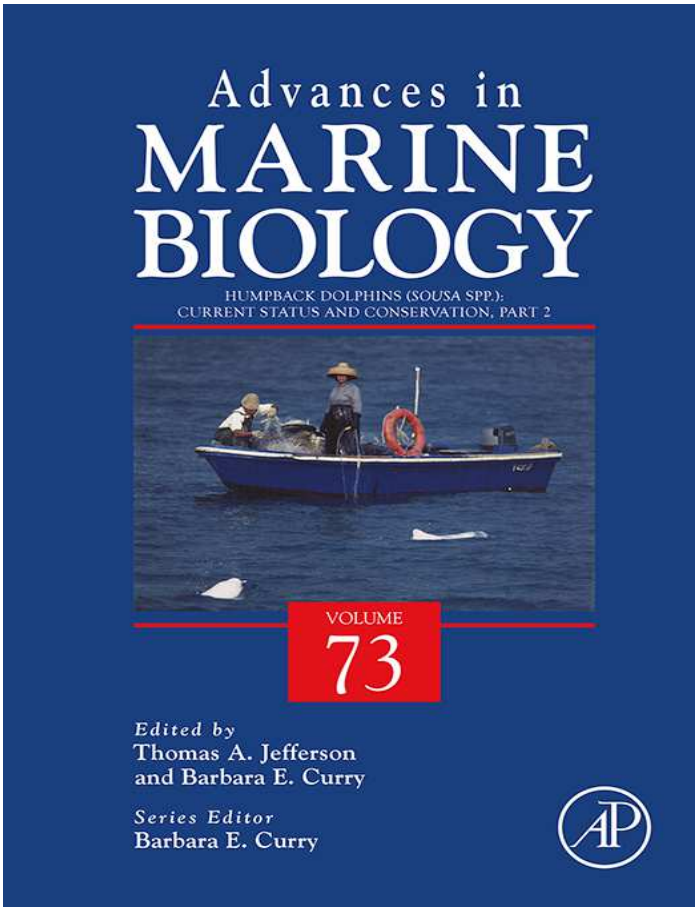

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CHAPTER FIVE

Conservation Status of the Indo-Pacific Humpback Dolphin (*Sousa chinensis*) in the Northern Beibu Gulf, China

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Contents

Abstract

There has been very little previous research on Indo-Pacific humpback dolphins (*Sousa chinensis*) in the Beibu Gulf of southern China. Here, we report on the population size, habitat and ecology, threats, and overall conservation status of this putative population. 'Population size' was estimated based on photo-identification mark/recapture analysis.

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It was estimated to number a total of 398–444 individuals (95% CI: 393–506), with two apparently distinct groups in the Dafengjiang–Nanliujiang Estuary and at Shatian–Caotan. Movements of dolphins in the Beibu Gulf appear to be limited, with high site fidelity. These dolphins were found to occur mainly in shallow coastal waters near estuaries. The main threats are fisheries interactions (including by-catch), vessel traffic, mariculture operations, dolphin-watching tourism, and habitat degradation (including marine construction activities and large-scale land reclamation). Although the conservation status of this putative population has been considered to be better than that of other populations of the species in more northern areas of China, there is still reason for strong concern about its future, and several management recommendations are made.

1. INTRODUCTION

The Indo-Pacific humpback dolphin (*Sousa chinensis*, also known as the Chinese white dolphin) is a shallow-water obligate species, found throughout China and Southeast Asia (Jefferson and Karczmarski, 2001). In China, Indo-Pacific humpback dolphins inhabit shallow waters, mostly <30 m deep (Jefferson and Smith, 2016) along a convoluted coastline that has many incisions. Recently, the taxonomy has been revised, and this species has received increasing levels of concern regarding its conservation in Asian waters (see Jefferson and Smith, 2016). Indo-Pacific humpback dolphins are thought to have originally occurred in most coastal areas of China. However, currently only six to eight putative populations are known to remain in China, mostly in and around several estuarine areas. These areas of occurrence include Xiamen (Chen et al., 2008, 2011; Liu and Huang, 2000), Hong Kong/Pearl River Estuary (Hung, 2008; Jefferson, 2000; Jefferson and Leatherwood, 1997; Karczmarski et al., 2016), eastern Taiwan Strait (Wang et al., 2004, 2007, 2016), Zhanjiang (Xu et al., 2012, 2015; Zhou et al., 2007), Beibu Gulf (Chen et al., 2009), Ningde (Chen et al., 2012), and Shantou (Wu, 2010). Although the dolphins that inhabit each of these areas are often assumed to form distinct populations, only the eastern Taiwan Strait population has been shown to be distinct through empirical data and it has recently been proposed as a subspecies, *S. c. taiwanensis* (Wang et al., 2015). Indo-Pacific humpback dolphins have been observed to have high site fidelity, with typical movements of only tens of linear km (Chen et al., 2011; Hung and Jefferson, 2004). The linear distance between these areas is over 150 km, which is apparently beyond the typical

ranging limits of this species, suggesting that there is a low possibility of mixing, and supporting the idea of isolation between groups.

The shallow waters of the northern Beibu Gulf (Figure 1) are the westernmost known range of Indo-Pacific humpback dolphins in China. The dolphins found there inhabit the Gulf year round (Wang and Sun, 1982; Zhou et al., 2003). Recent knowledge is based on studies by Jefferson and Hung (2004), Pan et al. (2006) and Chen et al. (2009). Surveys in 2000 and 2003–2004 (Chen et al., 2009) showed that the dolphins were distributed in the Gulf from Xi'niujiao to Shatian. Line transect surveys in 2003–2004 produced estimates of 39 (17–92, SE = 29.98) dolphins at Shatian and 114 (21–604, SE = 98.89) dolphins at Dafengjiang Estuary (Chen et al., 2009). Those estimates were very preliminary, with low precision, due to the low number of sightings (sample size). While systematic

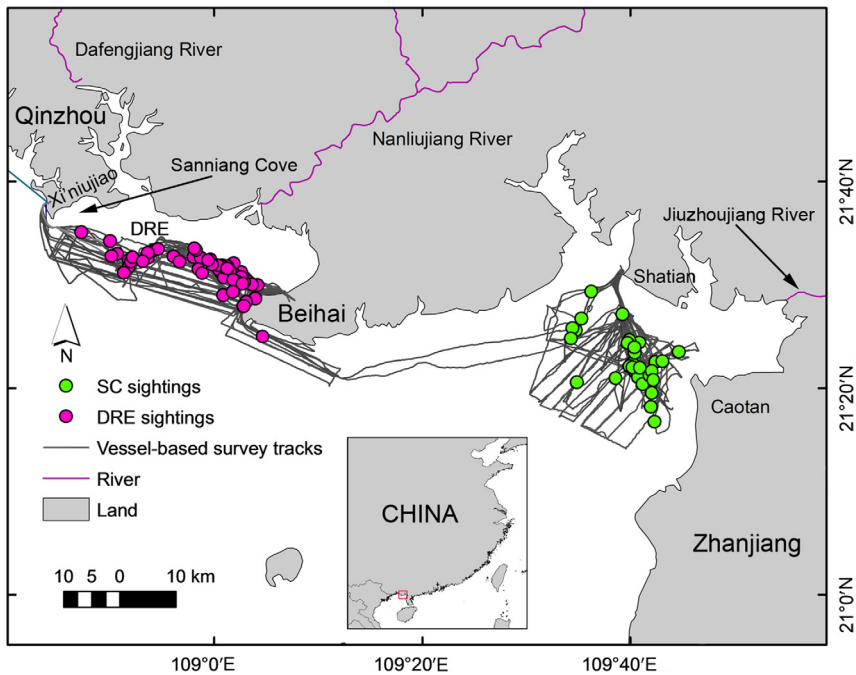

Figure 1 Map of study area at the Northern Beibu Gulf, showing the tracks of vessel-based surveys and locations of Indo-Pacific humpback dolphin, *Sousa chinensis*, sightings between January 2011 and October 2014. *Note*: SC, Shatian–Caotan waters; DRE, Dafengjiang–Nanliujiang River Estuary. The sightings in west Shatian included some records in 2003–2004. The area with low effort between SC waters and DRE is the transit area between the two main study sites.

photographic-identification and mark/recapture (M/R) methods were not employed. Pan et al. (2006) observed 98 individuals during opportunistic small-scale vessel-based surveys, but did not estimate population size.

Dolphin habitat in the Beibu Gulf is generally considered to be in better condition than that of the other known areas of Indo-Pacific humpback dolphin occurrence in China (with the exception of Zhanjiang). The Beibu Gulf is often recognized as the most productive fishing ground in China, with high biodiversity, including more than 500 fish species, 200 shrimps, 50 cephalopods, 20 crabs, and a variety of shellfish (Zhu, 2001). In addition to Indo-Pacific humpback dolphins, marine mammals known to be regular inhabitants of the coastal zone include Indo-Pacific finless porpoises (*Neophocaena phocaenoides*) and dugongs (*Dugong dugon*).

However, increasing coastal anthropogenic activities over recent decades have resulted in overexploitation of fisheries, habitat loss and damage, and marine pollution. Biodiversity has declined; for example, fisheries resources were recently estimated to have declined by more than 70% from the 1960s to 1998 (Wang and Yuan, 2008). Indo-Pacific humpback dolphins are known to feed on a variety of estuarine fishes (Barros et al., 2004), and the impacts of declines in available dolphin prey species have not been properly evaluated.

The only dolphin-watching tourism industry in mainland China has been operating at Sanniang Cove (northern Beibu Gulf, see location in Figure 1) for 10 years. Vessel density in the main observation area is very high during holiday periods. Because of the absence of effective management, this tourism has contributed to negative impacts on the dolphins in the area, including apparent stress reactions of the dolphins (B. Chen, unpublished data).

When the impacts of tourism are considered in combination with the reduction of prey resources, the presence of various vessels, and general deterioration of the local marine ecosystem, it is apparent that the survival of Indo-Pacific humpback dolphins in this area may be in jeopardy. Therefore, there is an urgent need to obtain basic information on population size and distribution patterns, which are integral components needed to manage human impacts on wild cetaceans (Parra et al., 2006; Tyne et al., 2014).

In 2011, we started a long-term research project on Indo-Pacific humpback dolphins in the northern Beibu Gulf, using photographic-identification and M/R methods. In this chapter, we report preliminary results on population size, habitat and ecology, threats, and overall conservation status.

2. POPULATION SIZE

2.1 Methods

2.1.1 Study Area and Survey Methods

Our study area design was based on data collected from local residents and fishers in 2000, using interview questionnaires, and from a vessel-based survey conducted in 2003–2004. The study area covers approximately 410.5 km^2 (E 108°40′–109°45′, N21°11′–21°37′) including the coastal waters of Beihai and portions of Qinzhou and Zhanjiang coastal waters (see Figure 1). There were two main study sites: Shatian/Caotan (hereafter referred to as SC), and the Dafengjiang River and Nanliujiang River estuary (hereafter referred to as DRE). The Beibu Gulf has diurnal tides, with the largest tidal range of 7 m. Within the study area, there are two estuarine systems: in the west, the Dafengjiang River and Nanliujiang River with 7.91 billion m^3 freshwater injected annually, and in the east, the Jiuzhoujiang River with a 2.8 billion m^3 freshwater injection. Most of study area has a depth of <20 m, but in more offshore areas greater depths are found.

Between 13 January 2011 and 12 October 2014, vessel-based photo-identification surveys were conducted for a total of 154 days, covering 8828.92-km of survey tracklines from Xiniujiao to Caotan in the northern Beibu Gulf (Table 1). Surveys were undertaken as weather conditions permitted (i.e. Beaufort <= 3 and swells <= 1 m). The surveys were conducted onboard fishing vessels that departed from the three ports: Xiniujiao, Beihai, and Shatian (see Figure 1). The vessels were from 15–18 m in length, powered by 100–150 hp diesel engines, and surveyed at a steady speed of 10–14 km/h. Observation platforms were 2–4 m above sea level. A minimum of two observers searched for dolphins using the

Table 1 Vessel Survey Effort (km) at Northern Beibu Gulf, China Between January 2011 and October 2014

Year	DRE	SC
2011	232.5	2539.6
2012	1015.02	1166.08
2013	1523.08	656.8
2014	1014.14	681.7
Total	3784.74	5044.18

naked eye. Once dolphins were sighted, the vessel would approach them slowly. Longitude and latitude (using a *Garmin* GPS, *Etrex* Venture, and MAP 60CSx) were simultaneously recorded. Group size was counted in the field as the total number of dolphins in different age/sex classes, i.e., unspotted calves, unspotted juveniles, mottled, speckled, spotted adults, and unspotted adults (see Jefferson, 2000; Jefferson and Leatherwood, 1997; Jefferson et al., 2012). A group was defined as those individuals moving in the same direction with predominantly the same behaviour pattern (Chen et al., 2011). The group members were usually distributed over a small area. But in some cases, the scale was too large to determine the group parameters. In these instances, we defined group members as those within 150 m from the first sighted animal. We aimed to photograph each dolphin in the group instead of following a focal animal. The maximum possible time was dedicated to following dolphin groups, until one of the following occurred: (1) all individuals were photographed, (2) the dolphins were lost from view, or (3) environmental conditions deteriorated.

2.1.2 Photographic Identification

Photographs were taken as perpendicular to the body axis of the dolphin as possible using digital cameras, *Canon* 1DS Mark II and III, with 400 and 100–400 mm zoom lenses (in some cases using an EF 1.4X extender). All images were examined and graded (excellent, good, or poor) according to the clarity, focus, degree of contrast, relative angle between the body axis and *x*-axis, dorsal fin visibility, and the proportion of the frame filled by the dorsal fin. To minimize the introduction of bias and to reduce misidentification, only the excellent or good photos (Figure 2) were used in the analysis.

The spotting patterns on the dorsal fin and body of sub-adult and adult Indo-Pacific humpback dolphins are highly distinctive among individuals (see Figure 2). By examining the unique combination of scars, marks, and pigment patterns on or near the dorsal fin, individual Indo-Pacific humpback dolphins could be identified unambiguously during the study period (see Jefferson and Leatherwood, 1997).

All the photos of identified dolphins were catalogued and indexed by age/sex class (see above), distinctiveness (scars, spots), and orientation of dolphin (right, left, both). Every individual was compared to all others in the catalogue before being assigned a unique identification code. Scars, nicks, and notches on/around the edges of the dorsal fin, which were visible from

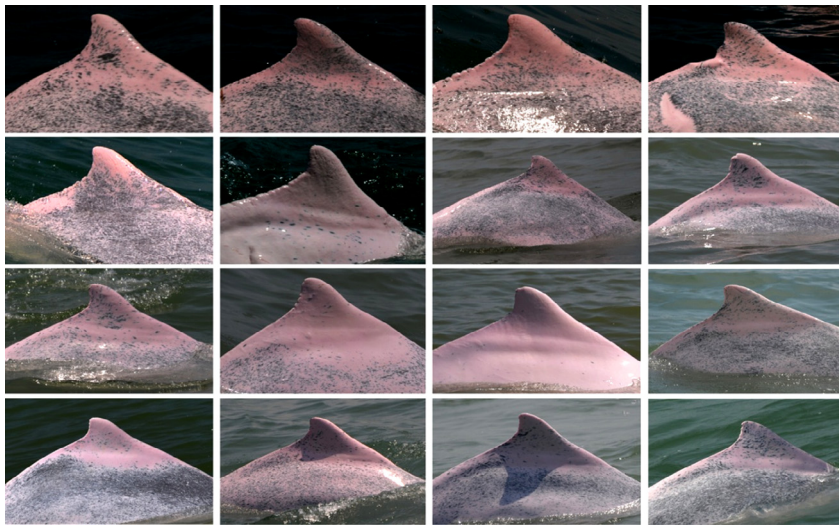

Figure 2 Photos of some of the Indo-Pacific humpback dolphin, *Sousa chinensis*, individuals photo-identified in the current study at Beibu Gulf, China. *Photo by X. Xu and B. Chen.*

both sides (see Figure 2), were used to compare left- and right-side photos to determine whether they represented the same dolphin.

2.1.3 Assumptions, Parameters, and Model Selection

The following assumptions were made pertaining to the M/R analysis:

(1) Individual spotting patterns did not significantly change during the study period. The repeated identification of individuals during our study periods showed spotting patterns on some dolphins did not change and others changed only gradually. The potential for mis-identification of individual dolphins is low, when combining spotting patterns with observed nicks and scars.

(2) All dolphins observed during a sampling occasion have the same probability of surviving until the next one.

(3) The probability of identifying all of the animals in a sample/occasion was approximately even. Although this probability could have been affected by variation among photographers, environment, dolphin behaviour, etc., we strived to photograph and identify animals evenly. We aimed to photograph each dolphin in the group.

The data were checked and if consecutive day surveys were carried out in the same area, only the first day's data were used. Population size was

estimated by M/R method using the program MARK version 8.0 (White, 2015). The data input in MARK were the encounter histories corresponding to whether or not an individual was 'captured' or 'recaptured' during a sampling occasion. Both open (POPAN) and close models (Closed captures) were used for calculating the population size. The parameters were set up as link functions of sin, and variance estimation of second part.

The appropriate model was selected using Akaike's Information Criterion corrected for small sample sizes (AIC_c) (Burnham and Anderson, 1998). Models differing by less than two units from the model with the minimum AIC_c (ΔAIC_c) also provide good descriptions of the data (Burnham and Anderson, 1998). When more than one model provided a good description of the data, we followed the principle of parsimony and selected the model with the lowest number of parameters as the most appropriate (following Parra et al., 2006).

Initial abundance estimates pertain only to the 'population' of identified animals. The total population size (and its variance) can be scaled by taking into account the proportion of identified individuals. Before getting the accurate function, we preliminarily used the formula of Karczmarski et al. (1999) and Keith et al. (2002): $P = I/\theta$, where P = adjusted total population estimate, I = population estimate of identifiable individuals, θ = the proportion of identified individuals within total population. The parameter θ was calculated by comparing the median difference between the average photographic group size and the average field-estimated group size (Keith et al., 2002). Group size was revised if the total number of photographically identified individuals was more than the field-estimated group size.

2.2 Results and Discussion

A total of 115 'groups' of Indo-Pacific humpback dolphins (including solitary dolphins) were sighted. More than 4000 photographs were classified as excellent or good for identification. A total of 206 individual Indo-Pacific humpback dolphins were identified, of which 55 and 151 were observed at SC and DRE, respectively. After matching, we found that no dolphin identified in DRE was found in SC or vice versa. Most identified animals (76.7%) were observed less than five times (Figure 3). The increase in the discovery curves suggest that not all marked dolphins have been identified, and more would likely be identified in the future, especially at SC, where the curve remained very steep until the end of the study period (Figure 4).

Population size estimates of marked animals from both open/POPAN and closed/'Close Capture' models fitted to the data are presented in

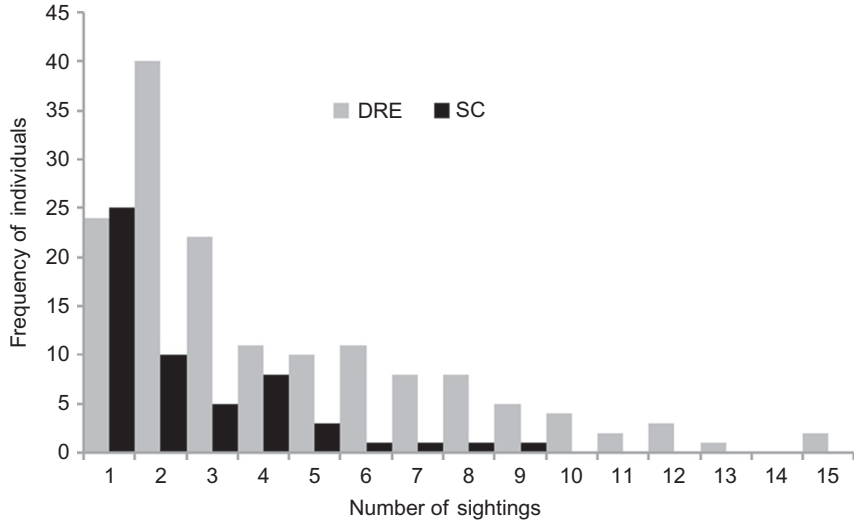

Figure 3 Frequency of sightings of individual Indo-Pacific humpback dolphins, *Sousa chinensis*, in the Beibu Gulf, China, from January 2011 to October 2014. SC, Shatian/Caotan dolphins; DRE, Dafengjiang–Nanliujiang River Estuary dolphins.

Table 2. An average of 398–444 (95% CI: 393–506) Indo-Pacific humpback dolphin individuals inhabited the overall study area (combined open and close models). For DRE, according to the average θ value of 0.61, the average 'population size' (including unmarked individuals) of humpback dolphins was 248–262 (95% CI: 248–282). For SC, adjusted by θ value of 0.38, the average 'population size' of humpback dolphins was 150–182 (95% CI: 145–224).

The present survey has produced the first M/R estimates of population size for Indo-Pacific humpback dolphins in the Beibu Gulf. The total population estimate of 398–444 Indo-Pacific humpback dolphins in the Beibu Gulf represents the fourth largest known population of *S. chinensis* in the world. It is smaller than the putative population of Hong Kong/Pearl River Estuary (Chen et al., 2010; Jefferson, 2000), Zhanjiang (Xu et al., 2015), and of Bangladesh (Smith et al., 2015), but larger than the other known putative populations in Chinese waters and in Thailand and Malaysia (see Jefferson and Smith, 2016). If the SC and DRE animals are determined to be distinct populations, the DRE dolphins would still be the world's fourth largest population. Both DRE and SC groups are apparently larger than the Xiamen or eastern Taiwan Strait populations, which each number <100 (see Jefferson and Smith, 2016).

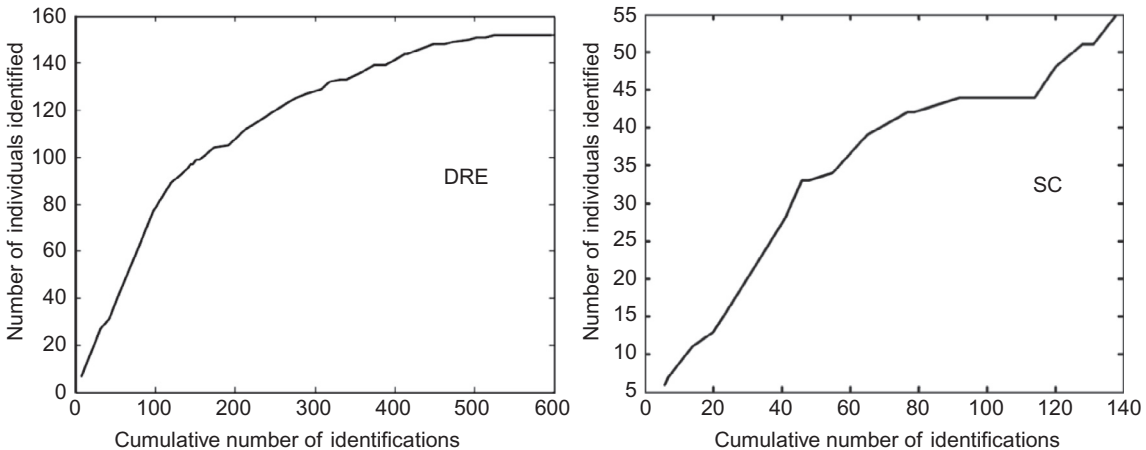

Figure 4 The discovery curve plotting the cumulative number of individual Indo-Pacific humpback dolphins, *Sousa chinensis*, identified at Dafengjiang–Nanliujiang River Estuary (left) and Shatian/Caotan (right) against the number of identifications.

Table 2 Estimates of 'Population Size' and relative parameters of Indo-Pacific Humpback Dolphins, *Sousa chinensis*, at Shatian–Caotan Waters (SC) and Dafengjiang–Nanliujiang River Estuary (DRE) of the Beibu Gulf, China

						Identifiable Dolphins				Total Population Size			
								95% CI				95% CI	
Population	Model	Interval	Number of Occasions	Model	Number of Parameters	*N*	SE	Lower	Upper	θ	*N*	Lower	Upper
DRE	Open	Yearly	4	$\phi.\ P_t\ b_t$	7	159	3.82	155	171	0.61	261	254	280
		Monthly	9	$\phi.\ P_t\ b_t$	12	160	4.07	155	172		262	254	282
	Close	Yearly	4	$P_t\ C.\ F_0$	5	151	0.27	151	151	0.61	248	248	248
		Monthly	9	$P_t\ F_0\ C_t$	10	155	2.62	152	164		254	249	269
SC	Open	Yearly	3	$\phi.\ P.\ b_t$	4	60	3.78	56	74	0.38	158	147	195
		Monthly	7	$\phi.\ P_t\ b_t$	13	69	5.13	62	83		182	163	218
	Close	Yearly	3	$P.\ C_t\ F_0$	4	57	2.6	55	69	0.38	150	145	182
		Monthly	7	$P.\ F_0\ C.$	7	62	6.36	56	85		163	147	224

Note: In closed model/POPAN: Φ, apparent survival probability; p, encounter probability; β, entry probability. In closed capture model: p, capture probability; f, never encountered; c, recapture probability.

Previous studies only surveyed portions of the DRE (Chen et al., 2009; Pan et al., 2006) and SC (Chen et al., 2009) core distribution areas, and did not include the entire coastline of the northern Beibu Gulf. While, the current estimate covered what we think is the majority of Indo-Pacific humpback dolphin habitats in the Chinese part of the northern Beibu Gulf, some dolphins may also occur in Shaya, China, and the species is also present in Vietnamese waters (Smith et al., 2003).

3. HABITAT AND ECOLOGY

3.1 Habitat

The habitat of Indo-Pacific humpback dolphins in the Beibu Gulf is typically inshore and shallow-water areas, usually <15 m water depth (see Chen, 2013). In the DRE, dolphins are distributed some distance from the coast (about 3–8 km) because of extensive shallow waters in the area. In the SC, dolphins occurred within 1–5 km of the coast, with relatively deeper waters beyond 5 km from the coast.

The median depth of water where dolphins have been sighted was 8.15 m (3.5–15 m) and 2.9 m (1.8–4.6 m), respectively, at SC and DRE, indicating significant depth separation ($p < 0.05$) (Figure 5; Chen, 2013). Median salinities of 29.4‰ (24–33‰) and 23.3‰ (15–30‰) have been recorded at SC and DRE, indicating significant differences in salinity levels between these two areas of the Gulf (Figure 6; Chen, 2013). The huge influx

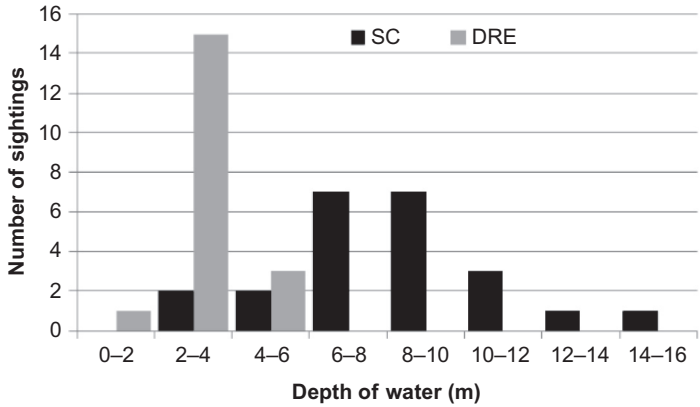

Figure 5 The frequency of sightings of Indo-Pacific humpback dolphins, *Sousa chinensis*, in different depth of water categories (SC, Shatian/Caotan; DRE, Dafengjiang–Nanliujiang River Estuary). *Modified from Chen (2013).*

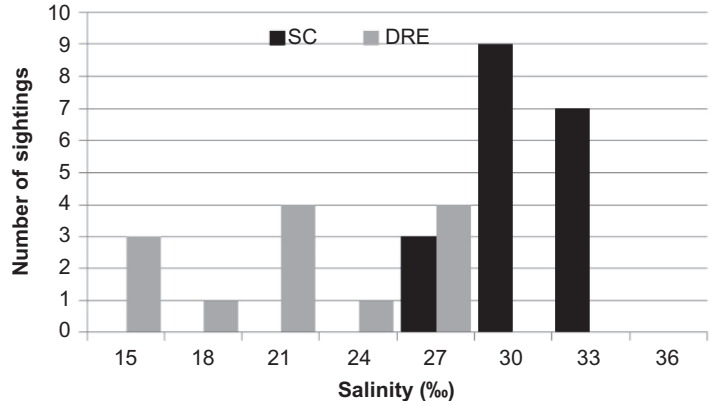

Figure 6 The frequency of sightings of Indo-Pacific humpback dolphins, *Sousa chinensis*, in different salinity categories (Shatian/Caotan; Dafengjiang–Nanliujiang River Estuary). *Modified from Chen (2013)*.

of fresh water from the Dafengjiang and Nanliujiang rivers (7.91 billion m^3) likely results in the lower salinity at DRE.

3.2 Social Structure

We used the data for Indo-Pacific humpback dolphins sighted at least twice at SC (28 individuals), and those sighted at least three times at DRE (75 individuals) to construct the social network using the eigenvector method of Newman (2006), with modularity 1 for gregariousness (see Chen, 2013 for more details).

Modularity for SC Indo-Pacific humpback dolphins was maximized at a half-weight association index (HWI) of 0.285, resulting in four clusters composed of 13, 3, 3, and 9 animals, respectively. At DRE, five clusters of 11, 9, 7, 21, and 26 individuals were delineated for these dolphins, with modularity being maximized at an HWI of 0.233. The social differentiation within both SC and DRE groups still needs further research.

The above analysis did not result in evidence that the dolphins form two distinct social communities, which was shown to be the case for the Xiamen, Taiwan, and PRE populations (see Jefferson and Smith, 2016). However, the Beibu Gulf 'population' has division trends to some extent, because the dolphins at SC and those at DRE do not appear from current data to intermix frequently.

3.3 Movements

Preliminary comparisons of Indo-Pacific humpback dolphin identification photographs taken from Ningde, Xiamen, Zhanjiang, and the northern Beibu Gulf indicated that there is no movement of individuals among these areas. This suggests that the current exchange of individuals among different populations in China is probably very low. Within the Beibu Gulf, some individuals also are found in Vietnam (Smith et al., 2003) and Sanya, which are at least 200 km away from each other. The possibility of exchange among humpback dolphins occupying these areas of the Beibu Gulf seems to be low.

In our study area, during the 4 years of our study, photo-identification analysis indicated that no dolphin identified in DRE was found in SC or vice versa. The distance between the SC and DRE study areas is only about 60 km, which is within the typical movement range of this species, and there is no apparent geographical barrier between SC and DRE areas. Possibly, our low survey effort in the transit area (see Figure 1) resulted in us missing some sightings of Indo-Pacific humpback dolphins there. Such areas are often used an exchange sites, for instance the Xiamen Northeastern and Western communities mix in their middle area (B. Chen, unpublished data; Chen et al., 2011), and the two communities of Hong Kong mix in their middle area (Dungan et al., 2012). However, in the current case, the amount of exchange is unknown, and current data suggest that it is low in the middle area. If so, it may result in partial genetic isolation (and in extreme cases, even inbreeding), which could accelerate population declines or/even extirpation.

4. THREATS

4.1 Fisheries

Some Indo-Pacific humpback dolphin individuals identified in the current study showed evidence of injury by fishing nets or ropes (Figure 7). By-catch of dolphins in fishing nets, especially gillnets and trawls, is likely a significant threat to these dolphins. Currently, we have very little data on the frequency with which dolphins become entangled. However, the problem is a persistent one for this species throughout its entire range (see Jefferson and Smith, 2016).

4.2 Vessel Traffic

Throughout this study, we observed that vessels, including various fishing boats, yachts, and container ships, operated in the SC and DRE regions.

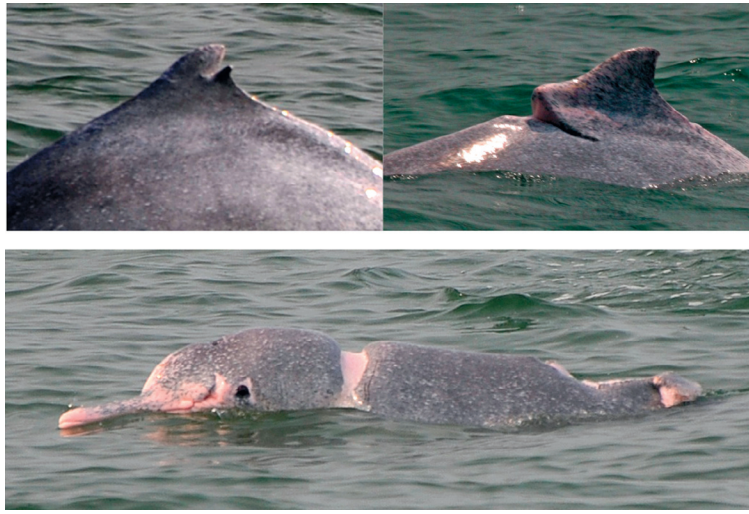

Figure 7 Three individual Indo-Pacific humpback dolphins, *Sousa chinensis*, showing anthropogenic injuries, possibly caused by fishing nets or collisions with vessels. The lower animal was named 'Strong-willed Dolphin' by X. Xu.

We found a strong overlap in vessel traffic and the dolphins' core areas (Figure 8). These vessels (mainly fishing boats such as commercial trawlers) are another threat to the dolphins. The average number of vessels operating in the core distribution areas of the dolphins reached 251 per day in December 2014 (B. Chen, unpublished data).

These vessels reduce availability of prey species, create noise, and also potentially cause direct injuries/impacts to Indo-Pacific humpback dolphins. Several photo-identified dolphins were determined to have possibly been injured by vessel collisions (see Figure 7). Most dolphins did not appear to exhibit avoidance behaviour in response to vessels, suggesting some level of habituation to boats. Some dolphins even appeared to intentionally follow trawlers to prey on fish evading, or stirred up by, the nets. Although we have not documented significant changes in distribution of these dolphins in the recent 4 years, and most dolphins appear to coexist with vessels without incident, it is possible that there are unobserved negative impacts on the dolphins' behaviour and movement patterns (see Karczmarski et al., 2016; Piwetz et al., 2015).

4.3 Mariculture

Mariculture operations have the potential to destroy and degrade habitat for coastal dolphins, and are known to be a factor in the conservation status of humpback dolphins in the Xiamen area (T.A. Jefferson, personal observations).

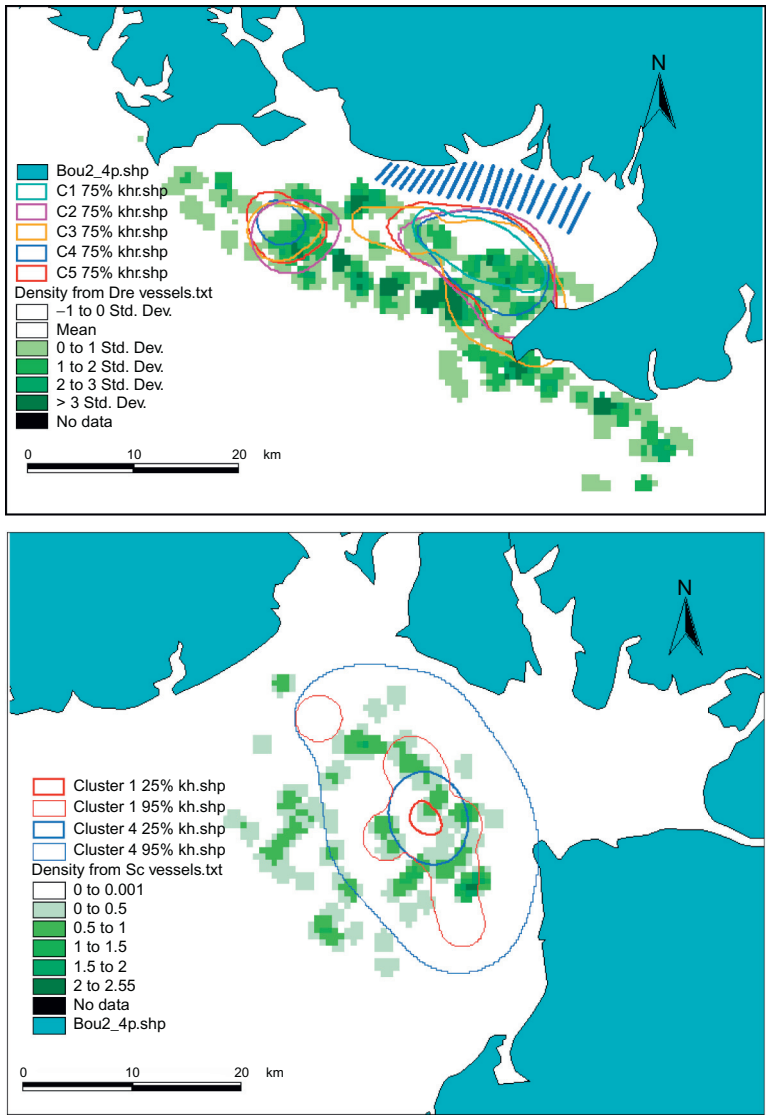

Figure 8 The overlap of vessel density and kernel home range of clusters of Indo-Pacific humpback dolphins, *Sousa chinensis*, at Dafengjiang–Nanliujiang River Estuary (top) and Shatian/Caotan (bottom). *Modified from Chen (2013).*

Extensive shellfish and oyster farms exist in the several kilometre-wide regions of shallow waters paralleling the shoreline of east DRE (Chen, 2013). While all of our dolphin sightings were located in the area outside of the known mariculture areas, we do not know if the dolphins ever enter these areas.

4.4 Dolphin-Watching Tourism

Dolphin-watching activity is intensive at the DRE area (Chen, 2013). This activity is not well monitored or regulated, and there is no enforced code of conduct for the vessels. In 2013, a cumulative total of about 3800 yachts occurred at that area during 230 days. On the weekends, the number of yachts (mean 25) is higher than that on weekdays (mean 9) (Figure 9). During 1 to 3 May 2014 (Labour Day holiday), a cumulative total of 838 yachts were recorded. Moreover, on 3 May 2014, the total number of yachts reached 300, in an approximately 10 km^2 area (B. Chen, unpublished data). Thus, the heavy pressure from dolphin watching is likely to have negative impacts on these dolphins, especially on weekends and holidays.

4.5 Habitat Degradation

Land reclamation and other marine construction activities are a major conservation issue for humpback dolphins in Chinese waters, often causing habitat loss and behavioural disturbance to dolphins (see Jefferson and Smith, 2016; Karczmarski et al., 2016). To date, at least 126 km^2 of habitat has been reclaimed in the study area. Reclamation has occurred in areas that were once key distribution areas for the dolphins (e.g. Beihai Port). Ports have

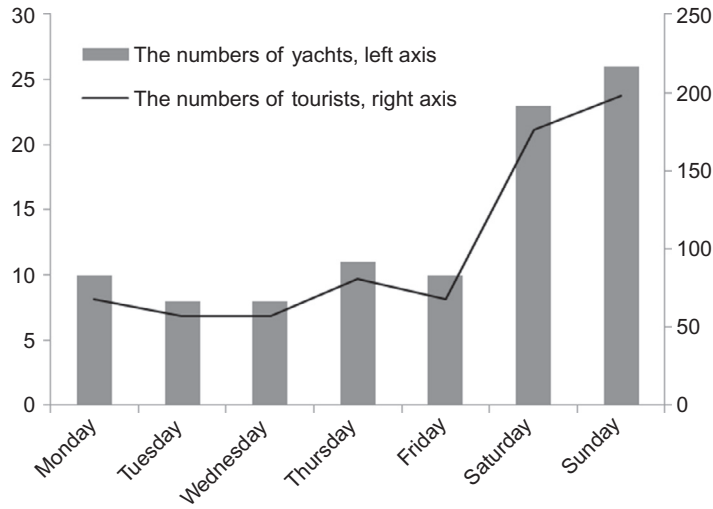

Figure 9 The average number of tourists and yachts at Dafengjiang–Nanliujiang River Estuary during different days of the week from May to September, 2013.

also been established in Qinzhou, Tiesan, and Shatian, in or around SC and DRE. Dredging in the turning basin of each port has damaged the benthic ecosystem.

5. CONSERVATION STATUS AND ACTIONS

Estimates of population size can provide valuable information for management agencies. A small population that exhibits a high level of site fidelity and a low level of exchange between other groups is likely more vulnerable to anthropogenic impacts. Indo-Pacific humpback dolphins residing in Zhanjiang and the northern Beibu Gulf have been considered to be less affected by anthropogenic activities than those of the Pearl River Estuary, Xiamen, or eastern Taiwan Strait areas, which are known to be seriously impacted by human activities (Chen et al., 2008, 2009; Jefferson, 2000; Karczmarski et al., 2016; Wang et al., 2004, 2016; Zhou et al., 2007). However, the threats to the survival of humpback dolphins in the northern Beibu Gulf may have been underestimated in the past. Many fishing vessels operate in the key distribution area of the dolphins, and this has deteriorated the local ecosystem (Fan et al., 2007; Li et al., 2005; Wang and Yuan, 2008) and threatened the long-term sustainable productivity of prey species for Indo-Pacific humpback dolphins. By-catch of dolphins in nets (at least in trawls and gillnets) is also very likely. Moreover, at least three dolphins in our study were observed to have net or propeller scars on their bodies (see Figure 7). Dolphin-watching tourism in Sanniang Cove is also likely to negatively affect Indo-Pacific humpback dolphins, as it has in other parts of the species' range (Piwetz et al., 2012, 2015; Tseng et al., 2011).

Considering the high proportion of calves, juveniles, and sub-adults (more than 50%) (Chen, unpublished data) and small population size (398–444), the number of adults was estimated at no more than 222 individuals. If it were determined that these dolphins do in fact form a discrete population, this estimate would just meet Criterion D for Endangered on the International Union for the Conservation of Nature (IUCN) Red List (i.e. population size estimated to number fewer than 250 mature individuals). In any case, this information indicates that the dolphins are under threat, and need better protection.

We recommended that: (1) the current fishing moratorium be extended, (2) the number of fishing boats and harvest quotas should be closely regulated, (3) the speed limit of vessels should be 10 knots or less in the key distribution areas of Indo-Pacific humpback dolphins, and (4) the dolphin-watching tourism industry should be monitored and regulated.

These measures should be implemented immediately, and they should be supplemented and modified, based on the results of future research on the population status of the Indo-Pacific humpback dolphins of the northern Beibu Gulf.

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