

Short Note

Group Sizes of Indo-Pacific Humpback Dolphins in Waters Southwest of Hainan Island, China: Insights into Rare Records of Large Groups

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Group size is important to both communication and social dynamics for many marine mammal species (Connor, 2000; Silk, 2007). Thus, group size estimation is essential to the research of marine mammal behavior (Gygax, 2002a; Gowans et al., 2007). Humpback dolphins (*Sousa* spp.) are small odontocetes widely distributed in the western Pacific, Indian, and eastern Atlantic Oceans (Jefferson & Curry, 2015). Recent taxonomic revision shows the existence of at least four species in the genus *Sousa*: Indo-Pacific humpback dolphin (*S. chinensis*), Australian humpback dolphin (*S. sahulensis*), Indian Ocean humpback dolphin (*S. plumbea*), and Atlantic humpback dolphin (*S. teuszii*) (Jefferson & Rosenbaum, 2014). These four species are well-known as obligate, shallow-water delphinids that inhabit water generally no more than 20 km from the coastline and at depths no deeper than 30 m (Parra & Ross, 2009; Jefferson & Curry, 2015). Humpback dolphins have been commonly observed in small groups with a mean size of no more than 10 (Würsig et al., 2016). In some regions, a substantial proportion (~10 to 40%) of humpback dolphin groups was found as solitary animals or in pairs (Parsons, 1998, 2004). Furthermore, humpback dolphins in large-sized groups of more than 50 individuals have rarely been reported (Baldwin et al., 2004; Smith et al., 2008).

The population of Indo-Pacific humpback dolphins southwest of Hainan Island (SW Hainan), China, was documented for the first time in 2014 by a questionnaire-based interview survey with local fishermen (Liu et al., 2017; Lin et al., 2019) and

from boat-based visual surveys (Li et al., 2016). Information on social behavior of this newly documented population remains insufficient. Observers' counts (i.e., on-site observations) and photo-identification (photo-ID) are techniques used to estimate delphinid group size that have been applied to humpback dolphins (e.g., Chen et al., 2010, 2018; Dares et al., 2014; Jutapruet et al., 2015; Xu et al., 2015; Wang et al., 2016a, 2016b). Still, group size estimates from these two approaches have not been adequately compared. Therefore, in this study, we carried out boat-based surveys and built two datasets for humpback dolphins: (1) *in situ* counts of group size from observers on small boats and (2) photo-ID estimates of group size based on qualified photos taken from boats but analyzed in the laboratory.

Although large-sized groups have been documented for some populations of humpback dolphins, it is not common for *Sousa* spp. (Parsons, 2004; Würsig et al., 2016). Therefore, we summarized the known reports of mean group size of Indo-Pacific humpback dolphins as background for our data to provide context for our observations of humpback dolphins documented in rare large-sized groups. In this short note, we present (1) baseline data on group size estimates of humpback dolphins around the SW Hainan Island and (2) potential factors that might influence the group size estimation of these animals.

Boat-based visual surveys were carried out monthly from April 2014 to June 2019 around the SW Hainan Island, China (Figure 1A). A *sighting* was defined as an observation of a single individual or a group of humpback dolphins (Li et al., 2016).

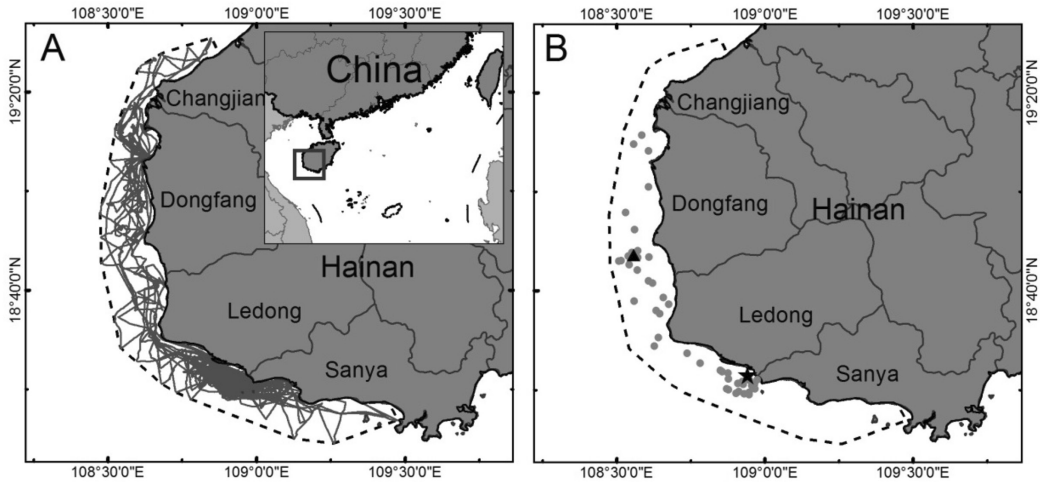


Figure 1. Map of study area: (A) the waters southwest of Hainan Island, China (SW Hainan; enclosed black dash line: survey area; grey tracks: survey routes) and (B) sighting locations of Indo-Pacific humpback dolphins (*Sousa chinensis*) from April 2014 to June 2019 (black five-pointed star: the sighting on 6 September 2015; black triangle: the sighting on 2 December 2018; grey dots: other sightings).

A *group* referred to any aggregation of humpback dolphins (including solitary or more) in an observer's effective field of view (Karczmarski, 1999). During each observation, group members were documented to be either socially (engaged in similar behaviors) or spatially (within 200 m of each other) associated (Baird & Dill, 1996; Wang et al., 2016a). Our survey method was based on Kinzey et al. (2000) and was described in detail by Li et al. (2016). For each sighted group, we recorded observers' counts, including minimum, maximum, and best estimates of group size (Jefferson, 2000). To minimize variance and bias, only the best estimate was used for analysis (Gerrodette et al., 2002).

When possible, we took high-quality digital photos, targeting both lateral sides of each animal, using an Olympus EM-1 camera (Olympus, Fuji Film, Japan) with 150- or 300-mm fixed-focus lens (1.5× amplifier) or a Canon 7D Mark II camera (Canon, Tokyo, Japan) with 100- to 400-mm zoom lens. Post-survey, we scored all photos based on the visibility, size, and orientation of the animal in the frame; image clarity; and contrast (scores ranged from 20 to 100 on a 100-point scale). Only photos with scores ≥ 60 were used for dolphin photo-ID (Fearnbach et al., 2012). For each group, dolphins were individually identified based on natural or non-natural marks on/around their dorsal fins; thus, we could estimate the size of each group (i.e., the number of identified dolphins in each group; Jutapruet et al., 2015; Wang et al., 2016b, 2018).

To place our observations into the context of the literature on humpback dolphin group size

estimates, we searched databases (Web of Science, Science Direct, ProQuest, Google Scholar, and CNKI) using the following key words: “*Sousa*,” “humpback dolphin,” or “hump-backed dolphin” and “group,” “group size,” “group characteristics,” “group dynamics,” “social dynamics,” “school size,” “pod size,” “population,” “abundance,” or “behavior.” In total, 105 relevant publications (journal papers, technical reports, and theses) were gathered; and 111 available records on humpback dolphin group size estimates were extracted (Table S1; this supplementary table is available in the Supplemental Material section on the *Aquatic Mammals* website: https://www.aquaticmammalsjournal.org/index.php?option=com_content&view=article&id=10&Itemid=147). From these references, details on geographic distribution of humpback dolphins were examined.

During the 6-y study period, we sighted 47 humpback dolphin groups (see sighting locations in Figure 1B). The total surveyed area was 3,319 km² with 15,548 km of surveyed routes (Figure 1A). From the 47 sighted groups, we had observers' counts for 45 groups and photo-ID estimates for 30 groups. Our group size data indicated that observers' counts (12.9 ± 10.1 ; $n = 45$; range of 1 to 40) were 25% smaller than photo-ID estimates (17.2 ± 18.2 ; $n = 30$; range of 1 to 84); however, the variances were so large that statistical analysis did not support a difference between the two approaches (Mann-Whitney U test, $Z = -0.590$, $p = 0.555$). The histogram distributions of group sizes based on these two measurements

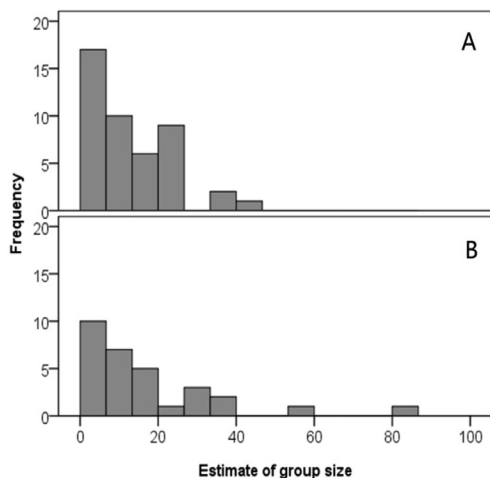


Figure 2. Histogram distribution of group size estimates from (A) observers and (B) photo-ID of Indo-Pacific humpback dolphins sighted around the SW Hainan Island during surveys performed between April 2014 and June 2019

were right-skewed, suggesting that most samples (42 of 45 observers' counts; 25 of 30 photo-ID estimates) were less than 30, and more than half of the group sizes (27 of 45 observers' counts; 17 of 30 photo-ID estimates) were less than 15 (Figure 2A & B). Two large-sized groups ($N \geq 50$ individuals) were documented during photo-ID analyses: one group ($N = 59$ individuals) was sighted on 6 September 2015, while the other ($N = 84$ individuals) was sighted on 2 December 2018 (Figures 1B & 2B).

It is challenging to precisely measure the size of dolphin groups (Scott et al., 1985; Gerrodette et al., 2019). *In situ* counts, even by experienced observers, may include considerable bias (Gerrodette et al., 2002). In this study, no statistical difference was found between observers' counts and photo-ID estimates, while mean group size from observers' counts was smaller than the value from photo-ID estimates. The occasional occurrence of dolphin groups in large sizes might increase both mean group size and standard deviation (Figure 2A & B); however, even if we remove the two large-sized groups (59 and 84 individuals) from our photo-ID dataset, the mean group size based on the remaining sampled groups (13.4 ± 10.5 ; $n = 28$; range of 1 to 38) was still larger than observers' counts, suggesting there was an inherent difference in these two group size estimate approaches. This finding was consistent with methodological differences observed in previous studies in the Eastern Taiwan Strait (Dares et al., 2014; Dungan et al., 2016), northern Beibu

Gulf (Wang et al., 2013; Yan, 2016), and Xiamen Bay (Wang et al., 2016a; Chen et al., 2018). If we compare data obtained from the same region, mean group size from observers' counts was typically smaller than the value based on photo-ID estimates (Table 1). The Pearl River Estuary was the only place where mean dolphin group size from observers' counts was slightly larger than the value from photo-ID estimates (Dungan et al., 2012; Würsig et al., 2016; Li et al., 2019), which may be due to differences and limitations of the survey areas among published studies.

Compared with observers' counts, photo-ID estimates often lead to larger mean group sizes for humpback dolphins (Table 1). This finding was similar to Gerrodette et al.'s (2019) study as they found that most observers tended to underestimate dolphin group sizes, and this tendency of underestimation increased with group size. Gerrodette et al. established a large dataset for comparison (2,435 group size observers' counts and photo-ID estimates of six oceanic dolphin species), while nearshore species like humpback dolphins were not included. Therefore, increasing the number of quantitative group size observations across a wider geographic region could offer more information from which to examine comparative data on humpback dolphin group sizes such as those presented in this short note. In addition, although photo-ID appears to be a much more credible way to estimate humpback dolphin group sizes, photo-ID estimates are still likely to underestimate humpback dolphin group sizes because it is not always possible to identify all individuals in each observed group with photographic gear. Thus, observers' counts and photo-ID estimates should be used together for more precise group size estimation (Scott et al., 1985; Gerrodette et al., 2002).

Notably, the mean humpback dolphin group size around the SW Hainan Island was larger than values reported for many other regions (Table 1), although our data were slightly smaller than group sizes along the Chennai coast, Bangladesh (mean: 20; Muralidharan, 2013); in Kuching Bay (18 ± 13.33 , mean \pm SD; Poh et al., 2016); and in the northern Bay of Bengal, Bangladesh (16.2 ± 21.9 , mean \pm SD; Smith et al., 2008) (Table 1). These differences may be due partly to small sample sizes (Chennai coast: $n = 4$, Kuching Bay: $n = 16$, and northern Bay of Bengal: $n = 6$). The reported geographic variation in humpback dolphin group sizes is likely an intraspecific trade-off between benefits and costs of being in a group (Gygax, 2002b; Gowans, 2019). Previous studies reported that various factors influenced dolphin group sizes (Parsons, 2004; Parra et al., 2011; Würsig et al., 2016), with social dynamics in coastal dolphins varying across space, time, and behaviors, especially as a result

Table 1. Geographic variation in mean group sizes (mean \pm SD, range, and number of sampled groups) of Indo-Pacific humpback dolphins (*Sousa chinensis*) in previous studies; NA = not available.

Region	Group size estimates, mean \pm SD (range; number of sampled groups)		References
	Observers' counts	Photo-ID estimates	
Chennai coast, Bangladesh	20 (10-30; $n = 4$)	--	Muralidharan, 2013
Cowie Bay, Sabah, Malaysia	2 (1-4)	--	Jaaman, 2006
Donsak, Thailand	--	4.7 \pm 3.4 (1-18; $n = 89$)	Jutapruet et al., 2015
Eastern Taiwan Strait, China	6.2 \pm 5.9 (1-31; $n = 221$)	7.6 \pm 5.9 (1-31)	Dares et al., 2014; Dungan et al., 2016
Jambongan, Sabah, Malaysia	NA (2-6)	--	Jaaman et al., 1997
Khanom, Thailand	--	NA (2-20; $n = 39$)	Jaroensutasinee et al., 2011
Koh Kong Bay, Cambodia	6 \pm 2.87 (2-8; $n = 4$)	--	Beasley & Davidson, 2007
Kuching Bay, Malaysia	--	18 \pm 13.33 (7-45; $n = 16$)	Poh et al., 2016
Leizhou Bay, China	--	8.12 \pm 5.85 (1-35; $n = 611$)	Xu et al., 2015
Matang and Langkawi, Malaysia	NA (3-31; $n = 7$)	--	Hoffman et al., 2015
Ningde, China	--	3.14 \pm 5.85 (1-6; $n = 7$)	Wu et al., 2014
Northern Bay of Bengal, Bangladesh	16.2 \pm 21.9 (2-55; $n = 6$)	--	Smith et al., 2008
Northern Beibu Gulf, China	5.63 ($n = 19$)	6.45 \pm 4.44 (1-22; $n = 155$)	Wang et al., 2013; Yan, 2016
Pearl River Estuary, China	8.0 \pm 6.8 (1-30; $n = 79$)	6.49 (1-33; $n = 153$)	Dungan et al., 2012; Li et al., 2019
Sesayap Delta, Kalimantan, Indonesia	NA (6-15)	--	Minton et al., 2016
Southwest Hainan, China	12.9 \pm 10.1 (1-40; $n = 45$)	17.2 \pm 18.2 (1-84; $n = 30$)	This study
Xiamen Bay, China	5.47 \pm 3.11 (1-16; $n = 157$)	7.2 ($n = 76$)	Wang et al., 2016a; Chen et al., 2018

of adaptations to different environments (Gomez-Salazar et al., 2012; Sutaria et al., 2019). Generally, humpback dolphins prefer brackish waters associated with estuarine systems that are isolated from open waters (Jefferson & Curry, 2015). Such isolation leads to low predation pressure (Gowans et al., 2007; Sutaria et al., 2019). The larger mean group size in our survey area may be due to the absence of large estuarine systems in the region (Li et al., 2016), and patch prey distribution in variable environments may promote increases in group size over time (Gowans et al., 2007; Gowans, 2019).

As discussed in other studies, a group size upper limit could be determined by food availability (Heithaus & Dill, 2002; Bouveroux et al., 2018). Humpback dolphins were observed in groups of ~ 10 ; however, they did aggregate in large-sized groups of nearly 100 individuals in some regions (Table S1), and this supports our two rare records of large-sized groups (Figure 1B). In

this study, where these two large-sized groups were observed might be important feeding or breeding grounds for this species (Figure 1B); this hypothesis is supported by previous observations in Hong Kong waters that large humpback dolphin groups were associated with feeding behind pair trawlers (Dungan et al., 2012; Würsig et al., 2016). Alternatively, in the Arabian region, groups of more than 50 humpback dolphins were considered to be temporary breeding aggregations (Baldwin et al., 2004).

To conclude, in this short note, we provide baseline information on humpback dolphin group sizes around the SW Hainan Island, China, which helps narrow the information gap on the social behavior of this newly documented population. We also found that observers' counts might underestimate mean humpback dolphin group sizes if we compared those values with photo-ID estimates. By using published records for background context,

we further pointed out that there might be a methodological difference in these two group size estimate approaches (observers' counts and photo-ID estimates), as well as presented geographic variation in humpback dolphin group sizes. Thus, we recommend that additional research is warranted to better understand how humpback dolphin group sizes form and how these groups relate to the species' social dynamics geographically.

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