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DISTRIBUTION OF SMALL CETACEANS IN THE NEARSHORE WATERS OF SARAWAK, EAST MALAYSIA

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***ABSTRACT.* –** Between June 2008 and September 2009, 56 days of small boat surveys were conducted off the coast of Sarawak, Malaysia with the aim of recording cetacean distribution. These surveys, which focused on the Miri, Bintulu-Similajau and Kuching regions, comprised 173 hours of survey effort and covered 2851 km of pre-determined systematic tracks. Surveys were clustered into three sets of seasonal snapshots: June-July, September-October and March-April. A total of 115 cetacean sightings were made, of which 65 were on-effort and used in analyses of cetacean encounter rates in relation to habitat characteristics. Species observed included (in order of frequency) Irrawaddy dolphins (*Orcaella brevirostris*), finless porpoises (*Neophocaena phocaenoides*), Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) and Indo-Pacific humpback dolphins (*Sousa chinensis*).

One hundred and ten of 115 sightings were made in less than 10 m water depth, highlighting the importance of nearshore coastal habitats for these species. Despite an apparent overlap in habitat, Irrawaddy dolphins showed a statistically significant affiliation with areas of shallower depth and closer proximity to shore and river mouths than finless porpoises or bottlenose dolphins. This preference for nearshore areas renders the species vulnerable to threats such as fisheries by-catch and habitat degradation from coastal development. Irrawaddy dolphins were more frequently encountered in Kuching, while the highest encounter rate for finless porpoises was in the Bintulu-Similajau region. Depictions of encounter rates in these regions in relation to survey effort in 2 km × 2 km grid-cells give an indication of the preferred habitats of Irrawaddy dolphins, and show that the highest encounter rates in both Kuching and Similajau occurred in areas that are destined for major coastal developments. The information presented here should help researchers and managers design effective future research and conservation strategies.

***KEYWORDS*. –** Malaysia, Sarawak, South China Sea, distribution, Irrawaddy dolphin, finless porpoise.

INTRODUCTION

Prior to 2008, formal research on the marine mammals of Sarawak was limited. Various incidental and historical records were reported by naturalists in the region (e.g. Lydekker, 1901; Gibson-Hill, 1949). Beasley and Jefferson (1997) also conducted some preliminary surveys, while aerial and boat surveys conducted jointly by the Sarawak Forestry Corporation (SFC), the University Malaysia Sabah (UMS) and the Sabah Wildlife Department provided further reports and overviews of the species present and their distribution (e.g. Jaaman, 2006; Bali et al., 2008). These collective sources of information on cetacean populations in Sarawak indicated that the species most commonly encountered in nearshore waters were the Irrawaddy dolphin (*Orcaella brevirostris,* Owen in Gray, 1866), finless porpoise (*Neophocaena phocaenoides,* Cuvier, 1829*),* bottlenose dolphin (*Tursiops aduncus,* Ehrenberg, 1833) and Indo-Pacific humpback dolphin (*Sousa chinensis*, Osbeck, 1765). However, these sources do not provide detailed information on the species' fine-scale distribution or habitat preferences.

Throughout their range, the documented preference of all four of these species for nearshore habitats exposes them to a number of threats, including by-catch in fisheries (Dolar et al., 2002; Read et al., 2006), habitat loss and degradation (e.g. Jefferson et al., 2009), decreased fitness from pollution/contaminants (e.g. Reeves et al., 2003; Adams et al., 2008), high levels of vessel traffic, underwater noise and dolphin watch tourism (Lusseau, 2003; Constantine et al., 2004; Beijder et al., 2006; Lusseau et al., 2007). The IUCN Red List of Endangered Species (IUCN, 2008) classifies both Irrawaddy dolphins and finless porpoises as "Vulnerable", while humpback dolphins are considered "Near-Threatened".

Bottlenose dolphins, most likely due to taxonomic uncertainty about different populations around the globe, are considered "Data-deficient". Five freshwater populations of Irrawaddy dolphins in Southeast Asia are already listed as "Critically Endangered" (IUCN, 2008).

The threats that affect these nearshore species throughout their range are also known to be present in Borneo (Dolar et al., 1997; Kreb & Budiono, 2005) and in Sarawak, Malaysia, specifically (Jaaman, 2006; Jaaman et al., 2009). Detailed scientific surveys are of great importance in order to assess more accurately each species conservation status and conservation requirements. As an important first step in this process, a series of small boat surveys was conducted in three locations along Sarawak's coastline with the aims of: 1) assessing more accurately the species composition, distribution and habitat requirements of coastal cetaceans in the region; 2) collecting baseline data on dolphin distribution and habitat use; and 3) facilitating management and conservation efforts. The results of these surveys as presented here should enable managers and researchers to identify areas of key importance for future conservation and research efforts and lay the foundation for more detailed and targeted study both within Sarawak and in other parts of the species' range.

MATERIAL AND METHODS

Data Collection. **–** Small boat surveys were conducted along the Sarawak coast of the Kuching, Bintulu-Similajau, and Miri regions (Fig. 1). These areas were chosen for reasons of logistical practicality, as well as their contrasting habitat composition. The Miri and Similajau coastlines both run from approximately north to south and are interspersed with rivers and streams of varying sizes at fairly regular intervals. The Kuching coastline runs from east to west and comprises a complex and interconnected series of wide rivers and mangrove channels, which empty into three major estuaries/bays. The Kuching study area includes some of the waterways encompassed in the Kuching Wetland National Park, while the Bintulu-Similajau study area includes the entire coastline bordering the Similajau National Park. A further reason for choosing the Kuching and Similajau areas was the large-scale coastal developments planned in both places.

Transects extended up to 15 km offshore and were systematically orientated at 45° angles to the primary coastline to ensure they were independent of habitat features and environmental gradients, and to allow for detection of cetacean density gradients alongshore as well as onshore/offshore (e.g. Dawson et al., 2008). The survey design function in DISTANCE (Thomas et al., 2009) was used to compare the coverage probability and proportion of survey time spent in transit between transects when transects were separated by 2, 3, 4, 5 and 6 km. A transect separation of 4 km was selected as this allowed a compromise between intense survey coverage and a realistic amount of survey effort. For the Kuching area, for example, the 4 km spacing allowed 74% of survey time to be spent on effort, with a coverage probability of 34.1%.

Survey vessels were open-decked and fibreglass-hulled, approximately seven to 10 m in length, and used either single or double outboard engines ranging from 90 to 200 hp. A minimum of three observers stood on decks or benches resulting in an eye height approximately three meters above sea level. All three observers searched with the naked eye, with one observer at the bow scanning a cone of about 30° and two observers on either side of the boat scanning arcs of approximately 90° to port and starboard (e.g. Parra et al., 2006). A minimum of two experienced cetacean observers were always on board, while other observers undergoing training had varying degrees of experience. Due to the high turnover of observers undergoing training, and the need for all observers to be standing together at deck level rather than separated by elevated observation platforms, the team opted to implement methods appropriate for calculating relative rather than absolute abundance.

Transects were navigated at a steady speed of 10 knots (18.5 km/h) and observers rotated through different positions on the boat at the end of each transect line (roughly half-hour intervals) to avoid fatigue. When cetaceans were detected, search effort was suspended to collect data on the group composition and behaviour following standardized data collection methods (e.g. Smith & Reeves, 2000). Positional data for both survey tracks and sightings were collected using a handheld GPS unit.

Effort was recorded to the nearest minute throughout each survey day in order to distinguish between time spent in optimal survey conditions (from here on referred to as on-effort), transiting to or from the start and end points of transect lines, working with cetacean groups, or simply off survey effort. Only sightings made on-effort were used in the generation of encounter rates, which were calculated both in relation to hours of survey effort and the distance covered during on-effort survey time. Weather conditions that could affect sighting probability were recorded on an hourly basis, or upon a rapid condition change, and search

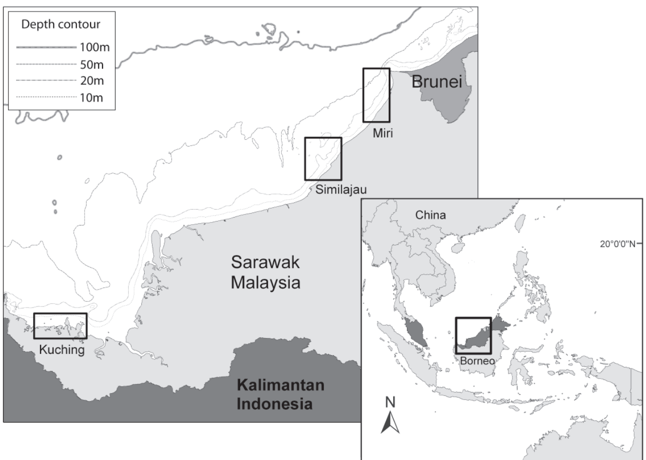

Fig. 1. Three main study areas in Sarawak.

effort was suspended during heavy rain and/or Beaufort Sea-states of four or higher.

Group size was estimated after approach, and behaviour classified into standardized categories of traveling, feeding (direct feeding observed), probable feeding (dive patterns consistent with feeding activity or fish observed at the surface near dolphins), resting/milling, socializing, or undetermined (e.g. Parra, 2006; Lusseau, 2006). Some of the survey vessels used were equipped with a depth sounder, in which case depth was recorded at the point of sighting. When a depth sounder was not available, depths at locations of sightings were interpolated during data processing. The presence of fishing effort in proximity to cetacean groups was noted, and the number of boats or set gillnets within an estimated 50 m of the group recorded at each sighting.

Photo-identification. **–** Whenever a group of dolphins or porpoises was sighted, active survey effort was suspended, the boat departed from the transect line and efforts were made to approach the group as close as possible without disturbing their natural behaviour. Digital SLR cameras with either 200 mm or 300 mm zoom lenses were used to take photos of the left and/or right sides of dorsal fins of as many individuals in the group as possible.

For Irrawaddy and Indo-Pacific humpback dolphins, photographs showing left or right sides of dorsal fins in sufficient detail were cropped and digitally enhanced and entered into a custom-designed MS Access® database which allowed for storage of sighting information as well as on-screen comparison of photographs. Left and right dorsal fin photos were treated as two separate data sets. Photographs were assigned scores of 1-4 for both overall quality and distinctiveness following the protocols described by Friday et al. (2000) with a score of 4 indicating excellent quality or a high level of distinctiveness, and a score of 1 indicating very poor quality or lack of distinguishing features on the dorsal fin area. Matching of photographs was conducted on-screen, and included photographs of every score in both the quality and distinctiveness categories. Unique ID numbers were assigned to each individual dolphin after matching to all previously collected photographs.

Data analysis. **–** Survey tracks and precise sighting locations recorded with the handheld GPS were downloaded at the end of each day and saved in different formats for later processing in Google Earth® and/or ArcMap®. Sighting details were entered into a custom-designed MS Access database, and both tracks and sightings were imported into Google Earth and ESRI's ArcMap for viewing, mapping and analysis.

Depth values were obtained from Arc-GIS compatible rasters of British Admiralty charts (issued by Seazone®). Digitized bathymetry points were generated by manually assigning depth values to each depth point on the chart, and various functions were tested to determine the "best fit" model for interpolating depths in our study area between the known depth values of the chart. The function chosen was Inverse Distance Weighted (IDW) with 0.5 nautical mile grid size. These interpolated values were used to assign depth values to dolphin sightings where no echo-sounder was available on the research vessel.

Sightings made while on effort were also imported into Google Earth in order to measure the distances to the nearest land and nearest river mouth. Only on-effort sightings were used to avoid the bias that might be introduced by including sightings made while speeding close to shore to the start and end-points of transect lines. Distance to land was measured to the nearest 100 m. Distance to the nearest river mouth was measured by creating a fixed mid-point in the line connecting the "corners" of the river mouth and measuring the distance from the sightings to this midpoint. Sighting locations inland/upriver of the midpoint were assigned a value of "0". The resulting distributions of sighting location characteristics for each species were tested for normality using the Anderson–Darling test. The tests showed a non-normal distribution for all three characteristics for both Irrawaddy dolphins and finless porpoises, and therefore, the non-parametric Kruskal-Wallis as well Wilcoxon ranked sum tests with correction for continuity were used to test the significance of the differences between each species' sighting locations with respect to the depth, distance to land and distance to river mouths. Bottlenose dolphins were not included in these analyses due to the small sample size of only three on-effort sightings.

On-effort tracks in the Kuching and Similajau areas were analysed in ArcGIS 9.3 and overlayed with a 2 km × 2 km grid. The number of on-effort Irrawaddy dolphin sightings in each grid cell was divided by the sum of on-effort survey tracks within each grid cell to generate an encounter rate for each cell. Cells with varying encounter rates were then colour-shaded to provide a graphic indication of high density areas.

RESULTS

Sightings and encounter rates. **–** Surveys completed as of September 2009 are detailed in Table 1. The completed tracks and sightings made during the surveys are depicted in Figures 2 a-c. During 56 days (over 389 hours) a total of 5,555 km was covered, of which 2851 km and 173 hours were spent on-effort. A total of 115 cetacean sightings were logged, of which 65 were on-effort and used in encounter rate and habitat analyses.

The number of dolphin or porpoise groups sighted per total number of hours spent on the boat across all areas was 0.30 groups per hour, while the on-effort encounter rate was 0.38 groups of cetaceans per hour. Irrawaddy dolphins were the most frequently sighted species, with an encounter rate of 0.20 sightings per hour of search effort and the highest encounter rate in Kuching (0.30 sightings per hour). Finless porpoises were sighted at a rate of 0.13 sightings per hour of effort across all regions, with the highest encounter rate in Similajau (0.22 groups per hour).

Table 1: Survey dates, distance covered, hours spent surveying and number of dolphin sightings per survey period in each region.

Dates Surveyed	Total Distance covered (km)	Hours on effort (hrs:mins)	Total Irrawaddy dolphin sightings	Irrawaddy encounter per hour of effort	Total Finless porpoise sightings	Finless porpoise encounter per hour of effort	Other species
Kuching							
15-17 July '08	319.57	9:00	5	0.333	2	0.222	1 (unid) [a]
16-18 Sept '08	299.33	10:56	6	0.366	1	0.091	1 (*Tursiops*)
14-16 Oct '08	254.34	9:04	7	0.551	1	0.000	
8, 13 Nov and 11 Dec '08	114.82	3:52	4	0.000	0	0.000	
4-6 Mar '09	279.403	10:19	3	0.194	2	0.097	
20-21 May, 6 June	235.01	7:13	6	0.139	2	0.277	
21-23 Jul '09	320.48	11:47	5	0.255	1	0.000	
19-21 Aug '09	235.34	7:02	3	0.427	0	0.000	
7-10 Sep '09	326.10	9:14	5	0.325	1	0.108	1 (unid) [a]
Kuching total	**2384.40**	**78.27**	**44**	**0.288**	**11**	**0.088**	**3**
Similajau							
11-13 June '08	272	6:16	7	0.479	6	0.319	1 (*Sousa*)
24-26 Sept '08	249.37	9:26	1	0.106	3	0.318	
18-20 Feb '09	334.78	7:35	4	0.132	5	0.132	1 (*Sousa*)
25-27 Mar '09	339.03	9:41	5	0.103	5	0.310	
8-10 Jul '09	305.18	8:47	2	0.228	2	0.000	
5-6 Oct '09[b]	18.34	0	0	0	0	0	
Similajau total	**1518.7**	**41:45**	**19**	**0.192**	**20**	**0.216**	**2**
Miri							
24 June, 7-9 Jul '08	351.05	13:29	1	0.074	3	0.148	
9 Sept and 4 Nov '08	199.8	6:22	0	0.000	1	0.157	1 (*Tursiops*)
16-18 Mar '09	258.195	10:15	0	0.000	0	0.000	
8-10 Jun '09	359.565	11:17	0	0.000	2	0.089	1 (*Tursiops*)
14-16-Sep '09	353.37	11:23	2	0.088	3	0.176	1 (unid) [a]
Miri total	**1617.18**	**52:46**	**3**	**0.038**	**10**	**0.133**	**3**
Total for all areas	**5554.62**	**172.58**	**66**	**0.197**	**41**	**0.133**	**8**

[a] Not identified to species level – sighting too brief and/or distant.
[b] Poor weather prevented surveys at sea – only one short river survey – no cetacean sightings.

Encounter rates were almost certainly affected by the "sightability" of the species involved. Bottlenose dolphins were sighted from up to an estimated 1 km from the survey vessel, with a mean estimated sighting distance of 550 m (SD 427). With a mean estimated group size of 20.3 (SD 8.4), these larger dolphins displayed more conspicuous surfacing behaviour, including occasional leaps and splashes from tail slaps and fast turns. The mean estimated sighting distance for Irrawaddy dolphins, on the other hand, was much lower at 126 m from the boat (SD 108 m). Group sizes for this species were smaller, with a mean estimated group size of 4.3 (SD 3.1). Finless porpoises were the least conspicuous species, with a mean sighting distance of only 100 m from the boat (SD 97) and mean estimated group size of 2.3 (SD 1.6).

Photo-Identification. **–** While Irrawaddy dolphins were encountered relatively frequently, they were elusive and extremely unpredictable in their surfacing patterns. Low light, haze and rain/drizzle contributed to the difficulty of obtaining good quality photographs of the left and right sides of individual dolphins' dorsal fins. Following selection and cropping for entry in the database, a total of 102 individual Irrawaddy dolphins were identified from the right side of the dorsal fin, and 101 by their left side. Only 27 individuals in each group were represented by a photograph of a quality 3 or higher, a quality considered suitable for inclusion in mark-recapture analysis (Table 2).

For Irrawaddy dolphins, only nine definite matches were made in the Kuching area, and one in the Similajau area. All but one of the matches were based on poor quality photos of distinctively marked individuals. There was a relatively high number of "possible matches", where dorsal fin shapes looked to be the same, but photographs were not sharp enough and the fins were not distinctive enough to

Table 2: Results of Photo Identification of Irrawaddy dolphins after processing in a tailor-made MS Access database.

	Left dorsal fin		Right dorsal fin	
Year	**Total no. of identified individuals**	**No. of individuals represented by Photo quality 3 or higher**	**Total no. of identified individuals**	**No. of individuals represented by Photo quality 3 or higher**
2007	0	0	6	3
2008	40	7	40	9
2009	62	20	56	15
Total[a]	101	27	102	27
Confirmed matches between surveys	5	1	4	0
Possible matches between surveys	12		18	

[a] Note the total is not the sum of all identifications as individuals re-sighted from one year to the next are only counted once.

show more subtle scarring or markings that would allow a confirmation of the match. This indicates that our data may include a high number of "false negatives" – cases where the same individual is not being recognized from one sighting to the next. Mark-recapture analyses using various filtering mechanisms for the sighting histories (e.g. selecting only photos with distinctiveness scores of 3 or higher) in the sample yielded conflicting results with very wide confidence intervals, and were not considered suitably robust for publication.

The confirmed matches do, however, yield insight into movement of the dolphin population within our study areas. The matches indicate movement between the Salak-Santubong estuary on the west side of the study area, and the Bako-Buntal bay on the east. Re-sights included individuals photographed between survey years as well as from one month to the next, confirming likely year-round residence in the survey area. Movement between the two main bays of the study area indicates that the home range of the population under study includes both bays, with the furthest distance between sightings being 17 km, but separated by a landmass which would take 25 to 30 km to navigate around (Fig. 2c). It is not clear whether movement between the two bays occurs through the river network or around the tip of the Santubong peninsula.

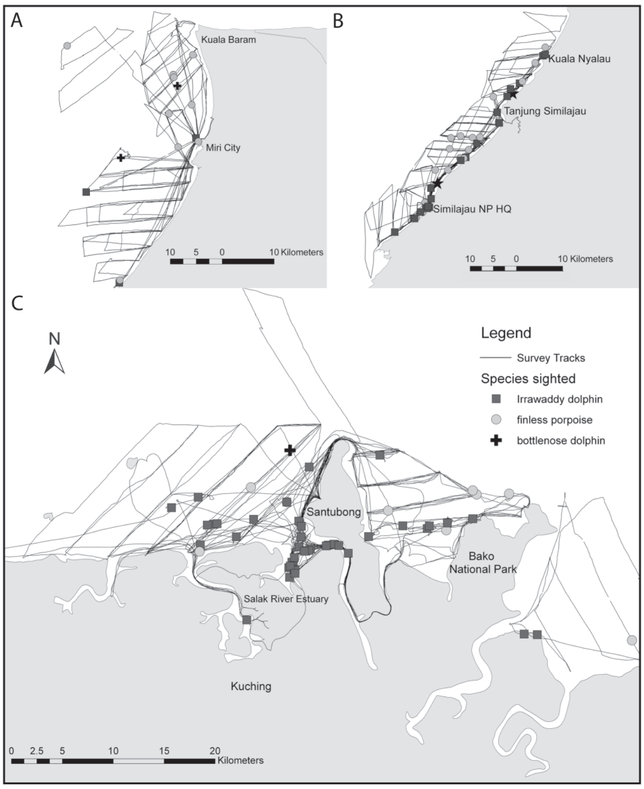

Fig. 2. Survey tracks (total track, including on- and off-effort portions) and sightings (on- and off-effort) in the three main survey areas of (a) Miri, (b) Similajau, and (c) Kuching.

Matches made in the Similajau survey area include one Irrawaddy dolphin and one Indo-Pacific humpback dolphin. In both cases, the re-sights indicate that the identified dolphin's range extends along coastline between the area encompassed by the Similajau National Park and Tanjung Similajau, an area which is being considered for large-scale industrial development.

Sighting distribution and habitat preferences. – Fig. 3 depicts the characteristics of dolphin and porpoise sighting locations with respect to depth, distance from shore and distance from river mouths. Bottlenose dolphins were sighted in depths ranging from 3.8 to 24.3 m, with a mean of 9.9 m (SD 10.3). Finless porpoises were sighted in depths ranging from 1.3 to 16.8 m with a mean of 9.6 m (SD 11.8). Irrawaddy dolphins were encountered in the shallowest depths, ranging from 2.0 to 5.4 m with a mean of 3.3 (SD 1.4). Similarly, Irrawaddy dolphins were found closest to shore (mean of 1.38 km, SD 1.90), and closest to river mouths (mean 3.53 km, SD 3.58). The box and whisker plots demonstrate little or no overlap in the median quartile values of all three habitat variables for all three species. Kruskal-Wallis tests and Wilcoxon ranked sum tests with correction for continuity confirmed that the differences between Irrawaddy dolphins and finless porpoises were statistically significant for all three variables of depth, distance to shore and distance to river mouths, with p-values lower than 0.01 (Table 3). The results indicate that Irrawaddy dolphins were found at locations that were significantly shallower (sample estimate difference of 2.6 m), closer to shore (sample estimate difference of 1.6 km), and most significantly closer to river mouths (sample estimate difference of 4.2 km) than finless porpoises.

Irrawaddy dolphin encounter rates (number of sightings divided by the total number of kilometers searched) per grid cell in the Kuching and Similajau study areas are depicted in Figures 4a and b. In the Kuching area, the cells with the highest encounter rates (darkest shading) are located near the four major river mouths in the study area. In the Similajau study area, the two cells with the highest encounter rates are located on either side of the Similajau River and Tanjung Similajau – the headland in the northern portion of the study area.

DISCUSSION

Species composition and distribution. **–** This series of three-day "snapshot surveys" has offered an important initial insight into the species composition and distribution of cetaceans in three nearshore areas of Sarawak's coastline.

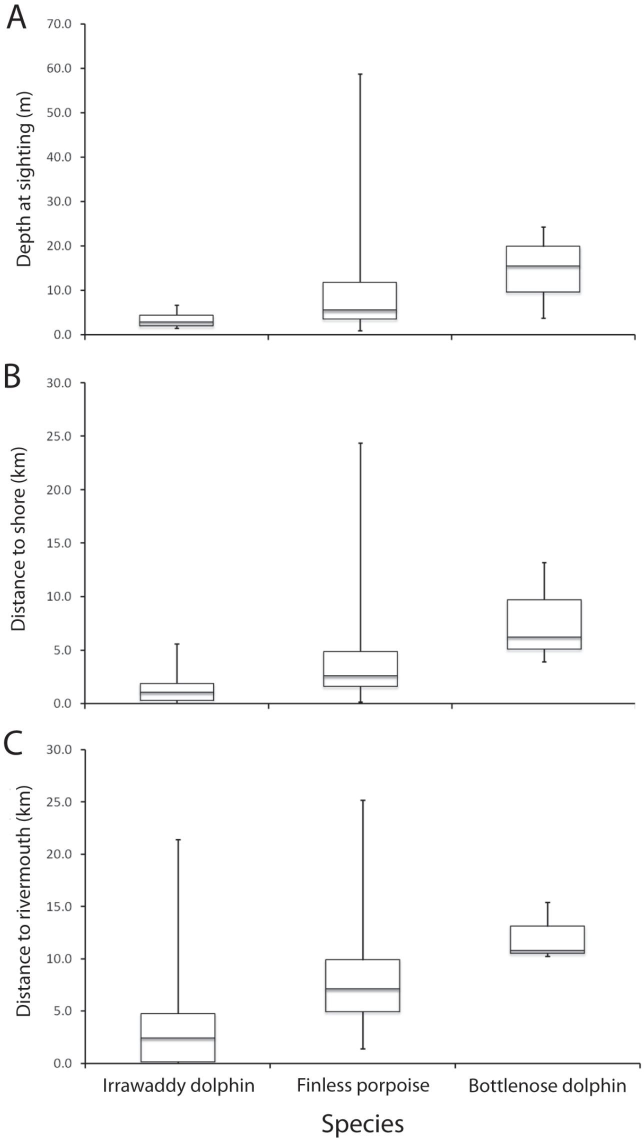

Fig. 3. Box and whisker plots showing the minimum and maximum values, median and upper and lower quartiles of the values for depth (a), distance to shore (b), and distance to nearest river mouth (c) for on-effort sightings of Irrawaddy dolphins (n=35), finless porpoises (n=24) and bottlenose dolphins (n=3).

Figs. 2 a-c and 4a-b demonstrate the importance of shallow coastal waters for all four species sighted during surveys, with 110 of 115 sightings taking place in depths of 10 m or less. While figures 4a and b indicate specific grid cells where Irrawaddy dolphin encounter rates were high during our surveys, readers should realise that these are not the only areas of dolphin distribution, but rather an indication of which types of habitats might be the preferred feeding, resting or breeding areas for this species.

With the exception of one sighting made roughly 8 km upriver in the Kuching area, Irrawaddy dolphins were exclusively encountered in coastal or estuarine areas. While this species may occur in freshwater habitats in other river systems in Sarawak, they do not appear to frequent the inland freshwater portions of the Miri, Similajau, Santubong or Salak rivers, which were occasionally surveyed during our study. However, more consistent survey effort is required in these river systems to determine whether or not this is the case.

The locations of our sightings indicate a high degree of overlap between the distribution of all four species, particularly that of Irrawaddy dolphins and finless porpoises in the Kuching and Similajau areas. Comparison of on-effort sightings indicates that Irrawaddy dolphins show a preference for shallower waters closer to shore and river mouths than finless porpoises or bottlenose dolphins. Current and ongoing research efforts involve the measurement of water parameters,

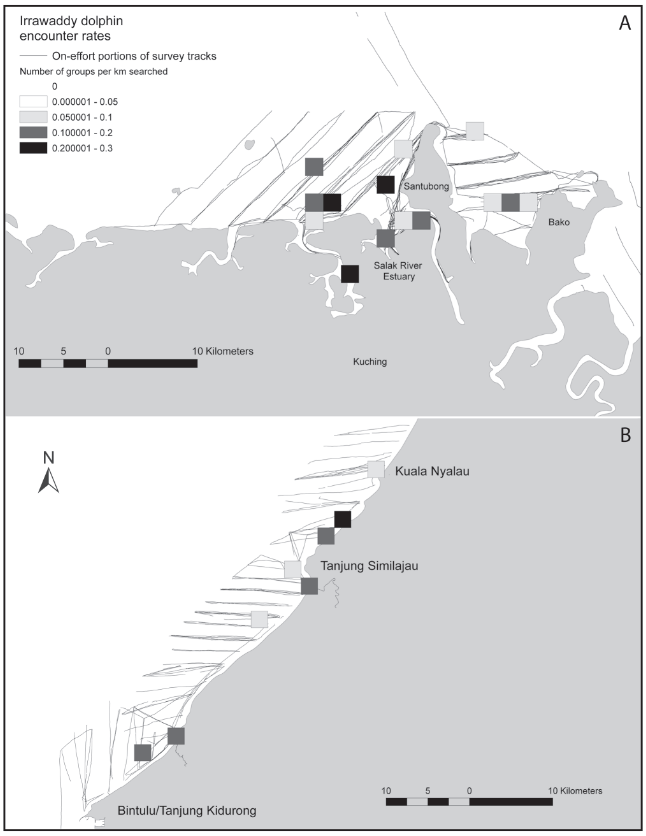

Fig. 4. (a) Kuching and (b) Similajau survey areas with 2k m × 2 km grid cells shaded according to encounter rate (number of sightings/distance searched in each grid cell). Only grid cells with dolphin sightings are shaded – others are left blank to better display underlying survey effort.

Table 3: Results of Kruskal-Wallis and Wilcoxon rank sum (also known as Mann-Whitney U-) testing for the statistical significance of the differences in depth, distance to shore and distance to nearest river mouth for on-effort sightings of Irrawaddy dolphins (n= 35) and finless porpoises (n=24). Bottlenose dolphin sightings (n=3) were not included in the analyses. All resulting p values were considered significant at < 0.01.

Kruskal-Wallis finless porpoise vs Irrawaddy dolphin	**$\chi 2$**	**P-Value**		**df**
Depth	10.3123	0.001321		1
Distance to shore	12.7501	0.000356		1
Distance to river mouth	16.405	5.115e-05		1
Wilcoxon rank sum test finless porpoise vs Irrawaddy dolphin	**W**	**P-value**	**Sample estimate of difference in location medians**	**95% confidence interval of differences in location medians**
Depth	633	0.001019	2.60	1.1- 5.8
Distance to shore	650	0.0003976	1.6	0.8-2.6
Distance to river mouth	674.5	8.618e-05	4.2	2.0-6.0

such as salinity, turbidity and temperature at sighting locations, and may provide a more detailed understanding of the subtle ecological differences that allow these species to share habitat (e.g. Parra, 2006; Parra et al., 2006).

The external morphology of the bottlenose dolphins that were observed in the Kuching and Miri study sites was consistent with *T. aduncus.* Body size was generally smaller and more slender than that of *T. truncatus*, with a more elongated rostrum a visible dark grey dorsal "cape" as well as speckling on more mature individuals ranging from the ventral surface up toward the flanks (Wang et al., 2000; Wang & Yang, 2009). Their occurrence in relatively shallow nearshore waters is consistent with the habitat described for this species (Wang & Yang, 2009). However, our infrequent encounters with the bottlenose dolphins indicate that this species may have a wider range which extends further offshore and/or along the shore than the Irrawaddy dolphins and finless porpoises which are observed more consistently within our survey areas.

External morphology of the finless porpoise observed on a by-catch specimen in October 2008 and on photographs of free-ranging animals is consistent with that described for *Neophocaena phocaenoides phocaenoides* – the subspecies characterized by a wide area of tubercles on the dorsal surface (Jefferson & Hung, 2004; Wang et al., 2008). Our observed distributions with respect to habitat type are also consistent with those observed in other areas of the species' range (Jefferson et al., 2002; Jefferson & Hung, 2004).

Indo-Pacific humpback dolphins were only observed twice off effort. Morphologically, they resemble *Sousa chinensis* (Parra & Ross, 2009). However, animals appear more robust and more mottled in colouration than those in Hong Kong, with only a very small percentage of animals (e.g. 1 per group of 15-20 animals) appearing fully "white" or pink (pers. obs.). An analysis of geographic variation in skull morphology led Jefferson and Van Waerebeek (2004) to conservatively label specimens obtained from several locations throughout the Indo-Pacific region under the species *Sousa chinensis*. However, Frère et al. (2008) concluded that humpback dolphins sampled in Australia differ significantly from those sampled in China and may comprise a new species. Further genetic sampling and morphological studies are required from Borneo to determine how significantly humpback dolphins in this region may differ from other parts of the species' range, and whether it might also merit a new species nomenclature, *Sousa borneensis* (drawing on the original nomenclature of *Sotalia borneensis* (Lydekker, 1901)).

Species habitat use and ecology. **–** Confirmed observations of small calves during sightings of Irrawaddy dolphins and finless porpoises indicate that the nearshore areas of Similajau and Kuching are used as breeding and nursing grounds for these species. On 20 August 2009, a sighting was made of an unusually large aggregation of Irrawaddy dolphins in the western part of our Kuching study area. The group of at least 20 individuals, three of which were recognized from previous surveys in the Kuching region, was tightly packed and displayed frequent body contact consistent with descriptions of gregarious mating or social aggregations for this species in Trat Province, Thailand (Ponnampalam et al. 2009), and with published descriptions of multi-pod aggregations of killer whales in the Kamchatka peninsula (Filatova et al., 2009). Anecdotal reports from dolphin watch tour operators indicate that these aggregations occur in the Kuching area more frequently in summer months than at other times of the year when smaller groups of two to six individuals are more commonly observed. Calves were also observed during sightings of humpback dolphins in the Similajau area, and bottlenose dolphin groups in both the Kuching and Miri study areas.

One observation of bottlenose dolphins in the Miri area included sub-groups tightly circling and tail slapping around schools of fish visible at the surface, indicating that feeding takes place in this area approximately 14 km offshore and within 5 km of a number of coral outcrops. Both Irrawaddy dolphins and finless porpoises were observed on several occasions chasing fish at the surface, both in Similajau and Kuching. While other priorities may influence cetacean distribution under particular circumstances (e.g. security from predation), prey availability is expected to be the primary factor in determining habitat choice (e.g. Hastie et al., 2004). Our observations indicate that both Irrawaddy dolphins and finless porpoises feed in shallow nearshore areas, and are thus likely specialised in hunting techniques and dietary preferences that restrict them to the nearshore habitats. As such, any coastal development that introduces significant changes to the salinity, turbidity, substrate or bathymetry, or introduces waterborne contaminants or toxins into the environment may seriously impact the dolphins' prey sources, feeding opportunities and overall health (e.g. Clark et al., 2002; Reeves et al., 2003; Hansen et al., 2004; e.g. Adams et al., 2008).

Conservation significance. – Fifty percent of all on-effort Irrawaddy dolphin sightings made in the Kuching area were in close association (within an estimated 50 m) with fishermen setting gill nets of varying mesh sizes from small (6-10 m) fibreglass boats. On many occasions, dolphins were observed approaching the boats as nets were being hauled in, and fishermen were seen throwing cast-off fish to the dolphins. Even though this does not involve the same level of cooperation as that described for the Ayeyarwady River in Myanmar (Smith et al., 2009), anecdotal information from fishermen during our surveys indicate that they feel positively toward the dolphins. At the same time, Jaaman et al. (2009) report high levels of by-catch in Sarawak and further research is required to determine the severity of the threat currently posed by fishing in our study areas.

Currently the Irrawaddy dolphin population in the Kuching region supports a local dolphin-watching industry involving six to eight separate tour operators and generating an income of an estimated $308,000 per year (O'Connor et al. 2009). This industry represents the only established dolphin-watching tourism in Malaysia. Threats to the dolphin population in the area may undermine efforts to expand the industry in other parts of the region, and thus provide more economic incentive to protect dolphin populations.

Without longer term data and more detailed water parameter analysis, it is difficult to determine precisely why encounter rates with Irrawaddy dolphins were so much lower in the Miri region than the Bintulu-Similajau and Kuching regions. The sections of Miri coastline covered by the surveys are more heavily developed than those in the other two survey areas, with a major port at the Baram River to the north, a number of offshore oil rigs located within the survey area, and high levels of pollution recorded in the Baram and Miri rivers (NREB, 2005). Planned coastal developments in the Similajau study area include extensive dredging for ports and wharves and the construction of a large industrial park near Tanjung Similajau. In Kuching, the construction of a flood mitigation channel will transport large volumes of silt laden fresh water into the Salak River estuary. In the Doubtful Sound of New Zealand, large increases in freshwater input resulting from the construction of a second tailrace tunnel for a hydroelectric power station were considered to be the most likely contributing factor to a sudden drop in bottlenose dolphin calf survival rates (Currey et al. 2009). Although we would expect Irrawaddy dolphins to be more tolerant of freshwater input, significant and rapid unnatural changes to salinity and turbidity resulting from the flood channel may prove harmful to this population. Dredging of large volumes of sand for construction materials is also common in the Salak River estuary (e.g. Naeg & Ten, 2010). Shirakihara et al. (2007) concluded that high levels of dredging were responsible for a lower finless porpoise density in a portion of their study area, and attributed the lower numbers to the fact that benthic prey may decline following removal of the sandy substrate.

The data presented here provide a baseline for comparison against future surveys which may take place during or after planned coastal developments in Sarawak. Surveys should continue on a monthly or quarterly basis, and should include new areas not yet covered in this study. Applying the same methods used for this study will allow direct comparison of encounter rates to monitor possible changes in relative abundance between seasons or between years. These surveys should also incorporate an element of water parameter sampling to understand more fully habitat preference in relation to environmental factors such as temperature, salinity and turbidity.

While relative abundance and photo–identification methods should be continued, it is also important that future research efforts work toward the generation of absolute abundance estimates. Photographs collected through September 2009 did not yield sufficient data for the application of mark-recapture analysis to generate absolute abundance estimates for the Irrawaddy dolphins in the study areas. As such, future studies should also make use of a vessel with a higher viewing platform, a more consistent and trained team of observers, and methods suitable for the use of DISTANCE software (Buckland et al., 2001; Thomas et al., 2009) to calculate absolute abundance estimates in those areas shown to be significant habitats for Irrawaddy dolphins and finless porpoises. Given the precarious conservation status of Irrawaddy dolphins and finless porpoises throughout their range, obtaining population estimates in this part of the species' range is of particular global conservation value.

The results offer the potential to enact some immediate conservation measures, in the form of improved communication, cooperation and information sharing between scientists, government planning bodies, and other relevant stakeholders in coastal management and conservation. Those bodies responsible for approving new developments (e.g. planning departments and environment boards responsible for reviewing and approving Environmental Impact Assessments), should be urged to include consideration for cetaceans and the integrity of cetacean habitats into their approval criteria. This is particularly true for Irrawaddy dolphins and finless porpoises, whose global conservation status is precarious. Dolphin watch and other coastal eco-tour operators should also be encouraged to contribute to conservation and research efforts by systematically collecting sightings data and reporting them to research teams, as well as by adhering to approach guidelines as published, but currently not enforced by government bodies.

Although the results include only 56 days of survey effort in three study areas, the data presented here represent some of the only fine-scale habitat analysis of coastal (as opposed to fresh water) populations of Irrawaddy dolphins in Southeast Asia. These results can be used to predict the likely species composition and distribution of coastal cetaceans in similar habitats throughout Sarawak's coastline and to guide managers in future research and conservation efforts.

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