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Distribution of Risso's dolphin (*Grampus griseus*) in the east-central coastal waters of Taiwan based on whale-watching records

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ABSTRACT: Risso's dolphin occurs in tropical and temperate waters worldwide, and is one of the most common cetacean species in Taiwanese waters. This study attempted to reveal its distribution in water-depth ranges and variations in group size and composition (with or without mother-calf pairs). Based on sighting records from experienced whale-watching guides on board whale-watching boats operated in eastern Taiwan, 1630 sightings of Risso's dolphin were recorded from 3939 touring trips near Hualien County from 1998 to 2014. Comparing the frequency distribution of water depths between ship tracks and dolphin sightings, we found that Risso's dolphin commonly occurred on the continental shelf and slope, and mainly stayed in waters of 300~1500 m in depth, with a mean of 862.1 ± 12.3 m (standard error). The frequency distribution of water depths showed a significant difference between sites (deeper in the Shirti area than in the Hualien area), but no significant difference was detected among various group sizes. Nevertheless, the spatial distribution significantly varied with group composition, but not with group size. Groups with mother-calf pairs stayed in significantly shallower water, which was proposed to be related to predator avoidance. In addition, the large fluctuation in annual sighting ratios of Risso's dolphin that ranged 0.1~0.7 sightings per trip during the 17-year period may be related to variations in prey abundances, the confirmation of which requires future investigation.

KEY WORDS: Citizen Scientist, Distribution, *Grampus griseus*, Group composition, Group size, Risso's dolphin, Taiwan.

INTRODUCTION

Risso's dolphins have been observed around the world in cold-temperate, warm-temperate, and tropical waters with surface water temperatures above 10 °C (Kruse *et al.*, 1999). They appear to prefer steep shelf-edge habitats of about 400~1000 m deep because they feed on vertically moving mesopelagic cephalopods (Baird, 2009; Blanco *et al.*, 2006). In the Mediterranean region, for instance, Risso's dolphins were found mainly in continental slope waters close to the coast and around the region's offshore islands and archipelagos (Bearzi *et al.*, 2011). In Monterey Bay, California, most Risso's dolphins were observed concentrated in areas with a steep bottom topography (Kruse, 1989). In the northwest Pacific Ocean, Risso's dolphin occurs in waters adjacent to Japan, Indonesia, Malaysia, Vietnam, the Philippines, and Taiwan (Perrin *et al.*, 2005). Most studies on the distribution of this species suggest close relationships with habitat, depth range, and steep topography.

In Taiwan, Risso's dolphins are commonly sighted off the eastern coast from southern Ilan County in the north to Taitung County in the south (Yang *et al.*, 1999; Chen, 2001; Lin, 2003; Yeh, 2001). In particular, off the east-central and southeastern coasts, Risso's dolphins frequently occur on the upper continental slope (Yeh, 2001; Lin, 2003). Little is known, however, about Risso's dolphin's presence in waters off the western and northwestern coasts of Taiwan. Only a few occasional sightings were recorded in previous surveys in southwestern waters (Huang, 1996) and stranding records in western Taiwan. Also, no systematic surveys have been conducted to explore the distribution of Risso's dolphin off northern Taiwan (Yu *et al.*, 2019). This study is an attempt to reveal the spatial distribution of Risso's dolphin off the east-central coast of Taiwan with water depth, and explore potential differences in various group sizes and the composition of groups with and those without mother-calf pairs.

Whale-watching activities in Taiwan were first launched in 1997, and have been doing well in recent years with about 400,000 tourists on board in 2015 (Chou, unpublished data). Therefore, whale-watching tours provide an economic platform for collecting information on cetacean occurrence. This study used sighting records collected from whale-watching trips during the years 1998~2014 (17 years) in Hualien County, east-central Taiwan. This is the first study based on citizen scientists' observations of cetaceans in Taiwanese waters.

MATERIALS AND METHODS

Study area

Whale-watching businesses operate out of two ports on the east-central coast of Taiwan (Fig. 1): (1) Hualien (HU) Port, located in northern Hualien, Hualien County and (2) Shirti (ST) Port, located at the southern end of Hualien County. The study areas covered around 617 km^2 (23°54'~24°12'N, 121°37'~121°48'E) off the HU area and 480 km^2 (23°22'~23°36'N, 121°27'~121°40'E) off the ST area.

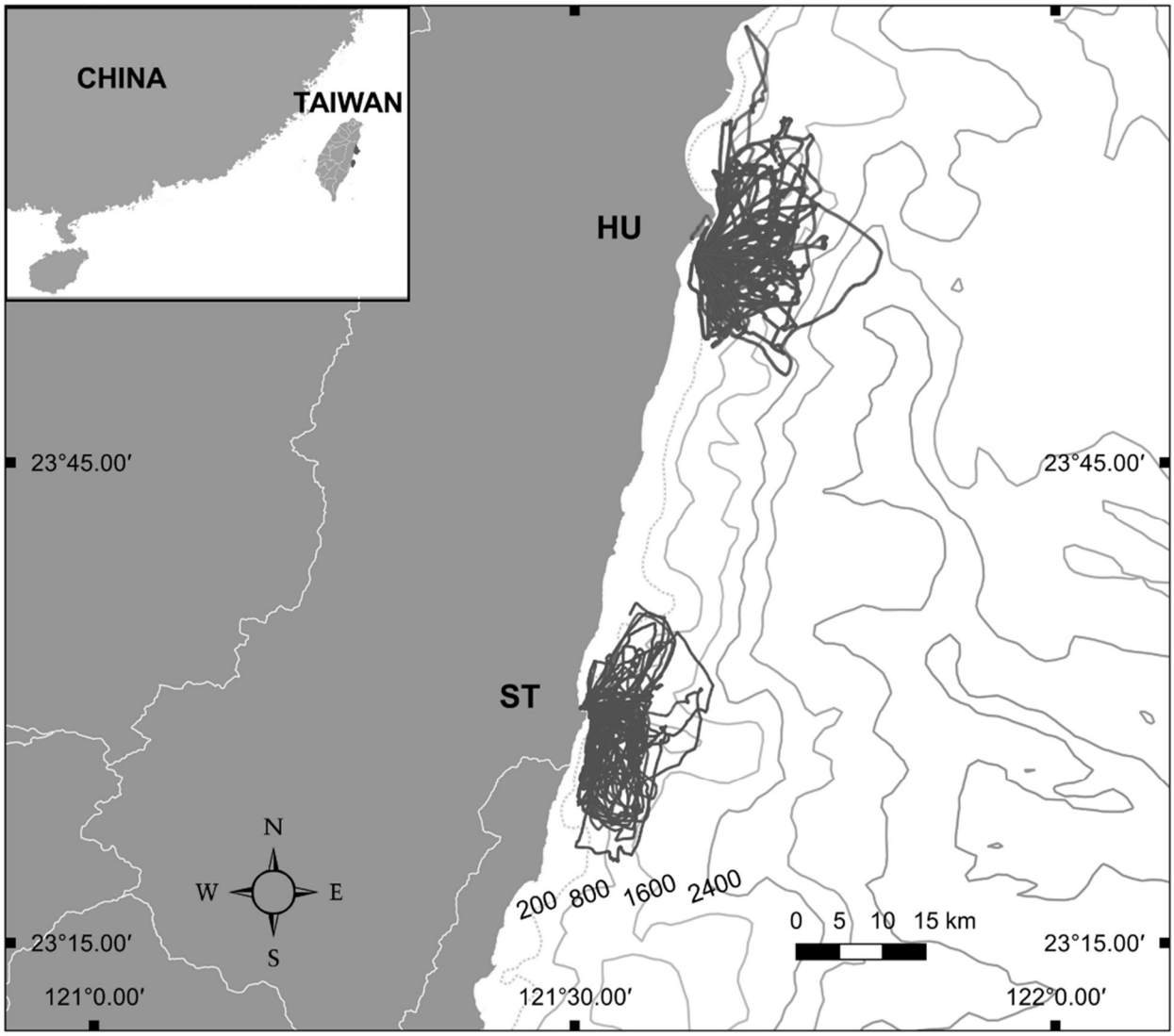

Fig. 1. Illustrative tracks of whale-watching trips conducted in the study area (30 trips in 2008). Gray lines are isobaths. The surveyed area off Hualien Port (HU) is about 617 km^2, and that off Shirti (ST) Port is 480 km^2.

These two areas share similar oceanic geographic features of a narrow continental shelf with a steep continental slope close to shore. Both the Kuroshio Current and local longshore currents work together to shape ocean environments in this area (Yu, 2014).

Sighting data and survey effort

Sighting data were collected by experienced guides on board whale-watching tour vessels, but with various levels of sighting effort by month and year (Table 1). During the period of 17 years (1998~2014), 1630 Risso's dolphin sightings were obtained from 3939 whale-watching trips, with 1141 sightings on 2859 trips in the HU area, and 489 sightings on 1080 trips conducted in the ST area. The major whale-watching season usually runs from May to September.

Each whale-watching trip usually last 2~2.5 h. During the whale-watching trip, experienced captains visually search the area. Sometimes, sighting information is passed by other captains of previous trips. If more than one sighting with similar group sizes occurred on the same trip, only the first sighting was used. The survey effort was not evenly distributed among various water depths throughout the touring area (Fig. 1), with most tracks occurring in near-shore than in offshore areas.

When dolphins were sighted, the global positioning system (GPS) position, time, group size, type of group composition (with or without mother-calf pairs), and species names were recorded by trained guides, who were provided by the Kuroshio Ocean Education Foundation on boats of the Turumoan Whale Watching Company at the HU port, and from the Cetacean Research Lab of National Taiwan University on boats of the Seawhale Company at the ST port. A dolphin reaching 2.5 m length was defined as an adult (Chen *et al.*, 2011). The calf of a mother-calf pair

Table 1. Survey effort (number of whale-watching trips) and number of sightings of Risso's dolphin (in parenthesis) in the Hualien (HU) and Shirti (ST) study areas

	Study area HU							Study area ST						
Year	May	June	July	Aug.	Sep.	Oct.	**Total**	May	June	July	Aug.	Sep.	Oct.	**Total**
1998	0 (0)	16 (4)	62 (32)	70 (41)	22 (12)	5 (2)	**175 (91)**	9 (4)	6 (2)	16 (2)	47 (14)	11 (4)	4 (0)	**93 (26)**
1999	15 (6)	27 (17)	47 (42)	48 (43)	19 (2)	2 (0)	**158 (110)**	0	0	34 (19)	52 (20)	0	0	**86 (39)**
2000	19 (13)	44 (21)	64 (25)	53 (48)	25 (7)	15 (7)	**220 (121)**	0	0	0	0	0	0	**0**
2001	0	0	0	0	0	0	**0**	13 (7)	19 (16)	54 (30)	55 (30)	24 (10)	0	**165 (93)**
2002	0	0	33 (8)	19 (3)	0	0	**52 (11)**	20 (12)	41 (11)	66 (38)	69 (33)	19 (5)	0	**215 (99)**
2003	0	0	48 (11)	52 (29)	27 (1)	3	**130 (41)**	0	0	0	0	0	0	**0**
2004	1 (0)	0	48 (8)	48 (17)	2 (2)	0	**99 (27)**	3 (1)	0	7 (2)	11 (5)	5 (1)	0	**26 (9)**
2005	0	0	30 (2)	28 (4)	0	0	**58 (6)**	5 (2)	0	2 (2)	47 (9)	3 (1)	0	**57 (14)**
2006	0	10 (1)	40 (3)	72 (18)	18 (5)	3 (0)	**143 (27)**	0	0	0	31 (6)	11 (2)	0	**42 (8)**
2007	24 (8)	40 (17)	95 (47)	48 (16)	14 (2)	4 (0)	**225 (90)**	0	0	35 (22)	15 (6)	0	0	**50 (28)**
2008	20 (8)	29 (9)	61 (33)	69 (20)	22 (8)	15 (1)	**216 (79)**	0	8 (4)	15 (9)	18 (6)	5 (3)	3 (2)	**49 (24)**
2009	20 (11)	13 (7)	96 (32)	77 (19)	16 (3)	6 (0)	**228 (72)**	0	0	21 (9)	16 (6)	0	0	**37 (15)**
2010	18 (10)	44 (30)	87 (51)	63 (42)	21 (5)	10 (2)	**243 (140)**	7 (4)	7 (3)	14 (11)	7 (2)	3 (0)	0	**38 (20)**
2011	14 (5)	27 (10)	18 (11)	59 (51)	37 (5)	13 (0)	**168 (82)**	4 (6)	16 (9)	36 (22)	22 (5)	4 (2)	0	**82 (44)**
2012	17 (6)	24 (8)	91 (26)	36 (4)	0	14 (2)	**182 (46)**	2 (1)	5 (3)	23 (11)	5 (3)	16 (5)	0	**51 (23)**
2013	16 (10)	21 (20)	63 (43)	72 (43)	54 (9)	18 (0)	**244 (125)**	0	0	16 (9)	29 (16)	11 (7)	0	**56 (32)**
2014	30 (3)	47 (14)	67 (18)	107 (25)	48 (12)	19 (1)	**318 (73)**	2 (1)	6 (4)	16 (6)	9 (4)	0	0	**33 (15)**

(they usually swim tightly together with a distance of less than one body length) was defined by its body length being <2/3 the length of the adult. The number of dolphins in a group sighting, as the group size, was estimated after observing them for at least 10 min, and a best estimation was made, as well as a possible range. In this study, we used the best estimation, and then pooled the group sizes into four classes of 1~10, 11~30, 31~50, and >50 individual counts. The sighting ratio is the total number of sightings divided by the total number of trips per year.

Data processing

Positions of the sightings and tracks of the trips were mapped using QGIS 3.4 software (http://www.qgis.org). The water depth of each sighting was extracted from the GPS location referenced to the Ocean Data Bank of the Ministry of Science and Technology, Republic of China (http://www.odb.ntu.edu.tw/) using the Extract Value to Points of the QGIS plugin toolbox. To compare differences in depth of the two study areas, among group-size classes, and for between-group compositions (with or without mother-calf pairs), we used a *t*-test and a one-way analysis of variance (ANOVA). A test of the goodness-of-fit was applied to test the independence of the ratios of mother-calf pairs in the four size class groups. All statistical analyses were conducted with SPSS 20 (IBM Corporation, 2011).

RESULTS

Effort and sightings

During the years 1998~2014, 2859 whale-watching trips were conducted with 1141 (sighting ratio= 0.40) Risso's dolphin sightings recorded in the HU area, and 1080 whale-watching trips with 489 (sighting ratio= 0.45) Risso's dolphin sightings in the ST area. Most sightings were recorded in the summer season (June to August), with 81% occurrence in the HU data and 88% in the ST data (Table 1). The average annual sighting ratio was 0.41, but high fluctuations were seen in the past 17 years (Fig. 2), with the highest rate of 0.70 in 1999 and then a big decline to the lowest of 0.1 in 2005. Fluctuations became somewhat steady after 2007. The fluctuating pattern was consistent between the two study areas.

Distribution with depth

The distribution of Risso's dolphins with respect to water depth reveals that they occurred in waters with an average depth of 862.1 m (SE=12.3 m, range: 9.5~3712.2 m, n=1615). The major range of water depth was 300~1500 m, which accounted for 72.4% of sightings in the HU area, and 80.4% of sighting in the ST area. However, there was a significant difference in depths between the study areas. The distribution of Risso's dolphins occurred in significantly shallower waters in the HU area (mean 829.1±14.6 m, n=1131) than in the ST area (mean 937.4±22.3 m, n=484) (t-test, p<0.001). Although proportions of water depths of the whale watching voyage tracking are not evenly distributed, Risso's dolphins occurred disproportionally more at 600~1500 m in the HU area and 900~1800 m in the ST area (Fig. 3).

Group size and group composition

Group sizes of Risso's dolphins in this study ranged 1~200 individuals per group, with a mean of 35. However, Risso's dolphin usually occurred in small groups, e.g., fewer than 30 individuals, which occupied 63.2% of sightings in the HU area and 71.1% of sightings in the ST area. Larger (51~100 dolphins) and very large groups (>100 dolphins) only respectively accounted for 15.1% and 4.8% of sightings in the HU area, and 8.6% of sightings in the ST area. No significant difference was detected in the frequency distribution of group sizes between the two

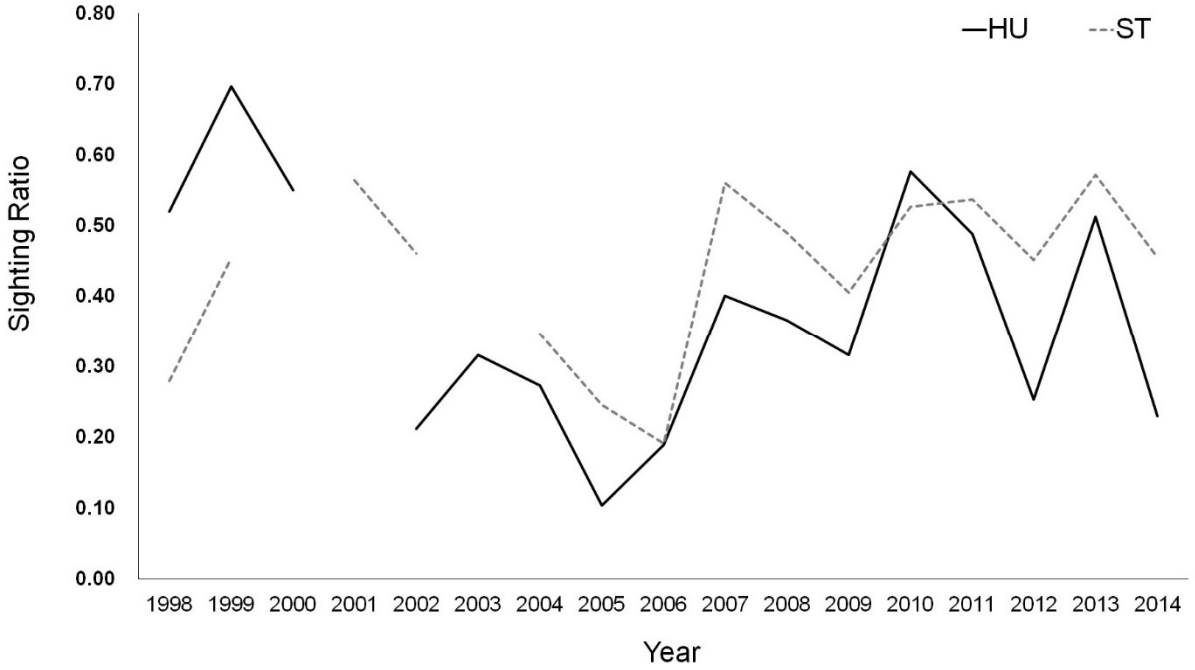

Fig. 2. Sighting ratio (sighting no./trip no.) of Risso's dolphin in the Hualien (HU) and Shirti (ST) areas. The sighting ratio is the number of sightings divided by the number of trips per year.

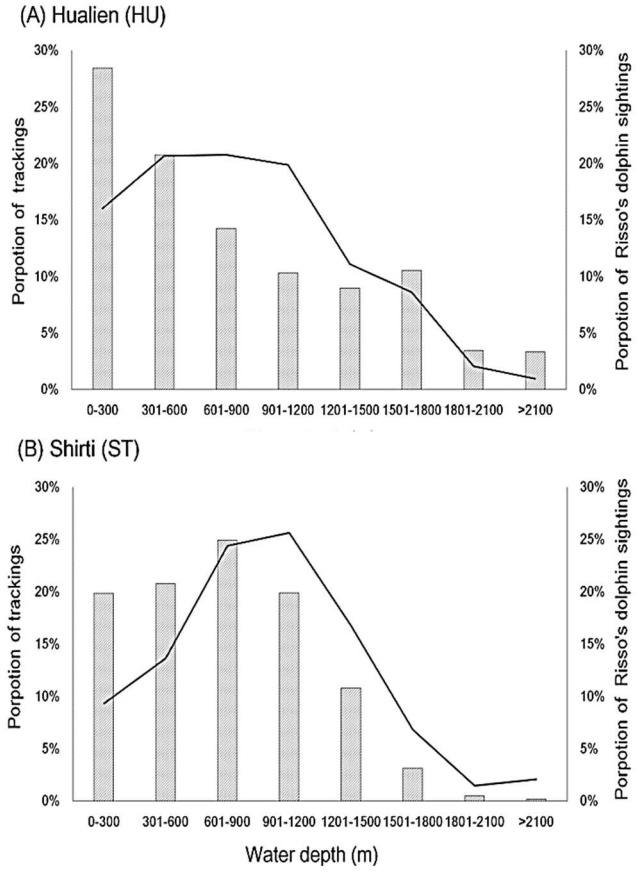

Fig. 3. Frequency (%) distribution of water depths between survey efforts (whale-watching tracks, gray bars) and Risso's dolphin sightings (dark lines) in the (A) Hualien (HU) area and (B) Shirti (ST) area.

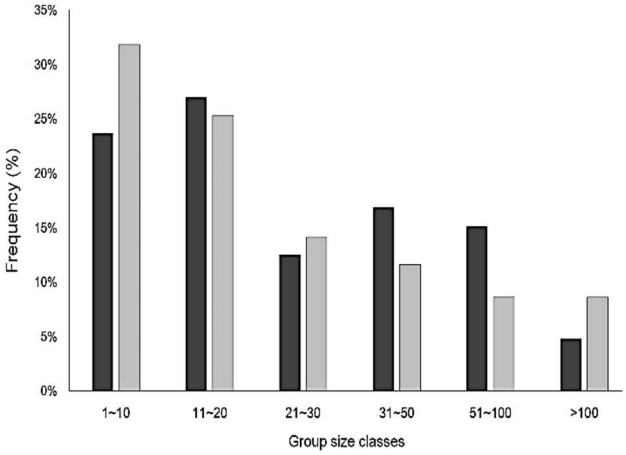

Fig. 4. Frequency (%) distributions of various group-size classes of Risso's dolphin in waters off Hualien (HU, dark bars) and Shirti (ST, light bars) areas.

areas (goodness-of-fit test, X^2=10.6, df=5, p>0.05) (Fig. 4). In addition, water depth also demonstrated no significant variations among the four size classes (ANOVA, $F_{3,1126}$=2.02, p=0.11) (Fig. 5A & B).

Groups with mother-calf pairs accounted for 55% of sightings (n=1095) in the HU area and 41% of sightings (n=313) in the ST area. Nevertheless, the proportion of mother-calf pairs significantly varied with group size (goodness-of-fit test, X^2=95.1, df=5, p<0.05). For smaller groups with fewer than 10 individuals, only 16%~22% of groups included mother-calf pairs. On the contrary, the proportion increased to 84%~87% for larger groups with more than 50 individuals in both study areas (Fig. 6).

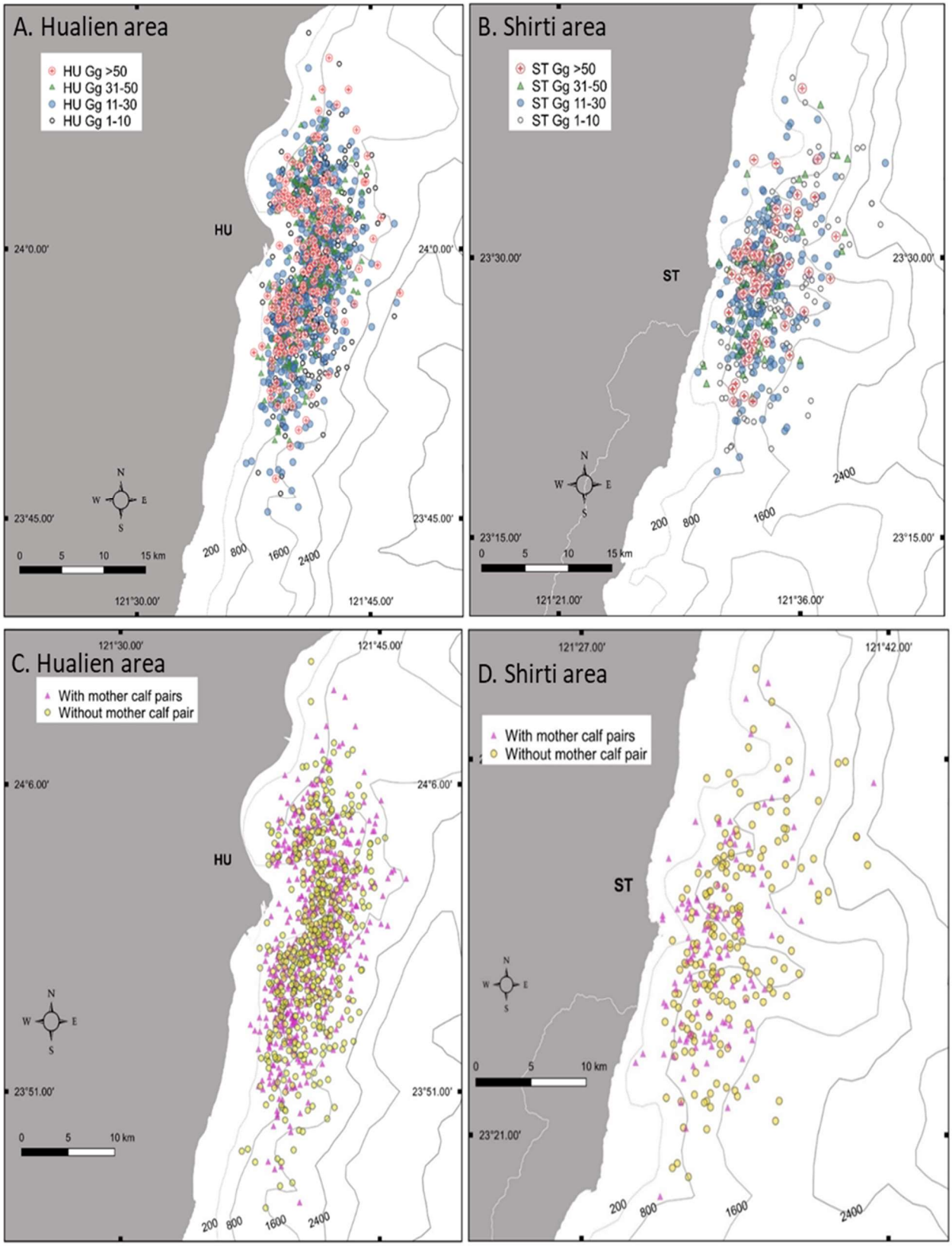

Fig. 5. Spatial distribution of Risso's dolphin. **A** & **B**. Sightings by four group-size classes, composed of 1~10, 11~30, 31~50, and >50 individuals. **C** & **D**. Spatial distributions of sighted dolphin groups, with (triangles) or without (circles) mother-calf pairs.

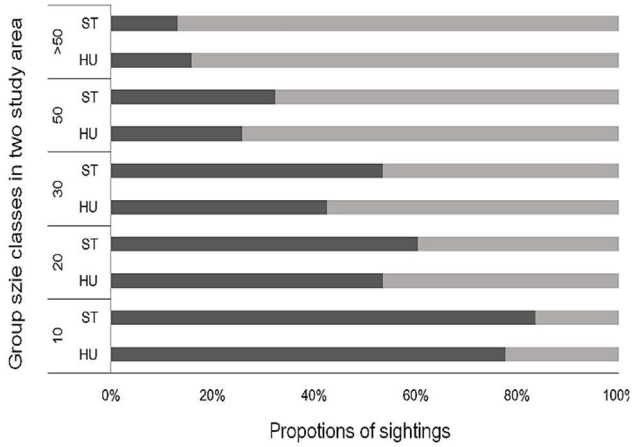

Fig. 6. Proportions (%) of sighting groups with (light bar) vs. without (dark bar) mother-calf pairs in five group-size classes in the Hualien (HU) and Shirti (ST) study areas.

Variations in depth distributions with dolphin group size and composition

Patterns of water-depth distributions significantly differed between groups with vs. without mother-calf pairs, but not among the four size classes. In HU waters, more groups with mother-calf pairs occurred in the range of 300~1200 m and fewer in the range of deeper than 1500 m. The average water depth of groups with mother-calf pairs was 810.5 m (SE=19.5 m, n=600), which was significantly shallower than the mean of 862.4 m of groups without mother-calf pairs (SE=22.4 m, n=495) (t-test, p=0.04) (Fig. 5C). This phenomenon also occurred in ST waters. Groups with mother-calf pairs occurred more often in the range of 300~900 m but less often in the range of >900 m, with an average depth of 870.3 m (SE=42.0 m, n=129), while the group without mother-calf pairs less often occurred in the range of 300~900 m but more in the range of 900~1200 m with a mean 1008.4 m (SE=37.6 m, n=184) (Fig. 5D). A significant difference was detected between the two groups of with and those without mother-calf pairs (t-test, p=0.016).

DISCUSSION

Limitations of data quality/availability

In this study, we used 1630 sightings of Risso's dolphins recorded by whale-watching guides to investigate distribution patterns in two areas off east-central Taiwan. Cetacean observations, especially systemic surveys, commonly lack sufficient financial support. Data collection from trained citizens on whale-watching boats provides a cost-effective alternative. This kind of approach has been used in quite a few studies on cetacean distribution patterns, e.g., distribution patterns of migrating humpback whales (Bruce *et al.*, 2014), seasonal patterns of killer whales (Esteban *et al.*, 2013), and monitoring of bottlenose dolphins (Alessi *et al.*, 2019). Such a large quantity of trustworthy data can offer a good method for long-term population monitoring tasks, especially when systematic surveys are financially out of reach.

One possible disadvantage of misidentifying species can occur with this kind of approach. In this study, Risso's dolphin could easily be identified by its unique body characteristics, such as many obvious whitish scratches on the body skin, the unique head shape, and relatively tall and falcate dorsal fin. In addition, Risso's dolphins usually swim slowly and stay together near the surface, so the group size of this species can easily be estimated without bias. Therefore, we believe that the quality of the data is reliable in this study.

Second, flaws in survey efforts can also be challenged, e.g., the extent and evenness in time and space of conducting the surveys. As to the time scale, surveys were limited by the whale-watching season and thus did not cover the entire year. An underwater passive acoustic study at a spot near Suao (Marine Cable Hosted Observatory), only 50 km away from the HU study area, revealed that cetacean acoustic frequencies are higher in the fall/winter seasons (Lin *et al.*, 2015). So, distribution patterns of Risso's dolphins may differ during the fall/winter seasons. As to the spatial scale, survey efforts of whale-watching trips are commonly aggregated in nearshore rather than offshore areas. Our data collection was limited to within 30 km off land, and cannot imply the distribution of Risso's dolphin beyond that range. Offshore areas can also be important habitat for this species. Extensive surveys conducted by Kanaji *et al.* (2016) in the northwestern Pacific Ocean and Forney *et al.* (2012) and Hamilton *et al.* (2009) in the eastern Pacific Ocean revealed that Risso's dolphin occurrence was not limited to nearshore areas, but there were also numerous sightings in offshore regions. For further advanced analysis, we suggest this kind of investigation should expand the survey effort in time and spatial distributions.

With some limitations, these 17-year long-term data with careful calibration (with verification of the recorded date, time, GPS location, and group composition) and analysis can still provide valuable information for insights into distribution patterns of Risso's dolphin in coastal waters off east-central Taiwan.

Water depth and habitat characteristics

This study demonstrated that Risso's dolphin occurs in waters off east-central Taiwan at a range of water depths of 15~3712 m, but it mainly occurred in areas with depths of 300~1500 m. Water depths of dolphin sightings in the ST area were significantly deeper than those in the HU area. This could be related to the width of the continental shelf/slope which is narrower at ST than at HU, and the shallow-water area (<800 m) is smaller in the ST area. Actually, the continental slope

covers almost the entire east coast, starting from southern Ilan County, through Hualien, and extending to Taitung and Pingtung Counties. The distribution of Risso's dolphin also stretches along this long continental/slope area. In addition to the east coast, a few Risso's dolphins have also been reported in the Taiwan Strait; e.g., Huang (1996) conducted boat surveys in waters off southwestern Taiwan, but was limited to four sightings of Risso's dolphin groups. In addition, quite a few stranding records have occurred on the west coast (Yu *et al.*, 2019). Nevertheless, we do not think that waters off western Taiwan are a major habitat for Risso's dolphin.

In conclusion, the distribution patterns of Risso's dolphin in Taiwanese waters is partially consistent with Jefferson's review (2014) that "Although Risso's dolphins occur in all habitats from coastal to oceanic, they show a strong range-wide preference for mid-temperate waters of the continental shelf and slope between 30° and 45° latitude". However, our empirical data provide strong evidence of the abundant distribution in a subtropical/tropical area, e.g., eastern coastal waters of Taiwan (at 22°~25° latitude). Although Risso's dolphin appears to be a widespread species, it strongly prefers the continental shelf and slope waters from nearshore to oceanic depths.

The major reason for Risso's dolphin's preference for the continental/slope area was commonly suggested to be related to prey resources. Its major foods, cephalopod (squids), can usually be found near continental slope waters, because of the mass of zooplankton in the upwelling or current front. In eastern Taiwanese waters, the diet prey of Risso's dolphin was studied by a stomach content analysis, which revealed that the enoploteuthid squid, *Enoploteuthis chunii* (family Enoploteuthidae), was Risso's dolphin's major food item (Wang *et al.*, 2012). *Wang et al.* (2002) suggested that these squid are mainly distributed in the mesopelagic zone and are associated with the continental slope off Taiwan. The high fluctuation of sighting chances (ratios) among years and varied distributions with depth could likely be a result of variations in squid abundances in eastern Taiwan.

Variations of group size and composition

Group sizes of Risso's dolphins in our results ranged 1~200 individuals per group, with a mean of 35. However, smaller groups with 1~30 members occupied 70% of sightings. Such smaller group sizes also commonly occur in the Mediterranean Sea (Bearzi, 2011), Monterey Bay (eastern North Pacific) (Kruse, 1999), and the Gulf of Mexico (western Atlantic) (Maze-Foley and Mullin, 2006). Hartman *et al.* (2008) found that smaller groups in the Azores maintained long-term social relationships. In contrast, larger groups, with >50 members occupied 25% of sightings. About 80% of these larger groups contained mother-calf pairs. Hartman *et al.* (2014) reported that adult females may form large nursing groups, and observed several mothers taking care of newborn calves in turn. Furthermore, larger groups usually occurred in late summer to early fall in east-central Taiwan**.** Lin (2003) made 2 years of observations on Risso's dolphins in the Shirti area, and she found that larger groups usually occurred at dusk in the summer/fall. Jefferson *et al.* (2008) also reported possible calving peaks in summer and autumn off Japan (Amano and Miyazaki, 2004). From stranding records in Taiwan, three cases of newborn calves were stranded during June-July, and their birth times were estimated to be the summer/fall of the preceding year (Chen *et al.*, 2011). In addition, Risso's dolphins in the study areas usually swim slowly and calmly, but social behaviors (e.g., frequently jumping, chasing, and rubbing) are usually observed when they are in larger groups (Yu's long-term observations). Such social behaviors are usually linked with breeding social behaviors. So, in addition to our group size patterns being consistent with those of other studies, we expect that the east-central coastal waters off Taiwan during summer/fall seasons could be a breeding habitat for Risso's dolphin.

Occasionally, Risso's dolphins in our study areas occurred in extremely large groups with >50~200 members, which occupied 5% of sightings. The function of these very large groups were proposed to be related to the abundance of food resources (Bearzi, 2011, Nuno and Pereira, 2008). Wang *et al.* (2002) reported that one major prey item, purpleback flying squid (*Sthenoteuthis oualaniensis*) occurred in Shirti coastal waters during July-September. Therefore, these very large groups may simply aggregate for prey foraging.

Determining whether smaller groups act as core social groups and larger groups are nursing groups or simply aggregation for prey requires further study with photo identification and social structure analysis in the future.

Distribution of mother-calf groups

Although differences between the two types of groups (i.e., with and without mother-calf pair) in their mean distribution related to water depth were only about 52 m in the HU area and 138 m in the ST area, they were statistically significant. Hartman *et al.* (2014) also found that Risso's dolphins stayed in closer coastal areas with shallower waters around Pico Island of the Azores when nursing newborn calves. Hartman *et al.* (2014) suggested that the vulnerable newborn calves could face fewer predator attacks in suitable nursery areas. This phenomenon of groups with mother-calf pairs being distributed in shallower waters is consistent with many studies on other species as well. For example, several cetaceans move to shallow waters to breed and nurse calves, thereby reducing the risk of predation, e.g., north

Atlantic right whales (*Eubalaena glacialis*), gray whales (*Eschrichtius robustus*), and humpback whales (*Megaptera novaeangliae*) reported by Ford and Reeves (2008) and dusky dolphins (*Lagenorhynchus obscurus*) in Weir *et al.* (2008). In east-central waters of Taiwan, various species of sharks which are potential predators for calves do occur, e.g., white sharks, tiger sharks, and shortfin mako sharks (Chen *et al.*, 2002). So sharks' predation pressure on calves on the east-central coast of Taiwan is highly expected. Mother-calf pairs may benefit from staying in shallower areas especially during the daytime when they are resting. In addition, lactating females need to obtain more food/energy for milk during their long lactating period, which lasts about 2 years according to an isotope analysis of teeth composition (Evacitas *et al.*, 2017). Hartman *et al.* (2014) also suggested that lactating females can save diving time and energy by foraging for squid in shallow areas. Finally, strong currents in the deep and offshore waters near the Kuroshio Current may affect the movement of calves. Therefore, mother-calf pairs staying in shallower water in continental/slope habitats may be beneficial because of decreased shark predation risks, saving mother's diving time/energy, and saving newborn's energy against strong currents.

CONCLUSIONS

This study confirmed the depth distribution of a common species, Risso's dolphin, in east-central coastal waters of Taiwan (subtropical/tropical waters), which is consistent with the major characteristics of other populations in temperate zones, i.e., this species prefers continental shelf/slope areas, and can occur in a wide range of water depths of 10~2000 m. The depth distribution patterns did not vary with group size, but significantly varied with group composition. Groups with mother-calf pairs stayed in significantly shallower waters, although the difference in the mean depth was only about 52~138 m. The proportion of groups with mother-calf pairs was quite high, at about 85% in very large groups (with >50~200 dolphins), but only about 20% in smaller groups (<30 dolphins). Such very large groups often occur in the summer/fall seasons. So, we expect east-central coastal waters off Taiwan could be a critical habitat for Risso's dolphin during summer/fall seasons. We suggest that fishing activities in these area need to be well managed during summer/fall seasons for the conservation of Risso's dolphin.

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