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DISTRIBUTION, ABUNDANCE AND DENSITY OF IRRAWADDY DOLPHIN (*Orcaella brevirostris*) IN RAJANG RIVER OF SARAWAK, EAST MALAYSIA

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ABSTRACT

The Irrawaddy dolphin (*Orcaella brevirostris*) locally known as "*empesut*" or "*pesut*" is the most common marine mammal and considered as the flagship species in Sarawak. Their habitats overlap with areas of intensive human activities. A study was conducted in Rajang River from April 2009 to October 2010 using a modified strip-transect boat survey where the river system was divided into two segments: Kuala Rajang-Sarikei (lower segment) and Sarikei-Sibu (upper segment). The main goal of the study is to provide scientific information to be used as a basis to plan conservation management strategies for Irrawaddy dolphins in the Rajang River system. Results of the study revealed that Irrawaddy dolphins were found in both segments of Rajang River but they were not evenly distributed. Higher mean sighting frequency, means the number of individual sighted per survey and sighting rate of Irrawaddy dolphins were recorded at the lower river segment of Rajang River. Number of individuals recorded in each sighting was highly statistically significant difference between the river segments with higher number individual per sighting recorded at the lower river compared to upper river segment (Mann-Whitney: U=17,487.0, n=240 and 187, p=0.000).

The farthest sighting was recorded 86 km from the river mouth of Rajang River. Higher probability of sighting of Irrawaddy dolphins were recorded at the lower part of Rajang River with statistically highly significant difference (McNemar: =38.726, df=1, p=0.000). The mean density and abundance values of Irrawaddy dolphins were higher at the lower river segment with abundance, N=12, 97.5% CI=5-18; CV=64.8% and Density, D = 0.20 animal per km^2, 97.5% CI= 0.08-0.33 in Kuala Rajang-Sarikei segment. In Sarikei-Sibu segment, N=2, 97.5% CI=0-6; CV=76% and D = 0.10 animal per km^2, 97.5% CI= 0.00-0.23. This study has contributed to the understanding of spatial and temporal distributions of Irrawaddy dolphins in both river segments of Rajang River. Data from this study provided should be assessed to ensure that the information can be used for the management and conservation of the species. There are research priorities that are recommended to overcome the knowledge gaps such as diet, threats, home range and applying new research technology for population estimation.

Key words: Irrawaddy dolphin, Distribution, Abundance and Density, Rajang River, Sarawak, Malaysia, Borneo

INTRODUCTION

Based on recent published literatures, a total of 30 species of marine mammals have been recorded in Malaysia consisting mainly of cetaceans and sirenians; 18 species were found in Peninsular Malaysia, 17 species in Sarawak and 19 species in Sabah. There are four species of inshore cetaceans, namely the Irrawaddy dolphin (*Orcaella brevirostris)*, Indo-Pacific Bottlenose dolphin (*Tursiops aduncus*), Indo-Pacific Humpback dolphin (*Sousa chinensis*) and Finless porpoise (*Neophocaena phocaenoides*), inhabiting the coastal waters and main estuaries of Sarawak (Beasley & Jefferson, 1997; Jaaman *et al*., 2001). Out of these four species, the Irrawaddy dolphin locally known as "*empesut*" or "*pesut*" is the most common marine mammal and considered as the

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flagship species in Sarawak. Their occurrences have been recorded in Rajang, Sematan, Bako, Muara Tebas, Saribas, Igan, Lupar, Lassa rivers, and in the coastal waters of Bintulu, Mukah, Sebuyau to Pulau Burong, Kabong to Pulau Bruit and Lawas (Minton *et al*., 2011; Jaaman *et al*., 2001; Bali & Tisen, 2012). Furthermore, in the Rajang River, Irrawaddy dolphins have been sighted more than 30 km upstream from the estuaries and in water salinity less than 10 parts per thousands (ppt) (Bali & Tisen, 2012). Overall, the abundance and density status of cetacean species in Malaysia are unknown due to the severe lack of scientific research efforts (Jaaman *et al*., 2001). The best mark-recapture estimate for Irrawaddy dolphins in Kuching Bay, Sarawak derived from photo-identification and line-transect studies was 233 (95% CI=151 – 360; CV=22.5%) and 149 individuals (95% CI=87 – 255; CV=28%), respectively (Minton *et al*., 2011). Minton *et al.* (2013) also reported the line-transect estimate for Finless porpoises in Kuching bay, Sarawak was 135 individuals (95% CI=74 – 246; CV 31%). Despite having laws to protect and conserve this species in Sarawak since 1958, Irrawaddy dolphin's population size, ecology, abundance and threats to their population have been poorly studied and monitored due to lack of funding and experts. Applied population biology and ecology can contribute greatly to the management of this species (Primack, 2002; Beasley *et al*., 2007).

Occasional sightings, stranding, and death incidents have attracted the media which has extended to the public; hence increasing the awareness of their presence in the state. Irrawaddy dolphins are mostly abundant in Rajang River as compared to the other river tributaries in Sarawak. (Beasley & Jefferson 1997; Beasley, 1998; Jaaman *et al*., 1999; 2001; Jaaman, 2000; 2001; Jaaman & Lah-Anyi, 2002). There are reasons for concern about the population ecology of the Irrawaddy dolphins in this river system. Their habitats overlap with areas of intensive human activities which created threats to their survival, such as getting accidentally trapped in fishing gears, declining fish resources and losing or degrading of aquatic habitats (personal observation, Bali, 2009). When managing threats and impacts, it is vital to have robust scientific understanding of a species' ecology, its distinctive characteristics, population status, and the dynamic processes that affect population size and distribution (Slooten & Lad, 1991; Primack, 2002). Primack (2002) stressed that conservation biologist need to answer question about species' environment, distribution, biotic interaction, systematic and morphology, physiology and life history, behavior, and genetic, to implement effective population-level conservation efforts. Thus, the main goal of this study was to provide scientific information to be used as a basis to plan conservation management strategies for Irrawaddy dolphins in the Rajang River system. The objectives of the study were to determine the spatial distribution, abundance and density patterns of Irrawaddy dolphins in Rajang River.

METHODOLOGY

The study was carried out in Rajang River or locally known as Batang Rajang, which is located in Sarawak, West Malaysia (Figure 1). The Batang Rajang originates from the Iran Mountains in Kalimantan, Indonesia and flows approximately 760 km through Kapit, Sibu, Sarikei and Mukah divisions. This river flows through the central region of Sarawak into Telukan Datu (Datu Bay) of the South China Sea ended with wide estuary systems.

The study was conducted in Rajang River from April 2009 to October 2010 (one and a half year), where samplings were carried out in April 2009, August 2009, October 2009, April 2010, September 2010 and October 2010. This study is only covers the areas where Irrawaddy dolphins have been sighted and reported. The study area used the width of the river as the strip width for each transects within the identified dolphin distribution areas starting from the river mouth until the upper river where Irrawaddy dolphins have been reported and considering the distance a boat could travel during the lowest neap tide. The river system is divided into two segments: Kuala Rajang-Sarikei (lower segment) and Sarikei-Sibu in Batang Rajang (upper segment).

Data collection (dolphin's sighting and water parameter measurement) in each segment were obtained with two survey replicates in one-day sampling using a modified strip-transect survey, following Kreb (2002). The modification includes strip width which was calculated as a function of perpendicular sighting distance because this distance is not a function of detection probability but off time taken with the consideration of the dolphins' preferred distribution due to restrictions imposed by river width (Figure 2).

A boat measuring 18-20 m in length was used to carry out surveys during daylight hours (from 0600 to 1800 hours) in calm water conditions (Beaufort scale 0-3). (Figure 3). Survey was only conducted during neap tide to avoid any difficulty of traveling using a boat during the lowest tide. Within the riverine area, the boat travelled along the central part of the river (Figure 2). Through the surveys, the speed of the boat was maintained at 12 kmh^{-1}. Aside from the boat crew, the survey team consisted of at least three observers searching for dolphins, one member scanned (from 270º to 90º in

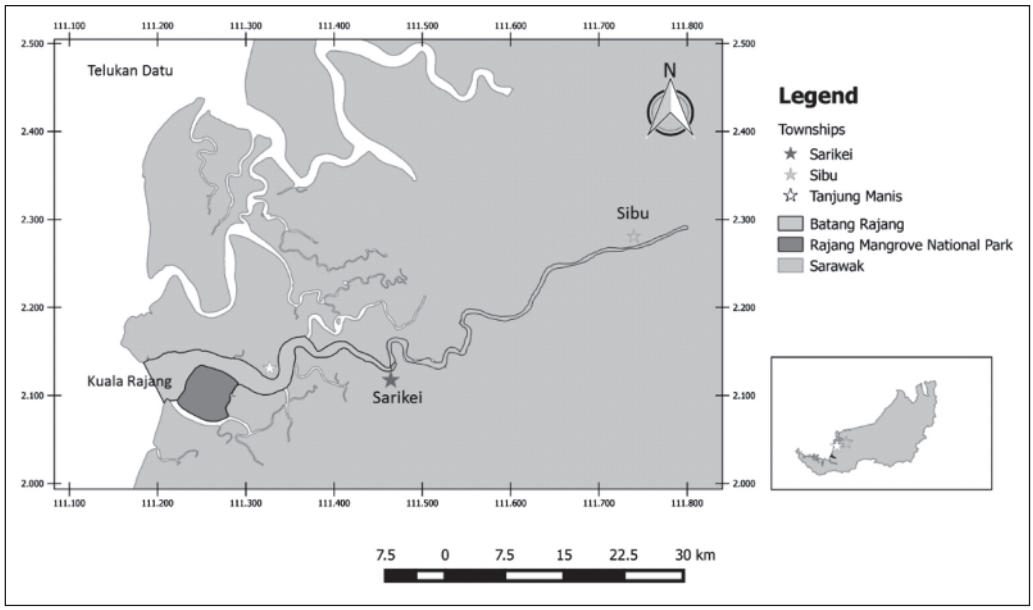

Fig. 1. The map of Rajang river system in Sarawak showing study site (in the box square).

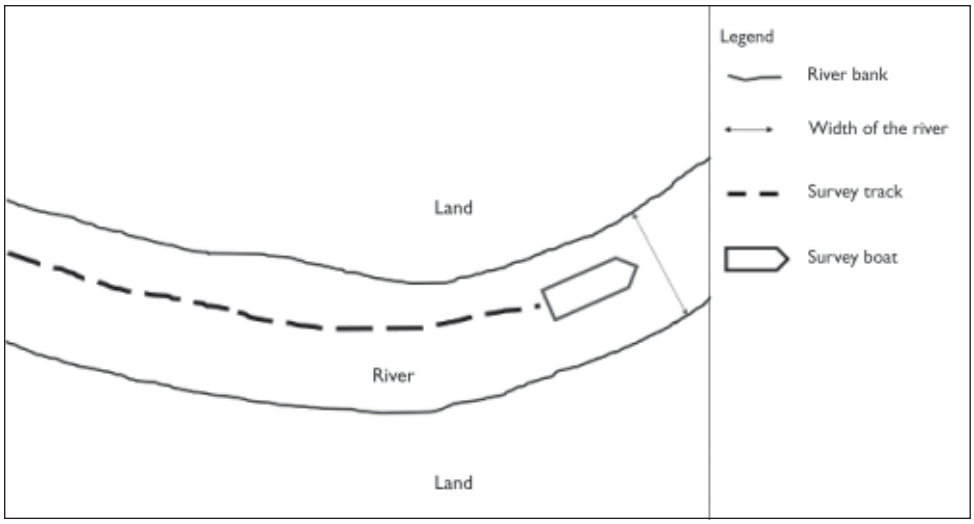

Fig. 2. Diagram showing the survey boat travelling along the central part Rajang river.

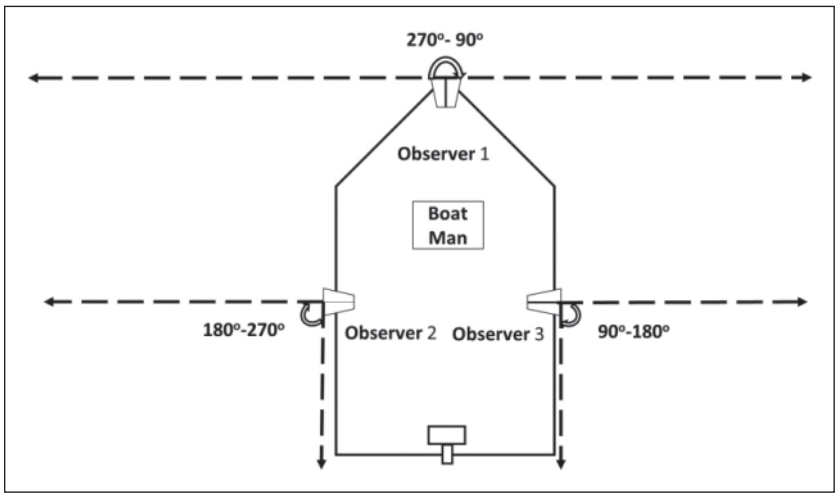

Fig. 3. Diagram showing the positions of the observers on the survey boat.

relation to bow as 0º) continuously with NIKON 7 X 50 magnifying marine grade binocular with built-in compass and reticules (primary observers), while the other two observers used their naked eyes and occasionally binocular scans on each side of the vessel (90º to 180º and 180º to 270º in relation to bow as 0º).

A dolphin group is considered as individuals with relatively close spatial cohesion (Smolker *et al.,* 1992), with each member within 100 m of any other member. When a dolphin or group of dolphins is sighted, the survey effort was terminated and all observers and boat crew were alerted to the location of the sighting. The following information was immediately recorded: time, the location of the boat and the distance of the animals from the boat. Dolphin position is recorded in one side of the transect line that occupies 25% of half the river width. Each side of the transect line, the area between centre and shore occupies 50% or, approximately half of the river width. The shore area is defined as an area with 25% on each side of the transect line nearest to the river bank. Three major types of information were aimed and collected when a sighting is made: (i) estimated group size (high, best, and low), (ii) sighting location and (iii) water physical parameters.

The locations of survey tracks were recorded using hand-held global positioning system (GPS) GARMIN GPSmap76CSx at 10-minutes interval. The occurrence of any dolphin is recorded when an animal or a group of the animal were sighted along the river and is classified as one ("1"). The dolphins were tail gated until they disappeared and any additional data was immediately recorded. One "sighting" is equal to an observation with 10-minutes interval. If dolphins were not found during the 10-minutes interval, the sighting was recorded as zero ("0").

Survey effort is a total number of "on effort" survey conducted in a unit of time (hour). Mean survey effort is derived from a total time of survey effort over number of survey replicates conducted:

$$\text{Mean survey efforts} = \frac{\text{Total time of survey efforts}}{\text{Number of survey replicates}}$$

Raw data on daily survey effort (classification of sighting, sighting location, estimated group size) is stored in a Microsoft Excel program, and a distribution map is generated using GPS points (coordinate of latitude and longitude), then, transferred into GARMIN Basecamp which is plotted using the OziExplorer and Google Earth map software. Legends were used to represent the number of animal sighted in each sighting based on the "best count" and then classified using three categories.

Probability of sighting or detection for different sizes of animals/groups in each sighting is based on these categories and was calculated using the R statistical software v. 2.1.5 with the linear modelling function. Class A represents one to three individuals; Class B represents four to six individuals and Class C represents more than six animals sighted.

All calculations for probability of sighting, *p* (detection) or encounter rate were made using sighting frequencies. Sighting frequency will be recorded as one (1) if there was sighting(s) observed during a 10-minutes interval of survey effort. In the event of no sighting within the 10-minutes interval period, frequency was recorded as zero (0). R statistical software v. 2.1.5 with linear regression modelling function were used to calculate the probability of sighting, *p* (detection) and confident intervals, CI (lower to upper value) of Irrawaddy dolphins in each river segment.

The temporal probability of sightings of Irrawaddy dolphins between different seasons in the lower and upper river segments was compared using the Cochron's Q tests (IBM SPSS v.20 software).

Density and abundance of the animals in each segment of the rivers were calculated using the formula according to Kreb (2002):

$$Ri = \underline{g.n}$$

$$Di = \frac{Ri}{Wi}$$

$$N = \Sigma\,(Di \,.\, Ai)$$

$$SD(Ri) = \frac{[\,\Sigma\,(ri - Ri)2\,]1/2}{(xj - 1)}$$

$$CV = \frac{SD.100}{Ri}$$

Where g=mean group size, Ri=mean sighting rate per river segment, rj=mean sighting rate per transect, i=river segment, j=transect, n=number of sightings, L=length of transect completed, D=mean dolphin density, W=mean strip width, N=total abundance within survey area, A=Total transect area, SD=standard deviation, Xj=number of transects completed, CV=coefficient of variation.

All spatial hypothesis tests were performed using IBM SPSS v.20 software. Spatial occurrence of Irrawaddy dolphins between the river segments in each river system was analysed using non-parametric independent sample McNemar test. Spatial density and abundance of animals between the river segments were analysed using non-parametric independent Mann-Whitney test.

RESULTS

A total of nine survey replicates with 40.2 hours survey efforts were conducted at the Kuala Rajang-Sarikei segment in Rajang River. The mean survey effort for each survey replicate is 4.5 ± 0.61 hours. In the Sarikei-Sibu segment, a total of 31 hours survey effort was recorded in seven survey replicates with the mean of 4.4 ± 0.79 hours survey effort per survey.

Irrawaddy dolphins were found in both segments of Rajang River but they were not distributed evenly. Higher mean sighting frequency, mean number of individual sighted per survey and sighting rate of Irrawaddy dolphins were recorded at the lower river segment of Rajang River (Table 1). Number of individuals recorded in each sighting was highly statistically significant difference between the river segments with higher number individual per sighting recorded at the lower river compared to upper river segment (Mann-Whitney: U=17,487.0, n=240 and 187, p=0.000).

The mean frequency of sightings recorded per survey in Kuala Rajang-Sarikei segment was 6.9 ± 3.90 with a mean of 22.2 ± 14.13 individual sighted and sighting rate of 1.5 sightings per hour survey effort or 5.0 animals sighted per hour survey effort. In the Sarikei-Sibu segment, the mean sighting frequency of Irrawaddy dolphins was 1.0 ± 1.15 with a mean of 1.3 ± 1.80 individual sighted per survey and sighting rate of 0.23 sighting per hour survey effort or 0.29 animals sighted per hour survey effort. The farthest upriver sightings of the Irrawaddy dolphins recorded were in Rajang River. The area is within the Sarikei-Sibu river segment at N15' 15.4"; E 111º 40' 18.0" and is located 86 km from the river mouth of Rajang River. Mean probability of sightings, *p* (detection) with 97.5% confident interval (CI) for Irrawaddy dolphins in 10 minutes survey effort for each segment in Rajang River are shown Table 2.

Higher probability of sighting of Irrawaddy dolphins were recorded at the lower part of Batang Rajang. Probability of sighting was statistically significant between the Batang Rajang-Sarikei and Sarikei-Sibu segment (McNemar: =38.726, df=1, p=0.000). In the Kuala Rajang-Sarikei segment of Batang Rajang, the mean probability of segment was 0.25 or a sighting recorded in every 40 minutes survey efforts with constant survey speed of 12 kmh^{-1}. The probability, *p* (detection) of sighting in the Sarikei-Sibu river segment was 0.04. The mean density of animals per square km (km^{-2}) and the best mean estimate for number of Irrawaddy dolphins or abundance (N) for each segment in Batang Rajang with confident intervals (CI) are shown in Table 3. There is no statistically different on density (Mann-Whitney: U=28.0, n=9 and 7, p=0.758) and abundance (Mann-Whitney: U=24.0, n=9 and 7, p=0.470) of animals between the river segments.

Table 1. Mean sightings frequency, mean individual sighted, sighting rates (number of sightings per hour survey effort and number of individual recorded per hour survey effort) of Irrawaddy dolphin recorded in each segment of Rajang River

River	River segment	
Parameters	Lower segment (Kuala Rajang-Sarikei)	Upper segment (Sarikei-Sibu)
Mean sightings frequency per survey (± SD per survey)	6.8 ± 3.90	1.0 ± 1.15
Mean individuals sighted per survey	22.2 ± 14.13	1.3 ± 1.80
Sighting rate (Number of sightings per hour survey effort)	1.5	0.2
Sighting rate (Number of individual recorded per hour survey effort)	5.0	0.3

Table 2. Mean probability of sightings, *p* (detection) with upper and lower values of confident interval for each segment in Rajang River

Parameters	River segment	
	Lower segment (Kuala Rajang-Sarikei)	Upper segment (Sarikei-Sibu)
p (detection)	0.35	0.04
Lower value	0.15	0.01
Upper value	0.35	0.06

Table 3. The density and abundance of Irrawaddy dolphins for each segment with lower and upper values of confident interval in each segment of Rajang River

Segment	Density, D (animal per km^2)			Abundance, N (individual)		
	Mean	Lower CI	Upper CI	Mean	Lower CI	Upper CI
Kuala Rajang-Sarikei	0.20	0.08	0.33	12	5	18
Sarikei-Sibu	0.10	0.00	0.23	2	0	6

DISCUSSION

Data collections were accumulated for duration of 18 months (April 2009 – October 2010) with samplings that were carried out in April, August, and October 2009, then again in April, September and October 2010. A few efforts to conduct survey during the Northeast monsoon season or wet season (November – March) were abandoned due to bad weather (heavy rain, strong wind, and large waves). Information on distribution, occurrence, density and abundance of Irrawaddy dolphins and their associations with water parameters during the wet seasons for both river systems were not available. The constraints encountered during the study included limited observation ranges especially during hazy conditions during dry seasons, as well as the detection and counting of the animals by the observers can only be made when the animals are at the surface during travelling, socializing, and feeding. The farthest upriver sighting of Irrawaddy dolphins was in Rajang River located 86 km (N 2º 15' 25.4"; E 111º 40' 18.0") from the respective river mouths. This is the first formal report of the farthest location of Irrawaddy dolphins in Malaysian river systems so far, although there were some local people who claimed that the Irrawaddy dolphins were sighted in a river flowing enroute Kapit town and Kuala Baleh in Batang Rajang, some 300 km from the river mouth. However, there was no sighting of Irrawaddy dolphin recorded from Sibu up to Kapit during the river boat survey conducted by the Sarawak Forestry Corporation in April 2014. Their occurrences in Kapit and beyond are possible because there were some records documented by many researchers in other countries of Asia region. In the Meghna River, Bangladesh, Irrawaddy dolphins were recorded more than 60 km from the river mouth (Smith *et al*., 2005). In Ayeryarwady River, Myanmar, Irrawaddy dolphins have been recorded 1,300 km upstream (Anderson, 1879; Leatherwood *et al*., 1984; Smith *et al*., 1997b; Thein, 1977; Arnold, 2002). The subpopulation of Irrawaddy dolphins in the Mahakam River of East Kalimantan, Indonesia, were sighted in the main stream of the river from 180 km above its mouth to 600 km upstream (Kreb, 1999). In the Mekong River (Vietnam, Cambodia, and Laos) Irrawaddy dolphins can be found 690 km upstream (Arnold, 2002).

The sighting rate of Irrawaddy dolphins at the lower river segment was higher as compared to the upper river segment in both river systems. Higher probability of sighting for Irrawaddy dolphins was also recorded at the lower river segment in both river systems. The same pattern was also recorded in the Mahakam River, East Kalimantan, Indonesia. According to Kreb *et al.* (2007), statistical significant differences have been recorded among the encounter rates of dolphins for 8-40 km segments on the river mainstream and tributaries (^{2}=35.91, df=7, p=0.01).

Many researchers in South Asian and Southeast Asian have the same findings on Irrawaddy dolphins' habitat in their respective countries. The species inhabit areas influenced by freshwater output; in India (Dhandapani, 1992), Bangladesh (IUCN, 2000; Smith *et al*., 2005; 2006; Smith &Tun, 2008), Myanmar (Smith *et al*., 1997b), Cambodia (Beasley *et al*., 2002a; Beasley *et al*., 2007), Malaysia (Kamaruzzan, 2012; Teoh *et al*., 2013), Thailand (Chantrapornsyl *et al*., 1999; Stacey & Leatherwood, 1997) Myanmar (Smith *et al*., 1997a; Smith & Beasley, 2004), Cambodia (Beasley *et al*., 2007), Indonesia (Rudolp *et al*., 1997; Tas'an & Leatherwood, 1984; Tas'an *et al*., 1980; Kreb & Budiono, 2005; Kreb *et al*., 2007). The Irrawaddy dolphins also inhabit two partially isolated freshwater/brackish lake or lagoons in India (Dhandapani, 1992; Pattnaik *et al*., 2007; Sutaria, 2009), Thailand (Kittiwattanawong & Chantrapornsyl, 2007), the Mekong river in Laos and Cambodia (Baird & Mounsouphom, 1994; Beasley *et al*., 2007; Perrin *et al*., 1996) and Indonesia (Tas'an & Leatherwood, 1984). There are some subpopulation restricted to freshwater like in the Ayeryarwady river in Myanmar (Anderson, 1871; 1879; Thien, 1977), the Mahakam River in Indonesia (Tas'an & Leatherwood, 1984) and the Mekong River in Laos, Cambodia and Vietnam (Smith *et al*., 1997b; Beasley *et al*., 2002b). In the Philippines, Irrawaddy dolphin's subpopulation is confined to a small are in the inner of Malampaya Sound and appear to be geographically isolated

from other sub-populations (Smith & Beasley, 2004).

Researchers stated that many factors that have contributed to the spatial and temporal occurrence and distribution of Irrawaddy dolphins at certain sites in Asia. Daily movements of Irrawaddy dolphins were observed in Indonesia and Laos (Stacey & Leatherwood, 1997). According to Stacey and Leatherwood (1997), the occurrence of Irrawaddy dolphins in Thailand is influenced by the time in a day. Seasonal changes in occurrence of Irrawaddy dolphins were also observed in Chilika Lagoon (Dhandapani, 1992).

The mean density and abundance values of Irrawaddy dolphins were higher at the lower river segment. The abundance estimates for Irrawaddy dolphins at Kuala Rajang-Sarikei segment (N=12, 97.5% CI=5–18; CV=64.82%), Sarikei-Sibu (N=2, 97.5% CI=0–6; CV=76%), were much lower as compared to another subpopulation in Asia including the Kuching Bay (N=145, 95% CI=87–255; CV=31%) (Minton *et al*., 2013).

Density and abundance of Irrawaddy dolphins in Batang Rajang recorded in this study might not reflect the 'real' population estimate in the particular river system. Geographically, the Rajang river is located at the middle of unique and open Rajang delta which is mostly covered by mangrove forests. Each main river systems within the Rajang delta such as Paloh, Belawai, Rajang, Selalang, Nyabor, and Krian rivers are connected to each other by mangrove channels and creeks. There is a high possibility that the Irrawaddy is moving in and out from one main river system to another by using the mangrove creeks and channels or via the sea. The occurrence of Irrawaddy dolphins in other river systems within the Rajang Delta and its coastal waters have been reported (Bali & Tisen, 2012). The population estimates of Irrawaddy dolphins in the Rajang River system might be much higher if other research methods such as photo-identification or hydro acoustic survey had been used. Population estimates of Irrawaddy dolphins in Kuching Bay were derived using a mark-recapture technique based on photo-identification which gave much higher population estimate as compared to the line transect estimate (Minton *et al*., 2013). In Cowie Bay, Sabah, Teoh *et al.* (2013) reported that mark-recapture technique had produced a higher population estimate as compared to using DISTANCE samplings.

Statistical rigorous abundance estimates of Irrawaddy dolphins are available for only a few portions of the Asian region: 77 (CV=27.4%) in the Malampaya Sound, Philippines (Smith *et al*., 2005); at least 125 (95% CI=114–154) in the Mekong river (Beasley *et al*., 2007); 58–72 in Ayeryarwady river, Myanmar (Smith *et al*., 2005); 5,383 (CV=40%) in the coastal water of Bangladesh (Smith *et al*., 2005); and 451 (CV=9.6%) in the Sundarbans mangrove forests of Bangladesh (Smith *et al*., 2006). In the Mahakam river, East Kalimantan, Indonesia, the best estimates of total population size of Irrawaddy dolphins varied between 67 and 170 dolphins (CV=10%; CL=59–79), based on direct count and Petersen mark-recapture analyses of photo identification, respectively (Kreb *et al*., 2007).

Certain researchers have reported the connection between the pattern of Irrawaddy dolphins' abundance and food availability. Feeding activities of Irrawaddy dolphins in the Mekong River basin may be heavily influenced by the seasonal migration of fish species (Stacey & Leatherwood, 1997). Tas'an and Leatherwood (1984) observed the Irrawaddy dolphins travelled from the Semayang Lake to Mahakam River in the early morning to feed and reverse their movement in the evening. There was significant decrease in sightings from dawn to dusk over a month observations at a deep pool in Mekong River (Stacey, 1996). Near Hang Sadam in Laos, Irrawaddy dolphins can be found year-round, but more sightings were recorded during the dry season (Baird & Mounsouphom, 1994; Stacey, 1996).

CONCLUSIONS

This study has contributed to the understanding of spatial and temporal distributions of Irrawaddy dolphins in each of the river segments Rajang river. The management authorities should cooperate with local and international institutions of higher learnings (universities) to conduct periodically monitoring on population trends and threats, extensive research on the ecology and biology of the Irrawaddy dolphin populations in the Rajang river. Data from the monitoring and studies provided should be assessed to ensure that the information can be used for the management and conservation of the species. The newly identified high conservation value areas or 'hot spots' in the Rajang river is recommended for eco-tourism development like the Salak-Santubong river mouth in Kuching. The establishment of new dolphin watching sites will benefit the local communities, and possibly even be the catalyst for setting up a foundation for dolphin conservation. A fee could be charged to the public for dolphin watching in these areas and the income can be used to support tourism based community development and setting up co-management team between local stakeholders. Dolphin watching guidelines should be developed and endorsed by the higher authority in the tourism industry in the state to ensure it is strictly followed by all tour boat operators. This is to ensure that dolphin watching activities do not threaten the

protected animals. The species management authorities should work closely with the local authorities, Sarawak Tourism Board, Ministry of Tourism Sarawak and Ministry of Tourism and Culture Malaysia in promoting this new tourism product of those areas. Dolphin-watching at Rajang river can be developed as a tourism package together with the mangrove tour in Rajang Mangrove National Park. Research priorities needed to overcome knowledge gaps for the conservation and management of the species in Rajang River and the surrounding areas are recommended below:

- Diet, food resources stock and feeding behaviour of the Irrawaddy dolphins.
- Assessment of threats to the Irrawaddy dolphin populations.
- Home range of Irrawaddy dolphins using latest research technology and method such as radio telemetry, satellite tracking, photo-identification, and DNA studies.
- Population of Irrawaddy dolphins in the two-river system can be better estimated using other research methodology such as using hydro-acoustic survey, aerial survey and mark-recapture photo-identification techniques.

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