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Fishers' knowledge as an information source to investigate by-catch of marine mammals in the South China Sea

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ABSTRACT

By-catch mortality is a significant driver of marine mammal population declines. However, there is little information available on patterns or magnitude of by-catch mortality in many heavily fished Asian marine systems such as the South China Sea. To address this limited knowledge-base, we conducted interviews with fishers to gather local ecological knowledge (LEK) on marine mammal by-catch around Hainan Island, China. Gillnets were the primary fishing gear used in local fisheries, and were also responsible for the majority of reported marine mammal by-catch events in recent decades. By-catch events were reported from all seasons but were most frequent in spring (38.4%), which might relate to seasonal variation of fishing activities. The spatial pattern of relative by-catch densities for Indo-Pacific humpback dolphins, Indo-Pacific finless porpoises and unidentified small dolphins varied around Hainan and neighbouring waters. A substantial proportion of informants (36.1% and 9.2%, respectively) reported that they have eaten or sold marine mammal meat, demonstrating the continued existence of cultural practices of consuming marine mammals on Hainan. Responses of fishers to by-catch events were dependent both on their existing attitudes and perceptions towards marine mammals and on other sociocultural factors. Almost half of informants agreed that marine mammal populations in the South China Sea have decreased. Declines were thought by informants to have been caused by overfishing, water pollution and vessel collisions, with by-catch responsible for further declines in dolphins.

KEYWORDS: by-catch mortality; local ecological knowledge (LEK); questionnaire-based interviews; marine mammal conservation; dolphins.

INTRODUCTION

By-catch in fisheries is a major cause of mortality for a diverse range of aquatic vertebrates (Reeves, 2003), and is widely considered to constitute one of the greatest threats to marine mammals at a global scale (Lewison *et al.*, 2004; Brown *et al.*, 2015). Increasing numbers of studies have demonstrated that both mobile and static gears, such as trawls, purse nets and gillnets, pose a potential risk to populations of many aquatic mammal species through capture and/or entanglement (e.g. Kirkwood *et al.*, 1997; Reeves *et al.*, 2013). It is estimated that the mean annual by-catch of marine mammals in US waters was 6215 ± 448 individuals between 1990 and 1999 (Read *et al.*, 2006). By-catch has also greatly contributed to mass mortality events in some species, for example short-beaked common dolphins (*Delphinus delphis*) in southwest England (Kuiken *et al.*, 1994).

Chinese waters contain a huge number of fishing gears, which have the potential to impact local populations of marine mammals (Jefferson *et al.*, 2009). By-catch associated with intensive fishing activity in the Yangtze River has been identified as a likely driver of decline for the country's two endemic freshwater cetaceans, the Yangtze finless porpoise (*Neophocaena asiaeorientalis asiaeorientalis*) and the Yangtze River dolphin or baiji (*Lipotes vexillifer*) (Zhang *et al.*, 2003; Turvey *et al.*, 2007; Zhao *et al.*, 2008; Mei *et al.*, 2012). Over 30 marine mammal species are

recorded to inhabit the South China Sea (SCS) (Jefferson *et al*., 2011), including the waters around Hainan Island, China's southernmost province, which comprises an area of approximately 3.3 million km^2. However, data on the population status, threats and mortality associated with artisanal fisheries for these species are currently very limited (Zhou & Wang, 1994; Yang *et al.*, 1999; Wang *et al.*, 2011, 2015). According to official statistics, there are over 200,000 registered marine fishers in Hainan, of which 83.0% make a professional living from marine fisheries in the SCS (China Fishery Statistics Yearbook, 2014). High-intensity fishing activities can increase the likelihood of harmful interactions with cetaceans, such as incidental by-catch events (Silvano & Begossi, 2012), indicating the need for a more robust evidence-base on the status of marine mammal populations in the SCS.

Over the last 30 years, local ecological knowledge (LEK) has increasingly been recognized as a potentially useful tool for addressing diverse questions on both ecological and applied conservation issues, and LEK can be integrated with biological data derived from more conventional research and monitoring approaches (Brook *et al*., 2008). Although patterns, levels, and validity of LEK will inevitably vary between different study systems (Davis & Wagner, 2003), informants who spend extensive periods of time in landscapes containing species of research interest or conservation concern potentially have LEK with significant insights into ecological processes and conservation management (López *et al.*, 2003; Moore *et al.*, 2010). Many marine mammal species are distributed over large geographic areas and spend much of their time underwater, making formal boat-based surveys costly, time-consuming, and

requiring well-trained researchers with experience in relevant species detection and identification (Maunder & Punt, 2004). Under such conditions, LEK collected from untrained local people who utilize the same environments as marine mammals may constitute an alternative, potentially useful source of data on species status and threats, particularly in geographic regions that have been the focus of relatively little formal scientific research but contain large human populations (Anadón *et al*., 2009; Turvey *et al*., 2015).

In order to address the current lack of data on marine mammal mortality associated with local fisheries in the SCS, we conducted a large-scale LEK survey of local marine fishers around Hainan using a questionnaire-based interview approach. This study aimed to provide new baseline data on regional fishing methods and activities, on associated geographic and seasonal patterns of by-catch for different marine mammal species around Hainan, and on patterns and drivers of other interactions between marine mammals and fishers, in order to strengthen the evidence-base for marine mammal conservation and management in the SCS.

METHODS

Fishers' LEK survey

A LEK survey was conducted around Hainan between 30 November and 21 December 2013 in 16 fishing communities or ports with sizeable local communities of professional fishers. Survey sites were situated 20-100 km apart, and distributed around the entire coastline of Hainan (Fig. 1).

LEK data collection was conducted using questionnaire-based interviews. LEK interview techniques and methods described by Chambers (1992) and developed for conservation research in Chinese fishing communities by Turvey *et al.* (2010a, 2010b, 2012, 2013) were used in the survey. Interviews were conducted by three scientific researchers and forty-two trained volunteers recruited from a local university. Informants were only selected for interview if they were born on Hainan or had lived on Hainan for most of their lives, and if they were professional fishers, practising fishing as their main source of economic income and within areas likely to be inhabited by marine mammals. Age, gender, and ethnicity were not used as further selection criteria. Only one member of each fishing family/vessel was interviewed to ensure independence of reported data.

Questionnaire-based interview

Our questionnaire included forty-two questions about the characteristics of local fisheries, commonly used fishing gears, distribution and abundance of marine mammals, and awareness of and responses towards marine mammal by-catch (see Supplementary Text S1 for details). Questions about by-catch consisted of whether, how often, when and where informants have experienced marine mammal by-catch events in their gear, which marine mammal species and gear types were involved in these events, and the response of the informant to any by-catch events they had experienced. Locations of reported by-catch events were marked on an 11 × 11 grid-cell map with grid size = longitude 0.5° × latitude 0.5° (Fig. 1). Colour

photographs of commercially important target fish species in the SCS (downloaded from http://fishbase.org.cn/) were shown to informants to learn about their catch targets (see Supplementary Table S1 for details), and images of 36 marine mammal species potentially present in the SCS, including 35 cetacean species and dugong (*Dugong dugon*) (Table 1, Jefferson *et al.*, 2011; Wang, 2012), were also shown to informants to enable species identification.

Each interview lasted 25 ± 5 minutes, with informants interviewed independently on a one-by-one basis without any prompting or influence from colleagues or peers. All participants were told about the aims of the survey and were guaranteed that all data would be anonymous. Interviews were only conducted if informants gave their consent to participate in the study. Survey design was approved by the Institute of Deep-Sea Science and Engineering, Chinese Academy of Sciences.

Data analysis

Some relatively frequently observed marine mammals, such as Indo-Pacific humpback dolphin (*Sousa chinensis*) and Indo-Pacific finless porpoise (*Neophocaena phocaenoides*), could be easily identified by informants based on external characteristics such as body size, skin colour, head morphology, and/or absence/shape of dorsal fin. However, informants had difficulty in identifying other small-bodied dolphins and most large baleen and toothed whales. Marine mammal species potentially occurring in the SCS were therefore grouped into the following categories or groups for analysis: Indo-Pacific humpback dolphin (SCH), Indo-Pacific finless

porpoise (NPH), grey whale (ERO), dugong (DUG), sperm whale (PHY), black cetaceans (BLC), beaked whales (BEW), small dolphins (SMD), other whales (OTW), and unidentified species (UNS) (Table 2). Data on reported marine mammal by-catch events dating between 2000 and 2013 were analyzed to determine patterns of by-catch; additional by-catch records were also collected dating from before 2000, but these data were generally limited and vague in detail, and so were excluded from further analysis.

To analyse spatial patterns of by-catch, we conservatively assumed that small vessels (length < 20 m) generally fished in coastal waters within c.50 km of ports, whilst large vessels (length ≥ 20 m) trawled/pursed in offshore waters within c.200 km of ports. Details on the number of vessels in different survey sites and fishing areas are given in Supplementary Table S2. A relative by-catch density model was used to determine levels of by-catch for each marine mammal category:

$$D_{rb} = \frac{n_{ig}}{N_{fg}} \times 100\%$$

Where D_{rb} is relative by-catch density of each marine mammal category per grid-cell; n_{ig} is number of reported by-catch events for each marine mammal category per grid-cell; and N_{fg} is number of informants who reported fishing per grid-cell.

The spatial patterns of by-catch density for the three marine mammal categories with the highest reported levels of by-catch were mapped using ArcMap 10.1. Other analyses were carried out in SPSS 16.0.

RESULTS

Demographic fisher profiles and local fishing activities

A total of 510 interviews with professional fishers were conducted, although not all informants answered all questions in the questionnaire. Descriptive statistics on informant age, gender, ethnicity, education level, income, fishing experience, and vessel length are shown in Supplementary Table S3. All informants in our study conducted fishing activities in waters around Hainan and/or neighbouring waters off southern mainland China. Gillnets associated with small sized vessels (Fig. 2) were the most commonly reported gear type used by informants (296 out of 510 informants, 58.0%). Other reported gear types, in decreasing reported frequency of usage by informants, were light traps, purse nets, trawls, stow nets, hooks (hand hooking/long-lines), triple-layer nets, drag nets, and pots. The use of illegal fishing gears or methods, including poison fishing, electric fishing and explosive fishing, which are extremely harmful to fishery resources and can easily injure or kill marine mammals, was also reported by some informants (21 out of 510 informants, 4.1%), likely representing a minimum estimate or underestimate of the actual usage of these gears in the region. A total of 22 commercially important fish species/genera were identified as target catches, including cutlass fish (*Trichiurus* spp.), horse mackerel (*Decapterus* spp.), sardinella (*Sardinella* spp.), filefish (*Navodon* spp.), and pike congers (*Muraenesox* spp.) (see Supplementary Table S1 for details).

Patterns of by-catch

During the survey, 130 fishers reported marine mammal by-catch events. In total, 150 by-catch events involving 603-639 marine mammal individuals were documented between 2000 and 2013 (Table 2). Indo-Pacific humpback dolphins, Indo-Pacific finless porpoises, and unidentified small dolphins were identified as the three marine mammal categories with the highest reported levels of by-catch. Gillnets accounted for the majority of by-catch events in all of the above categories, although some by-catch events were also associated with purse nets, trawls, light-traps, stow nets and other gears (Fig. 3).

Information on month or season was only reported for 86 of the 150 recorded by-catch events. By-catch events were reported across all seasons, but were most frequent in spring (33 out of 86 events, 38.4%), which is also the main regional fishing season with the highest reported level of fishing activity (437 out of 510 informants, 85.6%) (Fig. 4). Variation in by-catch intensity reported across different seasons does not differ statistically from seasonal variation in intensity of fishing activities reported by informants ($\chi^2 = 5.257$, $df = 3$, $P = 0.283$).

Spatial patterns of relative by-catch density for Indo-Pacific humpback dolphins, Indo-Pacific finless porpoises, and unidentified small dolphins vary around Hainan and in neighbouring waters off southern mainland China (Fig. 5). By-catch density for Indo-Pacific humpback dolphins is highest in southwestern coastal waters of Hainan and in the eastern region of Leizhou Bay (Guangdong Province, mainland China). By-catch density of Indo-Pacific finless porpoises is highest in western coastal waters of Hainan, including the Changhua River estuary and Qiongzhou Strait,

although by-catch events are also recorded in eastern coastal waters of Hainan. By-catch of unidentified small dolphins occurs widely around the coastal waters of Hainan, in both near-shore and offshore waters.

Fishers' behaviours

When responding to entangled or by-caught marine mammals, over half of the informants in our sample reported that they would make conservation-appropriate decisions, such as releasing living animals or informing the local fisheries administration (Table 3). However, several negative responses were also reported by informants, such as capturing, eating or selling by-caught animals or using them as shark bait (Table 3). The last time that any such negative behaviours were reported by informants to have taken place covered a long time span, with last reported events in some cases dating back several decades (Fig. 6). Forty-seven informants (out of 510 informants, 9.2%) reported that they had sold marine mammal meat, in some cases as long ago as the 1980s, and 184 out of 510 informants (36.1%) reported that they had eaten marine mammal meat, with only 19 informants able to identify the species or marine mammal category they had eaten (Indo-Pacific finless porpoises reportedly eaten by six informants, small dolphins reportedly eaten by 13 informants) (Fig. 7A-C).

Fishers' perceptions

The majority of informants considered that regional fishery resources had seriously decreased (424 out of 510 informants, 83.1%), whereas the number of fishing vessels had increased (303 out of 510 informants, 59.4%) (Fig. 8A). Overfishing and water pollution were the two main factors considered by informants to be responsible for decreases in fishery resources (see Supplementary Table S4 for details). Almost half of informants (258 and 233 out of 510 informants, 50.6% and 45.7%, respectively) also considered that populations of both dolphins and whales had decreased in the SCS (Fig. 8A), and most informants (498 out of 510 informants, 97.6%) did not report any recent dugong sightings between 2000-2013. Marine mammal species were considered by informants to be impacted by a range of human pressures in the SCS, including overfishing, water pollution and vessel collisions (Fig. 8B). By-catch was considered to be one of the major threats to dolphins in particular.

DISCUSSION

Fishing activities and by-catch

Our fishers' LEK survey around Hainan provides an important new baseline for understanding fishing activities and by-catch in the SCS. Many previous studies have found that by-catch events of marine mammals primarily occur in spring (e.g. Harris & Poiner, 1990; Wang *et al.*, 2015), although this seasonality has not been universally demonstrated. In our survey, by-catch events also reportedly occurred most frequently in spring, matching the seasonal intensity of fishing activities by local fishers (Fig. 4). Several commercial fishes identified as fishing targets in our survey (see

Supplementary Table S1 for details) also constitute important food resources for marine mammals, especially dolphins and other odontocetes (Pauly *et al*., 1998). For example, Barros *et al*. (2004) found that Indo-Pacific humpback dolphins in Hong Kong have a diet comprising croaker (*Johnius* spp.), lionhead (*Collichthys lucida*) and anchovies (*Thryssa* spp.), all of which are fished commercially in the SCS by our informants. Many pelagic cetaceans also prey primarily on other commercial target species such as cutlass fish, horse mackerel, sardinella, filefish, pike congers, cephalopods, and crustaceans (Jefferson *et al*., 2011). Exploitation of these fish resources may therefore have a negative impact on dependent marine mammal populations (Read, 2008).

Our data indicate that by-catch mortality in Indo-Pacific humpback dolphins, Indo-Pacific finless porpoises, and unidentified small dolphins, the three marine mammal categories in our study with the highest reported levels of by-catch around Hainan, is primarily due to gillnets (Fig. 3). This pattern may be attributed to the large amounts of gillnets used by local fishers in this region. Owing to their low cost and high fish catch efficiency, gillnets are popular worldwide in artisanal fisheries (Zappes *et al*., 2013). Marine mammals are consequently seriously threatened by gillnets at a global scale, especially in developing countries (Read, 2008). Many studies of by-catch patterns and selectivity have shown that gillnets are responsible for the majority of gear-related mortalities of marine mammals, especially small dolphins (e.g. D'Agrosa *et al*., 2000; Reeves *et al*., 2013). For example, Paudel *et al*. (2015) suggested that the intensity with which gillnets are used across Southeast Asia is

likely to have a severe impact on regional populations of small cetaceans. Most recent cetacean (84%) and pinniped (98%) by-catch events in the USA have also occurred in gillnet fisheries, with dolphins and porpoises constituting the majority of marine mammal by-catch in this system (Read *et al*. 2006).

Spatial distribution of by-catch

The spatial distribution of marine mammal by-catch in the waters around Hainan could reflect the distribution of marine mammals in this region. Indo-Pacific humpback dolphins and Indo-Pacific finless porpoises are known to generally inhabit and exploit near-shore environments (Jefferson *et al*., 2009, 2011), matching the areas from which by-catch events of these species are recorded (Fig. 5A-B). Other small dolphins are likely to be distributed more widely around the coastal waters of Hainan in both near-shore and offshore waters, and are therefore vulnerable to being by-caught across a wider area (Fig. 5C). Spatial overlap between fishing areas and critical marine mammal habitats could be also an important factor in reported patterns of by-catch. Marine mammal distributions are typically related to patterns of marine primary productivity (Trites *et al*., 1997), which frequently leads to competition between fisheries and marine mammals (Read, 2008). For example, the high level of reported by-catch events involving Indo-Pacific humpback dolphins in coastal zones is likely to be associated with the intensive level of regional fishery activities across the range of this species in near-shore environments.

Marine mammals and fishers

The behaviour of fishers when responding to by-catch events is not only determined by their existing attitudes and perceptions towards marine mammals (Alves *et al*., 2012), but also affected by other sociocultural factors. Although over half of our informants reported that they would make conservation-appropriate decisions if they encountered an entangled marine mammal, the fear of being punished for killing protected species may have led to under-reporting of both by-catch events and the fishers' real behaviour when responding to these events (Manzan & Lopes, 2015). Indeed, many informants in our study reported that they have eaten or sold marine mammal meat in the past, which confirms the recent and probably continuing cultural practice of consuming marine mammals on Hainan (Wang, 2012; Fig 6 and 7), and which may affect fishers' behaviour when responding to by-catch events.

Dugongs have not been seen in recent decades by most of our informants, which indicates that these animals in particular have seriously declined around Hainan and may even be regionally extinct (Wang *et al*., 2007). Other marine mammals in the SCS are threatened by a range of anthropogenic factors, of which by-catch is only one of the components (Ross *et al*., 2011). Informants in our study considered that marine mammal species in the SCS were also impacted by overfishing, water pollution and vessel collisions, with by-catch possibly constituting a significant danger particularly for small dolphins, which are more likely to become entangled in fishing gear due to their small body size (e.g. Hall *et al.*, 2000; Reeves *et al.*, 2013). The rapid ongoing

development of coastal areas of Hainan and neighbouring mainland China is likely to lead to further anthropogenic threats to marine mammals, and increased public attention and conservation action needs to be provided to protect marine mammals in the SCS (Jefferson *et al*., 2009).

Improving public attention, conservation suggestions and actions

Increasing media and public attention is being focused on conservation issues and efforts on marine mammals in China, including reporting of by-catch and stranding reports, and development of databases of these events (Wang *et al.,* 2015; http://tcsn.whale.org.tw/; http://www.cetacean.csdb.cn/). However, due to a lack of effective and timely studies and assessments, the threat status of marine mammals in the SCS may have been underestimated. Almost half of the species present in this region (41.7%) are still listed as Data Deficient by IUCN (2016). All marine mammals are listed as National Key Protected Animals in China; however, only two species occurring in the SCS, the Indo-Pacific humpback dolphin and dugong, are listed as Grade I National Key Protected Animals, whereas all other species in the region are listed under Grade II and thus receive a lower level of protection. Further scientific research and conservation activities for marine mammals across the SCS are therefore urgently required, to further strengthen the evidence-base on status and threats to marine mammals in this biologically and ecologically important but vulnerable and complex system.

It is strongly recommended that efforts should be made to mitigate marine

mammal mortality in gillnets around Hainan and more widely across the SCS. The use of gillnets and other harmful fishing gears and methods in waters occupied by resident or migratory populations of marine mammals should be controlled by the Chinese oceanic and fisheries administration. Acoustic pingers and gears such as "dolphin wall nets" that are demonstrated to reduce by-catch effectively (Barlow & Cameron, 2003; Werner *et al*., 2006; Prajith *et al*., 2014) should be promoted for widespread use in areas of the SCS with high reported levels of by-catch. Rescue organizations should be established to rescue marine mammals injured in by-catch events, and to educate fishers on how to assist animals entangled in fishing gear (Wang *et al*., 2015). It may be necessary to establish new marine protected areas (MPAs) to mitigate the ongoing pressure of fishing activities and conserve fish resources and marine mammals, especially in coastal or estuary regions around Hainan such as Sanya and Chuanghua estuary (Fig. 1) where marine mammals may be particularly vulnerable to both competition with fisheries and anthropogenic mortality (Pitcher *et al*., 2000; Ross *et al*., 2011). Hunting, killing, consumption and trade in marine mammals requires improved control around Hainan, both through increased community-based education initiatives to raise marine mammal conservation awareness, and through improved enforcement of wildlife protection laws and associated legislation already established to protect marine mammal populations (Whitty, 2015).

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Supplementary Information

Text S1 Questionnaire used in interview survey (English language version).

Table S1 Descriptive statistics for target fish species included in interview survey.

Table S2 Summary of interview data collected across Hainan.

Table S3 Demographic profile data of 510 informants.

Table S4 Factors considered by local fishers to be responsible for causing decreases in fishery resources.

Additional Information

Competing financial interests: The authors declare no competing financial interests.

Table 1 Details of marine mammal species potentially occurring in the South China Sea, which are assigned to ten groups for analysis. Key to IUCN status: LC, Least Concern; NT, Near Threatened, VU, Vulnerable, EN, Endangered, DD, Data Deficient (IUCN, 2016). Chinese conservation status indicates whether species included in each category or group are Grade I or II National Key Protected Animals.

Groups	Code	Common name	Latin name	IUCN status	Chinese conservation status
Indo-Pacific humpback dolphin	SCH	Indo-Pacific humpback dolphin	*Sousa chinensis*	NT	I
Indo-Pacific finless porpoise	NPH	Indo-Pacific finless porpoise	*Neophocaena phocaenoides*	VU	II
Grey whale	ERO	Grey whale	*Eschrichtius robustus*	LC	II
Dugong	DUG	Dugong	*Dugong dugon*	VU	I
Sperm whale	PHY	Sperm whale	*Physeter macrocephalus*	VU	II
		Pygmy sperm whale	*Kogia breviceps*	DD	II
		Dwarf sperm whale	*Kogia simus*	DD	II
Black cetaceans	BLC	Killer whale	*Orcinus orca*	DD	II
		Short-finned pilot whale	*Globicephala macrorhynchus*	DD	II
		Pygmy killer whale	*Feresa attenuata*	DD	II
		Melon-headed whale	*Peponocephala electra*	LC	II
		False killer whale	*Pseudorca crassidens*	DD	II
		Risso's dolphin	*Grampus griseus*	LC	II
Beaked whales	BEW	Cuvier's beaked whale	*Ziphius cavirostris*	LC	II
		Longman's beaked Whale	*Indopacetus pacificus*	DD	II
		Blainville's beaked whale	*Mesoplodon densirostris*	DD	II
		Ginkgo-toothed beaked whale	*Mesoplodon ginkgodens*	DD	II
Unidentified small dolphins	SMD	Indo-Pacific bottlenose dolphin	*Tursiops aduncus*	DD	II
		Bottlenose dolphin	*Tursiops truncatus*	LC	II

		Pacific white-sided dolphin	*Lagenorhynchus obliquidens*	LC	II
		Rough-toothed dolphin	*Steno bredanensis*	LC	II
		Short-beaked common dolphin	*Delphinus delphis*	LC	II
		Long-beaked common dolphin	*Delphinus capensis*	DD	II
		Spinner dolphin	*Stenella longirostris*	DD	II
		Striped dolphin	*Stenella coeruleoalba*	LC	II
		Pantropical spotted dolphin	*Stenella attenuata*	LC	II
		Fraser's dolphin	*Lagenodelphis hosei*	DD	II
Other unidentified whales	OTW	Humpback whale	*Megaptera novaeangliae*	LC	II
		Bryde's whale	*Balaenoptera brydei*	DD	II
		Pygmy Bryde's whale	*Balaenoptera edeni*	DD	II
		Blue whale	*Balaenoptera musculus*	EN	II
		Fin whale	*Balaenoptera physalus*	EN	II
		Sei whale	*Balaenoptera borealis*	EN	II
		Omura's whale	*Balaenoptera omurai*	DD	II
		Common minke whale	*Balaenoptera acutorostrata*	LC	II
		North Pacific right whale	*Eubalaena japonica*	EN	II
Unidentified species	UNS	-	-	-	-

562

563 **Table 2** By-catch events between 2000 and 2013 reported by 130 informants.

Group	Number of by-catch events	Number of marine mammal individuals involved
SCH	9	13-16
NPH	28	129-133
ERO	0	0
DUG	0	0
PHY	0	0
BLC	6	6
BEW	2	7
SMD	97	446-475
OTW	2	2
UNS	6	6-7
Total	**150**	**603-639**

564

565

566 **Table 3** Responses of 510 informants to marine mammal by-catch events.

Decision of local fisher	Out of 510 informants (%)
Release live animal	251 (49.2%)
Capture to sell	56 (11.0%)
Release live animal but discard dead animal	38 (7.5%)
Inform local fisheries administration	25 (4.9%)
Capture to eat	24 (4.7%)
Release live animal and inform local fisheries administration	22 (4.3%)
Release live animal but eat dead animal	20 (3.9%)
Release live animal but sell dead animal	19 (3.7%)
Capture to sell or eat	9 (1.8%)
Capture to sell live animal but eat dead animal	8 (1.6%)
Obey captain's order	6 (1.2%)
Release live animal but discard or sell dead animal	5 (1.0%)
Release live animal but sell or eat dead animal	4 (0.8%)
Release live animal but discard dead animal due to beliefs	4 (0.8%)
Capture live animal to eat but discard dead animal	3 (0.6%)
Release live animal but bury dead animal on land	2 (0.4%)
Use by-catch as shark bait	2 (0.4%)
Not sure	12 (2.4%)

567

Figure Legends

Figure 1 Map of surveyed fishing communities and ports (red triangles) around Hainan.

Figure 2 Typical gillnet fishing gear used by local fishers around Hainan.

Figure 3 Types of fishing gear reported to be responsible for by-catch events for Indo-Pacific humpback dolphins (SCH), Indo-Pacific finless porpoises (NPH), and unidentified small dolphins (SMD).

Figure 4 Percentages (%) of marine mammal by-catch events and fishing activities around Hainan in different seasons (Spring, Mar–May; Summer, Jun–Aug; Autumn, Sep–Nov; Winter, Dec–Feb).

Figure 5 Distribution patterns of relative by-catch density D_{rb} in the investigated waters for (A) Indo-Pacific humpback dolphins (SCH), (B) Indo-Pacific finless porpoises (NPH), and (C) unidentified small dolphins (SMD).

Figure 6 Temporal distribution of the reported last dates that informants experienced marine mammal by-catch events, ate marine mammals or sold marine mammals, and percentage (%) of informants who have ever experienced these events.

Figure 7 Examples showing marine mammal meats for sale in fishing markets on Hainan. (A) Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) calf; (B) Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) adult; (C) pantropical spotted dolphin (*Stenella attenuata*).

Figure 8 Perceptions of informants on: (A) changes in marine fishery resources, fishery vessels, and marine mammal populations (a = fishery resources, b = fishery vessels, c = population of whales, d = population of dolphins); and (B) factors responsible for decreases of whales (light grey) and dolphins (dark grey).

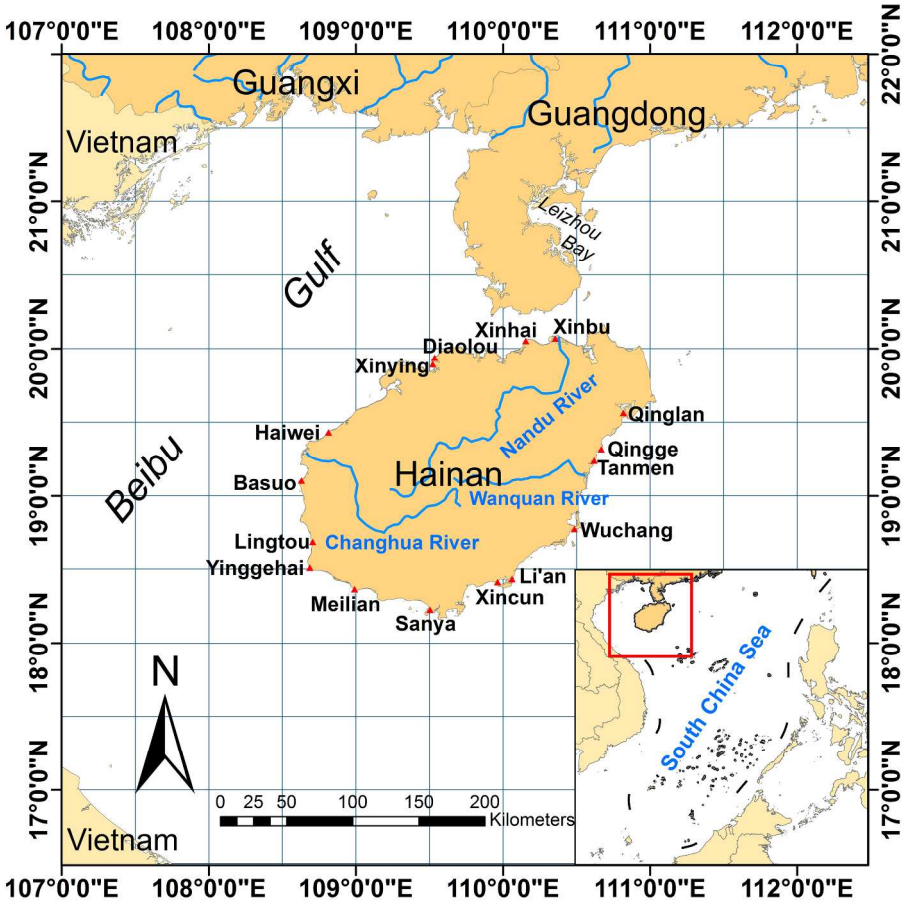

Figure 1 Map of surveyed fishing communities and ports (red triangles) around Hainan.

246x240mm (300 x 300 DPI)

Figure 2 Typical gillnet fishing gear used by local fishers around Hainan.

1587x881mm (72 x 72 DPI)

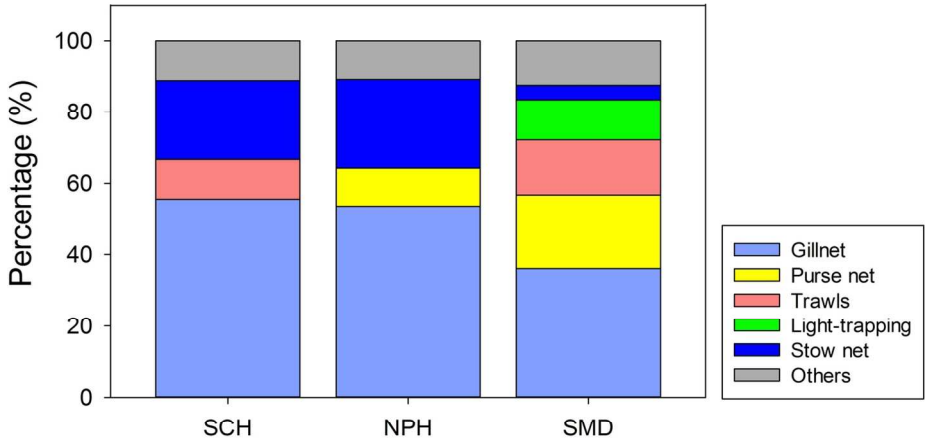

Figure 3 Types of fishing gear reported to be responsible for by-catch events for Indo-Pacific humpback dolphins, Indo-Pacific finless porpoises and unidentified small dolphins.

129x80mm (300 x 300 DPI)

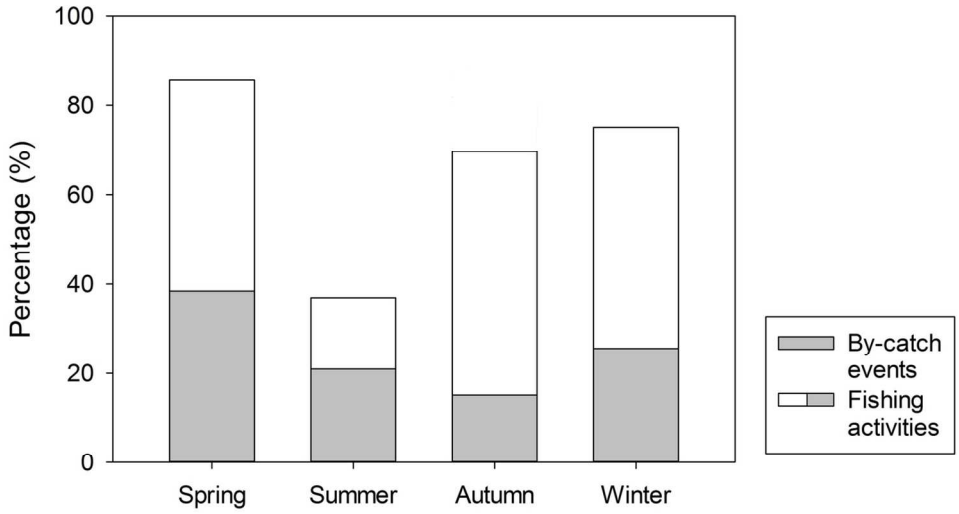

Figure 4 Percentages (%) of marine mammal by-catch events and fishing activities around Hainan in different seasons (Spring, Mar–May; Summer, Jun–Aug; Autumn, Sep–Nov; Winter, Dec–Feb).

122x74mm (300 x 300 DPI)

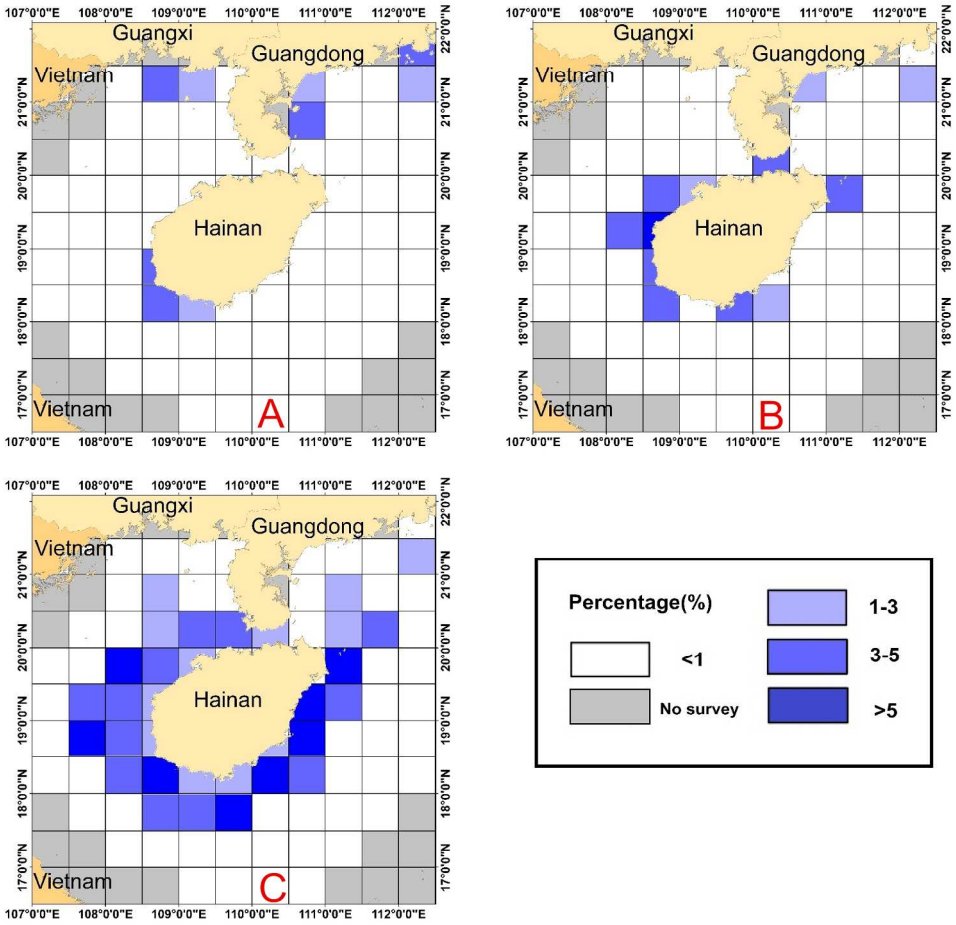

Figure 5 Distribution patterns of relative by-catch density D_rb in the investigated waters for (A) Indo-Pacific humpback dolphins (SCH), (B) Indo-Pacific finless porpoises (NPH), and (C) unidentified small dolphins (SMD).

180x175mm (300 x 300 DPI)

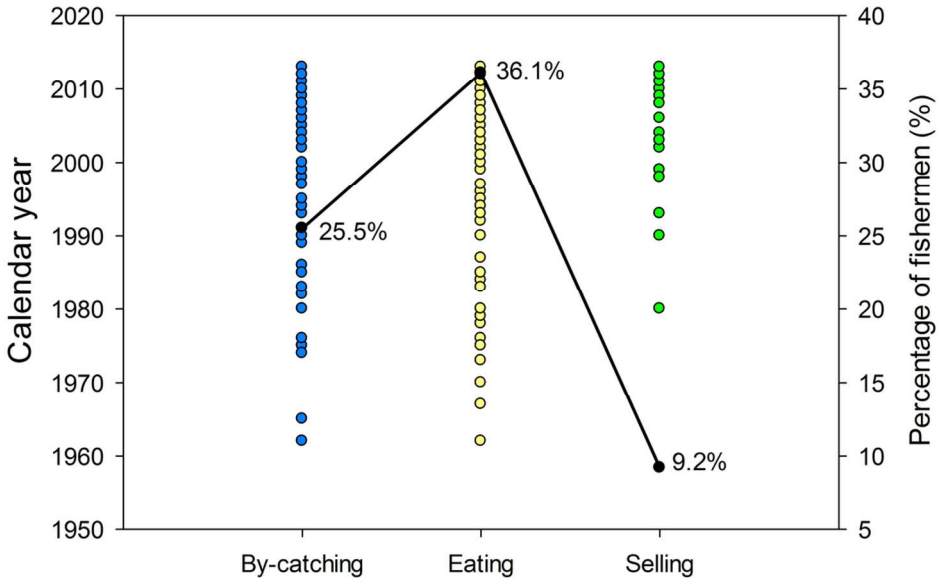

Figure 6 Temporal distribution of the reported last dates that informants experienced marine mammal by-catch events, ate marine mammals or sold marine mammals, and percentage (%) of informants who have ever experienced these events.

110x69mm (300 x 300 DPI)

Figure 7 Examples showing marine mammal meats for sale in fishing markets on Hainan. (A) Indo-Pacific finless porpoise (Neophocaena phocaenoides) calf; (B) Indo-Pacific finless porpoise (Neophocaena phocaenoides) adult; (C) pantropical spotted dolphin (Stenella attenuata).

275x416mm (120 x 120 DPI)

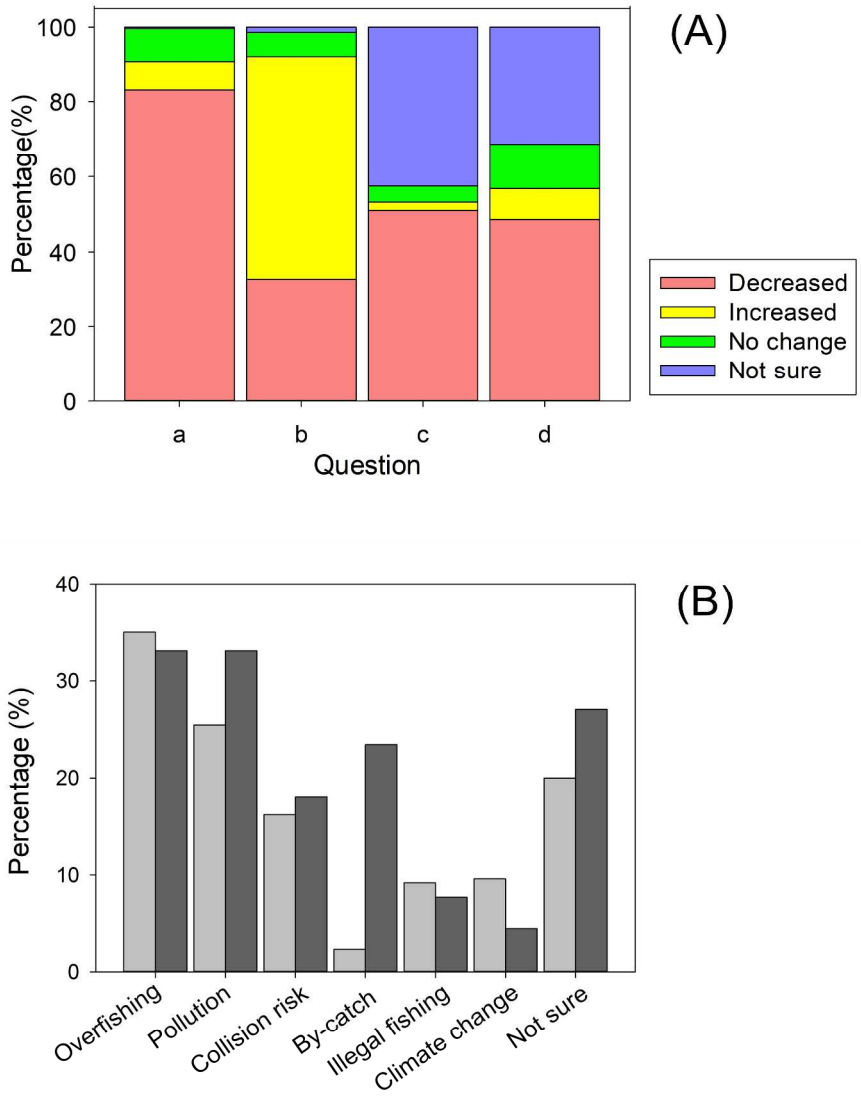

Figure 8 Perceptions of informants on: (A) changes in marine fishery resources, fishery vessels, and marine mammal populations (a = fishery resources, b = fishery vessels, c = population of whales, d = population of dolphins); and (B) factors responsible for decreases of whales (light grey) and dolphins (dark grey).

788x1048mm (120 x 120 DPI)

Table S1 Descriptive statistics for target fish species included in questionnaire survey. Ecological group: MS = middle and surface layer, MB = middle and near-bottom layer, NB = near-bottom layer, B = bottom layer. Temp: WW = warm-water species, WT = warm-temperature species, ET = eurythermal species. Major fishing gears: FT = floating trawl net, BT = bottom trawl net, G = gillnet, P = purse net, L = long-line, O = other fishing gears. Fishery yield data (Hainan, 2013) comes from Fishery Statistical Yearbook of China (2014).

Genus/Family	Ecological group	Temp.	Major gears	Frequency (percentage)	Yield (Hainan) (10kt)
Engraulis	MS	ET	P/FT	20(3.9%)	NA
Pampus	MS	WT	G/P/O	186(36.5%)	40,985
Pagrosomus	NB/B	WT/WW	G/BT/O	113(22.2%)	32,925
Pseudosciaena	NB/B	WT	BT/G/O	154(30.2%)	28,422
Trichiurus	NB	WW	BT/O	370(72.5%)	146,754
Etrumeus	MS	WT	G/FT/P	191(37.5%)	NA
Muraenesox	B	WT	BT/L/O	220(43.1%)	NA
Argyrosomus	NB	WT	BT/O	165(32.4%)	10,058
Nibea	NB	ET	BT/O	94(17.8%)	18,147
Nemipterus	NB	WT	BT/O	194(38.0%)	198,557
Decapterus	MS	WT	P/O	298(58.4%)	43,857
Scombermorus	MS	WW	G/P/O	181(35.5%)	36,985
Thunnus	MS	WT	L/P	45(8.8%)	16,750
Trachurus	MS	ET	P/O	194(38.0%)	14,275
Cynoglossidae	B	WT	BT/O	157(30.8%)	NA
Collichthys	MB	WT	BT/G	41(8.0%)	1,470
Branchiostegus	MB	WT	BT/O	149(29.2%)	13,411
Sardinella	MS	WT/WW	G/P/FT	240(47.1%)	NA
Mugil	NB	ET	G/O	113(22.2%)	13,689
Navodon	MB	WW	BT/O	223(43.7%)	17,887
Epinephelus	NB	WT	BT/O	145(28.4%)	39,442
Pneumatophorus	MS	WT	P/G	172(33.7%)	10,857

Table S2 Summary of interview data collected from Hainan.

Survey site	Latitude (N)	Longitude (E)	No. of informants	No. of small vessels	Fishing grids of small vessels	No. of large vessels	Fishing grids of large vessels
Meilian	18.365775°	108.991680°	31	31	h4,h5,g4,h3,i5,i4	0	h4,h5,g4,h3,i5,i4
Sanya	18.226533°	109.504893°	23	0	h4,h5,h6,g2,g3,h2,	23	h4,h5,h6,g2,g3,h2,h3,i2,i3,j3,i4,j4,i5,j5,k5,i6,j6,k6,i7,j7,k7,h8,i8,j8,k8,f9,g9,h9,i9,j9,e10,f10,g10,h10,i10
Xincun	18.412784°	109.964740°	36	18	h6,h7,h8,g7,g8,i7	18	h6,h7,g8,i3,i4,i5,i6,i7,i8,i9,i10,j4,j5,j6,j7,j8,j9,k5,k6,k7,k8,h8,h9,h10,h11,g9, g10,f9,f10,e9,e10
Li'an	18.433560°	110.062954°	26	23	h6,h7,h8,g7,g8,i7	3	h6,h7,g8,i3,i4,i5,i6,i7,i8,i9,i10,j4,j5,j6,j7,j8,j9,k5,k6,k7,k8,h8,h9,h10,h11,g9, g10,f9,f10,e9,e10
Yinggehai	18.509903°	108.688397°	32	28	f4,g3,g4,h3,h4,h5	4	e2,e3,f2,f3,g2,g3,g4,h2,h3,h4,i2,i3,i4,i5,i6,j3,j4,j5
Lingtou	18.689449°	108.707502°	26	25	h4,h5,g4,h3,i4,g3	1	d2,d3,d4,e1,e2,e3,e4,f1,f2,f3,g1,g2,g3,h1,h2,h3,h4,i2,i3,i4,i5,i6,j3,j4,j5
Basuo	19.103186°	108.630615°	49	11	e4,f3,f4,g3,g4,h4	38	c3,c4,d2,d3,d4,d5,e2,e3, e4,f1,f2,f3,g1,g2,g3,h1,h2,h3,i2,i3,i4,j3,j4
Qingge	19.318584°	110.669585°	16	13	e9,f8,f9,g8,g9	3	c9,c10,d9,d10,d11,e9,e10,e11,f8,f9,f10,f11,g8,g9,g10,g11,h8,h9,h10,i7,i8,i9,j8,j9
Tanmen	19.238267°	110.620655°	25	20	e9,f8,f9,g8,g9	5	c9,c10,d9,d10,d11,e9,e10,e11,f8,f9,f10,f11,g8,g9,g10,g11,h8,h9,h10,i7,i8,i9,j8,j9
Qinglan	19.564034°	110.819860°	49	11	d9,e9,e10,f8,f9,g8	38	a11,b8,b9,b10,b11,c8,c9,c10,c11,d8,d9,d10,d11,e9,e10,e11,f8,f9,f10,f11,g9,g10,g11,h8,h9,h10
Wuchang	18.776532°	110.486665°	31	30	f8,g7,g8,h7,h8	1	e9,e10,f8,f9,f10,f11,g8,g9,g10,g11,h5,h6,h7,h8,h9,h10, i5,i6,i7,i8,i9,i10,j7,j8

Xinbu	20.069750°	110.357691°	36	35	c6,c8,d5,d6,d7,d8	1	b5,b6,c4,c5,c6,d3,d4,d5,d6,d7,d8,d9,d10,d11,e4,e9,e10
Xinhai	20.053266°	110.156679°	12	11	c6,c8,d5,d6,d7,d8	1	b5,b6,c4,c5,c6,d3,d4,d5,d6,d7,d8,d9,d10,d11,e4,e9,e10
Diaolou	19.938860°	109.535621°	30	6	c5,c6,d5,d6,d7,e5	24	b3,b4,b5,b6,c3,c4,c5,c6,d2,d3,d4,d5,d6,d7,d8,e2,e3,e4,e5,f3
Xinying	19.893262°	109.523160°	25	13	c5,c6,d5,d6,d7,e5	12	b3,b4,b5,b6,c3,c4,c5,c6,d2,d3,d4,d5,d6,d7,d8,e2,e3,e4,e5,f3
Haiwei	19.432745°	108.814712°	63	44	f3,f4,e3,e4,e5,d5	19	b3,b4,b5,c3,c4,c5,d2,d3,d4,d5,e1,e2,e3,e4,e5,f1,f2,f3,f4,g1,g2,g3, h1,h2,h3,i2,i3

Table S3 Demographic profile data of 510 informants.

Demographic information	Category	Mean ± SD or n (%)
Average age	-	42.1 y ± 12.7
Average age of starting fishing	-	17.3 y ± 5.2
Average fishing experience	-	23.9 y ± 12.2
Average fishing days per year	-	177.2 d ± 57.4
Average vessel length	-	17.4 m ± 9.2
Sex	Male	498 (97.6%)
	Female	12 (2.4%)
Ethnic groups	Han	503 (98.6%)
	Minorities	7 (1.4%)
Age class	Young (< 30 y)	76 (14.9%)
	Middle aged (30 – 60 y)	396 (77.6%)
	Old (> 60 y)	38 (7.5%)
Age class of starting fishing	Child (5 - 12 y)	78 (15.2%)
	Adolescent (13 – 16 y)	164 (32.2%)
	Adult (17 - 30 y)	259 (50.8%)
	Middle (31 - 50 y)	8 (1.6%)
	Elder (> 51 y)	1 (0.2%)
Educational level	University/college	2 (0.4%)
	Senior middle school	58(11.4%)
	Junior middle school	239 (46.9%)
	Elementary school	169 (33.1%)
	Illiterate	26 (5.1%)
	Other	16 (3.1%)
Fishing income	< 4000 yuan/month	274 (53.6%)
	4000 - 8000 yuan/month	102 (20.1%)
	> 8000 yuan/month	134 (26.3%)
Vessel size	Small (< 20 m)	316 (62.0%)
	Large (≥ 20 m)	194 (38.0%)

Table S4 Factors considered by local fishers to be responsible for causing decreases in fishery resources.

Factor	Sub-factor	n (%)
Overfishing	General overfishing practices	399 (94.1%)
	Increase in advanced fishing methods and gears	357 (84.2%)
	Increase in marine fishers	206 (48.6%)
	Excessive use of illegal fishing gears	51 (12.0%)
	Increase in fishing vessels	25 (5.9%)
Water pollution		211 (49.8%)
Climate change		66 (15.6%)
Consumption by marine mammals		31 (7.3%)
Not sure		29 (6.8%)

LIST OF VOLUNTEERS

A total of 42 volunteers recruited from Sanya College participated in this interview survey: Cai Yuwen, Chen Dan, Chen Qiujun, Chen Ruyi, Cui Jia, Cui Jianing, Deng Hualan, Deng Yinying, Guo Lifang, Huang Shan, Huang Ziyuan, Hong Yiqiong, Liu Jiangtao, Lai Wenyi, Li Qian, Lin Shengxing, Li Hongbin, Liu Lu, Meng Shaomei, Na Mengying, Pan Yu, Qian Linlin, Qin Mi, Qiu Rijian, Qiu Xiuyun, Quan Chengjia, Ren Gaofan, Shao Chenxi, Shi Shanshan, Su Hongbei, Sun Lifei, Tan Jiaxi, Wang Renyi, Wu Hua, Wu Jianjun, Xu Qianqian, Yao Jianmin, Zhang Yiran, Zhou Jin, Zhou Qian, Zhu Junhao, Zuo Chen. We thank them very much for their hard work!

2013 年南海鲸豚类调查问卷

Text S1: Fishermen survey questionnaire (Hainan)

(English version)

DATE:_____ LOCATION:_____ INTERVIEWER:_____

The Chinese Academy of Sciences is undertaking an opinion survey related to fishers' local ecological knowledge on cetacean species. The outcome of the survey will be published in a peer-reviewed journal but will remain anonymous. Would you consent to participate in this study and answer questions related to this subject?

☐ **Yes** ☐ **No**

A: FISHERY AND CETACEANS

1) How old are you? _____

Gender _____

Nationality _____

What is your education level?

☐ University/College ☐ Senior mid school

☐ Junior mid school ☐ Elementary school

☐ Illiterate ☐ Other level (Please describe: _____)

2) You have engaged in fishing from _____ years old to _____ years old

3) Which months do you fish at sea each year? _____

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4) How long is your vessel? _____

5) Which fishing gears have you used recently? _____

- ☐ 1. Drift gillnets
- ☐ 2. Fixed gillnets
- ☐ 3. Trawls
- ☐ 4. Purse nets
- ☐ 5. Light-trapping
- ☐ 6. Electric-fishing
- ☐ 7. Hooking
- ☐ 8. Long-line
- ☐ 9. Stow nets
- ☐ 10. Bomb-fishing
- ☐ 11. Other fishing gears or methods (Please describe: _____)

6) Please identify your target fish species (A-V) with the help of photographs of commercial fishes in the South China Sea; please list and describe if you mainly catch other species such as crustaceans or cephalopods.

- ☐ A. *Engraulis* spp. (Anchoveta)
- ☐ B. *Pampus* spp. (Butterfish)
- ☐ C. *Pagrosomus* spp. (Sea bream)
- ☐ D. *Pseudosciaena* spp. (Croaker)
- ☐ E. *Trichiurus* spp. (Ribbonfish)
- ☐ F. *Etrumeus* spp. (Herring)
- ☐ G. *Muraenesox* spp. (Conger)
- ☐ H. *Argyrosomus* spp. (White croaker)
- ☐ I. *Nibea* ssp. (Yellow croaker)
- ☐ J. *Nemipterus* spp. (Nemipterus)
- ☐ K. *Decapterus* spp. (Scad)
- ☐ L. *Scombermorus* spp. (Horse mackerel)
- ☐ M. *Thunnus* spp. (Tuna)
- ☐ N. *Trachurus* spp. (Mackerel)

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- ☐ O. Cynoglossidae spp. (Tonguefish)
- ☐ P. *Collichthys* spp. (Croaker)
- ☐ Q. *Branchiostegus* spp. (Tilefish)
- ☐ R. *Sardinella* spp. (Sardine)
- ☐ S. *Mugil* spp. (Mullet)
- ☐ T. *Navodon* spp. (Filefish)
- ☐ U. *Epinephelus* spp. (Grouper)
- ☐ V. *Pneumatophorus* spp. (Chub mackerel)
- ☐ Other species (Please describe and list: _____)

7) How many days do you devote to fishing on average every year?

_____

8) Where do you typically engage in fishing?

_____(Please write down the grid numbers)

9) How have fishery resources changed during your fishing career?

a) Fishing catch

☐ Increase ☐ Decrease ☐ Unchanged

b) Number of fishing vessels

☐ Increase ☐ Decrease ☐ Unchanged

10) Recent incidental catch of cetaceans:

a) Which fishing gears or methods? _____
b) Which species? _____
c) How many? _____
d) Where? _____ (Write down the grid numbers)
e) When? _____

11) If you have incidentally caught a cetacean, please describe its status:

☐ Dead ☐ Alive but injured ☐ Alive and not injured

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☐ Other status (Please describe: _____)

12) Have you ever seen or heard that cetaceans were hit by propellers of fishing vessels?

☐ Ever seen ☐ Ever heard

☐ Never seen ☐ Never heard

If you have you ever seen or heard:

a) When did it happen? _____
b) Which species? _____
c) Where? _____ (Please write down the grid numbers)

13) Relationship between fishing gears and cetaceans:

a) Which fishing gear is able to catch cetaceans most easily? _____
b) How many cetaceans do you know this gear has caught? _____
c) Which other gears can also catch cetaceans? _____

B: DISTRIBUTION AND QUANTITY OF DOLPHINS

(Adult length <4m, typically without column of spray)

14) Please identify and list all dolphin species you have seen
(Identify species with the help of the illustrated handbook, without any prompting or influence from colleagues present)

a) Which dolphin species have you seen most frequently? _____
b) Which dolphin species have you seen in the greatest numbers?
_____

15) During which months is it easiest to see dolphins in your fishing area? During which months is it more difficult to see dolphins in your fishing area?

16) Where do you see dolphins most frequently?
_____ (Please write down the grid numbers)

17) About the largest size of dolphin group you have ever seen.

a) When? _____
b) Where? _____ (Please write down the grid numbers)

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18) How has the amount of dolphins changed during your fishing career?

☐ Increase ☐ Decrease ☐ Unchanged ☐ Do not know

19) About your recent sighting(s) of stranded dolphin(s):

a) Which species? _____

b) How many? _____

c) When? _____

d) Where? _____ (Please write down the grid numbers)

20) Have you ever seen Indo-Pacific humpback dolphins?

☐ Yes ☐ No

a) When? _____

b) Where? _____ (Please write down the grid numbers)

c) How many? _____

21) Have you ever seen finless porpoises?

☐ Yes ☐ No

a) When? _____

b) Where? _____ (Please write down the grid numbers)

c) How many? _____

C: DISTRIBUTION AND QUANTITY OF WHALES

(Adult length >4m, with recognizable spray column)

22) Please identify and list all whale species you have seen

(Identify species with the help of the illustrated handbook, without any prompting or influence from colleagues present)

23) Which whale species have you seen most frequently? _____

24) Describe recent sightings of whales at sea (not including stranded cetaceans):

a) Which species? _____

b) When? _____

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c) Where? _____ (Please write down the grid numbers)

25) About the largest group size of whales you have ever seen?

_____

a) Which species? _____
b) How many? _____
c) When? _____
c) Where? _____ (Please write down the grid numbers)

26) Have you ever seen or heard of stranded whale(s): ☐ Yes ☐ No

a) Which species? _____
b) How many? _____
c) When? _____
d) Where? _____ (Please write down the grid numbers)

27) How has the number of whales changed during your fishing career?

☐ Increase ☐ Decrease ☐ No change ☐ Not sure

D: PERCEPTIONS OF CETACEANS AND FISHERY

28) Average family income per month:

☐ <2000 RMB ☐ 2000-4000 RMB ☐ 4000-6000 RMB

☐ 6000-8000 RMB ☐ 8000-10000 RMB ☐ >10000 RMB

29) Do you think fishing is a good profession? ☐ Yes ☐ No

Do you hope that your children work as fishers? ☐ Yes ☐ No

30) How often do you talk about cetaceans with other fishers?

☐ Frequently ☐ Sometimes ☐ Occasionally ☐ Never

31) What topics do you discuss when you talk about cetaceans?

☐ Sighting cetaceans at sea ☐ Cetaceans hurt by vessels or nets

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☐ Too many fish eaten by cetaceans ☐ Stranding events

☐ Other topics (Describe: _____)

32) Have you ever eaten dolphin or whale meat? ☐ Yes ☐ No

When have you recently eaten it? _____

33) Have you ever sold cetaceans? ☐ Yes ☐ No

a) ☐ Dead ☐ Alive

b) How much? _____
c) When? _____
d) Purposes of the buyer: _____

34) Do you think cetaceans play an important role in the marine ecosystem?

☐ Yes ☐ No ☐ Not sure

35) Do you think cetaceans should be protected?

☐ Yes ☐ No ☐ Not sure

36) Will fishery resources increase cetaceans are removed?

☐ Yes ☐ No ☐ Not sure

37) Why have marine fishery resources decreased in your opinion?

☐ Increase of advanced fishing methods and gears

☐ Increased number of marine fishers

☐ Fishery resources consumed by cetaceans

☐ Increasing water pollution

☐ Other reasons (Please describe: _____)

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38) Why have cetacean populations decreased?

- [ ] Reduction of food resources due to overfishing
- [ ] Increased collision risk from increasing vessel traffic
- [ ] Increased water pollution
- [ ] Other reasons (Please describe: _____)

39) How do you deal with stranded cetaceans?

- [ ] Free
- [ ] Sell
- [ ] Eat
- [ ] Inform local fisheries administration
- [ ] Ignore
- [ ] Other choices (Please describe: _____)

40) How do you deal with entangled cetaceans?

- [ ] Free alive
- [ ] Discard dead
- [ ] Sell
- [ ] Inform local fisheries administration
- [ ] Eat
- [ ] Other choices (Please describe: _____)

41) Do you think cetaceans are national protected animals in China?

- [ ] Yes
- [ ] No
- [ ] Not sure

42) Do you think that hunting or selling cetaceans is illegal?

- [ ] Yes
- [ ] No
- [ ] Not sure

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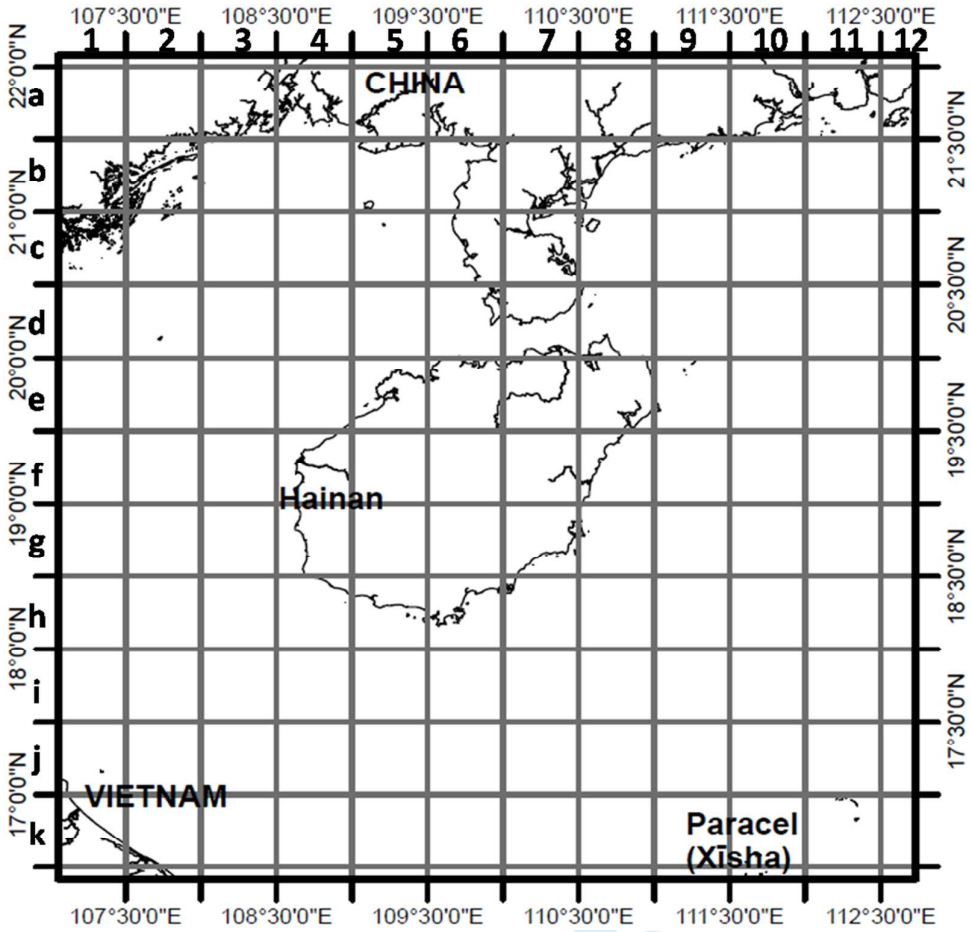

Figure S1 Grid map of Hainan and adjacent waters

1). Please write down grid numbers according to the format "Letter + Number" (e.g., b4).

2). Please record names or geographic locations on the map of other areas in the South China Sea that you have mentioned (e.g., Nansha, Xisha).

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