80.7%的消费者家庭年收入低于 200,000 元，84.5%的消费者认可鳃耙的医疗保健价值并购买。72.3%的消费者更愿意购买来源于非保护物种的进口便宜鳃耙，但同时也对大块鳃耙表现出强烈偏好，矛盾的是这类鳃耙通常来源于濒危物种，如双吻前口蝠鲼。这种矛盾的偏好可能来源于消费者对蝠鲼及其保护状况的了解不足。例如，我们发现，40 岁以上的女性消费者对蝠鲼物种保护状况以及鳃耙大小与蝠鲼物种稀有性之间的关联了解最少，这表明未来可能通过对这一人群展开蝠鲼保护教育来促进蝠鲼物种的保护。然而，也有 10.0%的消费者可能很难通过教育影响，因为他们对来源于受保护物种的鳃耙有积极的偏好（不管价格如何）。总体来说，我们认为仅靠教育是不够的，蝠鲼保护将受益于包括保护教育和加强贸易法规执行在内的综合方法，例如引入可追溯系统和对受保护物种的消费制定更严格的法律框架。

关键词：蝠鲼鳃耙，可持续渔业，野生动物贸易，选择实验法，中国

Introduction

Mobulids consist of nine species of devil rays and two species of manta rays. They are among the most spectacular and charismatic of ocean species, an important species in commercial terms, and widely harvested as a target fish and as bycatch (Fernando & Stewart, 2021; Fernando, 2018; Haque et al., 2021). Demand for mobulid gill plates has soared (O'Malley et al., 2017; Whitcraft et al., 2014), and these higher prices encourage more commercial targeting (Croll et al., 2016; Fernando, 2018). The surge in demand and slow growth and low reproductive rates of mobulids has led to a steep decline in populations (Dulvy et al., 2014; Lewis et al., 2015). For example, the population of the oceanic manta ray *Mobula birostris* worldwide has decreased by nearly 30% over the past 75 years (Marshall et al., 2011).

China is the main market for gill plate consumption, and its gill plate trade has always been highlighted as critical to conservation efforts (O'Malley et al., 2017). The Chinese trade in gill plates can be traced back to the 1960s, when they were imported by Filipino sellers (Acebes, 2013). By the late 1990s, China's gill plate trade had begun to rapidly expand (Acebes, 2013), and by 2013, the sales volume of gill plates in Guangzhou, China, was around 120 t, which is equivalent to about 130,000 individuals (O'Malley et al., 2017). In part this rapid expansion was driven by promotion of the alleged medicinal benefits of gill plates, for example, its ability to detoxify the body, reduce fever, and prevent coughs (Ye et al., 2022). However, these claims are not grounded in traditional Chinese medicinal practice or teaching (Whitcraft et al., 2014).

The international community has issued a series of policy measures to reduce the impact of unsustainable trade on mobulid populations. In 2011 *Mobula birostris* was listed in Appendix I and Appendix II of the Convention on Migratory Species (CMS) (CMS, 2012), and

in 2016 all species of *Mobula* were listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (CITES, 2016), and the International Union for the Conservation of Nature (IUCN) includes all species of mobulids on the IUCN Red List of Threatened Species. As one of the main consumer countries, China currently manages the trade of mobulids mainly under the framework of CITES and relies on domestic laws described in the Regulations of the People's Republic of China on the Administration of Import and Export of Endangered Wild Fauna and Flora (RPRCAIEE). Consumption of mobuild products is legal in China but the trade must be sustainable to further conservation efforts. A series of publicity activities have been carried out in China to help protect mobulids. For example, in November 2015, the National Forestry and Grassland Administration and WildAid jointly held a news conference in Guangzhou to ask the public to stop eating gill plates (Qin, 2015).

Policy measures to address unsustainable trade require a comprehensive understanding of the demands and preferences of consumers (Shairp et al., 2016), but thus far research has primarily focused on qualitative descriptions of gill plate consumers and consumption markets (O'Malley et al., 2017; Wu, 2016). There is therefore a critical knowledge gap in terms of quantifying consumer characteristics and preferences. This limited understanding obscures the fundamental drivers of trade, making it impossible to effectively implement measures to promote mobulid conservation and sustainable fisheries development.

We used the choice experiment method to explore consumer demand and preferences for gill plates based on key attributes, such as protection status, price, size, and source, and to

identify different key groups of gill plate consumers. We used the latent class approach to help identify subgroups among consumers based on their preferences and demographic characteristics. Additional questions from a semistructured questionnaire were used to gather additional data on the consumption characteristics of gill plate consumers on the Chinese mainland and on their understanding of the links between gill plate consumption and mobulid conservation. The overall aim was to identify the main driving forces and influencing factors of mobulid gill plate trade so as to provide a scientific basis for formulating mobulid trade management policies and help promote mobulid conservation and sustainable fishery development.

Methods

Research Location and Questionnaire Distribution

Guangzhou is the main distribution center for mobulid gill plates in China. The volume of gill plate trade was 60.5 t in 2011 and 120.5 tons in 2013. More than 90% of the total volume of trade in gill plates in China and Southeast Asia occurs in Guangzhou (O'Malley et al., 2017; Whitcraft et al., 2014). Based on previous studies on the mobulid gill plate trade in China (Whitcraft et al., 2014) and our preliminary assessment, Qingping Market and Yide Dry Seafood Market in Yuexiu District are the key market areas for the trade in Guangzhou and were therefore selected as the best location for our consumer research.

We used random sampling to identify interviewees and conducted face-to-face interviews at these sites during the peak season (O'Malley et al., 2017) of gill plate consumption (May to July, 2019). To maximize the representativeness of the sample, two investigators randomly

selected stores, neighborhoods, and surrounding buildings in or near the markets as specific sampling units at different times and places. Because we aimed to understand the opinions of consumers of mobulid gill plates, respondents were first asked if they had ever consumed mobulid gill plates. Only those who responded in the affirmative were invited to participate in the survey.

All survey respondents gave oral, informed consent prior to participation and investigators assured them that all information provided would be kept strictly confidential to ensure their privacy. The study meets the requirements of Declaration of Helsinki (2013) and was approved by the Ethics Committee of NEFU's organization (project identification code 2023052).

Research Design

Our questionnaire had five parts. The first part was an introduction in which the purpose and significance of the study were described briefly. The second part contained demographic questions (e.g., gender, age, family income, education, occupation). The third part set out the relevant questions about consumer consumption, including acquisition channels, consumption seasons, consumption prices, consumption reasons, etc. The fourth part was directed at gaining an understanding of consumer awareness. Questions pertained to medical and health effects, taste, and substitutability aspects of mobulid gill plate consumption, and answers were on a Likert five-point scale (strongly disagree, disagree, uncertainty, agree, strongly agree). We also used closed-ended questions (don't know, know, don't know the specific content, partially know, or know very well) to address specific knowledge about four specific aspects of mobulid conservation: source species of mobulid gill plates, mobulid fishing country origin, population

changes of mobulid, and wildlife conservation laws. The fifth part, explored consumer preferences for gill plate consumption with a latent class choice experiment.

Choice experiments (CEs) are a descriptive preference evaluation method that uses an assumed market to infer respondents' preferences and demands for products (Hanley et al., 1998). Respondents are asked to choose between different hypothetical products, each described by the same attributes at different levels. Each product has a different utility value for the respondents. Based on random utility theory and Lancastrian demand theory, CEs are based on the assumption that individuals will choose products that can provide them with the maximum utility (Lancaster, 1966) based on a comparison of levels for each attribute. Therefore, CEs can be used to infer which attributes most affect consumer choices and the relative importance of attributes and their levels (Liu et al., 2022). Latent class analysis is now widely applied in wildlife trade studies because it allows the heterogeneity of consumer preferences to be explored through identification of distinctive subgroups (classes) of consumers with similar preferences (Hanley et al, 2017; Zhou et al, 2021).

Selection of the four attributes and their levels was guided by relevant literature and expert recommendations (Table 1). Following the method of Hensher et al. (2005), we used an orthogonal design to combine the attributes and levels in Table 1. We chose an orthogonal design because there was not enough information to estimate accurate prior values to apply an efficient design approach because the market is small. Orthogonal design is one of the most widely used methods in discrete choice models and generates reliable parameter estimates under a range of conditions (Bliemer & Rose, 2011; Louviere et al., 2008; Walker et al., 2018).

We created 30 choice cards after deleting meaningless or obviously unreasonable combinations. Each choice card displayed two purchase options (A or B) and a third option if neither A nor B was preferred (Figure 1). To reduce the interviewees' time and cognitive burden, we asked respondents to randomly select 10 cards to answer.

To eliminate ambiguities and other possible sources of confusion in the questionnaire, we conducted a pretest with a small group of local consumers. As a result, we improved the questions and language (e.g., *mobulid* in the questionnaire was replaced with *pengyu* [*彭鱼*] and *mobulid gill plates* was replaced with *pengyu sai* [*彭鱼鳃*]), but the overall structure of the survey was unchanged.

Data Analyses

Descriptive analysis of respondents' demographic information, consumption characteristics of mobulid gill plates, and awareness of gill plates and mobulid conservation were carried out with SPSS 26.0. Given that income, age, and gender have relatively large effects on consumer perception and preference for wildlife products (Coals et al., 2020; Gratwicke et al., 2008; Ljung et al., 2015), we used one-way analysis of variance (ANOVA), factorial ANOVA, and chi-square tests to determine whether there were significant differences in respondents' awareness of mobulid conservation due to these characteristics. The multinomial logistic regression (MNL) in NLOGIT 4.0 was used to estimate respondents' overall consumption preferences for mobulid gill plates. Latent class modeling (LCM) was used to explore potential preference heterogeneity among subgroups (Boxall et al., 2002). The

optimal classification number was determined by balancing the Bayesian information criterion (BIC) and Akaike information criterion (AIC).

Results

We surveyed 6,327 people near the main mobulid gill plate trade markets in Guangzhou. Of these, 5,853 people (92.5%) reported they had never consumed mobulid gill plates, and the interview was terminated. A total of 474 people approached (7.5%) were consumers of gill plates, and of these, 428 agreed to be interviewed. Once incomplete questionnaires were discarded there were 420 valid responses (effective response rate of 98.1%).

Consumer Characteristics and Consumption Behaviour

Over one-half of the consumers were women (62.6%). Most consumers were over 40 years old (59.8%), had a junior college degree or below (95.2%), and had a family annual income of <200,000 yuan (80.7%). The main reasons for purchasing gill plates were the perceived medicinal and health benefits (84.5%) and nourishment (38.6%). Minor reasons included curiosity (1.2%), taste (1.0%), and gift giving (0.5%) (Appendix S2). The price at which consumers purchased mobulid gill plates was generally <2 yuan/g (63.8%), but it was as high as >4 yuan/g (0.7%). Almost all consumers (95.3%) thought that the price of gill plates should be below the level of 2.2 yuan/g. In terms of consumption, 70.9% of consumers had consumed gill plates in the past year (Appendix S2). The other demographic characteristics and consumption characteristics are in Appendices S1 and S2, respectively.

Consumer Awareness of Gill Plate Consumption

The majority of consumers generaly agreed that gill plates had medical and health care benefits (74.0%), although 18.8% of consumers were uncertain about this. In terms of specific health benefits, relieving a cough was most identified by consumers (90.7%), followed by treating acne (86.0%), improving the respiratory system (68.1%), and enhancing the immune system (51.0%). Most consumers (74.8%) agreed that mobulid gill plates tasted good and agreed that gill plates could be substituted for with other health products from Western or traditional Chinese medicine (53.5%). A minority (38.3%) believed gill plates are the only effective medicine for particular symptoms (Figure 2, Appendix S2).

Consumer Awareness of Mobulid Conservation

On the whole mobulid consumers had limited knowledge relevant to mobulid conservation and sustainable use (Figure 3). Approximately one-half (52.4%) of respondents said they did not know that gill plates come from mobulids, and 90.7% of consumers also did not know the main country of origin of the fishing vessel used to catch mobulids. In terms of mobulid population changes, most (77.9%) consumers agreed that the populations are declining. Illegal and unsustainable fishing (63.6%) and habitat destruction (60.5%) were the most frequently cited causes of this decline (Appendix S2). Most consumers were not familiar with conservation laws, although domestic laws were better known than international agreements, such as CITES. For example, 77.8% of consumers said they knew about China's wildlife conservation laws, and 65.5% said they had never heard of CITES.

Gender and age were the main factors influencing respondent awareness of mobulid conservation (Figure 3, Appendix S2). Male consumers were more aware of population

changes of mobulid (p= 0.018 <0.05) and wildlife conservation laws (p = 0.016 <0.05) than female consumers. Consumers over 40 years of age were less aware of wildlife conservation laws (p = 0.000<0.001), source species of mobulid gill plates (p = 0.001<0.01), mobulid fishing country origin (p = 0.000<0.001), and population changes of mobulid (p = 0.000<0.001) than other age groups.

Given the significant impact of gender and age on consumer awareness, we further explored their interaction to identify the key groups with the weakest overall awareness. For the issue of source species of mobulid gill plates, males over 40 years old were the least aware (p=0.01＜0.05). For mobulid fishing country origin (p= 0.000<0.001), and population changes of mobulid (p= 0.000<0.001), women over the age of 40 were the least aware of mobulid conservation (Table 2).

Choice Experiment and Consumer Preferences

When respondents are considered as a single group in the MNL model, all the main attributes (source, protection level, gill plate size, and price) had a significant impact on choice (Table 3). Compared with the reference levels of these four attributes, consumers preferred imported gills over domestic, large gills over small, gill plates from unprotected rather than protected species, and to pay lower prices.

The LCM model divided consumers into three groups based on their distinctive set of preferences. The first group of consumers, which accounted for the largest proportion of the sample (72.3%), had the same preferences as the entire sample under the MNL model; that is, they showed a strong willingness to purchase imported, large, low-priced mobulid gill plates

and were strongly opposed to purchasing gill plates from protected species. This group of consumers was mainly composed of women. The second group accounted for 17.7% of the total sample and showed significant preferences for large, domestically produced mobulid gill plates, regardless of their price and whether or not they came from protected species. The third group accounted for the smallest proportion of the total sample (10.0%). These consumers preferred gill plates from protected species at high prices and tended to prefer domestically produced gill plates regardless of their size.

Discussion

Mobulids are an endangered species globally, and the increasing trade of gill plates is believed be the main cause of its population decline (Haque et al., 2019; Lewis et al., 2015). We found that in the case of China, the mobulid gill plate trade, despite being focused in a specific area of China, there is considerable heterogeneity in terms of consumer characteristics, awareness, and preferences.

Consumer Preferences for Mobulid Gill Plates and What Influences Them

In terms of demographic characteristics of consumers, the seventh population census of Guangzhou (Guangzhou Statistics Bureau, 2020) showed that people aged over 40 years old in Guangzhou accounted for 38.5% of population; 47.2% of the public is female; 86.3% of the public attained a junior college degree or lower; and the average household disposable income in 2019 was 195,156 yuan. Hence this shows that compared with the average population

distribution in Guangzhou, our sample had the characteristics of older age, female, less wealthy and slightly less educated.

Overall, we found that perceived healthcare benefits were the main driver of consumer demand for gill plates (Figure 2, Appendix S2). Although there are similar findings elsewhere (Whitcraft et al., 2014; O'Malley et al., 2017), we found that consumers did not exhibit a very deep belief in the health benefits of gill plates. For example, more than half of consumers agreed that gill plates had substitutes in Western medicine, Chinese medicine, or other health products (Figure 2). This suggests that for many consumers, gill plate demand may exhibit a higher demand elasticity (Appendix S2) than other wild animal products, such as ivory, that are regarded to have few substitutes and exhibit inelastic demand (Do et al., 2021; Rock and MacMillan 2022).

According to the MNL model, consumers generally preferred to buy low-priced, large, imported gill plates (Table 3). This somewhat contradicts previous research by O'Malley et al. (2017), who found that consumers in the Chinese mainland generally preferred smaller plates. This may be due to the significant recent rise in public concerns about food safety in China in recent years (Pengpai news, 2021); many of our respondents were worried about the quality of small gill plates because they believed that they may have been cut from different large pieces of low quality gill plates in to disguise impurities or damage. Similar concerns have been raised about the quality of wildlife products and the authenticity of their sources in other marine wildlife studies (Brayden et al., 2018). In future, more in-depth research should be conducted

on how the quality of wildlife products affects consumer decision-making related to protected species because this may emerge as an important part of the demand-reduction narrative.

Most consumers strongly prefer gill plates from unprotected mobulid species (Table 3). This is contrary to the popular perception that consumers of wildlife products prefer products from endangered and rare wildlife (Gault et al., 2008; Tournant et al., 2012). The difference may come from the essential difference in the reasons behind a purchase. For some high-value wildlife products, such as ivory and rhinoceros horn, consumers may consume them to gain esteem or prestige among peers or to emphasize social status (Hanley et al, 2017; Krishna et al., 2019; Tournant et al., 2012; Zhou et al., 2021). However, gill plates are consumed as a family health care product (Appendix S2), which is highly fungible (Appendix S2). Therefore, in the context of China's efforts to conserve wildlife in recent years, consumers are more likely to resist eating gill plates derived from protected species due to their nascent conservation awareness.

Although consumer preference for gill plates derived from unprotected species is a positive sign for mobulid conservation, some caution is warranted because many consumers also preferred large gills, which usually come from more protected, rarer, large mobulids, such as the *Mobula birostris* (Stevens, 2011), which is listed in CITES Appendix II in 2013 and is considered endangered by IUCN. This contradiction in terms of preferences points to a cognitive vacuum regarding mobulid conservation and gill consumption; most respondents lacked a detailed understanding of the links between consumption and the conservation of mobulids (Figure 3). Cognitive weakness of this kind may undermine conservation efforts

unless supported by education and social marketing (Wasser & Jiao, 2010). Further research is urgently needed to explore the reasons for the deviation between individual awareness of conservation and actual behavioral choices with respect to mobulids and other species, as well as the role of awareness in influencing consumer behavior choices.

We also found that a small percentage (LCM3, 10% [Table 3]) of consumers that had low conservation awareness preferred to buy gill plates from protected species at higher prices. Consumer behavior of this kind may be connected to elitism and social esteem, whereby certain goods are preferred because they are expensive or because they come from protected species (Hanley et al 2017). Engaging such customers with mobulid conservation may prove more challenging because lack of knowledge is not the issue and shaming via social media may only amplify feelings of social elitism (Shairp et al., 2016).

Results from LCM3 consumers also showed a slight preference for mobulid gill plates originating from China. This suggests that such consumers may have a greater impact on mobulid populations distributed in Chinese waters. Future mobulid conservation management and education therefore needs to prioritize the mobulid populations (*Mobula japanica, Mobula tarapacana, Mobula thurstoni, Mobula birostris*) distributed in China. This is especially true of *Mobula tarapacana* and *Mobula birostris* because these species are highly favored and traded in large quantities because of their large size.

Our choice experiment results also revealed the importance of gender in consumer preferences. According to the LCM model, consumers were divided into three groups with different preferences, among which the first group was mainly composed of women (Table 3).

This confirms earlier findings that women are the main consumers of wildlife medicines (Davis, 2020; Ni et al., 2022; Shih et al ., 2012) because they fill the traditional role of family caregivers (Davis, 2022). Chinese women dominate many household aspects, including family food consumption and family health maintenance, and the dominant role of housewives in the consumption of wildlife products has been documented for various wildlife products, such as rhinoceros horns, antelope horns, and succulents (Doughty et al., 2019; Margulies, 2020; USAID, 2017). These studies also show that although men are the main direct consumers, women are highly influential in their role as purchasers.

Interestingly, the largely female consumer group (LCM1) had the highest conservation awareness and was the only group that strongly resisted eating gill plates from protected species (Table 3). However, this may not mean women are more conservation friendly because preferences among women are often influenced by social desirability bias (Hinsley et al., 2021) or perceived ethical beliefs (Agu & Gore, 2020). We therefore believe that the role of women as consumers in wildlife conservation and trade regulation is complex; more research on women's values and willingness to engage with wildlife conservation issues through marketing and education is required; and gender issues should be investigated explicitly in all aspects of wildlife conservation and trade management policies.

Using Consumer Gender, Awareness and Preferences to Design Demand-led Measures to Assist Mobulid Conservation

Unsustainable trade continues to threaten the survival of mobulid populations. The key to solving this problem lies in understanding the characteristics and demands of consumers and

developing scientific intervention measures on this basis (Shairp et al., 2016). However, in mobulid trade management, intervention measures developed over the long term often rely on anecdotes, traditional wisdom, and personal experience rather than key intervention information determined through systematic and structured consumer research (Challender et al., 2019). Our study, like other research involving choice experiments, can provide effective insights for the formulation of such intervention measures if the attributes are policy relevant (Hanley et al.,1998) and supported by supplementary questions about consumer behavior and motivation (MacMillan et al., 2006).

Our results suggest that dispelling the health myths of mobulid gill plates may be an effective way to reduce consumer demand for gill plates. This may be more easy to accomplish than for other trade products from endangered species, such as ivory and rhinoceros horn because most gill ray consumers, while believing in the medicinal value of gill plates, accept that the medicinal properties of gill plates are substitutable (Figure 2). Hence, with appropriate conservation advocacy and education, the trade of gill plates could, we believe, be reduced over time. Currently, information about the medical and healthcare effects of gill plates mainly comes from relatives, friends, or sales people (Appendix S2), which indicates that eating gill plates is actually a local family eating habit passed down by word of mouth (O'Malley et al., 2017). This is quite different from the trade in shark fins, which are often served as high-end dishes at banquets and other commercial and business settings (Zhou et al., 2021). Therefore, future conservation education activities should strongly focus on women, the main decision-makers in Chinese household consumption, and use information dissemination methods that

are popular among female consumers, such as television and live streaming on the internet, to convey the message that the proclaimed health benefits are without foundation in Chinese and Western medicine.

Moreover, laboratory toxicology tests show that tissues from mobulids contain heavy metals, such as mercury, arsenic, and cadmium, that are harmful to the human body (Essumang, 2009). Mercury, for example, is one of the top 10 chemicals of major public health concern recognized by the World Health Organization, and even trace amounts of mercury pose a serious threat to development in the early stages of life (Bose-O'Reilly et al., 2010). Hence, a wider educational effort based on these scientific toxicity findings may also deter consumption based on more routine chemical testing and monitoring of gill plates that are for sale.

Conservation knowledge and awareness also emerged as a key issue with respect to consumer choice, but our results indicated a major contradiction among consumer groups. By far the largest group of consumers (Table 3) were strongly opposed to purchasing gill plates from protected species. This group of consumers was mainly composed of women, and an educational program focused on conservation and threats to mobulids could be very effective. For example, Whitecraft et al. (2014) found that over 90% of Chinese consumers were willing to stop consuming gill plates after realizing that mobulids are highly protected. However, there were two other groups (accounting for 28% of the sample), who were indifferent to protected status or actually preferred to consume gill plates from protected species at a higher price. A high profile awareness-raising conservation campaign may be less effective with these consumers, and in the case of a small number of consumers (10% of our sample) may be

counter productive because they appear to prefer consuming gills from protected species. Although such people comprise a relatively small minority currently, there is a risk that consumption could be encouraged if rarity or protected status is more widely known. Consumer preferences can change quickly, especially if other animal products that appeal to this type of elite consumerism become less available due to government sanctions. Hence, for such consumers that prefer protected species, educational material and campaigns should focus on undermining social esteem associated with consumption, health threats, and the risk of arrest and penalty.

In addition to understanding which groups to target, conservation bodies must also consider how to disseminate this knowledge. Personal networks are extremely important, with middle-aged and elderly women more likely to influence other young women to consume wildlife through family networks (Davis, 2020). According to the Research Report on Internet Life of Chinese Middle-aged and Elderly People (Zhao et al., 2018), WeChat has become the main way for middle-aged and elderly people to disseminate information across their networks. Hence, the conservation information should be designed specifically for middle-aged woman through Wechat, whom are survey showed are least informed about conservation issues. Also, the information should use wording and imagery that resonates with this demographic (family-oriented imagery and messaging) and avoid using overtly scientific, legal, and technical terms and phrasing.

In short, strengthening education and publicity for conservation is an important demand-side intervention measure for changing public perception and protecting mobulid in the future,

but the messaging must be targeted and appropriate for the different consumer groups: woman and health, men and social esteem and law enforcement.

Supply side interventions also required

In addition to demand-side intervention measures based on consumer characteristics and preferences, macroeconomic trade regulations must also be considered essential as part of reducing the trade threat. We found that consumers were less wealthy and prefer cheaper prices for gill plates (Appendix S2); hence, measures, such as increased tariffs, a sales tax, and strengthening quality control and assurance around gill plates production and sales the price, could be effectively increased. Although a small minority of consumers are willing to pay high prices for protected species, these measures will reduce overall demand because the vast majority prefer lower prices. However, future research is needed to understand the effectiveness of such measures and to identify the optimum combination of instruments (economic, trade and legal) that should be deployed.

For many fishers who depend entirely on the ocean for their livelihood, the gill plate trade has become an important source of income (Booth et al., 2021; Haque et al., 2021). If the gill plate market is effectively curtailed through demand and supply measures, it will be important to also consider implications for those fishers. Community-based economic incentives are an effective way to promote sustainable development of mobulid fisheries (Booth et al., 2021) and include raising disposable income levels, bolstering local empowerment, and creating health care and educational institutions (Challender & MacMillan, 2014; Haque et al., 2021). At the same time, a payment scheme provided by state and non-governmental organizations based on

actual performance in managing or protecting mobulids could be introduced (Challender & MacMillan, 2014) in tandem with strengthened law enforcement and supervision of illegal fishing activities.

Ensuring the traceability of gill plates during trade is also an important aspect of mobulid conservation and the sustainability of this fishery. In the future, big data could be used to develop a blockchain database to record all data before, during, and after trade and to generate a unique gill plate code (Choy et al., 2022). The key to sustainable use of mobulids is to reduce the price difference obtained by intermediaries so that local fishers can obtain more income from legal and supervised channels. International cooperation is also essential on the supply side. In addition to gill plates, other body parts from mobulids are traded globally. For example, mobulid meat is considered one of the main food sources in the Bohol Sea, Philippines, and mobulid cartilage is used to produce chondroitin in many developed countries (Acebes & Tull, 2016; White et al., 2006).

In conclusion, we recommend that future measures specifically on the demand side be underpinned by more detailed studies on consumer characteristics and preferences. In the case of gill plate consumption in China, we identified gender, age, awareness, and preference characteristics of consumers as key to understanding and reducing demand. This knowledge can be used to design effective, tailor-made solutions to the trade threat including multidimensional measures relating to conservation knowledge and education, macro trade regulation, traceability, and strengthened law enforcement. This would help promote the

sustainable development of mobulid conservation and its fisheries and prevent mobulid and other large pelagic marine animals falling into the extinction vortex .

Supporting Information

Additional supporting information may be found in the online version of the article at the publisher's website.

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Table 1. Level of mobulid gill plate attributes and attribute description in choice experiment related to consumer preferences for mobulid gill plate.

Attribute	Attribute description
Source	Source can be an important influence on consumers' evaluation of products and their willingness to purchase in China (Liu et al., 2018). Because mobulids are not globally distributed, a preference for gill plates from one region may have an important impact on mobulid conservation and future fisheries management in that region. Mobulid gill plates sold in China usually come from China, Indonesia, Sri Lanka, Malaysia, Brazil, the Philippines, Vietnam, South Africa, India, Australia, Thailand, and Mauritius. Gill plates from China account for about 30% of the total (O'MALLEY et al., 2017). Considering that the gill plates have multiple sources and that complex attributes will increase consumers' cognitive burden, the level of this attribute is simplified as domestic or imported.
Domestic	
Imported	
Protection level	Protection status of species is the main factor affecting consumers' cognition and purchase intention of wildlife products (Hinsley, 2020), reflecting the multiple considerations of individuals relative to the biological, socioeconomic attributes, and management attributes of species (Jiang, 2016). In China protected species refers to the rare and endangered species of terrestrial and aquatic wild animals and the terrestrial wild animals of significant ecological, scientific, or social value, which includes three protection levels. To make it easier for respondents to understand, protection level is a binary attribute (unprotected or protected).
Unprotected	
Protected	
Size	Consumers attach great importance to the size of gill plates (O'Malley et al., 2017). Therefore, according to the literature and previous market research, we use the total length of the gill plates as a binary attribute: small (<20cm) or large (≥20cm) .
Small (<20cm)	

Large (>20cm)	
Price	Price is widely regarded as the main determinant of consumer willingness to purchase and demand elasticity. To explore this, we used price as an attribute and divided it into 5 levels that reflect price changes in different types of gill plate markets.
0.2 yuan/g	
1.2 yuan/g	
2.2 yuan/g	
3.2 yuan/g	
4.2 yuan/g	

Table 2. Interactive differences in attitude toward mobulid conservation of consumers by gender and age.[a]

Questions of mobulid conservation	Men under 40 years old	Women under 40 years old	Men over 40 years old	Women over 40 years old
Wildlife conservation laws	1.906 （0.053）	1.848 （0.050）	1.526 （0.054）	1.468 （0.036）
Source species of mobulid gill plates	48[b] （60.0%）	49[b] （55.1%）	31[b] （40.3%）	72[b] （41.4%）
Mobulid fishing country origin	13[c] （16.3%）	15[c] （16.9%）	5[c] （6.5%）	6[c] （3.4%）
Population changes of mobulid	72[c] （90.0%）	76[c] （85.4%）	60[c] （77.9%）	119[c] （68.4%）

[a] Wildlife conservation laws analyzed by factorial analysis of variance ANOVA, and result are presented as mean and SE (in parentheses). Source species of mobulid gill plates, mobulid

fishing country origin, and population changes of mobulid are chi-square test analyses, and the results are expressed as number (frequency) of consumers who answered know (i.e., have a high level of awareness about mobulid conservation).

[b]Significant at the 0.05 level .

[c]Significant at the 0.001 level.

Table 3. Estimated results of model parameters of multinomial logistic regression (MNL) and latent class modeling (LCM) of choice experiments on consumer preferences for mobulid gill plates.[a]

Attribute[b]	**MNL**	**LCM 1 (72.3%)**	**LCM 2 (17.7%)**	**LCM 3 (10.0%)**
Alternative Specific Constant	-0.595[c] (0.075)	-1.036[c] (0.084)	1.055[c] (0.144)	-0.901[c] (0.276)
Source	0.148[c] (0.048)	0.552[c] (0.078)	-0.729[c] (0.141)	-0.155[d] (0.089)
Protection level	-0.574[c] (0.050)	-1.385[c] (0.077)	-0.154 (0.131)	0.614[c] (0.132)
Size	1.068[c] (0.056)	2.180[c] (0.082)	0.907[c] (0.089)	0.075 (0.152)
Price	-0.007[c] (0.0004)	-0.017[c] (0.001)	-0.001 (0.001)	0.007[c] (0.001)
Gender		-0.630[d] (0.363)	-0.235 (0.435)	

Income		-0.2449 (0.3962)	-0.1280 (0.4643)	
Age		0.0972 (0.1596)	0.2867 (0.1855)	

[a]The model was selected based on the detection values (penalty factor of 3) of the two most conservative criteria, Bayesian information criteria (BIC) and Akaike information criteria (AIC), when additional variables were included. In this model, as the number of classifications increased, the test values of BIC and AIC gradually decreased (i.e., the model was constantly optimized). When the number of classifications was 3, the detection value was the smallest, so the optimal number of classifications for the model was 3. The multinomial logistic regression (MNL) and latent class model (LCM) estimate the utility function for each attribute (SE in parentheses).

[b]The reference levels of attributes: source, domestic; protection level, unprotected ; size, small; price, 0.2 yuan/g; gender, female; age, under 40 years old; income, <100000 yuan/year.

[c]Significant at the 0.001 level.

[d]Significant at the 0.05 level.

Please consider the following options and then choose a plan			
Option A		**Option B**	
Source:	Domestic	Source:	Imported
Protection level:	Protected	Protection level:	Unprotected
Size:	⩾20cm	Size:	<20cm
Gills price willing to pay:	2.2 yuan/g	Gills price willing to pay:	4.2 yuan/g
please check one option: I choose option A ( ) I choose option B ( ) I don't choose either plan A or B ( )			

Figure 1. Example of choice experiment card used in surveys of consumer preferences for mobulid gill plates.

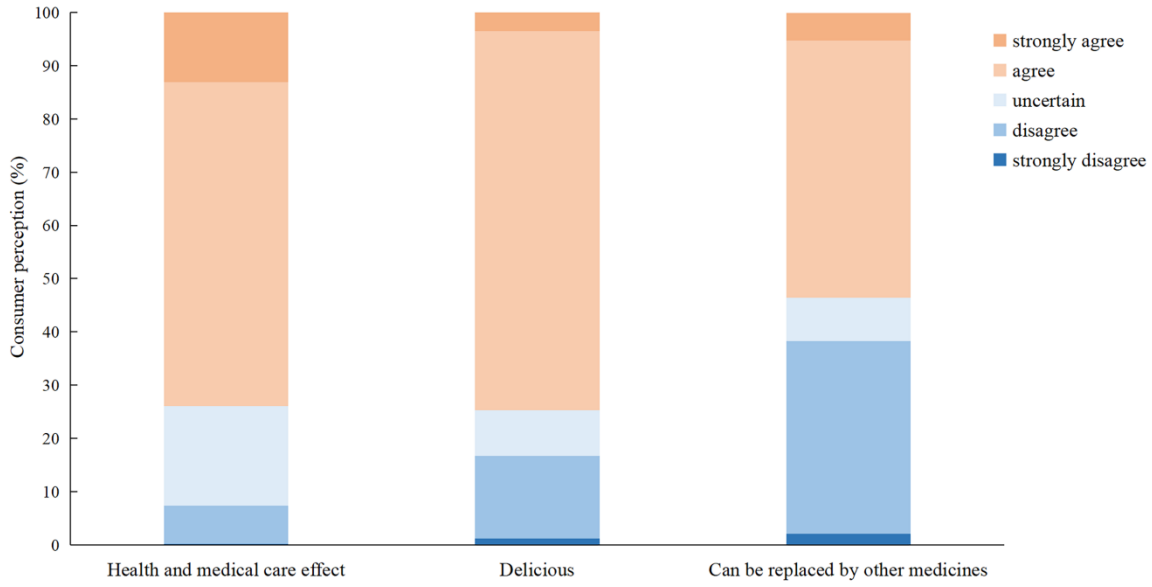


Figure 2. Consumers' perception of mobulid gill plates.

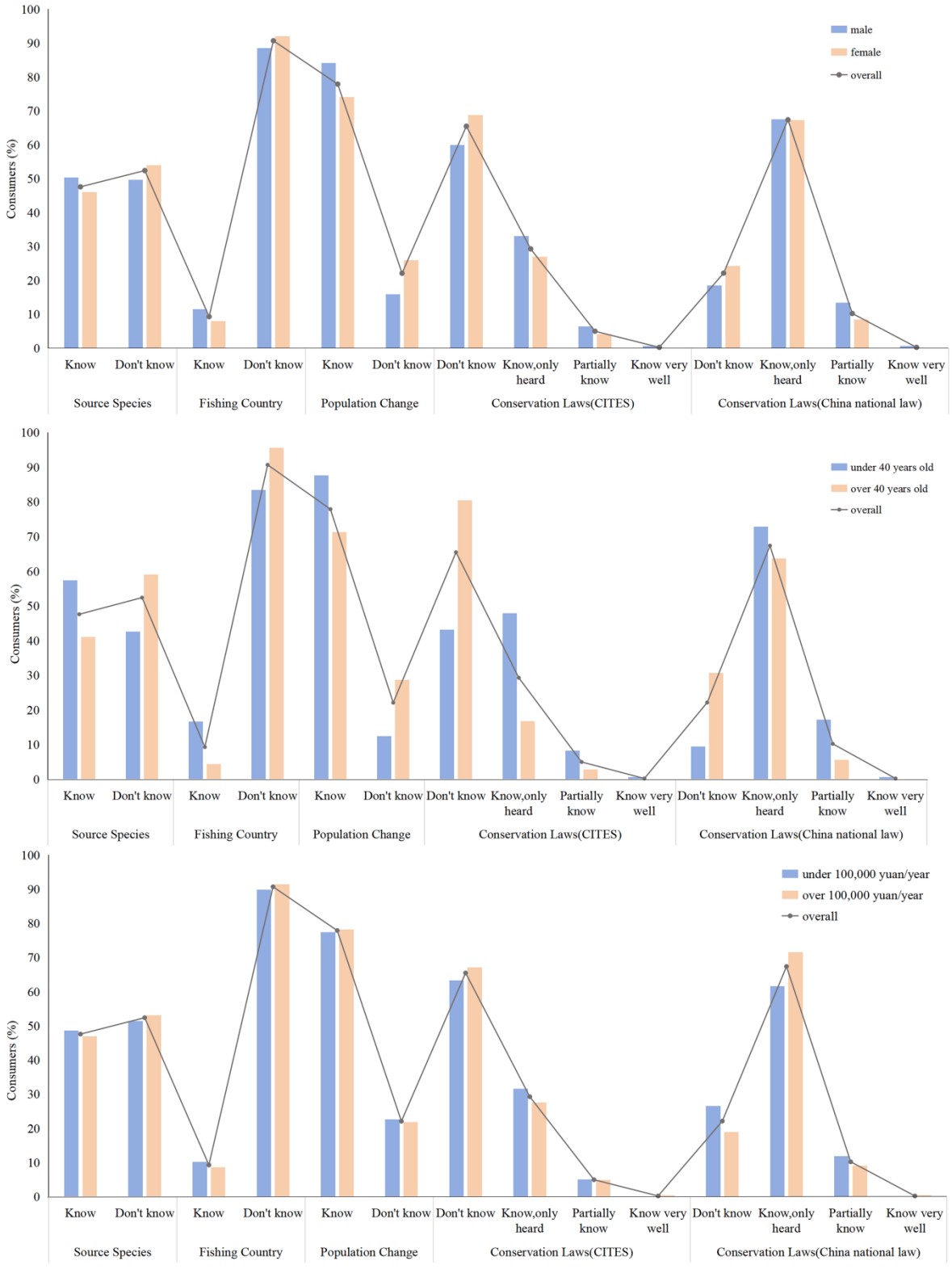


Figure 3. Awareness of mobulid conservation among consumers by demographic: (a) gender, (b) age, (c) income (overall, awareness of mobulid conservation of overall consumers; source species, query was "Do you know what kind of fish the pengyu sai come from?"; fishing

country, query was “Do you know the main fishing countries for pengyu?”; population change, query was “Do you think the population of pengyu is declining?”; conservation laws (CITES), query was “Do you know about CITES?”; conservation laws (China national law), query was “Do you know about the Wild Animal Conservation Law of the People's Republic of China?”; CITES, Convention on International Trade in Endangered Species of Wild Fauna and Flora)