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Habitat use and behaviour of the Irrawaddy dolphin, *Orcaella brevirostris* and the Indo-Pacific finless porpoise, *Neophocaena phocaenoides* off the west coast of Penang Island, Malaysia

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Abstract. This study aimed to study the habitat preferences and daylight behaviour of the Irrawaddy dolphin (*Orcaella brevirostris*) and the Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) off the west coast of Penang Island, Malaysia. Between February 2019 and April 2021, 87 boat-based surveys were undertaken using predetermined survey routes. Species occurrence, behaviour, and habitat use were recorded. Irrawaddy dolphins (n = 52 sightings) were recorded with a mean group size of 3.6 (SE = 0.4) and finless porpoises (n = 35 sightings) with a mean group size of 2.5 (SE = 0.2). Both species were found between 0.4 km and 7.9 km from the shore. Encounter rate for Irrawaddy dolphins was 0.19 sightings per effort hour and 1.4 sightings per 100 km while for finless porpoises it was 0.13 sightings per effort hour and 0.9 sightings per 100 km. A higher coefficient of area use (AU> 1.5%) for Irrawaddy dolphins occurred at the estuarine areas off Sungai [=River] Pinang and Sungai Burung while higher coefficient of area use for finless porpoises was seen near Teluk [=Bay] Kampi and Sungai Pinang. In terms of activity budget, milling behaviour was the most recorded behaviour for both Irrawaddy dolphin and finless porpoise at 36.4% and 51.6% respectively. Resting behaviour for both the Irrawaddy dolphin and the finless porpoise was recorded for the first time off west Penang. The information obtained for habitat use and behaviour would contribute towards better management of Penang marine areas and conservation strategies for the Irrawaddy dolphin and the finless porpoise.

Key words. Penang Island, Irrawaddy dolphin, finless porpoise, habitat use, daylight behaviour

INTRODUCTION

In Southeast Asia, many marine mammals are found in nearshore waters which include habitats such as muddy and sandy beaches, mangrove swamps, and estuaries (Beasley et al., 2002; Dolar et al., 2002; Beasley, 2007; Kreb et al., 2020; de la Paz et al., 2020). Malaysia is home to 26 species of cetaceans as well as one sirenian, i.e., the dugong (*Dugong dugon*) (Ponnampalam, 2012, Minton et al., 2013; Teoh et al., 2013; Abdul-Patah et al., 2014; Hoffman et al., 2015; Rajamani et al., 2018; Kuit et al., 2019; Rodríguez-Vargas et al., 2019). The distribution of inshore cetaceans in Malaysia and the habitat characteristics of various species have been documented in Penang Island (Penang) (Rajamani et al., 2018; Rodríguez-Vargas et al., 2019), Langkawi (Kedah) (Ponnampalam, 2012), Matang (Perak) (Hoffman et al., 2015, Kuit et al., 2019), Cowie Bay and Kinabatangan (Sabah) (Teoh et al., 2013, Van Bressem et al., 2014), and Kuching Bay (Sarawak) (Minton et al., 2013). These various species include the Irrawaddy dolphin (*Orcaella brevirostris*) and the Indo-Pacific finless porpoise (*Neophocaena phocaenoides*; from here on referred to as the finless porpoise), which prefer habitats influenced by freshwater input (Stacey & Arnold, 1999; Dolar et al., 2002; Smith et al., 2006; Smith, 2009; Minton et al., 2011).

In Malaysia, Irrawaddy dolphin populations have generally been estimated to be small e.g., Cowie Bay, Sabah in 2010, with a population of 28 individuals (95% confidence limits, CL = 28–34) (Teoh et al., 2013), Kuching Bay, Sarawak, 149 individuals (95% CL = 151–360 with CV = 22.5%) (Minton et al., 2013), and Penang Island (32 to 52 individuals), as are other populations in its range. Irrawaddy dolphins have been classified as Endangered (EN) under the IUCN Red List of Threatened Species for coastal species but are Critically Endangered for river species and in the Malampaya Sound subpopulation in the Philippines (Smith & Beasley, 2004; Minton et al., 2017). The reduction in the population sizes of Irrawaddy dolphins has largely been due to threats such as gillnets that caused incidental mortality in small-scale fisheries (Kreb & Budiono, 2005; Smith, 2009). Habitat

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loss and degradation are also contributing factors leading to the Irrawaddy dolphins' population decline (Stacey & Leatherwood, 1997; Minton et al., 2017) in many freshwater areas in Southeast Asia, especially from existing and planned dams in large rivers (i.e the Mekong), as well as the declining freshwater flow, increased commercial vessel traffic, and water pollution in coastal estuarine habitats (Minton et al., 2017; Kreb et al., 2020).

Finless porpoises are even less studied in Malaysia. However, there was one study at Kuching Bay which focused on a population of finless porpoises estimated at 135 individuals (95% CL = 74–246 with CV: 31%) (Minton et al., 2013). In Penang finless porpoises were observed in waters off the west coast of Penang on 20 occasions (Rajamani et al., 2018). Under the IUCN Red List of Threatened Species criteria, the finless porpoise is listed as 'Vulnerable' due to human induced mortality caused by combination of fishing pressure (such as incidental entanglement in gill nets), coastal development and industrialisation, water pollution, and heavy vessel traffic (Reeves et al., 1997; Collins et al., 2005; Braulik et al., 2010). Sixteen strandings have been documented in western Penang and northern Penang from 2011 to 2013 with some stranded porpoises reported to be missing tail flukes, possibly due to entanglement in drift nets (Rajamani et al., 2018).

Both the Irrawaddy dolphin and finless porpoise are known to share the same habitats in west Penang. Habitat sharing was also observed in Irrawaddy dolphins and finless porpoises in Cowie Bay, Sabah, Malaysia (Kamaruzzan & Jaaman, 2013). However, it is unclear how both species overlap or interact with each other. It is critical to understand how they share resources across different niches, such as food niche (preferred and available foods), spatial niche (climatic and geographical factors that a species needs to survive), and behaviour niche (how a species interacts with others, such as foraging) (Raj, 2010). Habitat ranges of a species are often defined by the heterogeneity of resources and biological requirements of a species (Rosenzweig, 1981; de la Paz et al., 2020). This refers to resource-rich areas being unevenly distributed throughout a given habitat. Any wild animal population's home range must include a minimum availability of preferred habitats (key habitats), and it is likely to be greater when these habitat patches are smaller and more scattered. A preference in staying in a particular area for long periods can indicate that the area provides reliability of food resources, availability of mates, and protection from predators (Karczmarski et al., 2000; Parra et al., 2006; de la Paz et al., 2020).

Behavioural studies help us understand how dolphins use habitats based on the prevalence of certain behaviours seen in particular areas. For instance, if the predominant behaviour observed is feeding, then the habitat is very important for obtaining nutrition. Behaviours such as feeding, milling, socialising, and travelling, as well as surfacing reactions to boats, have been recorded for Irrawaddy dolphins (Kreb & Rahadi, 2004; Rodríguez-Vargas et al., 2019;), while very few behavioural studies have been carried out for the finless porpoise largely because of their elusive nature. They have been observed to show avoidance behaviour in the presence of boats (Jefferson & Hung, 2004; Nor Hashim & Jaaman, 2011; Morimura & Mori, 2019).

In this study, we documented the distribution of Irrawaddy dolphins and finless porpoises to study their behaviour in relation to habitat use. We have also attempted to explain how these two species share the same habitat for important behaviourial needs such as milling, feeding, resting, and socialising. As their distribution overlaps with intensive human activities, many factors may be influencing population size and distribution of these species and their interactions with each other.

MATERIAL AND METHODS

Study area. The Malaysian island of Penang (Fig. 1) has year-round high humidity (56–89%) with a mean annual precipitation rainfall of about 1600 mm and a relatively constant air temperature ranging between 23°C and 31°C throughout the year (Hii et al., 2016; Malaysian Meteorological Department, 2019a; Kh'ng et al., 2021; Weather Online, 2022). The island is approximately 293 km^2 in area and is located on the western seaboard of Peninsular Malaysia in the northern Malacca Strait (5°8′N to 5°35′N and 100°8′E to 100°32′E). The western coastline of Penang Island comprises of 14 km of mangrove coastline with a shallow, mesotidal estuarine habitat where freshwater comes from six different rivers, including the two largest rivers, Sungai Pinang and Sungai Burung (Fig. 1; see also Rosli & Yahya, 2013).

In this area, fisheries are a major activity where fishing gear such as drift nets are used inshore, whilst trawl nets and purse seines are used offshore (Rajamani et al., 2014). Some dolphin mortalities are caused by entanglement in drift nets (Rajamani et al., 2014). There are 363 fishermen in Teluk Bahang and 78 in Sungai Pinang that depend on small scale fisheries for income generation (Rajamani et al., 2014), suggesting high boat traffic in these areas. The current study covers an area from Teluk Kampi and Sungai Pinang in the north to Sungai Burung and Pulau[=Island] Betong in the south (refer to Fig. 2). It incorporates a larger area than a previous study in 2013 (80 km^2 to 104.4 km^2, Rodríguez-Vargas et al., 2019) and is part of a long–term research project. This study thus builds on existing knowledge and expands our understanding of cetacean occurrence, habitat use and behaviour in western Penang waters.

Data collection. Boat surveys were conducted from a small fibreglass boat (7.6 m in length) between 0730 to 1400 hrs for five days every month. Boat surveys were weather-dependent and conducted during this time as surveys later than this time frame usually encountered rough weather conditions. Since the area of survey was always at or above 0.5 m depth during the time of surveys, we conducted the

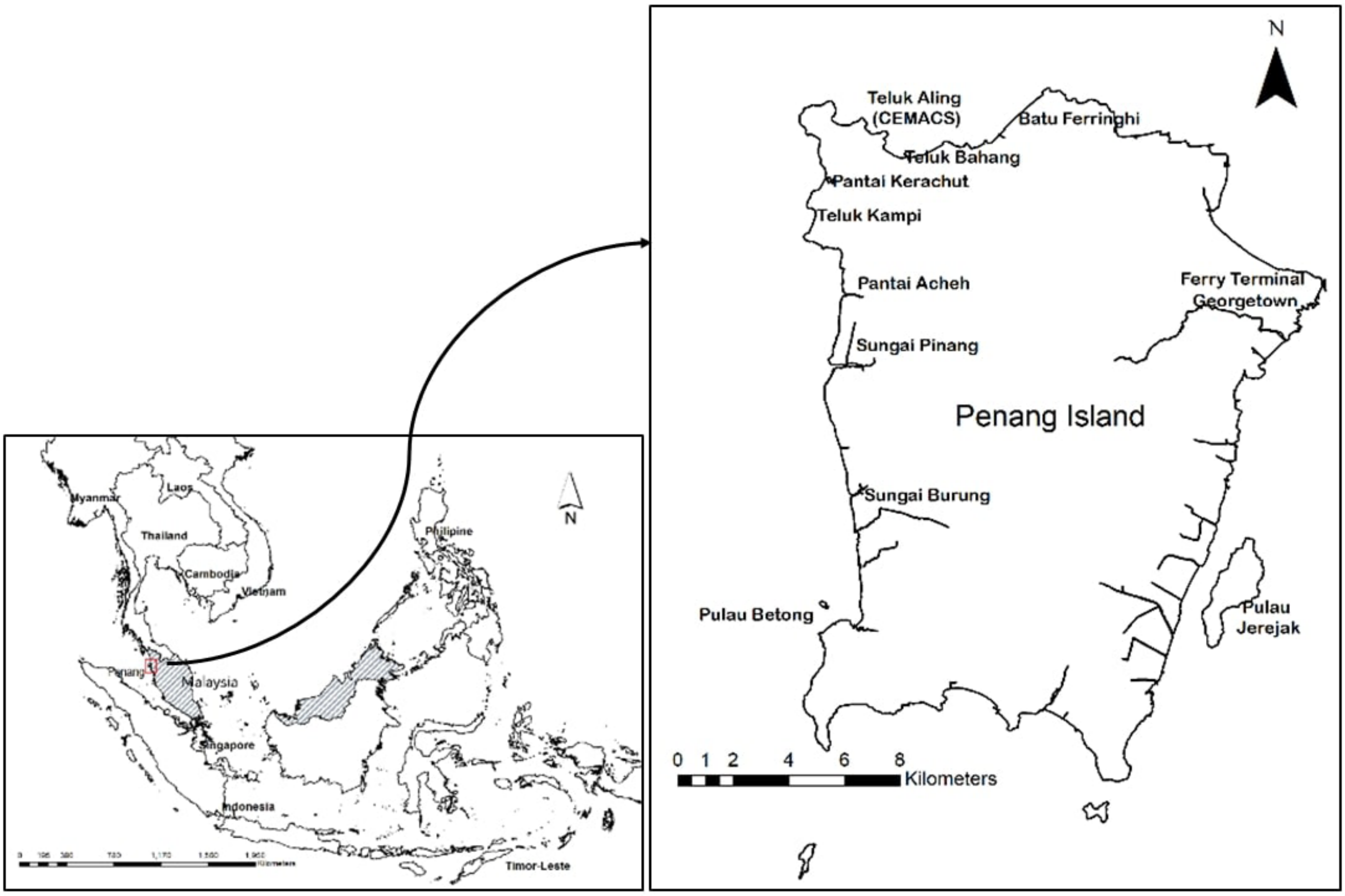


Fig. 1. Map of Penang Island in Southeast Asia.

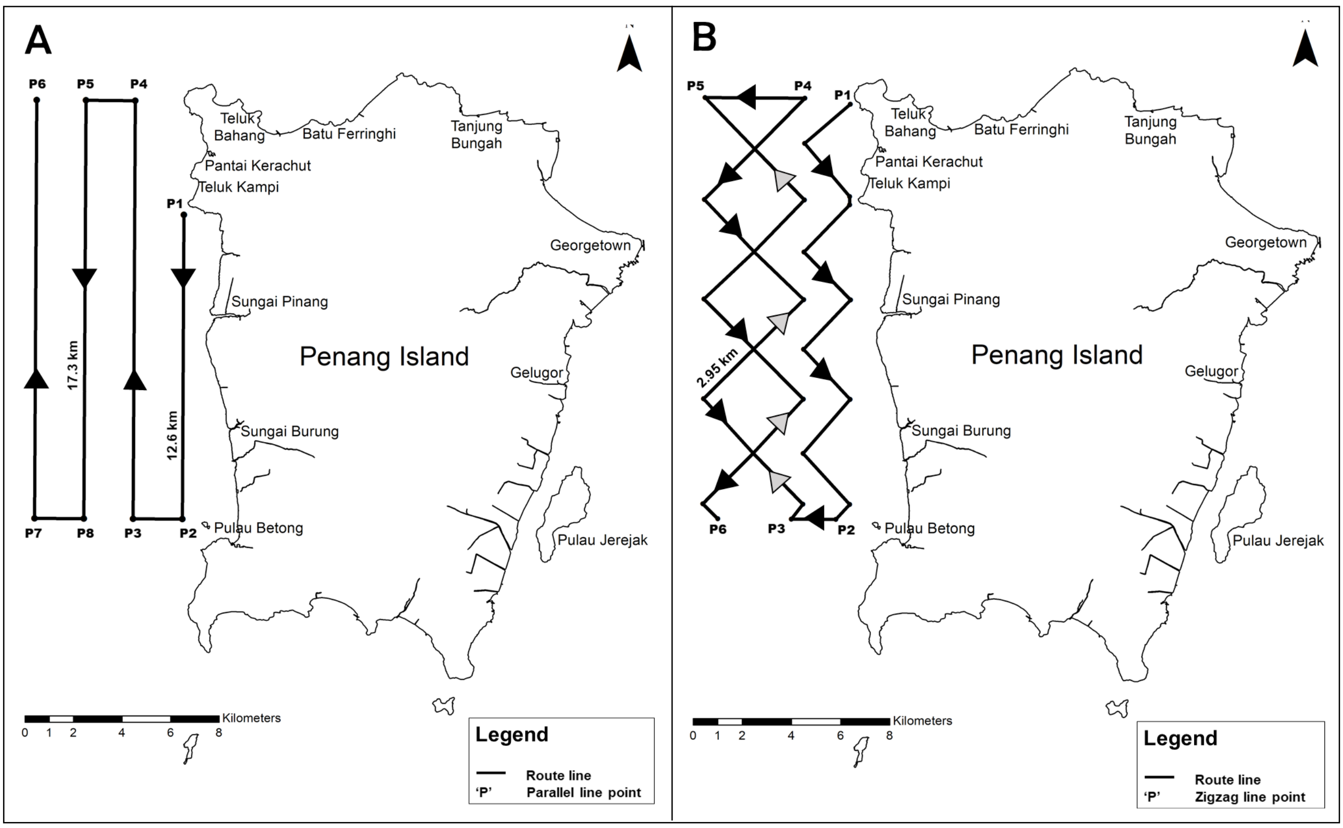


Fig. 2. Two survey routes where the research boat travelled, consisting of a parallel line route and a zig–zag route in west Penang

surveys at any time without considering the effects of neap and spring tide. The study area covered approximately 17.3 km × 6.0 km (103.8 km^2) and included water depths between 0.5 m and 29.5 m.

Two types of survey routes were used in the same study area which included a parallel line route which was 64.5 km long and a zig-zag route which was 71.4 km length. The first parallel-line transect (P1/P2) was approximately 12.6 km (see Fig. 2) followed by the next three transects (P3/P4, P5/P6 and P7/P8) of 17.3 km each. For the zig-zag transects, each transect was approximately 2.95 km. Distance between the transects was 2.0 km for the parallel line route.

One survey was considered to be completed when both the parallel line route and the zig-zag route were done. Both routes were used to improve observer sight ability to uniformly cover all the potential dolphin habitats within the survey area both along and across a depth gradient. These two survey pathways are an adaption of those done by Rodriguez-Vargas et al. (2019) who also conducted both block and zig-zag surveys, but on a smaller scale in west Penang. During the survey, two observers stood at the front of the boat, alternating shifts every 20 minutes checking for the presence of dolphins with the aid of binoculars. Both observers observed at an eye height of approximately 1.8 m above the water. At the start of each survey, effort status and environmental conditions, e.g., sea state, wave height, visibility, and glare, were recorded. These conditions were recorded every 20 minutes, or when dolphins or porpoises were encountered. In addition, the position of the vessel was logged, using a GPS (Garmin Montana 360), and sea surface temperature (SST) (°C), water depth (m), salinity (psu) and turbidity (NTU) recorded every 20 minutes (YSI Professional Plus Quatro, HawkEye Depth Sounder and Hach 2100P Turbidimeter). These data were collected to record the values of the environmental parameters during observations of both Irrawaddy dolphins and/or finless porpoises. Surveys were conducted at sea conditions of Beaufort ≤ 3.

A cetacean sighting is registered when a dolphin or porpoise is first sighted and a sighting is considered to have finished when the cetacean is no longer seen 15 minutes after its last surface (Rodríguez-Vargas et al., 2019). For each dolphin sighting, information on date, observer, group size (low, best and high estimate), and group age composition (adult, juvenile, calf) were recorded. The low estimate is the lowest possible estimate of group size, the best estimate is the what the observer believes to be the correct estimate, and the high estimate is the highest possible estimate for the group size. The high and low estimate is done to help reflect the accuracy of the best estimate of the number of individuals during the sighting (Sinha & Sharma, 2003). Adult size is usually around 2.1 to 2.2 m in length for females and up to 2.8 m for males while juveniles were defined as those which were roughly 2 m in length and swim independently from larger dolphins (Parra et al., 2006; Smith, 2009). A calf was defined as an animal that was less than 2/3 the length of an adult (Parra et al., 2006).

Daylight behaviour of the cetaceans was recorded while they were at the surface of the water. The behaviour was recorded as long as the animals were seen, and the observers waited for another 15 minutes after the animal was not visible. Behaviours such as feeding, milling, avoidance behaviour, playing and socialising, resting and travelling were distinguished with reference to Shane et al. (1986), Karczmarski et al. (1999), Parra (2006), and Rodríguez-Vargas et al. (2019) (Appendix 1). A group was defined as any group of cetaceans closely engaged in the same activity and moving in the same direction (Garaffo et al., 2007). Avoidance behaviour was defined as seeing the cetacean surface once or twice, but was not seen again after waiting for a duration of 15 minutes. Undetermined behaviour was defined as behaviour that cannot be categorised into known behaviours, i.e., feeding, playing and socialising, milling, resting, avoidance behaviour, and travelling.

During each encounter, the activity budget was recorded every two minutes and the duration of each behaviour was calculated. This is known as instantaneous scan sampling (Altman, 1974; Neumann, 2001), where the focal group was scanned every two minutes until the encounter ended. This method allowed for the determination of changing behaviours and identification of the predominant behaviour of each group (Neumann, 2001), which is the activity in which most of the animals were engaged (Mann, 1999). While a sighting may have more than one particular behaviour, any behaviour which was observed more than 50% of the entire duration of the sighting was considered predominant behaviour. In addition, when Irrawaddy dolphins were encountered, images were taken of the dorsal fin region (Nikon DSLR D3200; and zoom lens 70–300mm) so that individuals within each group could be recorded. To reduce the potential impact of the research boat on the behaviour, approaches were made from the side and in the same direction and at the same speed of animals encountered, at a distance of approximately 10 m from the animals (modified from Parra & Corkeron, 2001).

Coefficient of Area Use. In assessing the time spent by a cetacean within a quadrat (intensity of area use) per total dolphin observation time during a particular day, Coefficient of Area Use (AU) was used within 74 quadrats, each of size 1.5 km × 1.5 km in area (modified from Garaffo et al., 2007). The AU was calculated using the formula:

$$AU = (D/T) * 100$$

where D = cumulative time (min) following dolphins in a particular quadrat,

and T = total time (min) following dolphins during the sampling period

We calculated the total time for the entire sampling period and not each year as in Garaffo et al. (2007), since we did not sample for the entire year. As there were some quadrats that had more than one dolphin sighting, the time spent by the cetaceans and total observation time within the quadrat were summed respectively. The value of AU was transformed into a percentage and these values were divided into three

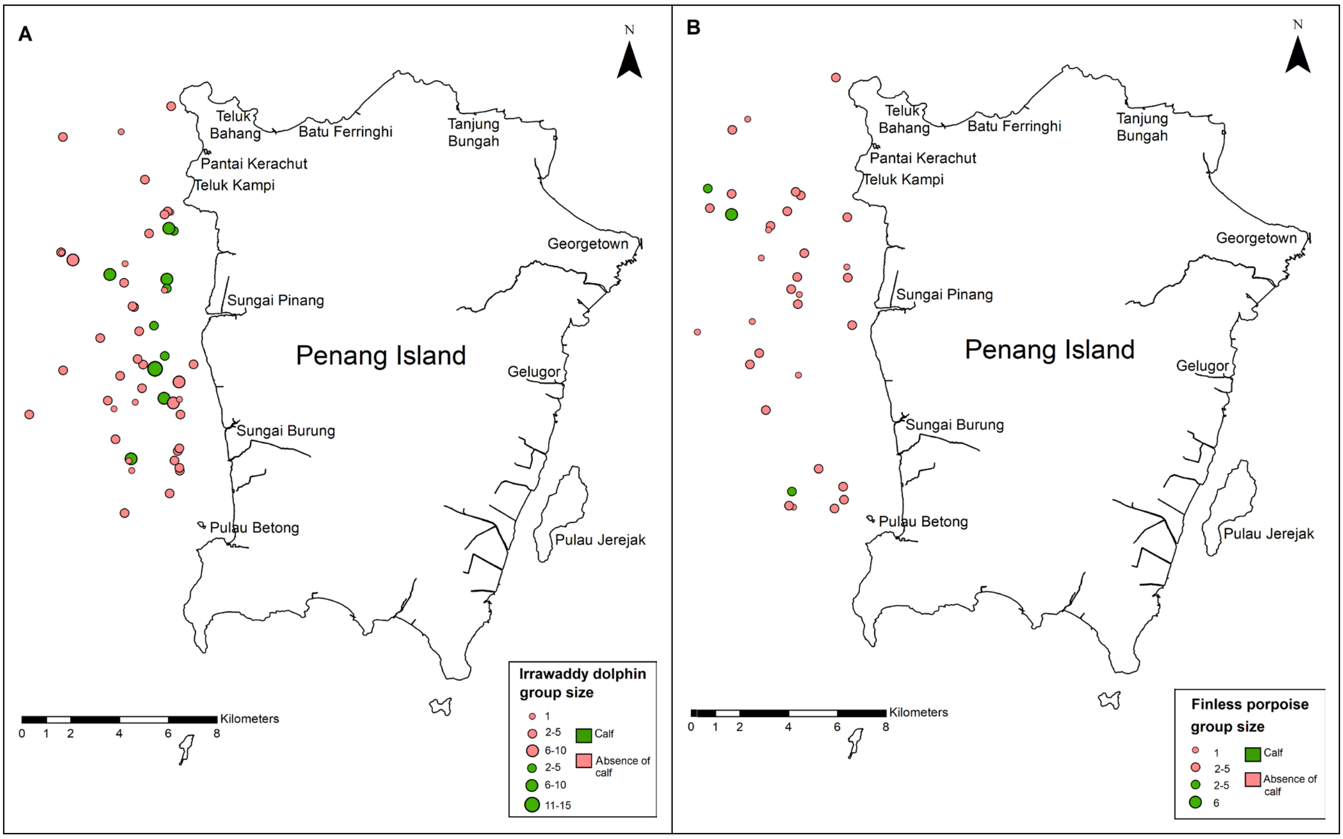


Fig. 3. Cetacean encounters in the western coastal waters of Penang Island (February 2019–April 2021) during on-effort surveys. A, Irrawaddy dolphin group size; and B, finless porpoise group size.

categories of use: low use (0% < AU < 0.74%), medium use (0.75% < AU < 1.4%), and intense use (AU > 1.5%). AU indicates the intensity of use of each specific cell and represents the proportion of time that dolphins/porpoises spend in a particular cell (Garaffo et al., 2007).

Activity Index. Dolphin behaviour was quantified using an Activity Index (AI) within the survey region (Karczmarski et al., 2000). This index (ranging from 0.0 to 1.0) was used to represent the duration during which the animals were engaging in a certain activity (behaviour) within a sector, as a proportion of the total time spent in that sector by the dolphins during each day. Activity Index was quantified by the formula:

$$AI = B/S,$$

where B = the time (min) animals were engaged in a particular activity (behaviour) within a quadrat,

and S = the time (min) spent by dolphins in any one quadrat.

Analysis. Sighting details such as date, observer, species, latitude and longitude, group size, numbers of females, their calves and juveniles, environmental parameters, as well as sea conditions and behavioural information were entered into a Microsoft Excel spreadsheet. Statistical Package for the Social Sciences (SPSS) version 26.0 was used to determine the mean, the standard error, and the range values (maximum and minimum values) of animal group size and environmental parameters. The Pearson Chi-squared test was used to determine whether monsoonal seasons during the year affected the number of sightings of cetaceans for the year of 2019. Cetacean distributions, predominant behaviour and environmental parameter gradients were mapped using ArcMap software (Version 10.7). Multivariate analysis of AI per behaviour and section was conducted using RStudio version 1.4 (using Non-metric Multidimensional Scaling (nMDS)), to understand the relationship between the amount of time spent doing an activity (activity index) within a section. Only sections that contained AI data were considered for this nMDS analysis (R Core Team, 2022; RStudio Team, 2022). Quadrats were divided into sections as shown in Table 5.

RESULTS

Cetacean distribution. A total of 39 surveys were conducted over 87 days, from 18 February 2019 to 29 April 2021. (Data collected on finless porpoises in 2019 was included from Rajamani et al., in press, to provide a comprehensive dataset covering 2019 to 2021). A total of 280.4 hours of survey effort was conducted covering a cumulative distance of 3,746 km (refer to Table 2). There were 101 sightings comprising three species: Irrawaddy dolphin (n=52), Indo-Pacific finless porpoise (n=35) (Fig. 3) and Indo-Pacific humpback dolphin (n=1), while several cetaceans could not be identified (n=10). Irrawaddy dolphins were recorded in 23 out of 39 surveys (59.0%) and finless porpoises were recorded in 19 out of 39 surveys (48.7%).

Table 1. Encounter rate and sighting rate for Irrawaddy dolphin and finless porpoise.

	Encounter rate (sighting per hour)	**Encounter rate (sighting per 100 km)**	**Sighting rate (sighting per day)**
Irrawaddy dolphin	0.19	1.4	0.60
Finless porpoise	0.13	0.9	0.43

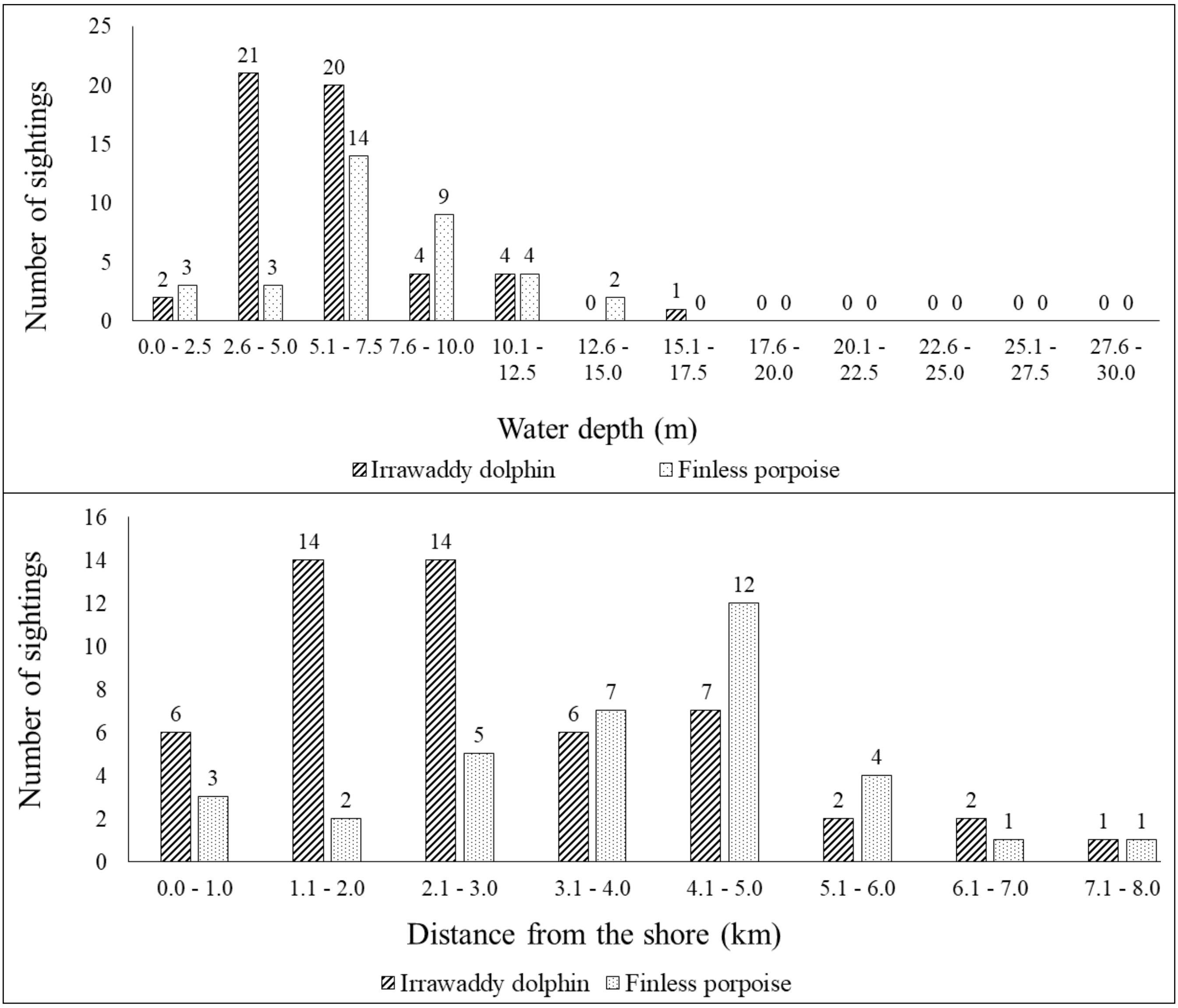


Fig. 4. Comparison of Irrawaddy dolphin and finless porpoise sightings across distance from the shore (km) and depth of water (m) in west Penang Island, Malaysia.

Generally, sightings of the Irrawaddy dolphin were at the inshore estuarine areas of Sungai Pinang, Sungai Burung and Pulau Betong (Fig. 3). In contrast, finless porpoises appeared to be concentrated between Teluk Kampi, Pantai [=Beach] Acheh and Sungai Pinang (Fig. 3). The encounter rate for the Irrawaddy dolphin was 0.19 per hour or 1.4 sightings per 100 km (Table 1). Sighting rate (sightings per day) was 0.60 per day. The encounter rate for the finless porpoise was 0.13 per hour or 0.9 sightings per 100 km (Table 1). Sighting rate (sightings per day) was 0.43 per day.

Group size and social structure. The majority of observations (68 out of 87 sightings) involved group sizes of more than one individual in both species (Appendix 2), of which there were 42 sightings of the Irrawaddy dolphin and 26 sightings of the finless porpoise. There were ten Irrawaddy dolphin sightings and nine finless porpoise sightings where the group size was one.

The mean group size of the Irrawaddy dolphin was 3.6 ± 0.4 SE with a range from 1–15 individuals. Seven juvenile

Table 2. Months, dates, distance and hours travelled on effort in 2019 and 2020.

Year	Month	Date of survey	Distance travelled on effort (km)	Effort hours (h)
2019	February	18, 19 and 20	96	11.4
	April	12, 15, 16, 17 and 18	230	20.6
	May	13, 14, 15 and 16	182	18.8
	June	24, 25, 26, 27 and 28	239	19.2
	July	19, 22, 23, 24 and 25	219	21.5
	August	20, 26 and 27	119	6.2
	September	12, 13 and 18	189	10.6
	November	13, 15, 18 and 19	251	12.8
	December	4, 12, 13 and 15	242	10.9
2020	January	29, 30 and 31	113	9.3
	February	1, 24 and 25	116	7.7
	March	16 and 17	143	10.5
	June	22, 23, 24, 25 and 26	192	16.9
	July	16, 17, 20, 21 and 22	184	15.5
	September	23, 25, 28, 29 and 30	147	14.3
	October	19, 20, 21 and 22	135	7.4
	November	21, 22, 24, 25 and 26	183	12.9
2021	January	25, 26, 27 and 28	167	14.0
	February	22, 23, 24, 25, 26 and 27	255	11.3
	March	24, 25, 26, 27 and 28	198	14.4
	April	22, 26, 28 and 29	145	14.4
		Total	3745	280.4

individuals were seen in four sightings (n = 1, 1, 2, and 3 respectively). There was a total of ten sightings out of 52 sightings (n = 10/52, 19.2%) involving Irrawaddy dolphin mother and calf pairs. They were observed in February, April, May and September 2019 and in February 2021.

Finless porpoises were observed with a mean group size of 2.5 ± 0.2 SE in groups of 1–6 individuals. In two out of 35 sightings (5.7%), mother and calf pairs were identified in November 2019 and March 2020.

The pattern of dolphin and porpoise sighting locations with respect to depth and distance from shore was investigated (Fig. 4). Both Irrawaddy dolphin and finless porpoise were observed at depths of less than 17.5 m throughout the survey. Most Irrawaddy dolphin sightings occurred at depths between 2.6 m to 7.5 m (41/52 sightings, 78.8%). These sightings were distributed as follows: Irrawaddy dolphins occurred at depths ≤ 5.0 m (23/52 sightings, 44.2%), 5.0 < depth ≤ 10.0 m (24/52 sightings, 46.2%), and depths > 10.0 m (5/52 sightings, 9.6%) (Fig. 4).

Finless porpoises had the highest number of sightings (n = 14/35) at a water depth range of 5.1 to 7.5 m (Fig. 4). They were not sighted at depths greater than 15.1 m (Fig. 4). Generally, for finless porpoises, they occurred at depths ≤ 5.0 m (6/35 sightings ,17.1%), 5.0 < depth ≤ 10.0 m (23/35 sightings, 65.7%), and depth > 10.0 m (6/35 sightings, 17.1%).

Both the Irrawaddy dolphin and finless porpoise were observed at a minimum distance of 0.6 km to 7.9 km from the shoreline. Most Irrawaddy dolphin sightings occurred from 1.1 to 3.0 km from the shore (n = 28/52 sightings) (Fig. 4). There were 13 sightings (n = 13/52) of Irrawaddy dolphins at distances between 3.1 to 5.0 km and five sightings (n = 5/52) which were observed at between 5.1 to 8.0 km (Fig. 4).

The finless porpoise was observed between 0.7 km and 7.1 km from the shore (survey limit was up to 8 km). Ten sightings were found at a distance from 0.0 to 3.0 km from the shore. A major proportion of sightings were between 3.1 and 5.0 km from the shoreline, with a total of 19 sightings (n = 19/35) (Fig. 4). Four sightings (n = 4/35) were found at distances of 5.1 to 6.0 km. One sighting (n = 1/35) of finless porpoises occurred at two distance intervals: 1) 6.1 to 7.0 km, and 2) 7.1 to 8.0 km.

The data were also examined for possible seasonal variations in the number of sightings during the four monsoon periods as defined by the Malaysian Meteorological Department (2019b). The seasons included the Northeast Monsoon (January–March, and December 2019), first inter-monsoonal period (April–May 2019), Southwest Monsoon (June–September 2019) and second inter-monsoonal period (October–November 2019). The year 2019 was also taken into consideration as there were consistent surveys almost every month except for March and October (Fig. 5). In 2019, the highest number recorded for the Irrawaddy dolphin was

Table 3. Mean and range of water parameters in the presence of Irrawaddy dolphins and finless porpoises.

	Presence of Irrawaddy dolphin		**Presence of finless porpoise**	
	Mean ± SE	**Range**	**Mean ± SE**	**Range**
Depth of water (m)	5.9 ± 0.38	1.6 -17.2	7.3 ± 0.51	2.2 - 14.4
Sea surface temperature (°C)	30.7 ± 0.11	29.1 - 32.1	30.1 ± 0.11	29.0 - 31.8
Salinity (ppt)	30.3 ± 0.10	29.1 - 31.8	30.4 ± 0.13	28.9 - 31.9
Turbidity (NTU)	9.8 ± 1.74	1.2 - 48.8	8.45 ± 1.97	2.1 - 53.0

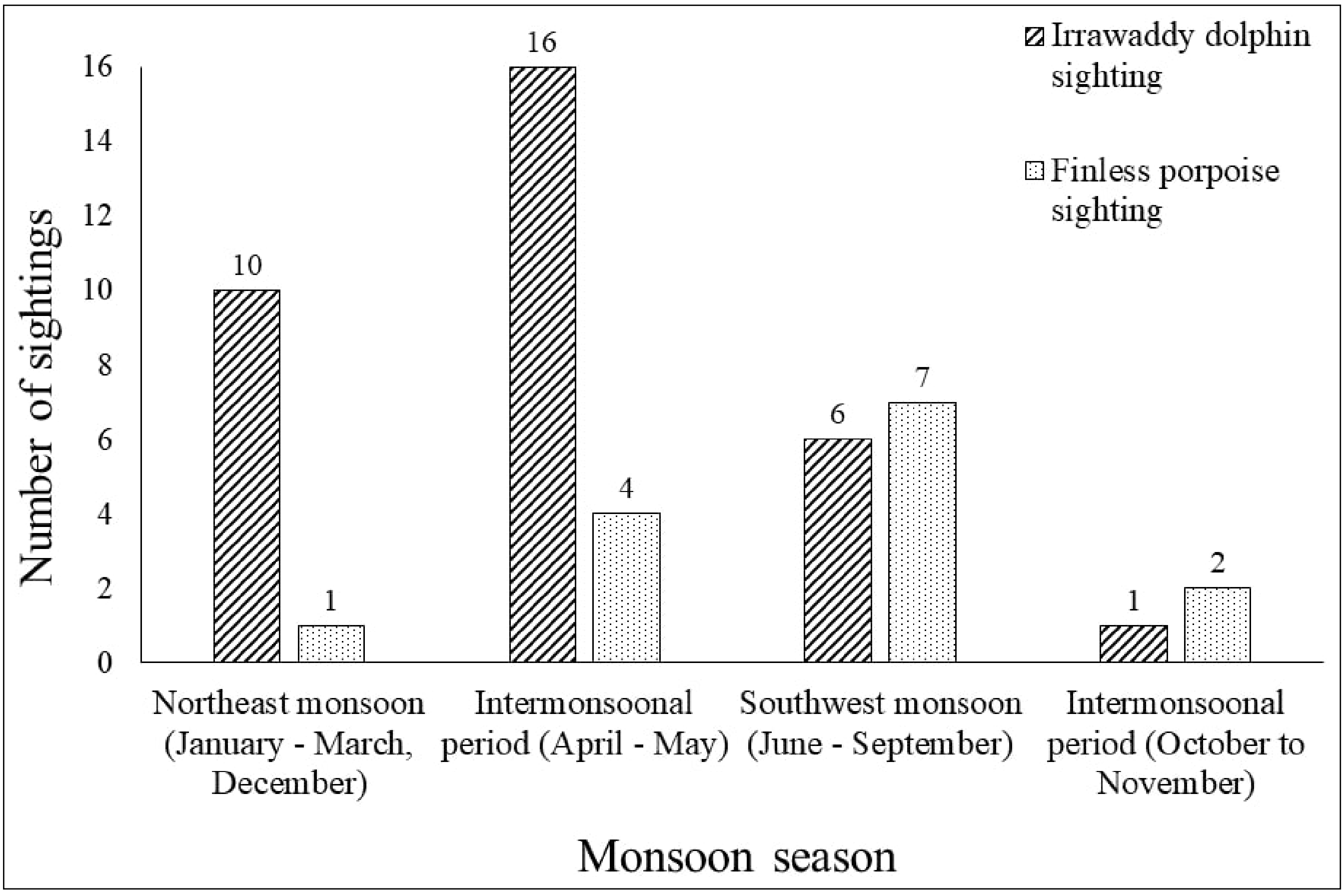
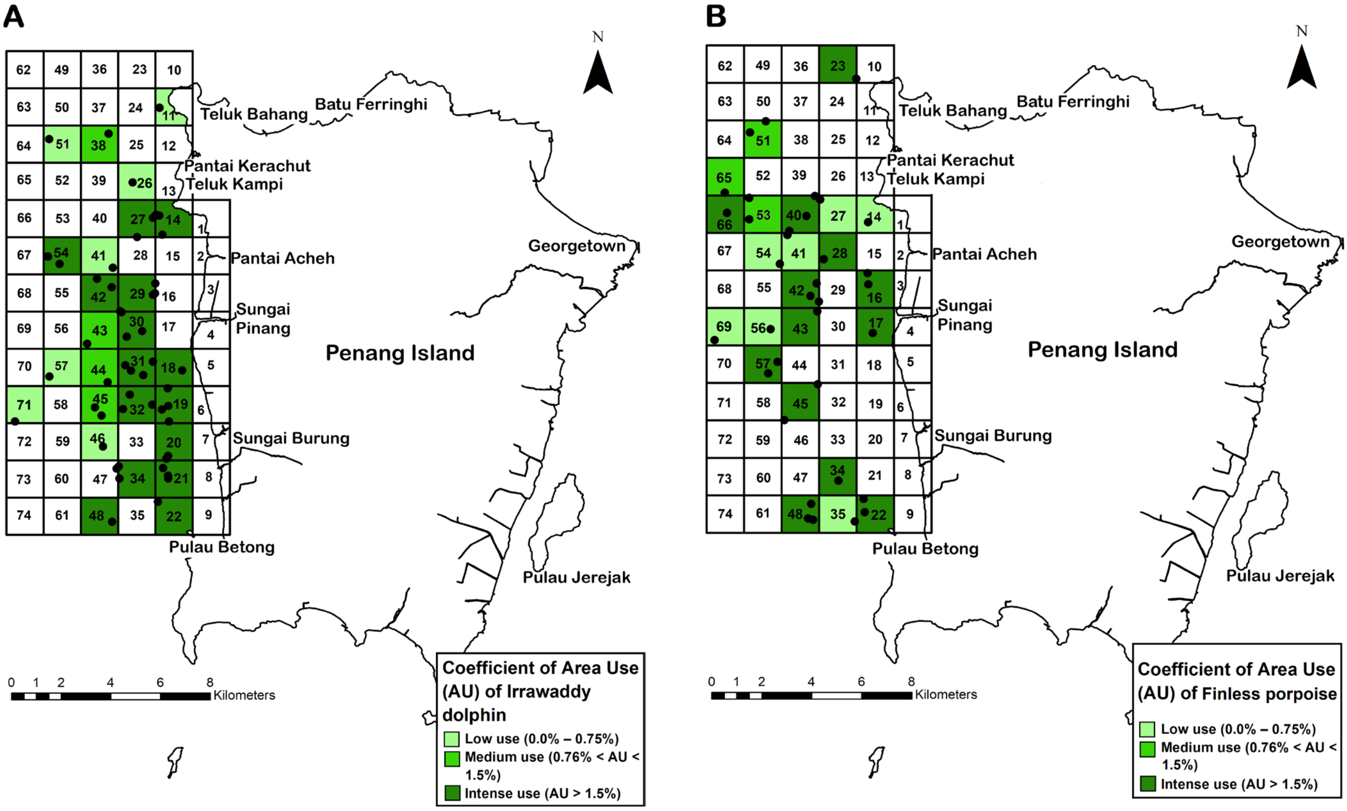


Fig. 5. Occurrences of Irrawaddy dolphin and finless porpoise across the different monsoon seasons in 2019.

during the first inter-monsoonal period (April–May) with 16 sightings (16/33 sightings). For the finless porpoise, the highest number recorded in 2019 was during the Southwest Monsoon with 7 sightings (7/14 sightings). The lowest number of sightings (1/33) was recorded during the inter-monsoonal season from October to November in 2019 for the Irrawaddy dolphin. whereas for the finless porpoise, the lowest number of sightings was during the Northeast Monsoon (1/33) (Fig. 4). Pearson's Chi-square test shows that the occurrences of Irrawaddy dolphin and finless porpoise sightings observed in 2019 were significantly impacted by monsoon seasonality ($\chi^2 = 8.718$, df = 3, p = 0.033) ($p<0.05$).

Habitat characteristics. Irrawaddy dolphins were observed at a mean water depth of 5.9 m ± 0.4 SE (range: 1.6–17.2) during the entire survey (Table 3). The mean value of salinity recorded was 30.3 psu ± 0.1 SE (range: 29.1–31.8), while the mean water turbidity value recorded was 9.8 NTU ± 1.7 SE (range: 1.2–48.8). For sea surface temperatures (SST), Irrawaddy dolphins were observed at mean values of 30.7˚C ± 0.1 SE, (range: 29.1–32.1) (Table 3).

Finless porpoises were observed at mean water depths of 7.3 m ± 0.5 SE between depths of 2.2 to 14.4 m (Table 3). Mean salinity levels were 30.4 psu ± 0.1 SE with a range between 28.9 and 31.9 psu. Mean water turbidity was 8.5 NTU ± 2.0 SE (range between 2.1 to 53.0 NTU) and mean water temperature was 30.1 °C ± 0.1 SE (range between 29.0 to 31.8 °C) (Table 3). Both species were found within waters at depths of <20 m whereas the survey area included depths of up to 29.5 m. The distributions of the Irrawaddy dolphin and the finless porpoise across different environmental variables within the survey area was mapped and the data are available in Appendix 3.



Habitat use. Irrawaddy dolphins appeared to intensely use areas that were nearer to Pantai Acheh, Sungai Pinang and Sungai Burung which were between 0.5 km to 5.5 km of the shoreline (quadrat: 14, 18, 19, 20, 21, 22, 27, 29, 30, 31, 32, 34, 42, 48 and 54). Four quadrats (38, 43, 44, and 45) were recognised to have medium intensity area use, and seven quadrats (11, 26, 41, 46, 51, 57, and 71) were observed to have low intensity use (see Fig. 6, Map A).

Finless porpoises seemed to show intense area use between Teluk Kampi and Sungai Pinang (quadrat: 16, 17, 22, 23, 28, 34, 40, 42, 43, 45, 48, 57, and 66), where they could be found between 0.5 to 7.5 km from shore (Fig. 6). Medium intensity area use was noted in quadrat 51, 53, and 65. Low intensities of area use occurred at quadrats 14, 27, 35, 41, 54, and 69.

Daylight behaviour. Activity budgets for both the Irrawaddy dolphin and finless porpoise were recorded. For Irrawaddy dolphin, the total duration of all behaviours observed was 324 minutes. Milling was the most observed behaviour (118 minutes, 36.4%), followed by playing and socialising (105 minutes, 32.4%), feeding (53 minutes, 16.4%), travelling (12 minutes, 3.7%), resting (3 minutes, 0.9%), avoidance behaviour (8 minutes, 2.5%), and undetermined behaviour (25 minutes, 7.7%).

The total duration of all behaviours recorded for the finless porpoise was 159 minutes. Milling (82 minutes, 51.6%) was the main activity recorded during the survey, followed by travelling (21 minutes, 13.2%), resting (20 minutes, 12.6%), avoidance behaviour (6 minutes, 3.8%), and playing and

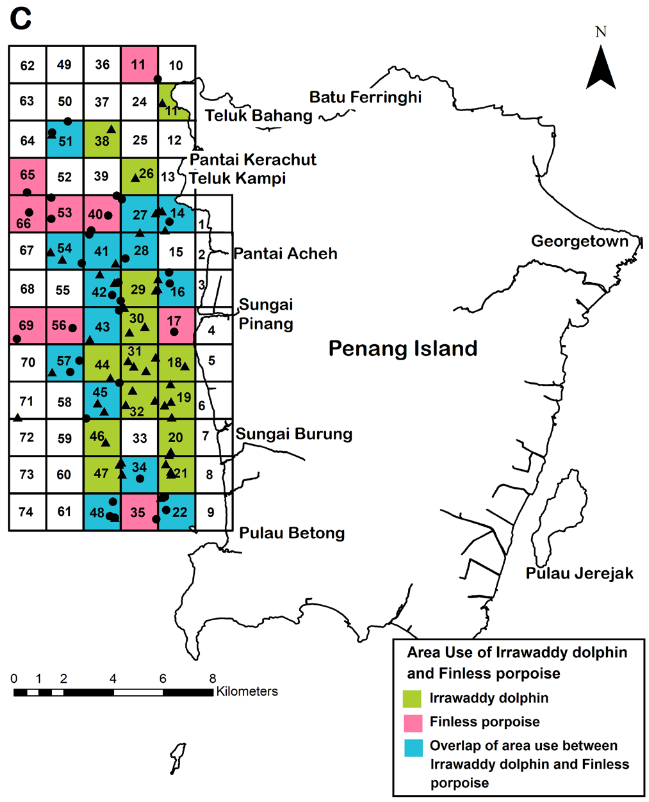


Fig. 6. Coefficient of Area Use (AU) for both species in west Penang Island. A, AU for the Irrawaddy dolphin, B, AU for the finless porpoise and C, combination and overlap of area use for both Irrawaddy dolphin and finless porpoise

socialising (16 minutes, 10.1%). Undetermined behaviour accounted for 7 minutes (4.4%) and feeding accounted for 7 minutes (4.4%).

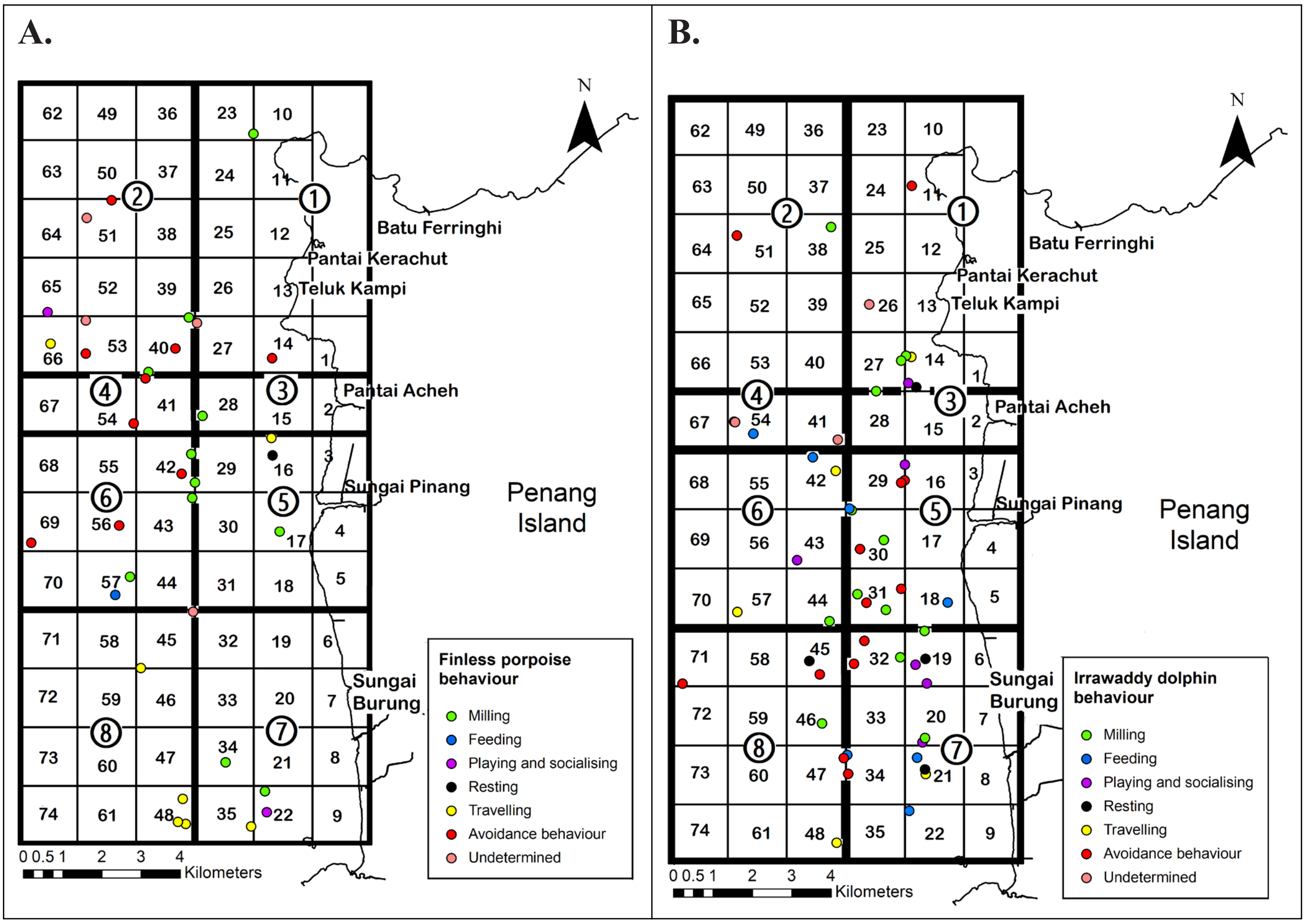


Fig. 7. Predominant behaviour exhibited by the Irrawaddy dolphin and the finless porpoise during behavioural observations. Sections were divided for Non-metric Multidimensional Scaling (nMDS).

The predominant behaviour in each sighting for the cetaceans is shown in Fig. 7. The predominant behaviour exhibited by the Irrawaddy dolphins during sightings included avoidance behaviour (25.0%), milling (25.0%), feeding (15.4%), travelling (9.6%), resting (7.7%), and playing and socialising (11.5%) when discovered, while the rest was undetermined behaviour (5.8%).

For finless porpoises, the predominant behaviour exhibited included milling (31.4%), travelling (20.0%), avoidance behaviour (25.7%), resting (2.9%), feeding (1.9%), and playing and socialising (5.7%), while the rest was undetermined behaviour (11.4%) (Fig. 7).

Some interesting behaviour observed was when Irrawaddy dolphins were recorded foraging on the fish caught in fishermen's nets on 18 April 2019. During this sighting, Irrawaddy dolphins were spotted leaping over the net to search for food (see Appendix 4 for an image of dolphins foraging on fish close to a fishing net).

Resting behaviour of the Irrawaddy dolphins was observed four times during the survey period. They remained motionless at the water surface and seemed undisturbed by the presence of the research vessel as we quietly approached the dolphins. This is the first record of resting behaviour of Irrawaddy dolphins in Penang. Finless porpoises also displayed resting behaviour on one occasion. Both species were observed floating motionless on the surface even as we approached the animals.

We also observed avoidance behaviour on several occasions for both Irrawaddy dolphins and finless porpoises. Irrawaddy dolphins exhibited avoidance behaviour ten times (19.2%) and finless porpoises nine times (17.3%). They displayed this behaviour when there were other fishing boats surrounding them, although some animals also displayed avoidance behaviour when only our research boat was present.

Activity Index. The value of the Activity Index (AI) was calculated to determine the intensity of time spent on the behavioural activities of Irrawaddy dolphins and finless porpoises within each quadrat.

There was a total of 24 quadrats that recorded behavioural activities for the Irrawaddy dolphin**.** Nine out of 24 quadrats (37.5%) were occupied with only one behaviour, while 15 quadrats had more than one behaviour (62.5%) (Fig. 7). Milling was the majority behaviour recorded at 14/24 quadrats (58.3%), where the highest AI value of 1.0 was recorded at quadrat 38, 44, and 46 (see Fig. 8, Table 5). Avoidance behaviour occurred at 11 quadrats (45.8%) with the highest AI of 1.0 occurring at quadrat 11, 47, and 71. Feeding behaviour occurred in 10 quadrats (41.7%) with the highest

Table 4. Range of AI values, quadrats observed, and general area of observation for behaviours recorded for Irrawaddy dolphins and finless porpoises.

Species	Activity / Behaviour	AI value	Quadrat observed	General area
Irrawaddy dolphin	Milling	0.14 to 0.46	14, 19, 20, 22, 27, 29, 48 and 54	Teluk Kampi, Pantai Acheh, Sungai Burung
		0.75 to 1.00	30, 31, 32, 38, 44 and 46	Sungai Pinang, Sungai Burung, Pantai Kerachut
	Playing and socialising	0.25 to 0.65	14, 19, 20, 27 and 29	Teluk Kampi, Pantai Acheh, Sungai Burung, Sungai Pinang
	Feeding	0.03 to 1.00	18, 19, 20, 21, 22, 27, 29, 34, 42 and 54	Sungai Pinang, Sungai Burung, Pantai Acheh, Pantai Acheh
	Resting	0.01 to 0.83	14, 19, 21 and 45	Teluk Kampi, Sungai Burung
	Travelling	0.04 to 1.00	14, 21, 42, 48 and 57	Teluk Kampi, Sungai Pinang, Sungai Burung
	Avoidance behaviour	0.04 to 1.00	11, 27, 29, 30, 31, 32, 34, 45, 47, 51 and 71	Pantai Acheh, Pantai Kerachut, Sungai Pinang, Sungai Burung
Finless porpoise	Milling	0.24 to 1.0	16, 17, 22, 23, 28, 34, 40, 42 and 57	Sungai Pinang, Sungai Burung, Teluk Kampi, Pantai Acheh,
	Playing and socialising	0.4, 1.0	22 and 65	Pantai Acheh, Pantai Kerachut, Sungai Burung
	Resting	0.32, 0.59	16 and 42	Sungai Pinang
	Travelling	0.18 to 1.00	16, 35, 45, 48 and 66	Sungai Pinang, Sungai Burung, Teluk Kampi
	Feeding	0.25, 0.44	34 and 57	Sungai Burung, Sungai Pinang
	Avoidance behaviour	0.03 to 1.00	14, 40, 41, 42, 43, 51, 53, 54, 56 and 69	Teluk Kampi, Pantai Acheh, Sungai Pinang

Table 5: Division of sections and quadrats according to sections for nMDS calculation.

Location	Section (Depth (m))	Quadrat No.
North-west Penang Island (Teluk Bahang, Pantai Kerachut, Teluk Kampi)	Shallow region (0.0–12.5 m)	1, 10, 11, 12, 13, 14, 23, 24, 25, 26, 27
	Deeper region (5.1–17.5 m)	36, 37, 38, 39, 40, 49, 50, 51, 52, 53, 62, 63, 64, 65, 66
Pantai Acheh	Shallow region (0.0–5.0 m)	2, 15, 28
	Deeper region (5.1–15.0 m)	41, 54, 67
Sungai Pinang	Shallow region (0.0–7.5 m)	3, 4, 5, 16, 17, 18, 29, 30, 31
	Deeper region (5.1–15.0 m)	42, 43, 44, 55, 56, 57, 68, 69, 70
South-west Penang Island (Sungai Burung to before Pulau Betong)	Shallow region (0.0–7.5 m)	6, 7, 8, 9, 19, 20, 21, 22, 32, 33, 34, 35
	Deeper region (5.1–27.5 m)	45, 46, 47, 48, 58, 59, 60, 61, 71, 72, 73, 74

AI of 1.0 occurring at quadrat 18 (Fig. 7; Table 4). Resting only occurred at four quadrats (16.7%) where the highest AI value of 1.0 occurred at quadrat 45 (Fig. 8; Table 4).

Behavioural activities observed in the finless porpoise were recorded in 22 quadrats. 16 out of 22 quadrats (72.7%) were observed with one behaviour only while six quadrats had more than one behaviour (27.3%) (Fig.7). Avoidance behaviour was the main activity recorded for the finless porpoise (10/22; 45.5%), with seven out of 10 quadrats (14, 41, 43, 51, 53, 54, 56, and 69) having the highest AI value (1.00). This was followed by milling with nine quadrats (40.9%); with high AI occurring at quadrats 23 and 28 (Fig. 7, Table 4). Resting only occurred at two out of 22 quadrats (9.1%). Feeding was the behaviour that was observed the least for finless porpoises and only happened once, at quadrat 57 (1/22; 4.5%) (Fig. 8, Table 4).

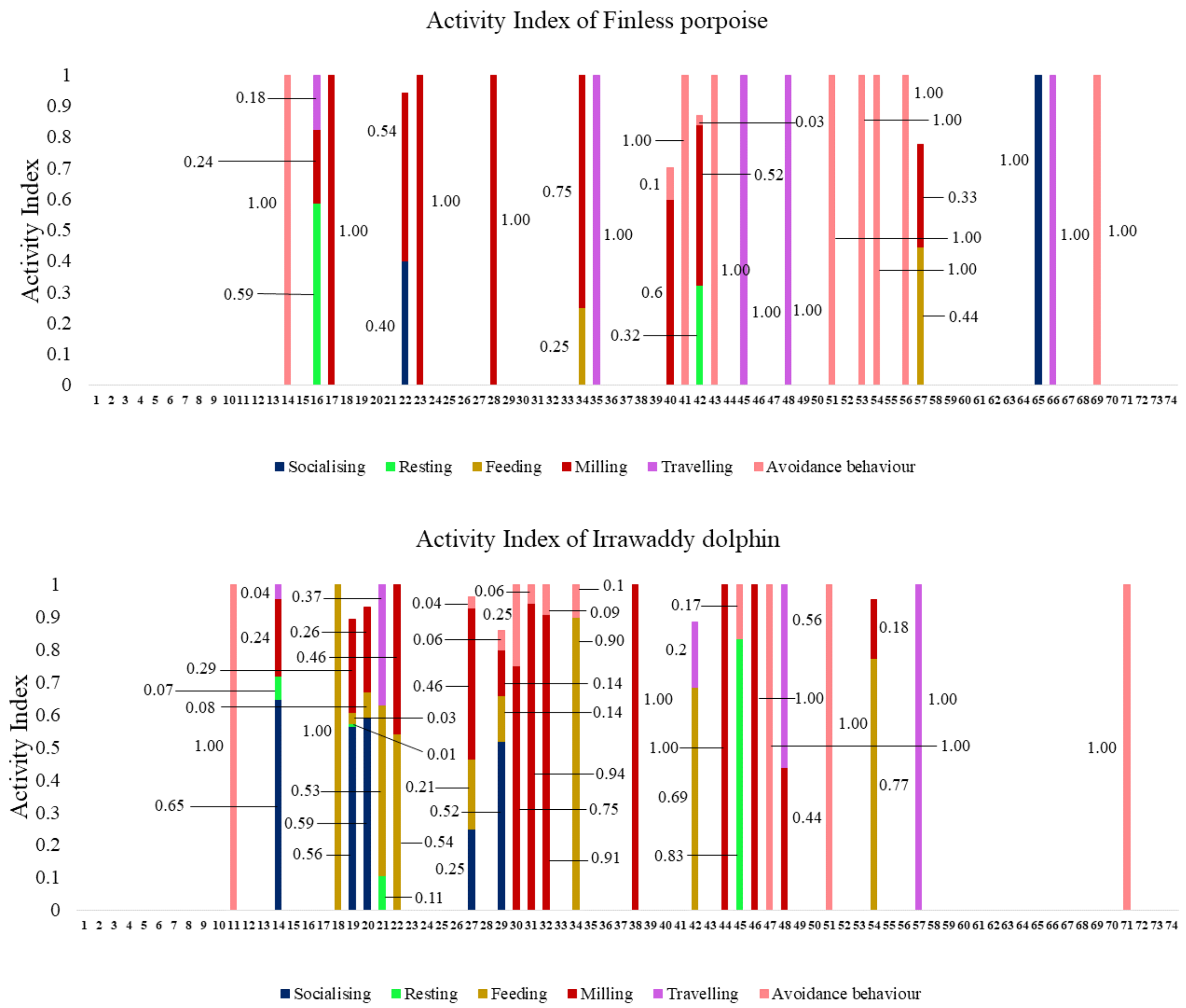


Fig. 8. Mean activity index (AI) of Irrawaddy dolphins and finless porpoises for each quadrat in the west Penang Island study.

Non-metric Multidimensional Scaling (nMDS) was constructed to visualise the time spent on each activity (from AI value) within the eight sections of our survey area (see Appendix 5). The quadrats were grouped into larger sections to conduct the analysis (Table 5). nMDS was conducted with six variables, which were feeding, milling, socialising, resting, travelling, and avoidance behaviour activity index.

There was no preference in the Irrawaddy dolphin for any section in terms of socialising, resting, and avoidance behaviour (see Fig. 7 and Appendix 1–5). Milling and feeding occurred mostly at Section 5 and Section 6 respectively (shallow region of Sungai Pinang area). More time was spent travelling at Section 7, the shallow area close to the shore region of Sungai Burung (see Appendix 5).

Travelling was preferred at shallow areas (Section 7) and deep areas (Section 8) of Sungai Burung (see Fig. 7 and Appendix 5) for the finless porpoise. Socialising and feeding were preferred at Section 6 (deep area of Sungai Pinang. Avoidance behaviour was preferred at Section 2 (deep region of Teluk Bahang and Teluk Kampi). There was no preference for resting and milling at any section.

DISCUSSION

Species distribution. The surveys indicated that there are at least two species of inshore cetaceans that can be regularly observed off west Penang Island, namely the Irrawaddy dolphin and the finless porpoise. Irrawaddy dolphins were mostly seen at the inshore estuarine areas of Sungai Pinang, Sungai Burung, and Pulau Betong. The finless porpoise was more concentrated in both inshore and offshore areas of Teluk Kampi, Pantai Acheh, and Sungai Pinang. These areas are known to be areas where these species were previously seen (Rajamani et al., 2014; Rodríguez-Vargas, 2015; Rajamani et al., 2018).

Encounter rates. Encounter rates (0.19 sightings/hour) for Irrawaddy dolphins appeared to have become less frequent compared to a previous study for the Irrawaddy dolphin in 2013 in this same area, which recorded encounter rates of 0.25 sightings/hour (Rodríguez-Vargas et al., 2019). In Miri, Bintulu-Similajau, and Kuching regions of Sarawak, the average encounter rate was 0.20 per hour (Minton et al., 2011). The encounter rate for the finless porpoise in west Penang was 0.13 sightings per hour, which is the same as what was reported across the three regions of Similajau, Miri, and Kuching in Sarawak (Minton et al., 2011).

Group sizes. The mean group size (3.6 ± 0.4 SE) of Irrawaddy dolphins recorded in this survey was less than previously reported in the same area (5 ± 0.5 SE) (Rodríguez-Vargas et al., 2019). The number of Irrawaddy dolphin mother and calf pairs observed (n_{pair} = 10/52, 19.2% of all Irrawaddy dolphin group sightings) was also less than those observed in a previous study (n_{pair} = 14/43, 32.5%) in the same area (Rodríguez-Vargas et al., 2019). The mother and calf pairs were observed in the months of May and September in both studies.

Finless porpoises had a mean group size of 2.5 ± 0.2 SE in groups of one to six individuals. Mother and calf pairs were also observed in this study (5.7%, n_{pair} = 2/35). This suggests that the area of west Penang may be able to support both species of dolphins and is important for breeding even though the populations are small. Minton et al. (2011) observed small calves of Irrawaddy dolphins and finless porpoises within the nearshore areas of Similajau and Kuching in Sarawak (Malaysia) and confirmed this area as a breeding/nursing ground for these species. However, small populations can decrease and become locally extinct even if both sexes are present. This can happen due to inbreeding depression, leading to a reduction in the fitness trait values of animals, or due to changing environments (Sutherland, 1998).

The decline in group size, number of mother and calf sightings, and encounter rates from a previous study in 2013 which used a similar survey design (Rodríguez-Vargas et al., 2019) may indicate that the population is declining or that the population may have moved to an area where there is better prey availability. Possible reasons for changes to this coastal population are that there might be changes and/or decline in size of prey resources, seasonal variations in species distribution, and changing habitat use patterns from one niche habitat to another habitat (Hartel et al., 2014; Lin et al., 2021). Threats from boat disturbances, incidental entanglement in nets, pollution, and eutrophication also contribute to increased pressure on the viability of the population. All these physical factors are prevalent in west Penang (Rajamani et al., 2014; Zanuri et al., 2020; Tan et al., 2021).

Depth preferences and distance from shore. The majority of the Irrawaddy dolphin sightings were concentrated in the central survey area (Fig. 7; between 1.5 km to 5.5 km from the shoreline), closer to Sungai Pinang, Sungai Burung, and north Pulau Betong (Fig. 7). These results were similar to a study carried out in 2013 in west Penang (Rodríguez-Vargas et al., 2019). These areas are within the shallow regions of the coast, with depths of between 2.6 m to 7.5 m (Fig. 4) which may be a favoured area for daily life activities such as feeding, socialising and resting, and making its importance to their life clear.

Finless porpoises were also found close to shore with the majority (82.9%, n = 29/35) observed less than 5 km from shore. Finless porpoises were found in lower densities (17.1%, n = 6/35) in relatively deep areas of Teluk Kampi and the Sungai Pinang area, between 5.1 to 8.0 km offshore, compared to shallow areas (Fig. 4). While they can also be found at deeper regions, they were not observed at the deepest depths of 17.2 m where Irrawaddy dolphins were found (Table 3). For both the Irrawaddy dolphin and the finless porpoise, depth and distance from the shore seem to influence the presence of these animals, and both species appear to prefer shallow areas close to shore.

The mean depth at which Irrawaddy dolphins were observed was 5.9 m ± 0.4, with the majority of the sightings at depths of between 2.6 to 7.5 m (n = 41/52). There were fewer sightings between 7.6 to 17.5 m depth (n = 9/52), indicating a preference for water depths less than 7.5 m (Fig. 4).

Similar occurrences of Irrawaddy dolphin in shallow waters have also been recorded in Miri, Similajau and Kuching region (Sarawak) (2.0 to 5.4 m) and Malampaya Sound, the Philippines (waters less than 6 m deep) (Dolar et al., 2002, Minton et al., 2011). However, Irrawaddy dolphins have also been recorded in waters more than 20 m deep in Brunei Bay (Malaysia) with a depth range of 2.0 to 30.4 m. Similarly, Irrawaddy dolphins occurred at a range from 2.0 to 46.0 m (mean value = 14.6 m) in Balikpapan Bay, east Kalimantan, Indonesia (Kreb et al., 2020).

The mean depth at which finless porpoises were observed was 7.3 m ± 0.5 with most sightings occurring between 0.0 m to 7.5 m (n = 20/35). Other sightings that were deeper than 7.5 m were also recorded (n = 9/35). Beyond 10.0 m, there were only four sightings (n = 6/35). This preference for depths of less than 10.0 m was also reported from the Sarawak coast of the Kuching, Bintulu-Similajau, and Miri regions (Minton et al., 2011). These findings also mirror the results obtained in the Bay of Bengal, Bangladesh, where the water depth was less than 20 m during finless porpoise encounters (mean: 11.0 m, SD 3.5, range: 5.9 to 16.0 m) (Smith et al., 2008).

For both the Irrawaddy dolphin and the finless porpoise, most of the sightings occurred in distances less than 5.0 km from shore, although they can still be observed less than 8 km from shore. At the coastal areas of Bago-Pulupandan, Negros Occidental, the Philippines, Irrawaddy dolphins were found less than 2.0 km from the shore (de la Paz et al., 2020). In comparison, in Trat Province in the Gulf of Thailand, Irrawaddy dolphins were encountered 12 km from the coast (Hines et al., 2015). In other studies, finless porpoises occurred in areas less than 20 km distance from the shore at the eastern coast of Sendai Bay to Tokyo Bay (Amano et al., 2003). More research is needed with a focus on areas more than 8 km from the shore to determine the distance limits of both the Irrawaddy dolphin and finless porpoise.

Effects of monsoons. Both the Irrawaddy dolphin and the finless porpoise were sighted throughout the year, although a higher number of sightings of Irrawaddy dolphins occurred in the inter-monsoonal period, and a higher number of finless porpoise sightings occurred in the southwest monsoon period. Chi square analysis of the relationship between number of sightings and the different monsoon seasons revealed that the seasons in Malaysia do play a role in determining the absence or presence of dolphins for one year of surveys in 2019. However, in the Kep Archipelago, Cambodia, Irrawaddy dolphins were sighted across all seasons (Tubbs et al., 2020). Therefore, it is possible that the monsoon conditions might have affected the sighting ability of the observers and it is not necessarily the monsoon itself that led to an increase or decrease in sightings.

Habitat preferences. Based on the results obtained, there appears to be one distinct area used by the Irrawaddy dolphin and one distinct area used by the finless porpoise. These areas were the inshore estuarine areas off Sungai Pinang, Sungai Burung and Pulau Betong for Irrawaddy dolphins and both inshore and offshore areas in the vicinity of Teluk Kampi, Pantai Acheh and Sungai Pinang for finless porpoises. However, both species also shared 14 quadrats (18.9%, n = 14/74 quadrats) most of which were found between the areas of Teluk Kampi and Sungai Pinang (Fig. 6). The overlap of use of the same habitat between four cetacean species (Irrawaddy dolphin, finless porpoise, Indo-Pacific humpback dolphin and Indo-Pacific bottlenose dolphin) has been also documented along the coast of Sarawak (Miri, Bintulu-Similajau and Kuching region) (Minton et al., 2011), whereas Irrawaddy dolphins in Balikpapan Bay (Indonesia), had an overlapping habitat with finless porpoises and Indo-Pacific bottlenose dolphins (Kreb et al., 2020). Although both species utilised most of the survey area, only one mixed group of Irrawaddy dolphins and finless porpoises has been recorded (Rajamani et al., in press). This clearly indicated that habitat partitioning is occurring off west Penang between the two species so that there is less competition for resources. Habitat partitioning has also been observed for inshore bottlenose dolphins and pantropical spotted dolphins in Golfo Dulce, Costa Rica (Oviedo et al., 2018).

In this study Irrawaddy dolphins and finless porpoise were observed to be further away from shore than observed in the earlier study by Rodríguez-Vargas et al. (2019), indicating a greater coverage of area and home range of the two species than previously thought. This may be because they could be travelling in search of prey resources. Fishery activities are very predominant in west Penang close to shore as well as further westward, indicating lesser prey availability for the dolphins as well.

Temperature, turbidity and salinity. Presence of Irrawaddy dolphin was recorded at a mean temperature of 30.7 °C ± 0.1 (range: 29.1 to 32.1 °C), which was comparable to other places such as Malampaya Sound, Philippines, where the mean surface temperature was 30.2°C, with a range of 27.0 to 32.5 °C (Smith et al., 2004) as well as in Balikpapan Bay, Indonesia with a mean surface temperature of 30.3 °C (SD; 1.2; 28.1–32.4 °C) (Kreb et al., 2020). However, temperature was slightly lower, ranging from 24.9 to 28.6 °C at the Eastern Gulf of Thailand, where the highest number of dolphins was recorded at 24.9 °C (Jackson-Ricketts et al., 2017). Finless porpoises in west Penang Island occurred at a mean temperature of 30.1 °C ± 0.1, with a range from 29.0 to 31.8 °C. However, in Bengal Bay, Bangladesh, the finless porpoise was sighted at lower temperature (mean: 22.9 °C, SD 1.0, range = 21.8 to 24.6 °C) (Smith et al., 2008). The occurrences at two different levels of temperature shows that this species can adapt to different temperature environments where the limits of temperature have not been determined. Turbidity during Irrawaddy dolphin sightings fluctuated between turbid and slightly clear waters (mean: 9.8 NTU ± 1.7 SE, range: 1.2 to 48.8 NTU). Many sightings occurred near turbid regions at Sungai Pinang and Teluk Kampi. In Malampaya Sound, the Philippines, Irrawaddy dolphin groups were sighted at a slightly lower mean turbidity value of 2.2 NTU (range 0 to 9.6 NTU) (Smith et al., 2004). A previous study in west Penang in 2013 indicated higher values of turbidity (25.1 ± 3.0 NTU) during dolphin sightings, with turbidity ranging from 7.1 to 70.2 NTU (Rodríguez-Vargas et al., 2019). This was probably due to an increase of survey area coverage with the seawater becoming less turbid further seawards from the river mouths and mangrove areas. Finless porpoises in west Penang appeared to have no preference for either clear or turbid waters and they were observed in different water turbidities (ranging from 2.1 to 53.0 NTU, mean: 8.45 NTU ± 2.0 SE). Further studies may be needed to determine the limitations of occurrence of Irrawaddy dolphins and finless porpoises in terms of turbidity.

Mean salinity was recorded at 30.3 psu ± 0.1 SE in west Penang Island during Irrawaddy dolphin sightings, which is almost similar to that obtained in Malampaya Sound (Philippines), with a mean 28.3 psu (SD = 4.7, range = 14.0 to 34.0 psu) (Smith et al., 2004). Within coastal areas of Bangladesh, Irrawaddy dolphins occurred at a mean salinity of 16.1 psu (Smith et al., 2008), while in Balikpapan Bay the mean value was 20.6 psu (SD: 3.1; range 20.7–32.8 psu) (Kreb et al., 2020). The different salinity values between these three habitats of Irrawaddy dolphin shows that the dolphins are tolerant of a range of salinities, which suggests that the dolphins' preference for low-salinity waters is more likely due to ecological factors (possibly linked to prey) than physiological sensitivity to high-salinity environments (Smith et al., 2004). Hence, salinity is unlikely to affect the habitat preferences of this species.

The mean salinities of waters where the finless porpoise was observed was 30.4 psu ± 0.1 SE (range: 28.9 to 31.9 psu). This value is similar to those recorded in Kuching (Sarawak) and Matang (Perak), where the mean values of salinity were 30.5 and 31.19 psu respectively (Peter et al., 2016; Kuit et al., 2019). However, in Bangladesh, mean value was just 25.7 psu (SD: 6.5, range from 15.0 to 32.0 psu) (Smith et al., 2008). This suggests that the finless porpoise is able to tolerate lower salinity habitats such as estuaries (Smith et al., 2008).

Daylight behaviour. Behaviours such as milling, socialising, feeding, resting, and travelling were exhibited by the Irrawaddy dolphin. Milling was the main behaviour and was observed for a total of 118 minutes over the course of this study. Milling was mostly seen in Sungai Pinang and Sungai Burung from shallow regions of 1.3 km to approximately 5 km away from shore. Such behaviours were in contrast to those observed in a previous study where feeding was the most observed behaviour (Rodríguez-Vargas et al., 2019). The reason for this discrepancy in behaviour could be that they were foraging, but were unable to find nutritional resources such as fish. Milling behaviour is usually a transition behaviour to other behaviours such as feeding or socialising (Constantine et al., 2004).

Irrawaddy dolphins also displayed socialising behaviour for 32.4% (105 minutes) of the observation time in the shallow regions of Teluk Kampi, Sungai Pinang, and Sungai Burung which also agreed with previous observations of feeding and socialising behaviours in the area (Rodríguez-Vargas et al., 2019). Feeding by Irrawaddy dolphins was observed in 16.4% of all sightings (predominant behaviour during a sighting), mainly in the deep areas of Pantai Acheh (7.2 to 10.7 m) and the shallow areas of Sungai Pinang and Sungai Burung (1.6 to 5.8 m). In a previous study, feeding behaviour was reported to comprise 60% of the sightings (also categorised as the predominant behaviour during the sightings) and was particularly intensive in Sungai Pinang and Sungai Burung (Rodríguez-Vargas et al., 2019). However, the results of the previous study may not be directly comparable to the current one due to different survey area sizes and different timeframe used for the boat-based surveys.

The current pattern of feeding was therefore different from those observed in 2013 (Rodríguez-Vargas et al., 2019). The area surveyed was considerably larger than the previous study area where more feeding areas were reported by Rodríguez-Vargas et al. (2019). There could have been a change in niche preferences, making this area no longer an area of intense feeding activities. The main reason for this change could be disturbances due to a larger number of boats, their widespread use, high noise level, speed, and mobility (Green & Moore, 1995) since the previous study, that may cause prey movement and the decline of fish resources for these animals.

Low dissolved oxygen levels due to algal blooms were reported in the seawater in 2019 after Typhoon Lekima (Tan et al., 2021). The storm created by Typhoon Lekima had churned up sediments in the shallow coastal areas which had caused additional sediment and nutrients in the ecosystem, leading to algal blooms and depletion of oxygen levels in the water, causing mass fish mortality (Tan et al., 2021). Heavy metal contamination in the water was also reported in the seawater in Teluk Bahang, north of the study site (Zanuri et al., 2020). Higher than normal levels of nickel, cadmium, copper and iron were reported (Zanuri et al., 2020). It is unclear what the sources of these heavy metals are, and further investigations are needed. These low oxygen levels and high heavy metal content could affect the survival of the main prey of the Irrawaddy dolphin and finless porpoise which would result in an increase in milling, a decrease in feeding activity, and a higher level of travel behaviour to locate new food sources. Further investigation of water quality and toxin levels in Penang coastal waters to elucidate this phenomenon may be needed.

For the first time, daylight behaviour of the finless porpoise was observed where various behaviours including milling, socialising, travelling, feeding, resting and avoidance behaviour were recorded. Milling behaviour was most frequently observed, indicating an activity precedent to feeding or socialising behaviour. It is possible that the resources for these porpoises were insufficient and they needed to mill while foraging for food. Very few behavioural studies have been done on finless porpoises, except studies on avoidance behaviour (Morimura & Mori, 2019). Resting was recorded for the first time for Irrawaddy dolphins in Sungai Burung and Teluk Kampi, and for finless porpoises in Pantai Acheh. During these instances, no boats were recorded nearby, indicating that boat disturbances may play a role in their behaviour patterns.

The locational preferences of the Irrawaddy dolphin for Sections 5 and 6 (see Fig. 7) at the shallow, inshore areas of Sungai Pinang and Sungai Burung for milling and feeding respectively indicated that this area may be an important niche for these behaviours. Travelling occurred for the longest period within section 7 (Sungai Burung shallow region), while there were no preference sections for socialising, resting, and avoidance behaviours. Finless porpoises also preferred Section 7 and 8 (deeper regions of southeast Penang waters) for travelling. Section 7 and 8 may be acting as a link to other areas that these cetaceans go to in the south of Penang Island.

Unlike the Irrawaddy dolphin, the finless porpoise displayed avoidance behaviour at deeper regions of north-west Penang (Section 2) whereas the Irrawaddy dolphin had no preference for any section. Socialising and feeding were preferred by the finless porpoise at Section 6. This showed that different areas were preferred by both species of dolphin to conduct their daily behaviours. Only resting and milling behaviours were not preferred at specific sections. However, due to data limitations, more studies of a longer duration need to be conducted.

Both Irrawaddy dolphins (n=13/52, 25%) and finless porpoises (n=9/35, 25.7%) exhibited avoidance behaviour for a duration of eight minutes and six minutes respectively. Avoidance behaviour seemed to be more frequently reported, indicating they were reacting to boat disturbances and were undertaking long dives to leave the area. A similar case was reported by Nor Hashim and Jaaman (2011) where Irrawaddy dolphins and Indo-Pacific Humpback dolphins avoided high-speed vessels in Cowie Bay, Sabah, Malaysia. Avoidance behaviour was mostly recorded in Sungai Pinang and Sungai Burung in shallow waters of 1.5 to 3.0 km in the same area where Rodríguez-Vargas et al. (2019) reported feeding behaviour. This supported the assumption that the reduced occurrences of feeding behaviour observed was due to the disturbance of marine mammals by boats, which is of particular concern in coastal regions (Green and Moore, 1995). Avoidance behaviour in cetaceans is hazardous because boats might force dolphins to adjust their movement patterns, change their behaviour, or even collide with other dolphins (Gubbins, 2002).

Future insights. The data provided here suggests that more research is definitely necessary to fully understand the significance of these waters as a habitat for cetaceans. This may include group follows that allow for longer observation time to assess activity budgets. A comprehensive study on water pollution, prey abundance and diversity, and productivity would provide important information to conservation managers. More information on the abundance of cetaceans here is also needed. Implementation of conservation zones with gillnet bans needs government and community support as well as enforcement (Kreb et al., 2021). These measures usually take time, therefore, a temporary solution to gillnet entanglement could be explored using acoustic pingers. They can emit sounds of different frequency (depending on which species is to be deterred) to dissuade the dolphins at a short distance from the pinger itself, resulting in them avoiding the nets (Kreb et al., 2021). However, trial testing is needed, as their effectiveness may be uncertain or low as the animals become habituated (Leeney et al., 2007; Gazo et al., 2008; Amano, 2017).

The co-existence of cetaceans and fisheries and boat activities in west Penang Island shows that the cetaceans have habituated to some extent by feeding close to fishing nets although there were some avoidance behaviours towards non-fishing boats. Just like in a supply and demand relationship, when demand is higher and humans need to gain resources such as fishes, the overall supply will decrease and hence deplete the resources for these animals. Gathering of data such as the magnitude of fisheries activities and annual catch data can be initiated to study the impact of fishing activities towards cetaceans, abundance of resources available for the cetaceans, and the effects on their behaviour during the presence of the boats. Avoidance behaviour and its frequency and contributing factors also needs to be researched in greater detail.

Conclusion. It is confirmed that there are two species, namely, the Irrawaddy dolphin (*Orcaella brevirostris*) and finless porpoise **(***Neophocaena phocaenoides***)** with substantial populations living and sharing the waters off west Penang in the Malacca Strait. These two species appeared to prefer shallow waters to 15 m depth and distances from shore of less than 5 km. It is clearly seen that the occurrence of these two species is determined by depth and distance and is less affected by turbidity, salinity or temperature. The two species showed habitat partitioning, with the Irrawaddy dolphin population occupying distinct inshore areas between Sungai Pinang and Sungai Burung and the finless porpoise occupying overlapping but similarly well-defined inshore and offshore areas between Teluk Kampi, Sungai Pinang, and Sungai Burung that are further from shore than the Irrawaddy dolphin. The partitioning of similar behaviours in the two species across different areas also suggested habitat and activity partitioning off the west coast of Penang Island. Avoidance behaviour was recorded for the first time, and is becoming more prominent for both species. Milling behaviour appeared to be the predominant behaviour for the Irrawaddy dolphin, although feeding behaviour was predominant in a previous study by Rodríguez-Vargas et al. (2019). This indicated that the Irrawaddy dolphins may have changed their niche preference from feeding to milling, although more surveys are needed in the future to determine such changes in habitat use. Current known threats include disturbances from boats, entanglement from fishing nets, and pollution based on recent evidence (Rajamani et al., 2018). A comprehensive conservation and management plan needs to be developed for the survival and sustenance of these cetacean species in west Penang while bearing in mind community needs for fishing activities in this area. Overall, there also needs to be continuous dialogue with the local fishing communities on sustainable fishing, dolphin protection, and to promote win-win situations for both dolphins and humans.

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APPENDIX

Appendix 1. Description of behavioural states for coastal cetacean dolphins based on Shane et al. (1986), Karczmarski et al. (1999), Parra (2006), Rodríguez-Vargas et al. (2019) and consistent personal observations.

Behaviour	Definition
Feeding	Swimming slowly in circles around a specific area. All individuals display a characteristic movement, starting with a momentary pause before showing a vertical submersion, usually exposing the tail, and a long dive. Individuals can be seen going different directions or making circles as groups, and re–surfacing is unpredictable. On one occasion, one individual was observed spitting water, and another one was seen flipping a fish up using its tail.
Travelling	Groups swimming relatively fast in the same direction. Individuals show short dives and predictable re–surfacing. Full body and half-body leaping were observed on a few occasions.
Milling	Slow swimming around the same area, with smooth and short dives and long surfacing. No evidence of vertical diving.
Playing and socialising	Group swimming slowly within a small area, maintaining cohesion and rubbing against and on each other. Individuals rolling on their ventral axis exposing ventral area and pectoral fins. Superficial dives and frequent breaths.
Resting	Animal floats and is motionless on the surface of water.
Avoidance behaviour	Animal surfaces once or twice then dives, and is not seen again after waiting for a duration of 15 minutes.
Undetermined	Undetermined behaviour is behaviour that cannot be categorised into known behaviours such as feeding, playing and socialising, milling, resting, avoidance behaviour, and travelling.

Appendix 2A. On-effort sightings of Irrawaddy dolphin throughout the survey period

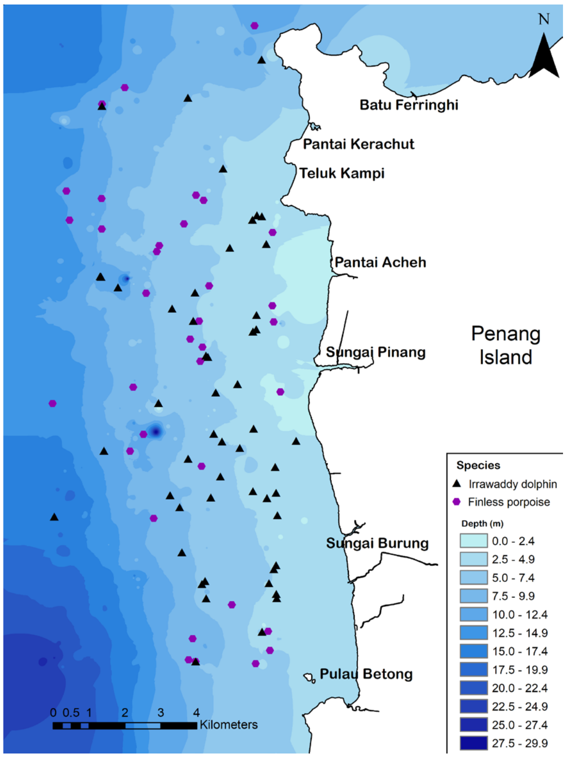
No	Date	Latitude	Longitude	Location	Species	Group size
1	18 February 2019	5.37395	100.18202	Sungai Rasa	Irrawaddy dolphin	3
2	18 February 2019	5.36499	100.16301	Sungai Rasa and Sungai Pinang (in between)	Irrawaddy dolphin	3
3	18 February 2019	5.37377	100.16340	Sungai Pinang	Irrawaddy dolphin	4
4	18 February 2019	5.38609	100.16186	Sungai Pinang	Irrawaddy dolphin	2
5	19 February 2019	5.33445	100.15945	Sungai Pinang	Irrawaddy dolphin	1
6	19 February 2019	5.35975	100.16062	Jalan Baru Sungai Pinang	Irrawaddy dolphin	1
7	19 February 2019	5.37701	100.17138	Sungai Pinang	Irrawaddy dolphin	5
8	19 February 2019	5.37218	100.16789	Kuala Jalan Baru	Irrawaddy dolphin	15
9	20 February 2019	5.40552	100.17207	Sungai Pinang	Irrawaddy dolphin	8
10	12 April 2019	5.36130	100.17122	Sungai Pinang	Irrawaddy dolphin	8
11	12 April 2019	5.33882	100.15919	Jalan Bharu	Irrawaddy dolphin	6
12	12 April 2019	5.35728	100.15280	Sungai Pinang	Irrawaddy dolphin	1
13	16 April 2019	5.42335	100.17457	Sungai Pinang	Irrawaddy dolphin	5
14	16 April 2019	5.42432	100. 17274	Pantai Acheh	Irrawaddy dolphin	6
15	16 April 2019	5.371478	100.133826	Pulau Betong	Irrawaddy dolphin	2
16	17 April 2019	5.346016	100.153371	Sungai Pinang	Irrawaddy dolphin	2
17	18 April 2019	5.411187	100.156636	Sungai Pinang	Irrawaddy dolphin	1
18	18 April 2019	5.369497	100.154956	Sungai Pinang	Irrawaddy dolphin	3
19	18 April 2019	5.360323	100.150419	Sungai Pinang	Irrawaddy dolphin	2
20	18 April 2019	5.338264	100.175215	Kuala Jalan Bharu	Irrawaddy dolphin	4
21	13 May 2019	5.404055	100.156214	Pantai Acheh	Irrawaddy dolphin	5
22	13 May 2019	5.407143	100.150935	Pantai Acheh	Irrawaddy dolphin	6
23	13 May 2019	5.415241	100.132868	Pantai Acheh	Irrawaddy dolphin	3
24	15 May 2019	5.460062	100.154889	Pantai Kerachut	Irrawaddy dolphin	1
25	15 May 2019	5.415119	100.133075	Pantai Acheh	Irrawaddy dolphin	1
26	23 July 2019	5.341745	100.176436	Pulau Betong	Irrawaddy dolphin	5
27	23 July 2019	5.318598	100.156852	Pulau Betong	Irrawaddy dolphin and finless porpoise	4
28	26 August 2019	5.354972	100.121353	Kampung Perlis	Irrawaddy dolphin	3
29	12 September 2019	5.334491	100.17717	Pulau Betong	Irrawaddy dolphin	2
30	13 September 2019	5.395	100.15992	Sungai Pinang	Irrawaddy dolphin	5
31	18 September 2019	5.401945	100.17203	Sungai Pinang	Irrawaddy dolphin	2
32	15 November 2019	5.342776	100.177	Pulau Betong	Irrawaddy dolphin	4
33	04 December 2019	5.335554	100.17705	Kuala Jalan Baharu	Irrawaddy dolphin	2
34	03 March 2020	5.412485	100.13732	Pantai Mas	Irrawaddy dolphin	8
35	17 July 2020	5.401418	100.17122	Sungai Pinang	Irrawaddy dolphin	1
36	21 July 2020	5.430304	100.17342	Pantai Mas	Irrawaddy dolphin	1
37	21 July 2020	5.430588	100.17222	Pantai Kerachut	Irrawaddy dolphin	3

No	Date	Latitude	Longitude	Location	Species	Group size
38	21 November 2020	5.367391	100.17679	Kuala Jalan Bharu	Irrawaddy dolphin	7
39	24 November 2020	5.359608	100.17472	Jalan Kuala Bharu	Irrawaddy dolphin	8
40	25 January 2021	5.395363	100.1594	Sungai Pinang	Irrawaddy dolphin	3
41	27 January 2021	5.422387	100.16539	Sungai Pinang	Irrawaddy dolphin	2
42	24 February 2021	5.375742	100.16133	Sungai Pinang	Irrawaddy dolphin	2
43	24 February 2021	5.383473	100.14749	Sungai Pinang	Irrawaddy dolphin	2
44	27 February 2021	5.326032	100.17347	Pulau Betong	Irrawaddy dolphin	4
45	27 February 2021	5.38821	100.16735	Sungai Pinang	Irrawaddy dolphin	4
46	24 March 2021	5.442301	100.16372	Teluk Kampi	Irrawaddy dolphin	2
47	24 March 2021	5.429451	100.17108	Pantai Mas	Irrawaddy dolphin	4
48	24 March 2021	5.355287	100.17735	Kuala Jalan Bharu	Irrawaddy dolphin	5
49	25 March 2021	5.469629	100.17335	Teluk Ketapang	Irrawaddy dolphin	2
50	26 March 2021	5.457984	100.13331	Pantai Kerachut	Irrawaddy dolphin	4
51	28 March 2021	5.338023	100.1584	Kuala Jalan Bharu	Irrawaddy dolphin	1
52	22 April 2021	5.360928	100.17699	Sungai Pinang	Irrawaddy dolphin	1

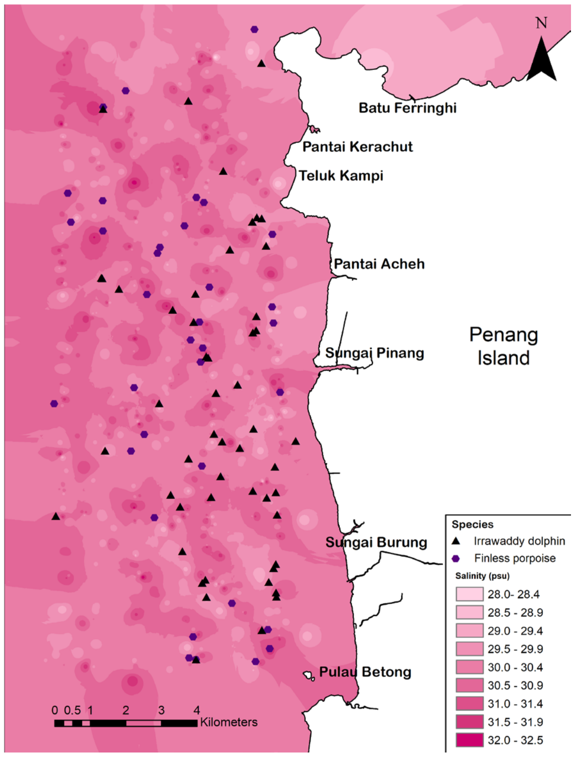
Appendix 2B. On-effort sightings of finless porpoise throughout the survey period

No	Date	Latitude	Longitude	Location	Species	Group size
1	15 April 2019	5.42717	100.13329	Sungai Pinang	Finless porpoise	6
2	17 April 2019	5.428451	100.15391	Teluk Kampi	Finless porpoise	3
3	13 May 2019	5.43484	100.13324	Pantai Acheh	Finless porpoise	2
4	15 May 2019	5.478173	100.17164	Muka Head	Finless porpoise	3
5	28 June 2019	5.354576	100.14632	Sungai Pinang	Finless porpoise	3
6	23 July 2019	5.318598	100.15685	Pulau Betong	Finless porpoise	1
7	20 August 2019	5.403882	100.17642	Pantai Acheh	Finless porpoise	3
8	26 August 2019	5.383413	100.12096	Sungai Pinang	Finless porpoise	1
9	27 August 2019	5.426329	100.17618	Pantai Emas	Finless porpoise	4
10	12 September 2019	5.407914	100.17611	Pantai Acheh	Finless porpoise	1
11	12 September 2019	5.386287	100.17813	Sungai Pinang	Finless porpoise	4
12	19 November 2019	5.399531	100.15551	Sungai Pinang	Finless porpoise	2
13	19 November 2019	5.436692	100.12443	Pantai Acheh	Finless porpoise	2
14	12 December 2019	5.387464	100.14118	Sungai Pinang	Finless porpoise	1
15	03 March 2020	5.324361	100.15613	Pulau Betong	Finless porpoise	3
16	03 March 2020	5.429411	100.12519	Teluk Kampi	Finless porpoise	4
17	16 March 2020	5.319072	100.15508	Pulau Betong	Finless porpoise	2
18	16 March 2020	5.375654	100.14376	Kuala Jalan Baru	Finless porpoise	4
19	17 March 2020	5.434381	100.15885	Teluk Kampi	Finless porpoise	2
20	17 July 2020	5.412912	100.1602	Sungai Pinang	Finless porpoise	2
21	22 November 2020	5.371452	100.14039	Sungai Pinang	Finless porpoise	3
22	25 November 2020	5.458539	100.13334	Pantai Kerachut	Finless porpoise	2
23	25 January 2021	5.32623	100.17507	Sungai Burung	Finless porpoise	3
24	25 January 2021	5.367626	100.15833	Sungai Pinang	Finless porpoise	1
25	25 January 2021	5.393935	100.15799	Sungai Pinang	Finless porpoise	2
26	27 January 2021	5.3181	100.17193	Pulau Betong	Finless porpoise	3
27	27 January 2021	5.42302	100.14772	Pantai Acheh	Finless porpoise	2
28	27 January 2021	5.42154	100.14708	Pantai Acheh	Finless porpoise	1
29	22 February 2021	5.404069	100.15772	Pantai Acheh	Finless porpoise	2
30	23 February 2021	5.462646	100.13904	Pantai Kerachut	Finless porpoise	1
31	24 February 2021	5.321415	100.17549	Pulau Betong	Finless porpoise	5
32	27 February 2021	5.332857	100.16596	Pulau Betong	Finless porpoise	4
33	26 March 2021	5.411077	100.14441	Pantai Acheh	Finless porpoise	1
34	26 March 2021	5.435645	100.15694	Teluk Kampi	Finless porpoise	4
35	27 March 2021	5.397529	100.15858	Sungai Pinang	Finless porpoise	1

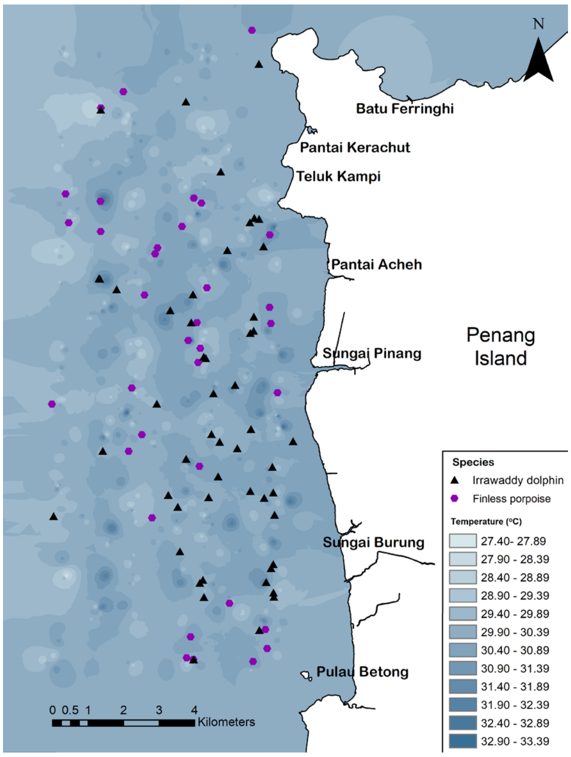
Appendix 3.



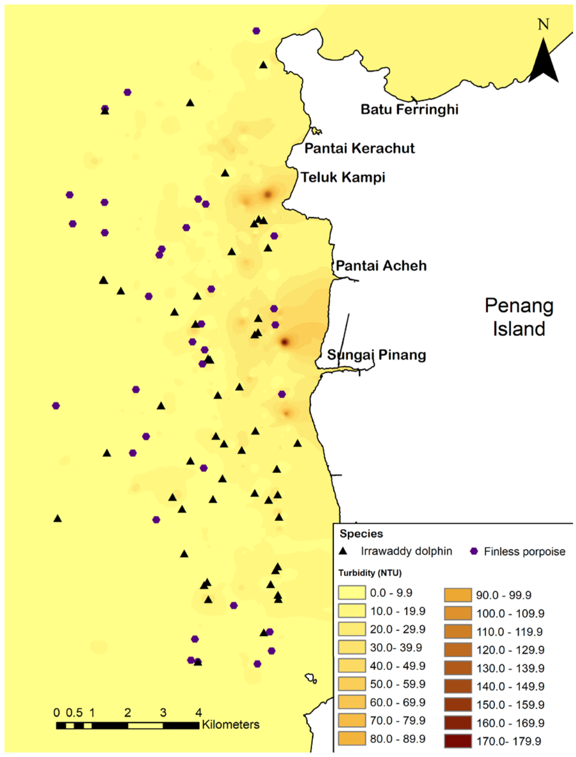
(a)



(b)



(c)



(d)

Maps showing the relationship between environmental parameters and sightings of Irrawaddy dolphins and finless porpoises in west Penang. The distribution of Irrawaddy dolphins and finless porpoises in relation to water parameter values are as follows:

(a): water depth (m); Sightings of Irrawaddy dolphin and finless porpoise were distributed evenly throughout different water depths

(b): sea surface temperature (°C): Dolphin and porpoise sightings occur over a narrow variation of temperature

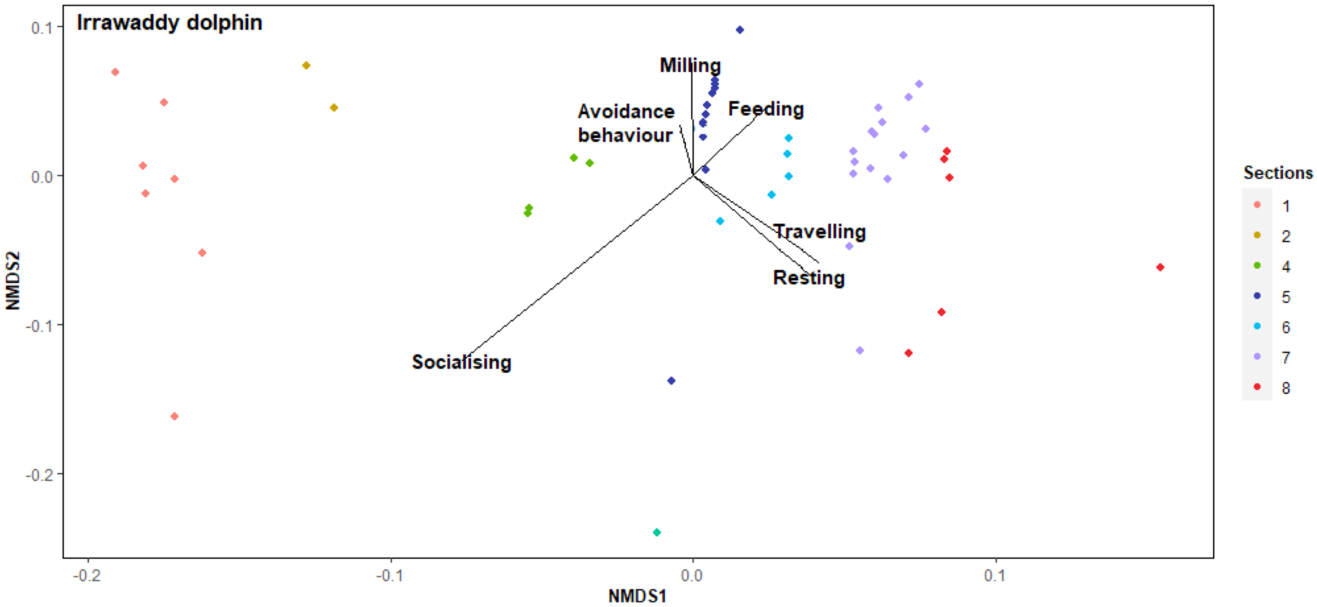
(c): salinity (psu) Dolphin and porpoise occurrences are not affected by varying levels of salinity

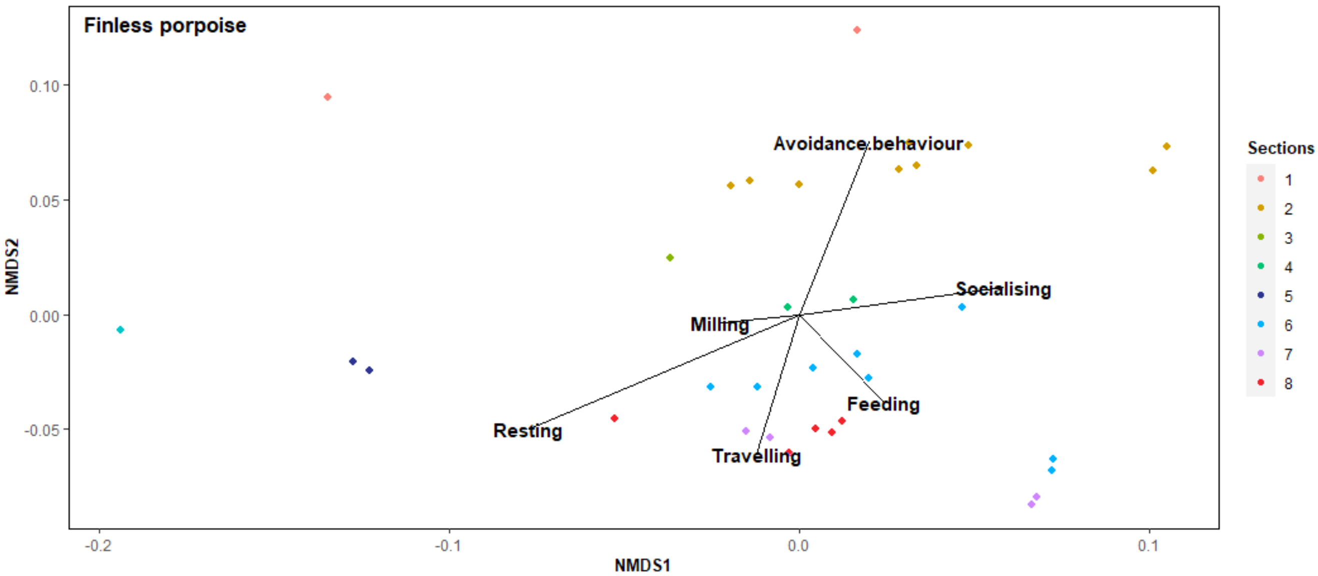
(d): turbidity (NTU) Higher turbidity was observed at the river mouth of Sungai Pinang and inshore areas of Teluk Kampi to Sungai Pinang. Irrawaddy dolphin and finless porpoise sightings occur closer to this high turbidity region and also at between low (range: 0.0 to 9.9 NTU) to medium levels of turbidity (81.1 to 90.0).

Appendix 4.

An Irrawaddy dolphin foraging close to a fishing boat during surveys in west Penang

Appendix 5.





Non-Metric Multidimensional Scaling (nMDS) plot of activity index for resting, socialising, milling, feeding, travelling and avoidance behaviour in west Penang Island inshore and outer shore sections; (above) nMDS for the Irrawaddy dolphin, (below) nMDS for the finless porpoise.

Appendix 6. Calculation for Area Use (AU) in quadrat 11 and 14 for Irrawaddy dolphin. Quadrat size: 1.5 km X 1.5 km = 2.25 km^2.

Quadrat and total AU (land and water)	**Water area (km^2) [land – water area]**	**AU for water area only**
11 - 0.01964637	2.25 - 0.625 = 1.625	2.25 km^2 = 0.01964637 1.625 km^2 = y y = 0.00098 (AU)
14 - 0.1257367	2.25 - 0.25* = 2.0	2.25 km^2 = 0.125736739 2.0 km^2 = y y = 0.1117659 (AU)

*land area was calculated from ArcGis software