ECOLOGY OF INDO-PACIFIC HUMPBACK DOLPHIN (*Sousa chinensis*) AND IRRAWADDY DOLPHIN (*Orcaella brevirostris*) IN THE MATANG MANGROVE AND ADJACENT COASTAL WATERS IN PENINSULAR MALAYSIA

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FACULTY OF SCIENCE
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THESIS SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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ECOLOGY OF INDO-PACIFIC HUMPBACK DOLPHIN (*Sousa chinensis*) AND IRRAWADDY DOLPHIN (*Orcaella brevirostris*) IN THE MATANG MANGROVE AND ADJACENT COASTAL WATERS IN PENINSULAR MALAYSIA

ABSTRACT

The coastal waters of Matang in Perak, Peninsular Malaysia, are internationally designated as the Matang Mangroves and Coastal Waters Important Marine Mammal Area (IMMA) by the International Union for Conservation of Nature (IUCN). As ecological baseline data were lacking on coastal delphinids that are threatened by anthropogenic activities, this Ph.D. study was conducted to contribute new scientific knowledge and critical understanding of the animals' ecology in the coastal waters of Matang. Boat-based surveys were conducted from 2013 to 2016, while interview surveys with local fishers were conducted from 2014 to 2017 to determine the abundance, distribution and habitat characteristics, movement and ranging patterns, and human-dolphin interactions of Indo-Pacific humpback dolphins (*Sousa chinensis*) and Irrawaddy dolphins (*Orcaella brevirostris*). The abundance estimates of Irrawaddy dolphins in Matang were 763 individuals (CV = 13.3%; 95% CI = 588-990), estimated via line-transect distance sampling. Annual abundance estimates of Indo-Pacific humpback dolphins (hereafter humpback dolphins) via mark-recapture fluctuated from 138 individuals (95% CI = 118-162) in 2013-2014 to 171 individuals (95% CI = 148-208) in 2014-2015, to 81 individuals (95% CI = 67-98) in 2015-2016, likely due to the presence of offshore individuals that moved in and out of the study area. The humpback dolphins exhibited a clustered distribution and were mostly found closer inshore in the shallow estuarine waters and riverine waterways that are less than 10 m deep. The Irrawaddy dolphins had a relatively homogenous distribution and were mostly found in farther coastal waters that are less than 15 m deep. The core areas of feeding and nursery grounds of humpback dolphins were mainly in the estuaries of Kuala Sangga Besar, Kuala Larut and Kuala Jarum Mas. As for Irrawaddy dolphins, the core areas of feeding and nursery grounds were mainly around the coastal waters off Kuala Larut and Kuala Trong. The core areas of these two species overlapped minimally, and likely reflected the distribution of preferred prey resources, species interactions, their differential responses to anthropogenic activities and species dominance. The Minimum Convex Polygon (MCP) ranges of 13 inshore resident humpback dolphins overlapped considerably in the estuaries, where the animals remained within 7 km from shore with a mean MCP range of 217.4 ± 65.2 km^2. This ranging pattern in the estuaries is most likely linked to their use of the productive estuarine habitats by optimizing the exploitation of their estuarine prey aggregations that are tidal-driven. Out of 198 local fishers interviewed, 14% (n = 28) had cetacean bycatch that mostly occurred in gillnets and trawl nets. The prevalence of anthropogenic injuries in Irrawaddy dolphins (28.5%) and humpback dolphins (16.5%) also indicated interactions with fishing gears that could threaten their survival. A bycatch risk assessment (ByRA) revealed medium to high dolphin bycatch risk in gillnets and trawl nets throughout most of the study area. This study established important baseline information for future studies to identify abundance trends and habitat shifts, and identified areas that should be prioritized for conservation and habitat management.

Keywords: Abundance, bycatch, conservation, distribution, Indo-Pacific humpback dolphin, Irrawaddy dolphin, marine mammals, movement, threats

EKOLOGI LUMBA PUTIH (*Sousa chinensis*) DAN LUMBA EMPESUT (*Orcaella brevirostris*) DI PAYA BAKAU MATANG DAN PERAIRAN PANTAI BERDEKATAN DI SEMENANJUNG MALAYSIA

ABSTRAK

Perairan pantai di Matang, Perak, Semenanjung Malaysia ditetapkan sebagai *Important Marine Mammal Area* (IMMA) oleh *International Union for Conservation of Nature* (IUCN). Memandangkan terdapat kekurangan data garis dasar ekologi bagi lumba-lumba perairan pantai yang terancam oleh aktiviti manusia, kajian Ph.D ini dijalankan untuk menyumbangkan pengetahuan baru dan pemahaman kritikal mengenai ekologi lumba-lumba perairan pantai di perairan Matang, Perak. Pemantauan menggunakan bot dijalankan dari 2013 hingga 2016, dan temuramah bersama nelayan tempatan dijalankan dari 2014 hingga 2017 untuk menentukan kelimpahan, taburan dan ciri-ciri habitat, corak pergerakan dan kawasan rayau, dan interaksi antara manusia dengan Lumba-lumba Putih (*Sousa chinensis*) dan Lumba-lumba Empesut (*Orcaella brevirostris*). Anggaran kelimpahan Lumba-lumba Empesut melalui persampelan jalur transek *Distance* di Matang adalah 763 individu (CV = 13.3%; 95% CI = 588-990). Anggaran kelimpahan tahunan Lumba-lumba Putih melalui kaedah tanda-tangkap semula yang berubah-ubah dari 138 individu (95% CI = 118-162) pada 2013-2014, kepada 171 individu (95% CI = 148-208) pada 2014-2015, kepada 81 individu (95% CI = 67-98) pada 2015-2016, yang besar kemungkinan disebabkan oleh kehadiran individu lepas pantai yang keluar masuk dari kawasan kajian. Lumba-lumba Putih menunjukkan taburan berkelompok dan kebanyakannya dijumpai berdekatan tepi pantai di dalam sungai-sungai dan perairan muara yang cetek dengan kedalaman kurang dari 10 m. Lumba-lumba Empesut mempunyai taburan yang agak seimbang dan kebanyakannya dijumpai di perairan pantai yang lebih jauh dengan kedalaman kurang dari 15 m. Kawasan teras pemakanan dan asuhan bagi Lumba-lumba Putih kebanyakkannya berada di Kuala Sangga Besar, Kuala

Larut dan Kuala Jarum Mas, manakala kawasan teras pemakanan dan asuhan Lumba-lumba Empesut kebanyakkannya berada di sekitar perairan pesisir Kuala Larut dan Kuala Trong. Kawasan teras kedua-dua spesis ini bertindih secara minimum, dan ini berkemungkinan berkaitan dengan taburan sumber mangsa, interaksi antara spesis, perbezaan gerak balas terhadap aktiviti antropogenik dan penguasaan spesis dominan. Kawasan Poligon Konveks Minimum (MCP) bagi 13 ekor Lumba-lumba Putih yang menduduki kawasan muara banyak bertindih, di mana haiwan tersebut kekal dalam jarak 7 km dari persisiran pantai, dengan purata kawasan MCP sebanyak 217.4 ± 65.2 km^2. Corak pergerakan di kawasan muara ini berkemungkinan berhubung-kait dengan penggunaan habitat muara yang produktif dengan mengoptimumkan eksploitasi agregasi mangsa di kawasan muara yang dipengaruhi oleh pasang surut. Daripada 198 orang nelayan tempatan yang ditemuramah, 14% (n = 28) pernah mengalami tangkapan sampingan mamalia marin yang kebanyakannya berlaku pada pukat insang dan pukat tunda. Kelaziman kecederaan yang disebabkan oleh aktiviti antropogenik pada Lumba-lumba Empesut (28.5%) dan Lumba-lumba Putih (16.5%) turut menunjukkan interaksi dengan alat-alat tangkapan ikan yang boleh mengancam kelangsungan hidup lumba-lumba. Penilaian risiko tangkapan sampingan menunjukkan risiko tangkapan sampingan lumba-lumba yang sederhana hingga tinggi bagi pukat insang dan pukat tunda di sebahagian besar kawasan kajian. Kajian ini telah menyediakan data garis dasar yang penting bagi mengenalpasti arah alir kelimpahan dan peralihan habitat untuk kajian lanjut di masa hadapan, dan mengenalpasti kawasan yang harus diutamakan untuk usaha pemuliharaan dan pengurusan habitat.

Kata kunci: Ancaman, kelimpahan, Lumba-lumba Empesut, Lumba-lumba Putih, mamalia marin, pemuliharaan, pergerakan, taburan, tangkapan sampingan

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S	:	apparent survival probability
A	:	area of region for which abundance is estimated
(.)	:	constant parameter
L	:	length of transect line surveyed
$\hat{N}_m$	:	mark-recapture population estimate
n	:	number of observations
(t)	:	parameter varies with time
p	:	probability of capture
c	:	probability of recapture
$\hat{\theta}$	:	proportion of distinctive individuals
$\hat{N}_T$	:	total population size
g(0)	:	trackline detection probability
E(s)	:	unbiased mean group size
f(0)	:	value of probability density function at zero perpendicular distance
$\hat{c}$	:	variance inflation factor
AIC	:	Akaike's Information Criterion
ANOVA	:	Analysis of variance
ByRA	:	Bycatch Risk Assessment
CV	:	coefficient of variation
CI	:	confidence interval
CBD	:	Convention on Biological Diversity
CITES	:	Convention on International Trade of Endangered Species
QAICc	:	corrected quasi Akaike's Information Criterion
°C	:	degree Celcius
DO	:	dissolved oxygen

D	:	distinctiveness
E	:	ebb
exp	:	exponential
F	:	flood
GLM	:	generalized linear model
GPS	:	Global Positioning System
GRT	:	gross registered tonnage
H	:	high
HP	:	horsepower
h	:	hour
ID	:	identification
IMMA	:	Important Marine Mammal Area
IUCN	:	International Union for Conservation of Nature
KDE	:	kernel density estimation
km	:	kilometer
KG	:	Kuala Gula
KJM	:	Kuala Jarum Mas
KL	:	Kuala Larut
KSB	:	Kuala Sangga Besar
KT	:	Kuala Trong
LDF	:	left side of dorsal fin
L	:	low
MMFR	:	Matang Mangrove Forest Reserve
MCP	:	Minimum Convex Polygon
m	:	meter
min	:	minute

ln	:	natural logarithm
n.m.	:	nautical mile
NC	:	North Coastal
NE	:	North Estuarine
No.	:	number
ppt	:	parts per thousand
%	:	percentage
PVC	:	Percentage Volume Contour
Q	:	quality
QQ	:	quantile-quantile
RDF	:	right side of dorsal fin
SST	:	sea surface temperature
SLR	:	single lens reflex
SC	:	South Coastal
SE	:	South Estuarine
SD	:	standard deviation
SE	:	standard error
TDS	:	total dissolved solids
var	:	variance

LIST OF APPENDICES

CHAPTER 1: INTRODUCTION

1.1 Overview of coastal delphinids in Malaysia

Out of the five marine mammal groups (i.e., cetaceans, sirenians, pinnipeds, marine and sea otters, and polar bear), only cetaceans (26 species) and sirenian (one species of dugong) from seven taxonomic families were recorded in Malaysian waters (Ponnampalam, 2012). "Cetacean" is the collective name for whales, dolphins and porpoises. Delphinidae, commonly known as oceanic dolphins or delphinids, is the most diverse family of marine mammals (Jefferson & LeDuc, 2018), and 16 species in this family were recorded in Malaysian waters (Ponnampalam, 2012). While some delphinids prefer offshore or deeper waters, others are more coastal and may occasionally enter rivers, but they should not be confused with true river dolphins in the family of Platanistidae, Iniidae, Pontoporiidae and Lipotidae that are not found in Malaysia.

Marine mammals in Malaysia are protected by several laws such as the Fisheries Act 1985 (Part VI, Aquatic Animals), Fisheries (Control of Endangered Species) Regulation 1999 and Convention on International Trade of Endangered Species (CITES) Act 2008 that prohibit any marine mammals in Malaysia water from being caught, taken, harmed, disturbed, killed or traded.

1.2 Background and significance of present study

Malaysia ratified the Convention on Biological Diversity (CBD) in 1994, and has the obligation under the CBD to promote biodiversity conservation. Despite Malaysia, being one of the world's megadiverse countries and blessed with high biodiversity of wildlife, the ecology and conservation needs of marine mammals in Malaysia are still barely understood as dedicated marine mammal research are still lacking in most parts of the country, and there is an urgent need to fill in information gaps on cetaceans in Malaysia. The charismatic marine mammals are prime indicators of ocean health that is intricately linked to human health, as many marine mammal species are long-term coastal residents that consume the same seafood as humans and may be exposed to environmental stressors (Bossart, 2011; Moore, 2008).

Establishing baseline population data such as abundance and distribution to understand the population status and conservation needs of a species is crucial for effective species and habitat management (Cañadas & Hammond, 2008; Forcada, 2018; Peter, 2012). Baseline population data serve as a reference point to detect population trends in the future, and evaluate the effectiveness of management and conservation actions taken (Hines et al., 2015a; Ponnampalam et al., 2018). Coastal cetaceans are particularly vulnerable to threats due to their proximity to human activities nearshore. As the populations of Indo-Pacific humpback dolphins and Irrawaddy dolphins show decreasing trends globally (Jefferson & Smith, 2016; Minton et al., 2017) and likely in Matang, Perak, an area with intense fishing pressures and dolphin-watching tourism, there is an immediate need to understand both species' ecology and conservation needs in Matang through dedicated and systematic research efforts.

This Ph.D study was carried out with the overall aim to contribute new knowledge and critical understanding of the ecology of Indo-Pacific humpback dolphins (*Sousa chinensis*) and Irrawaddy dolphins (*Orcaella brevirostris*) in the coastal waters of Matang, Perak. The present study provided the much-needed ecological information pertaining to their abundance, distribution, habitat characteristics, movement, ranging patterns and threats from anthropogenic activities, which in turn helps to form recommendations of conservation actions and habitat management strategies to be shared with policy and decision makers in the federal and state governments.

1.3 Research questions

In view of the lack of ecological baseline data of Indo-Pacific humpback dolphins and Irrawaddy dolphins in the coastal waters of Matang, key research questions addressed in the present study are as follow:

1) What are the abundance estimates of Indo-Pacific humpback dolphins and Irrawaddy dolphins in Matang?
2) What are the distribution patterns of Indo-Pacific humpback dolphins and Irrawaddy dolphins in Matang?
3) What are the habitat preferences (e.g., water depth, salinity, distance to river mouth) of Indo-Pacific humpback dolphins and Irrawaddy dolphins in Matang?
4) Where are the feeding and nursery areas for Indo-Pacific humpback dolphins and Irrawaddy dolphins within their habitat in Matang?
5) What are the individual movement patterns of inshore resident Indo-Pacific humpback dolphins within the study area?
6) Where are the core areas and ranging areas of Indo-Pacific humpback dolphins and Irrawaddy dolphins within the study area?
7) Are Indo-Pacific humpback dolphins and Irrawaddy dolphins in Matang threatened by fisheries bycatch?

1.4 Objectives of study

In order to address the above research questions and improve our understanding of the ecology of Indo-Pacific humpback dolphins and Irrawaddy dolphins in the coastal waters of Matang, the objectives of this Ph.D study are:

1) To obtain abundance estimates of Indo-Pacific humpback dolphins and Irrawaddy dolphins in the riverine and adjacent coastal waters of Matang

2) To investigate the distribution and habitat characteristics of both dolphin species in relation to water parameters and distance to river mouth
3) To study the movement patterns and ranging patterns of Indo-Pacific humpback dolphins and Irrawaddy dolphins within the study area
4) To determine the level of overlap between dolphin distribution and human activities with an emphasis on fisheries interaction

CHAPTER 2: LITERATURE REVIEW

2.1 Current knowledge of Indo-Pacific humpback dolphins and Irrawaddy dolphins

According to Jefferson & Rosenbaum (2014), there are four valid species of humpback dolphins that are recognized in the genus *Sousa*: the Indian Ocean humpback dolphin (*Sousa plumbea)*, the Atlantic humpback dolphin (*Sousa teuszii)*, the Australian humpback dolphin (*Sousa sahulensis)* and the Indo-Pacific humpback dolphin (*Sousa chinensis).* Compared to the other species, the Indo-Pacific humpback dolphin (hereafter referred to as humpback dolphin) does not have a dorsal hump and has little to no sexual dimorphism (Jefferson & Curry, 2015). The humpback dolphin has a stocky body, a long, well-defined beak and a slightly falcate dorsal fin that broadens at the base (Figure 2.1a). Calves of humpback dolphins are born dark grey and the skin lightens as the animal matures, causing the skin to turn a mottled greyish-pink (Jefferson et al., 1993; Kurihara & Oda, 2009). However, there appears to be slight morphological differences in terms of the prominence of the hump on the dorsal fin, broadness of the fin base, and pigmentation patterns between the humpback dolphins observed off the west coast of Peninsular Malaysia and Borneo (Minton et al., 2016). The Bornean humpback dolphins have a broadly triangular dorsal fin with a wide base, and a small percentage of individuals attain the almost all-white/pink colouration, whereas the ones off the west coast of Peninsular Malaysia have a more falcate dorsal fin that is not as broad at the base and no adults attain all-white status (L. Ponnampalam, pers. comm., cited in Minton et al., (2016)).

Irrawaddy dolphins are characterised by a bulbous, rounded head that lacks a rostrum, a small and rounded-tip dorsal fin (Figure 2.1b), and colours that vary from light to dark grey (Stacey & Arnold, 1999). Irrawaddy dolphins in Balikpapan Bay and Mahakam River appeared to have sexual dimorphism, where individuals with calves had smooth necks with no neck crests (Kreb, 2004).

Figure 2.1: Photographs of (a) Indo-Pacific humpback dolphins (*Sousa chinensis*) and (b) Irrawaddy dolphins (*Orcaella brevirostris*) in Matang, Perak, Peninsular Malaysia

Taiwanese humpback dolphin (*S. c. taiwanensis*) from the Taiwan Strait was described as a new subspecies by Wang et al. (2015). The older individuals of Taiwanese humpback dolphin subpopulations in the eastern Taiwan Strait was reported to be clearly diagnosable from those of the Jiulong River and Pearl River Estuary of mainland China, based on subtle but noticeably different pigmentation patterns (Wang et al., 2015). Jefferson & Curry (2015) suggested that the humpback dolphins in the Bay of Bengal may comprise a fifth species based on molecular evidence.

Currently, there is very little published information about genetic structure of dolphins in Malaysia. Genetic data suggested that there are two clades among Irrawaddy dolphins within Asia, with Mekong River samples from Cambodia and southern Laos forming one clade, and all others in Thailand, Indonesia and Philippines forming another clade (Beasley et al., 2005). The Chilika Lagoon subpopulations of Irrawaddy dolphins in India were reported to show closest genetic proximity to the haplotypes from Thailand (Jayasankar et al., 2011). Freshwater subpopulation of Irrawaddy dolphins in the Mekong River had very low genetic differentiation, with at least 85% of all individuals in Kratie and Stung Treng reported to bore the same mitochondrial haplotype (Krützen et al., 2018).

In contrast, significant genetic differentiation in mitochondrial DNA was reported to be apparent among coastal Irrawaddy dolphins in the eastern, northern and western Gulf of Thailand, and Andaman Sea (Dai et al., 2021).

In 2017, the International Union for the Conservation of Nature (IUCN) Red List Criteria uplisted the Indo-Pacific humpback dolphin's conservation status to 'Vulnerable' (Jefferson et al., 2017) and that of the Irrawaddy dolphin to 'Endangered' (Minton et al., 2017) due to both species' declining population trends throughout their ranges. However, other subpopulations such as the Taiwanese humpback dolphin (*S. c. taiwanensis*), Irrawaddy dolphin subpopulations in Iloilo-Guimaras and Malampaya Sound, and freshwater subpopulations of Irrawaddy dolphin in Ayeyarwady River, Mahakam River, Mekong River and Songkhla Lake are listed as 'Critically Endangered' (Dolar et al., 2018; Jefferson et al., 2008; Smith, 2004; Smith & Beasley, 2004b, 2004c, 2004a; Wang & Araujo-Wang, 2018).

2.1.1 Distribution

Understanding marine mammal distributions are essential to identify critical habitats where management actions can be taken for conservation (Bonizzoni et al., 2019). The general distribution patterns of a population are the sum of individual specific movements over space and time (Forcada, 2018). Marine mammal distributions are affected by several factors: ecology, habitat characteristics, anthropogenic activities, demography and evolution (Forcada, 2018). Key environmental variables such as depth and salinity typically affect prey distribution, and subsequently influence cetacean distribution (Dares et al., 2014; Griffin & Griffin, 2003; Heithaus & Dill, 2002; Hooker et al., 2002).

2.1.1.1 Humpback dolphins

The humpback dolphin is distributed in shallow coastal waters from east India in the eastern Indian Ocean to China and Southeast Asia in the western Pacific Ocean (Jefferson

& Rosenbaum, 2014). Studies on humpback dolphin distribution have been conducted in Western Taiwan (Wang et al., 2004a, 2007), Hong Kong (Hung, 2008), China (Chen et al., 2010; Li et al., 2016; Lin et al., 2012; Wang et al., 2016; Wu & Cheng, 2017; Yang et al., 2005), Thailand (Jutapruet et al., 2017); Vietnam (Smith et al., 2003) and along India and Sri Lanka (Sutaria & Jefferson, 2004). Humpback dolphins often enter rivers, estuaries, and mangroves, with preference for coasts with mangrove swamps, lagoons, estuaries, areas with reefs, sandbanks, and mudbanks (Jefferson & Curry, 2015; Jefferson & Karczmarski, 2001).

Humpback dolphins in Lantau Island, Hong Kong, were present all year round in the north but their distribution shifted to the south and east during the summer monsoon season (Parsons, 1998). Seasonal occurrences of humpback dolphins in Hong Kong were higher in June-November (wet monsoon seasons) than December-May (dry monsoon seasons) (Würsig et al., 2016), and may be linked to higher abundance of prey during the wet season when water temperature rises and salinity decreases (ERM-Hong Kong, 1998). This is further supported by findings of Chen et al. (2010) who suggested that variations in humpback dolphin distribution during the wet and dry seasons are probably associated with the movements of their prey species. Lin et al. (2015) reported that humpback dolphins in western Taiwan mainly stayed near river mouths during dry seasons and shifted seaward during rainy seasons and after heavy rainfall, as changes in water quality including turbidity and salinity can affect the prey distribution. Higher number of calves in areas with steeper seafloor were observed by Hung (2008). Dungan et al. (2012) further suggested that herding of fish schools may be facilitated in steeper seafloor or preferred as habitat by the prey species of humpback dolphins.

In Malaysia, humpback dolphins have been recorded in Melaka, Penang Island, Matang, Langkawi Island, Johor, along the east coast of Peninsular Malaysia and the northwestern coasts of Borneo from Sematan in Sarawak to Sandakan in Sabah (Kuit et al., 2019a; Minton et al., 2013; Nadarajah, 2000; Ponnampalam, 2012; Ponnampalam et al., 2012, 2018; Ponnampalam & Fairul Izmal, 2011; Rajamani et al., 2014; Rice, 1998; Teoh et al., 2013; Zulkifli Poh et al., 2016). However, very limited comprehensive studies had been conducted to determine the distribution of local cetaceans and underlying factors shaping their distribution patterns.

2.1.1.2 Irrawaddy dolphins

The range of Irrawaddy dolphins include the nearshore marine waters of the Indo-Pacific, three large rivers (Ayeyarwady River in Myanmar, Mahakam River in Indonesia and Mekong River in Cambodia, Lao PDR and Vietnam) and two marine-appended brackish water lakes (Songkhla Lake in Thailand and Chilika Lagoon in India) (Smith et al., 2009a). Compared to coastal populations, freshwater populations of Irrawaddy dolphins have been studied more extensively in the Mekong (Baird & Beasley, 2005), Ayeyarwady (Smith et al., 2007) and Mahakam Rivers (Kreb, 2004), Chilika Lagoon (Sutaria & Marsh, 2011; Sutaria, 2009), and Songkhla Lake (Beasley et al., 2002). Coastal populations of Irrawaddy dolphins have been studied in Bangladesh (Smith et al., 2006), Indonesia (Kreb et al., 2020; Kreb & Budiono, 2005a; Kreb & Lim, 2009), Thailand (Hines et al., 2015b; Junchumpoo et al., 2014; Ponnampalam et al., 2013; Tongnunui et al., 2011) and the Philippines (de la Paz et al., 2020; Dolar et al., 2002; Whitty, 2016).

Coastal Irrawaddy dolphins were mostly found near river mouths or bays within a few kilometers from shore (Jackson-Ricketts et al., 2020; Mahmud et al., 2018b; Minton et al., 2011; Rodríguez-Vargas et al., 2019). Irrawaddy dolphins in the Gulf of Thailand were seen up to 11 km from shore (Jackson-Ricketts, 2017), whereas they were recorded up to 10 km upriver in Kuching Bay, Sarawak, Malaysia (Peter, 2012). The extent of the inshore range of Irrawaddy dolphins in the Bay of Bengal, Bangladesh were reported to be highly dependent on freshwater flow that varies seasonally (Smith et al., 2008).

In Malaysia, there are several scientific studies of coastal Irrawaddy dolphins such as in Penang Island (Rodríguez-Vargas, 2015) and in East Malaysia (Minton et al., 2011, 2013; Peter et al., 2016; Teoh et al., 2013). Additionally, there are confirmed records of Irrawaddy dolphins elsewhere in the coastal waters of Malaysia, namely near Mersing, Bernam River, Kuala Perlis, Muara Island, Sandakan and Kuching Bays, and in the mouths of the Sarawak, Rajang, Kinabatangan, Baram, and Batang Rivers (Beasley & Jefferson, 1997; Dolar et al., 1997; Minton et al., 2011; Morzer Bruyns, 1965; Nadarajah, 2000; Ponnampalam, 2012; Ponnampalam et al., 2012; Ratnam, 1982).

2.1.2 Abundance

2.1.2.1 Humpback dolphins

To date, the world's largest population of Indo-Pacific humpback dolphins is outside the Southeast Asian region, in China, where Chen et al. (2010) estimated that the total population size of humpback dolphins in the Pearl River Estuary to be 2,555 (CV = 19%) during the wet season using line-transect analysis in a large study area of 3,848 km^2. However, the population of humpback dolphins in the Pearl River Estuary was estimated to decline at a continuous rate of 2.46% per annum (Huang et al., 2012). The second largest humpback dolphin population in the world is in Zhanjiang, China, where Xu et al. (2015) estimated 1,485 individuals (SE = 63.8), based on a 7-year photo-identification dataset from 2,310 hours of survey effort. Zhou et al. (2007) estimated 237 humpback dolphin individuals (95% CI: 189-328) around Leizhou Bay, China. Chen et al. (2016) estimated an average of 398 – 444 (95% CI: 393-505) humpback dolphin individuals in the Northern Beibu Gulf, China. In Xiamen, Jefferson and Hung (2004) estimated that there are 80 individuals (CV = 1.08) of humpback dolphins. Chen et al. (2008) estimated an average of 76 individuals (SE = 8.59) in Xiamen, 114 individuals (SE = 87.89) in the Partial Dafengjiang River Estuary, and 39 individuals (SE = 29.98) in the National Hepu Dugong Nature Reserve in China.

In Hong Kong, a 5-year mark-recapture study yielded the seasonal abundance estimates of humpback dolphins to be ranging from 87 to 111 in the winter, and 144 to 231 in the summer (Chan & Karczmarski, 2017). However, these seasonal abundance estimates from photo-identification were higher than the annual estimates from line-transect survey of a separate study by Hung (2019) who estimated 32 individuals in West Lantau, North West Lantau and Southwest Lantau with decline in abundance.

Wang et al. (2007) surveyed the Eastern Taiwan Strait between 2002 and 2004 and estimated the humpback dolphin population to be 99 individuals (CV = 51.6%), with a density of 19.3 individuals/100km^2 using the program DISTANCE. Subsequently, Wang et al. (2012) conducted photo-identification surveys between 2007 and 2010 and estimated 74 individuals (CV = 4%) via mark-recapture analysis which was about 25% lower and had 13 times higher precision than the initial line-transect abundance estimates, suggesting that the mark-recapture method may be superior to line-transect method in estimating abundance of humpback dolphin population.

Within the Southeast Asian region, abundances of humpback dolphins had been estimated only in several locations in Thailand and Malaysia in study areas smaller than 500 km^2 (Cherdsukjai & Kittiwattanawong, 2013; Jaroensutasinee et al., 2010; Jutapruet et al., 2015; Zulkifli Poh et al., 2016). In Thailand, the minimum population size of humpback dolphins off Donsak, Surat Thani, Thailand was estimated to be 193 (95% CI = 167-249) using mark-recapture analysis (Jutapruet et al., 2015). However, the progressively ascending cumulative sighting curve suggested that the actual population size may be higher than this estimate. Around Sukon Island and Sarai Island, Thailand, Cherdsukjai & Kittiwattanawong (2013) estimated 56 (SE = 21.5) dolphins and 29 (SE = 4.2) individuals respectively. In Khanom, Thailand, Jaroensutasinee et al. (2010) estimated 49 humpback dolphin individuals in their study site.

In Malaysia, abundance estimates of humpback dolphins are available in East Malaysia from Kuching Bay, Sarawak and Cowie Bay, Sabah. The best estimate in Kuching Bay, Sarawak using mark-recapture with inverse CV-squared weighted mean was 84 individuals (CV = 16.4%, 95% CI = 61-116) (Zulkifli Poh et al., 2016). In Peninsular Malaysia, Ponnampalam & Jamal Hisne (2012) and Teoh (2018) are researching humpback dolphins in Kuala Perlis, Kuala Kedah and Langkawi Island, and have catalogued at least 409 individuals based on photo-identification, and the analyses for abundance is underway (L. Ponnampalam & Z. Y. Teoh, personal communication, 25 January 2021).

2.1.2.2 Irrawaddy dolphins

As the present study is focused on coastal populations of Irrawaddy dolphins, the literature review on abundances presented here only covers estimates from studies on coastal populations and excludes the freshwater populations. While the freshwater populations of Irrawaddy dolphins have been studied more extensively than coastal populations, efforts to study the coastal populations of Irrawaddy dolphins in the last decade have increased.

The largest estimate of Irrawaddy dolphins to date was in a large study area of 16,779 km^2 in Bay of Bengal, Bangladesh, where Smith et al. (2008) estimated 5383 individuals (CV = 39.5%) using line-transect method. In the Sundarbans mangrove forest, Smith et al. (2006) estimated 451 dolphins (CV = 9.6%) using concurrent counts. Within the Southeast Asian region, the study area sizes varied greatly but were mostly smaller than 500 km^2 with associated abundance estimates of tens to fewer than 500 individuals for each species (e.g., Cherdsukjai and Kittiwattanawong, 2013; Minton et al., 2013b; Hines et al., 2015a; Kreb et al., 2020). A five-year boat-based line transect study by Hines et al. (2015) estimated an average relative abundance of 423 dolphins within a 12-km stretch along the eastern Gulf Coast of Thailand. At the Malampaya Sound in the Philippines, Smith et al. (2004) conducted line-transect surveys in April to November 2001 and estimated the abundance of dolphins there to be 77 individuals (CV = 27.4%) using the program DISTANCE. A study by Kreb et al. (2020) in Balikpapan Bay, Indonesia estimated the abundance of dolphins in 2015 to be 45 individuals based on line-transect density analysis and 73 via mark-recapture method.

Published scientific studies on abundances of Irrawaddy dolphins in Malaysia are sparse, and had mostly conducted in East Malaysia. Minton et al. (2013) conducted surveys between 2007 and 2010 and estimated a population of 149 dolphins (CV = 28%) in Kuching Bay, Sarawak based on line-transect surveys, and 233 individuals (CV = 22.5%) using mark-recapture of dorsal fins. In Cowie Bay, Sabah, Teoh et al. (2013) conducted photo-identification surveys from October 2009 to September 2010, and estimated a population of 31 individuals of dolphins using mark-recapture. In Brunei Bay, line-transect boat surveys were conducted from April 2013 to October 2015 and the estimated population size was 41 individuals (Mahmud et al., 2018b). The geographically closest Irrawaddy dolphin study to Matang is on the west side of Penang Island, approximately 80 km north of Matang, whereby 32 to 43 individuals were estimated in a small study area of 80 km^2 using closed and open models respectively (Rodríguez-Vargas et al., 2019). Information on abundance trends are however not yet available for dolphins in most of those sites, but according to the IUCN Red List of Threatened Species, both species show declining trends elsewhere (Jefferson et al., 2017; Minton et al., 2017).

2.1.2.3 Approaches to abundance estimation for humpback dolphins and Irrawaddy dolphins

According to Tarsi & Tuff (2012), population size is defined as the number of individuals present in a subjectively designated geographic range. Obtaining reliable population estimates are important for effective species protection and habitat management strategies, but it is often difficult especially for marine mammals that spend most of the time underwater and have an extensive moving range. Abundance estimates of humpback dolphins and Irrawaddy dolphins are generally still limited and are only available for a few selected sites. However, there has been increasing effort to estimate the population abundance of both species throughout their ranges in recent times. In cetacean studies, absolute abundance estimates often refer to the estimated number of cetacean individuals in a defined geographic area, whereas the index of relative abundance is often expressed in terms of encounter rate per unit of time (e.g., hour) or transect length (e.g., km) (Peter, 2012). Line-transect distance sampling and mark-recapture (photo-identification) methods are most commonly used to estimate the abundance of humpback dolphins and Irrawaddy dolphins in Southeast Asia (Hines et al., 2015b; Jutapruet et al., 2015; Peter, 2012; Zulkifli Poh et al., 2016). To a lesser extent, acoustic methodologies are used for abundance estimation of cetaceans (Akamatsu et al., 2013).

Mark-recapture and line-transect distance sampling methods have advantages and disadvantages; choosing the most suitable method may depend on a number of factors. These may include the aims of the study, the target species (e.g., its behaviour and the distinctiveness of natural marks), distribution patterns, resources available (e.g., time, finances and logistics) and the size of the study area (Hammond, 2010; Parra & Corkeron, 2001; Sutaria & Marsh, 2011).

Distance sampling is a widely used methodology to estimate the abundance or density of cetacean populations (Buckland et al., 2001, 2004; Hammond, 2010). Distance sampling comprises methods in which the perpendicular distances of animal groups to the transect line or point are recorded, from which the average density within the study area is extrapolated to obtain the abundance estimate of the animals (Thomas et al., 2010). The line transect survey design for cetaceans primarily comprises a set of straight lines that are either randomly or systematically placed throughout the study area, which are covered by observers on a boat or aircraft during daylight hours for visual or acoustic detection (Buckland & York, 2009). A series of parallel lines are commonly placed perpendicular to the coastline to improve efficiency for inshore surveys, or systematic zig-zag lines are used to reduce off-effort ship time traversing from one line to the next particularly for large survey areas (Buckland et al., 2004; Thomas et al., 2010). The observer records the detection distance and detection angle to calculate the perpendicular distance of the sighting from the transect line.

Distance sampling method is more suitable for dispersed populations (Buckland & York, 2018). According to Buckland et al. (2001), at least 60 sightings are recommended to achieve better precision for the estimates. Some studies did not have sufficient number of humpback dolphin sightings encountered on the transect lines for distance analysis (Hines et al., 2015b; Zulkifli Poh et al., 2016). Studies in very large study area (>3,000 km^2) have employed the line-transect method and generated estimates of over 2500 individuals in each study area (Chen et al., 2010; Smith et al., 2008), which may be highly challenging for mark-recapture studies as it would be difficult to capture photographs of gregarious groups and require a lot of effort to match photographs of thousands of individuals. The assumptions for line transect sampling are explained in further detail in Chapter 3.

Mark-recapture method which tends to be more labour-intensive than distance sampling, is applicable to populations that are not amenable to distance sampling method (Buckland & York, 2018). The mark-recapture method is based on multiple samplings of uniquely marked animals to record the marked animals in the population and the proportion of well-marked animals to extrapolate the mark-recapture estimates to total population size (Hammond, 2018). The basic data required for mark-recapture are the capture histories of individuals, based on whether the identified individual was captured

(1) or not captured (0) during sampling occasions (Hammond, 2018). The assumptions for mark-recapture are explained in further detail in Chapter 3.

While there are other identification methods such as attachment tags, scarring and branding (Wells, 2009), photo-identification of natural markings on cetaceans had been more frequently used in recent years as it is less invasive (i.e., does not require physical capture and marking of the animals) and relatively inexpensive (Hupman et al., 2018). Naturally-marked individuals in a population are typically identified based on the physical characteristics on their body parts such as the dorsal fins, flukes, backs, and heads that are visible above the water surface when the animals are surfacing (Wells, 2009). Marked cetaceans exhibit variations in dorsal fin shape, nicks and notches along fin edges, body scarring and colour patterns (Hammond et al., 1990). Obtaining good photographs of the natural markings is important in photo-identification studies, and is largely dependent on the ability to approach the animals, their behaviour and having good photographic equipment (Hammond et al., 1990). Mature humpback dolphin individuals have been reliably identified from its pigmentation and scarring patterns on its dorsal fins (Chan & Karczmarski, 2017; Wang et al., 2008; Zulkifli Poh et al., 2016).

Mark-recapture is more applicable to populations that are small and with at least 30% of the identifiable individuals marked (Sutaria, 2009). Mark-recapture methods are used in most abundance studies of humpback dolphins (Chan & Karczmarski, 2017; Peng et al., 2020; Wang et al., 2012; Xu et al., 2015; Zulkifli Poh et al., 2016). Irrawaddy dolphins are elusive animals and are challenging to be studied through photo-identification, but has been used to study small populations (<250 individuals) (Mahmud et al., 2018b; Minton et al., 2013; Rodríguez-Vargas et al., 2019; Teoh et al., 2013).

2.1.3 Group size

Group size refers to the number of individuals in an aggregation, whereby the individuals were observed in apparent association, moving in the same direction and usually engaged in the same activity (Shane, 1990). Accurate group size estimation is important for abundance estimation, such as in line transect distance sampling, whereby the estimated density of groups is multiplied by an estimate of expected group size (Buckland & York, 2009; Gerrodette et al., 2018). This estimation is however particularly challenging for cetaceans as the groups can be large, animals are moving, an unknown fraction of the group is underwater and this fraction could change with behaviour (Gerrodette et al., 2018). Dolphin group sizes from observers' counts are usually recorded in minimum, maximum and best estimates, and the best estimates are used for analysis to minimize bias (Jefferson, 2000; Liu et al., 2020).

2.1.3.1 Humpback dolphins

Humpback dolphins are mostly seen in small schools of less than 10 animals, with solitary animals and schools of two to six individuals being most common (Parra & Ross, 2009). Group sizes of humpback dolphins appear to vary according to behaviour, and as adaptations to different environments and trade-off between benefits and costs of living in a group (Liu et al., 2020). Hung (2008) reported that the group size of dolphins in Hong Kong and mainland waters ranged from one to 44 individuals, with mean of 4.5 individuals per group. The mean group size of dolphins in Hong Kong that were associated with fishing trawlers was largest, followed by groups that were socializing, and feeding, whereas groups that were milling or travelling had the smallest mean group size (Parsons, 1998; Würsig et al., 2016).

The two main techniques for estimation of humpback dolphin group size are observers' counts (i.e., on-site observations) and photo-identification (Liu et al., 2020). In the eastern Taiwan Strait, the mean group size of Taiwanese humpback dolphins was

6.2 ± 5.9 (range: 1-31; n = 221) and a median of 4, but photo-identification revealed that there were at least 41 individuals in the largest group (Dares et al., 2014). In southwest Hainan, China, Liu et al. (2020) found that observers' counts (12.9 ± 10.1, range: 1-40, n = 45) were 25% smaller than photo-identification estimates (17.2 ± 18.2, range: 1-84, n = 30). Although observers may have the tendency to underestimate dolphin group size, particularly when the groups are large, it appears that photo-identification remains a more credible method to estimate humpback dolphin group size despite being likely to miss capturing all individuals (Liu et al., 2020).

In Zhanjiang Bay, China, Xu et al. (2015) reported mean group size of humpback dolphins was 8.1 ± 5.9 (range 1-35, n = 611). In Xiamen, China, mean group size was 7.2 individuals (n = 76) (Chen et al., 2018). In Thailand, the average group size of dolphins was 4.72 ± 3.4 individuals (range: 1-18; n = 89) in Donsak (Jutapruet et al., 2015) and 5.9 ± 5.4 individuals (range: 2-20) in Khanom (Jaroensutasinee et al., 2010).

In Malaysia, mean group size of humpback dolphins in Kuching Bay, Sarawak, was 18.0 ± 13.33 individuals (range = 7-45, n = 16) (Zulkifli Poh et al., 2016). The mean group size in Kuching Bay is one of the largest documented for humpback dolphins (Minton et al., 2016). However, it was argued that this may be partly due to the small sample sizes (Liu et al., 2020). Mean group size of humpback dolphins in Penang was 12 individuals, and ranged between two to 30 individuals (Rajamani et al., 2018). In Langkawi Island, Kedah and Perlis, large groups of more than 120 dolphins were occasionally observed (Ponnampalam et al., 2012; Teoh, 2018).

2.1.3.2 Irrawaddy dolphins

Throughout its range, the mean group sizes of Irrawaddy dolphins were generally low at less than seven individuals per group. The highest mean group size was recorded in Koh Kong, Cambodia, whereby the mean group size of dolphins was 6.7 ± 7.8 individuals and ranged between one to 19 individuals during systematic search, whereas during non-systematic search, mean group size was 7.0 ± 4.4 individuals and ranged from one to 13 individuals (Smith et al., 2016).

The mean group size of dolphins in Malampaya Sound, Philippines was 5.3 (SE = 1.06) (Dolar et al., 2002). Kreb & Budiono (2005b) reported a mean group size of dolphins in east Kalimantan, Indonesia to be 3.0 individuals in nearshore waters, 3.4 individuals in the bay and 4.8 individuals in the river delta. Mean group size of Irrawaddy dolphins in the Bay of Bengal, Bangladesh was 2.2 ± 1.8 individuals, and ranged from one to seven individuals (Smith et al., 2008).

In Thailand, Tongnunui et al. (2011) reported mean group size of 2.5 ± 3 individuals in Bangpakong Estuary. The group size of Irrawaddy dolphins observed in Trat Bay which is approximately 250 km away was larger, with a mean group size of 4.9 ± 4.9 individuals and ranged between five to 20 individuals (Junchumpoo et al., 2014). In a more recent study in Trat Bay, the mean group size was estimated to be 5.22 ± 3.45 individuals, and ranged between two to 13 individuals (Niu et al., 2019). Occasionally, unusually large aggregations of up to 20-30 dolphins that displayed herding with probable mating were reported in Trat, Thailand (mean group size of 17.3 ± 7.6 individuals) (Ponnampalam et al., 2013) and in Kuching Bay, Malaysia (Minton et al., 2011).

In the nearshore waters of Sarawak, Malaysia, Minton et al. (2011) reported the mean group size of Irrawaddy dolphins to be 4.3 ± 3.1 individuals (n = 66). In the Malaysian part of the Brunei Bay, the mean group size was 6 (SE = 0.66) (n = 47) and ranged between one to 18 individuals (Mahmud et al., 2018b). The mean group size of dolphins in west Penang was 5 ± 0.5 (SE) (n = 43) individuals, and ranged between two to 15 individuals (Rodríguez-Vargas, 2015).

2.1.4 Habitat use and preferences

According to Morrison et al. (1999), habitat use refers to the way an animal uses a collection of physical and biological entities in a habitat, whereas habitat preference is used to describe the relative use of different locations by an individual or species. Explanations on habitat use by marine mammals can be due to extrinsic factors (e.g., prey availability, predation risk, intraspecific competition, human influence) or intrinsic factors (e.g., body size, age, sex, individual variability, life history) (Acevedo-Gutiérrez, 2009),. In ecological studies, it is important to document how marine mammal distribution is influenced by the environment at different spatial and temporal scales, and most explanations on marine mammal habitat use are linked to environmental factors such as prey availability that are relevant to habitat suitability (Acevedo-Gutiérrez, 2009; McClellan et al., 2014).

2.1.4.1 Humpback dolphins

Humpback dolphins typically inhabits coastal waters that are less than 20 m deep, and are rarely found in waters that are more than 20-30 m deep, or more than a few kilometers from shore (Jefferson & Smith, 2016; Ross et al., 2010; Würsig et al., 2016). A study by Jutapruet et al. (2015) reported that dolphins in Donsak, Thailand, inhabited the coastline within 0.5 – 2.9 km from shore, at an average depth of 4.9 m, whereas dolphins in Kuching Bay, Malaysia were found in deeper waters ranging from 4.4 to 9.1 m (Zulkifli Poh, 2013).

Variations in habitat use of the dolphins in Hong Kong may be linked to its prey, shelter from stormy weather and predators, and movement corridors between feeding and resting habitats (Hung, 2008; Würsig et al., 2016). Hung et al. (2008) reported that prey availability was the most important factor in the habitat use of the dolphins in Hong Kong, where significantly higher dolphin densities were observed in higher fisheries yield areas.

Hydrological parameters such as temperature, salinity and water clarity appeared to be secondary to food availability (Hung et al., 2008). Waters around islands and at corners of headlands also appear to be favourable habitats of the dolphins in Hong Kong, potentially due to higher concentrations of prey resources and as a safer refuge from vessels that avoid these geographical features (Hung, 2008).

A study by Lin et al. (2013) suggested that the habitat use of humpback dolphins are likely to be influenced by the tidal-driven activity of their epipelagic prey. Dolphin encounter rates were found to be lowest during ebb tides than other tidal phases (i.e., high, low, flood) in the Xin Huwei River Estuary, Western Taiwan (Lin et al., 2013).

2.1.4.2 Irrawaddy dolphins

Coastal Irrawaddy dolphins exhibit preference for nearshore areas, particularly muddy, brackish waters at river mouths, where sightings mostly occur within only a few kilometers of the coastline (Culik, 2010). The most inshore observation of coastal Irrawaddy dolphins in Indonesia was 10 km upstream of the river mouth during high tide (Kreb & Budiono, 2005b). Peter et al. (2016) reported that the dolphins in Kuching Bay, Sarawak, occurred inshore during high tides and further offshore during low tides, and suggested that river mouth affiliation was potentially more driven by water flow and tidal currents which possibly affected prey abundance, rather than salinity or depth. It was found that the nearshore areas of Similajau and Kuching, Sarawak, were used as breeding and nursery grounds for these dolphins (Minton et al., 2011).

Irrawaddy dolphins in the central-western Gulf of Thailand and Kuching Bay, Malaysia were mostly found within 7 km from the mainland shoreline or river mouths (Jutapruet et al., 2017; Peter et al., 2016). Generally, the Irrawaddy dolphins in east Kalimantan, in the central-western Gulf of Thailand and in Kuching Bay, Malaysia were reported to occur in mean water depths of less than 15 m, and ranged between 2 to 30 m

(Jackson-Ricketts, 2017; Jutapruet et al., 2017; Kreb & Budiono, 2005b; Kreb & Rahadi, 2004; Peter et al., 2016). Irrawaddy dolphins in Bago-Pulupandan, Philippines preferred areas with a steep increase in water depth, where they were often observed to be foraging (de la Paz et al., 2020).

As Irrawaddy dolphins can be found in many types of habitat such as estuaries, bays, deltas, coastal and offshore, they are found in wide range of salinity. In Kuching Bay, the mean salinity where the dolphins were observed was 31.19 ± 2.26 ppt (Peter et al., 2016). The mean salinity in the core habitat of the dolphins in the central-western Gulf of Thailand was 30.55 ± 2.26 ppt and ranged between 25 to 36 ppt (Jutapruet et al., 2017). In Koh Kong, Cambodia, the mean salinity of waters where the dolphin sightings were made was 27.9 ± 2.7 ppt (range = 23 to 31) (Smith et al., 2016). In east Kalimantan, Indonesia, Irrawaddy dolphins were also recorded in brackish waters with mean salinity of 12 ± 10 ppt (range = 4.6-19.3 ppt). The mean water pH where Irrawaddy dolphin sightings in Kuching Bay could be found was 8.11 ± 0.19 (Peter et al., 2016). Similarly, the mean pH in the core habitat of the dolphins in the central-western Gulf of Thailand was 8.28 ± 0.36 and ranged between 7.98 and 9.06.

2.1.5 Movement and ranging patterns

Studies on ranging patterns are important to provide insights into how an individual understands and uses its environment, as most animals tend to have preference for particular areas that are used more intensely (Cribb et al., 2013; Oshima & Santos, 2016). Marine mammals do not necessarily follow strict periodic movement patterns, but instead respond to the limitations of their environment such as resource availability, predation risk and social interactions (Forcada, 2018). Foraging animals depend on predictable resources at a specific place and time to fulfill their energy requirements, and patchy distribution of prey resources require animals to adapt to this variability in space and time and move between places in their home range (Forcada, 2018). Home range is defined as the area normally traversed by an animal for its normal activities such as finding food, mating, and caring for young (Burt, 1943). Localized and directional movements are foraging responses to unpredictable and patchy prey distribution (Ogle, 2005). Localized movement refers to dolphins moving back-and-forth along shore, often over several kilometers or less in a restricted area, whereas directional movement refers to dolphins travelling parallel to the coast (Hwang et al., 2014). On the other hand, ranging is the movement across various parts of their home range in search of favourable conditions such as higher resource density or better environmental conditions (Forcada, 2018).

The most widely used approaches for range analysis of dolphins are minimum convex polygon (MCP) and the kernel density estimation (KDE) (Brusa et al., 2016; Flores & Bazzalo, 2004; Oshima & Santos, 2016; Wedekin et al., 2007). Minimum convex polygon is constructed based on the smallest convex polygon containing all points of animal presence, whereas kernel density estimation calculates the probability density (or utilization distribution) which can be used to identify areas that are used more intensively (Burgman & Fox, 2003; Hung, 2008; Worton, 1989).

2.1.5.1 Humpback dolphins

Individual ranging patterns of humpback dolphins have been studied in only a few locations using photo-identification (Jefferson & Smith, 2016). The individual ranging patterns of humpback dolphins in the Pearl River Estuary were reported to be irregularly shaped polygons, with linear distances (i.e., distance between two most extreme sightings of each individual) of only tens of kilometers (Hung & Jefferson, 2004). Using MCP, Xu et al. (2015) found that the range sizes of eight individuals in Zhanjiang, China, varied from 2.07 to 331.20 km^2. Chen et al. (2011b) reported that most individuals in Xiamen, China had a MCP range of 51-120 km^2, 95% KDE range of 51-250 km^2, and 50% KDE range of 10-40 km^2. The MCP ranges of individuals in Hong Kong and the Pearl River Estuary varied from 24 to 304 km^2, averaging at 99.5 km^2 (Hung & Jefferson, 2004).

Similar range sizes were found for 16 humpback dolphin individuals in Hong Kong with ≥ 30 sightings that ranged from 39-339 km^2 (Hung, 2008). Hung (2008) reported no significant difference between the range size of males and females, but a significant difference was found for range size among individuals of different age classes. Hung and Jefferson (Hung & Jefferson, 2004) suggested a possible tendency of smaller ranges of sub-adults (80.7 km^2 ± S.D. 61.04 km^2) compared to adults, with adults potentially requiring larger areas for access to more mates for reproductive success. The MCP range of humpback dolphin in the central-western Gulf of Thailand was 280.16 km^2 and the core habitat (50% KDE) was 13.05 km^2 (Jutapruet et al., 2017).

2.1.5.2 Irrawaddy dolphins

Little is known about the movement and home range sizes of Irrawaddy dolphins, particularly coastal Irrawaddy dolphins due to a lack of investigation into the topic. In Kuching Bay, Malaysia, the furthest linear distance between resightings of an Irrawaddy dolphin individual was 26 km, and the actual distance to navigate around the land mass of the peninsula at that site would be about 30 to 40 km (Peter, 2012). The MCP range of the Irrawaddy dolphins in the central-western Gulf of Thailand was 125.17 km^2 and the core habitat (50% kernel density estimate) was 14.71 km^2 (Jutapruet et al., 2017). The MCP range of Irrawaddy dolphins in Bago-Pulupandan, Philippines was 12.68 km^2 and was reported to be one of the smallest core areas ever recorded for Irrawaddy dolphins (de la Paz et al., 2020). However, it is uncertain whether this small core area was limited by the small number of individuals (19 distinct individuals over seven years) or the small study area (16 km^2 of inshore waters).

2.1.6 Behaviour

Behavioural studies of marine mammals include understanding of their foraging behaviour, predator avoidance, dispersal and migration, competition and agonistic behaviour, sexual behaviour, parental behaviour, and social behaviour and relationships

(Tyack, 2018), all of which are influenced by how individuals interact with their environment and with other organisms. Knowledge about behavioural ecology is important, as behaviours of some of the most well-studied delphinids are known to potentially vary greatly among and within species (Parra, 2005). Human activities such as habitat modification, changes in predation pressure and changes in food availability and distribution can affect the behaviour of mammals (Chilvers et al., 2001). Repeated disruptions from human activities to critical cetacean social behaviours such as maternal care, breeding, feeding and resting could ultimately decrease the survival or reproductive success (Bejder & Samuels, 2003). Behavioural studies of cetaceans often use behavioural state classifications of foraging/feeding (repeated dives in one location and surfacing in various directions), travelling (unidirectional movement), resting (floating at surface or slow forward movement), socializing (high levels of interaction in close proximity) and milling (slow movement with no apparent direction) (Karczmarski et al., 2000; Parra, 2005; Shane, 1990).

2.1.6.1 Humpback dolphins

Humpback dolphins, unlike more pelagic species such as stenellid dolphins (*Stenella* spp.), are typically not gregarious and are not frequently surface active. The observed daytime behaviours of humpback dolphins are foraging/feeding, followed by traveling, socializing and resting (Parsons, 2004). For humpback dolphins in Zhanjiang, China, the majority of their behavioral budget were represented by feeding (45.5%) and travelling (25.2%), followed by socializing (8.4%) and resting/milling (6.8%) (Liu et al., 2021).

The humpback dolphins swim at a slow speed of about 5 km/h, and surface at up to one minute intervals, but longer dives can last up to five minutes, with the fluke typically raised before a deep dive (Parra & Ross, 2009). While they typically avoid boats and rarely bowride, humpback dolphins that are used to the presence of boats such as those in Hong Kong, had been observed to bow-ride (Parra & Ross, 2009). Humpback dolphins in Hong Kong appeared to be well adapted to surrounding traffic, with juveniles approaching dolphin-watching vessels more frequently than the adults (Ng & Leung, 2003).

Humpback dolphins in Hong Kong were observed to be feeding frequently in the freshwater/saltwater mixing zone (Parra & Ross, 2009). Parsons (1998) suggested that this pattern of estuarine habitat use may be due to prey aggregation or to avoid predation by certain shark species. Some dolphins were documented to be attracted to fishing trawlers as these fishing boats provide concentrated and easy food source that were either discarded or had escaped from the trawl nets (Cagnazzi, 2010; Jefferson, 2000; Parsons, 2004). However, the risk of injury and mortality from entanglement, and persecution from fishers may outweigh the short-term energetic and nutritional benefits to these dolphins that prefer to associate with fishing vessels (Dungan et al., 2012; Fertl & Leatherwood, 1997; Jefferson, 2000). Hung (2008) reported frequent observations of humpback dolphins in the Pearl River Estuary feeding behind fishing boats such as pair trawlers, hang trawlers, shrimp trawlers and single trawlers. Photo-identification revealed that some individuals were more likely to follow trawlers than others (Jefferson, 2000) and there were individuals that were considered to be trawler-associating and non-trawler-associating (Or, 2017).

Travelling behaviour was mostly observed in areas of high vessel traffic between feeding habitats of humpback dolphins in Hong Kong, which may be linked to avoidance of interactions with vessel traffic (Hung, 2008; Würsig et al., 2016). There is not much information on the resting behaviour of humpback dolphins. Resting behaviour of humpback dolphins in Hong Kong and other areas may occur more often at night, as heavy human activities require dolphins to stay alert during daytime (Hung, 2008; Würsig et al., 2016).

Socializing (including mating) in humpback dolphins is characterized by high levels of physical interaction including body contact (e.g., biting each other, body-rubbing) between individuals, and frequent aerial behaviour such as leaps and somersaults (Parra & Jefferson, 2018). Other behaviours that humpback dolphins may exhibit include epimeletic, or care-giving, behaviour which can be either nurturant (care towards young) or succorant (care towards individual in distress) (Parsons, 2004). Epimeletic behaviour towards both live and deceased individuals had been observed in humpback dolphins in Hong Kong waters (Hung, 2014; Würsig et al., 2016). Several reports of epimeletic behaviours of healthy individuals supporting dead, newborn calves by carrying them in their mouth or on their back were recorded in Hong Kong (Hung, 2014; Parsons, 1998; Würsig et al., 2016).

2.1.6.2 Irrawaddy dolphins

Irrawaddy dolphins are shy towards boats, surfacing rather inconspicuously with only the uppermost dorsal surface of the animal becoming visible during a slow rolling dive, and are not known to bowride (Smith, 2018). Irrawaddy dolphins occasionally leap when they are disturbed, socializing or swimming against a strong current (Smith, 2018). In Indonesia, Irrawaddy dolphin generally surfaced less in the presence of boats with stronger boat avoidance in the freshwater Irrawaddy dolphins compared to the coastal individuals (Kreb & Rahadi, 2004). Coastal Irrawaddy dolphins in Indonesia were reported to react only to speedboats that are within 50 m distance (Kreb & Rahadi, 2004). However, Irrawaddy dolphin in Cowie Bay, Malaysia were reported to show boat avoidance behaviour and actively moved away from boats at a larger distance (< 1 km) (Hashim & Jaaman, 2011).

Spyhopping (rising vertically out of the water), body rubbing and tail slaps are sometimes observed in Irrawaddy dolphins, and they are known to occasionally expel narrow, well-directed streams of water from their mouths that can reach up to 1 to 2 m

(Smith, 2018). This behaviour is termed as "water spitting", and is associated with herding fish for feeding or for social interactions (Smith, 2018). In Trat Province, Thailand, Ponnampalam et al. (2013) observed large groups of Irrawaddy dolphins engaging in intense social behaviour that appeared to be herding with probable mating. These Irrawaddy dolphins engaged in herding behaviour surfaced synchronously, swam aggressively in a compact group and were not evasive of boats whilst in that behavioural state (Ponnampalam et al., 2013). For Irrawaddy dolphins in Pulupandan, Phillipines, foraging behavior were reported to dominate their activity budget with mean activity index value of 0.77, followed by socializing (0.16), travelling (0.09) and resting (0.08) (Casipe et al., 2013). Similarly in Chilika Lagoon, India, the three most frequent daytime behaviors exhibited by Irrawaddy dolphins were feeding (79%), milling (39%), and socializing (42%) (Sutaria, 2009).

2.1.7 Conservation threats

Conservation of marine mammals are challenging, as they are long-lived, late-maturing, and slow-reproducing animals require specific habitats that are often threatened by human activities that occur at sea and on land (Evans et al., 2012; Notarbartolo di Sciara et al., 2016; Symons et al., 2018). As coastal cetaceans share much of their habitat with various types of human activities, the main anthropogenic threats that generally impact these animals in Southeast Asia are bycatch in fisheries, habitat loss and degradation from coastal development, oil and gas development, marine vessel traffic, tourism, prey depletion and pollution (Hines et al., 2015a; Minton et al., 2016; Niu et al., 2019; Perrin, 2002). In particular, bycatch or accidental entanglement in fishing gears such as gillnets, trammel nets and trawls is considered as one of the most serious threats and source of injuries and mortality to humpback dolphins and Irrawaddy dolphins (Dungan et al., 2011; Hines et al., 2020; Reeves et al., 2013; Slooten et al., 2013; Wang et al., 2004b). Humpback dolphins and Irrawaddy dolphins were among the top 10 species that are most susceptible to fisheries bycatch risk in a recent global assessment of small-scale fisheries (Temple et al., 2021). When overlap of human activities and dolphins occur in time and space, biologically important activities such as foraging behaviour, movement patterns and social or mating behaviour are affected (Berger-Tal et al., 2011; Piwetz et al., 2015).

2.1.7.1 Humpback dolphins

The humpback dolphin has a declining population trend across its global range (Jefferson et al., 2017). The cumulative threats from anthropogenic activities and environmental conditions are major concerns for humpback dolphins (Dungan et al., 2011). Bycatch particularly in gillnets is a major problem for humpback dolphins in Hong Kong, eastern Taiwan Strait (Taiwan), Kalimantan Timur (Indonesia), Thailand and Malaysia (Hines et al., 2015a; Jaroensutasinee et al., 2010).

Several studies have reported the presence of fisheries-related injuries in humpback dolphins, with varying levels of prevalence. The presence of net scars and propeller cuts were observed on the body of humpback dolphins in Hong Kong (Jefferson, 2000). In Bangladesh, 15.0% of humpback dolphins had injuries related to entanglements in fishing gears (Smith et al., 2015). Similarly, in the eastern Taiwan Strait, gill or trammel nets and trawls were primarily involved in incidental catches of Taiwanese humpback dolphin, and 31.2% of the identifiable individuals exhibited injuries caused by fishing gear (Slooten et al., 2013). Unsustainable human-induced injuries and severe mutilations by fishing lines were also reported in Taiwanese humpback dolphin (Wang et al., 2017a; Wang & Araújo-Wang, 2017).

Humpback dolphins off the Donsak-Khanom coast in Thailand were frequently sighted in close proximity to fishing nets and were approached by local dolphin-watching boats, and many of those dolphin individuals had scars from propeller cuts (Jutapruet et al., 2015). Threats to the population of Taiwanese humpback dolphins in the eastern Taiwan Strait include habitat loss, underwater noise and disturbance, fisheries interactions, chemical and biological pollution, and reduced freshwater outflow to estuarine ecosystems (Dungan et al., 2011; Wang et al., 2015a). Humpback dolphins in the eastern Taiwan Strait were observed in poor body condition in recent years, where nutritional stress and/or subsequent disease may be linked to reduced prey availability or quality (Slooten et al., 2013). Presence of skin disorders are likely to indicate compromised immune system which may be exacerbated by anthropogenic factors such as pollutants (Karczmarski et al., 2016). In Hong Kong, approximately 50% of humpback dolphins had at least one type of epidermal lesions that are likely related to degraded environment (Chan & Karczmarski, 2019). The most prevalent epidermal conditions in humpback dolphins in Hong Kong and Taiwan were nodules, pox-like lesions and orange films possibly from diatom infestation (Chan & Karczmarski, 2019; Yang et al., 2013).

Piwetz et al. (2015) described the avoidance behaviour of humpback dolphins to human activities such as marine vessel traffic, dolphin-based tourism, cetacean-fishery interactions, noise pollution, habitat loss and degradation. Avoidance behaviour such as longer dive durations and fleeing the area often disrupts the behaviour and social life of humpback dolphins, and may cause death and injury (Ng & Leung, 2003). However, no apparent behavioural changes by dolphins to slow-moving vessels were observed, and this may be either because the dolphins became more tolerant, or the underwater reactions (e.g., heightened vigilance, increased heart rate) underwater were not detectable or examined (Ng & Leung, 2003; Piwetz et al., 2015; Würsig et al., 2016).

Large-scale coastal development projects such as those around the Pearl River Delta, Hong Kong that involve intense land reclamation and coastal dredging could permanently decrease the natural habitats available to dolphins and cause immense behavioural disturbance (Karczmarski et al., 2016), such as the observed change of socio-spatial dynamics of humpback dolphins (Or, 2017). The construction of canals and industrial park in Sarawak's coastline could increase freshwater input into the nearshore habitat of humpback dolphins (Minton et al., 2016).

2.1.7.2 Irrawaddy dolphins

The Irrawaddy dolphin was reported to have declining population trends throughout their range (Minton et al., 2017). Irrawaddy dolphins are particularly vulnerable to threats from human activities, with mortality from entanglement in fishing gears such as gillnets being the most severe threats (Minton et al., 2017). Bycatch of Irrawaddy dolphins in gillnets and bottom trawls were reported in Vietnam, and in coastal Myanmar, the dolphins have been observed with scars and fishing gears (Hines et al., 2015a).

Besides incidental entanglement, there were also directed catches of coastal Irrawaddy dolphins, such as in Vietnam where Irrawaddy dolphins were hunted and eaten in some parts of Vietnam (Hines et al., 2015a), a practice that may still prevail presently. In the past, some dolphins in Vietnam and Cambodia were also captured for captive displays in dolphinariums and circuses (Hines et al., 2015a).

In Malaysia, Rodríguez-Vargas et al. (2019) reported that the threats to coastal dolphins in Penang include fishing nets, high-speed boats and polluted rivers. Peter et al. (2016) reported that the dolphins in Sarawak, Malaysia, are at risk of entanglement in fishing gears, noise pollution, and disruption of feeding and resting activities from unregulated dolphin-watching. Additionally, the construction of a flood mitigation channel would direct floodwater into the core area of the species' habitat and may be harmful to the population (Peter et al., 2016).

Other threats to Irrawaddy dolphins include the presence and progression of cutaneous nodules on animals in several parts of Malaysia (Penang Island, Kinabatangan region in Sabah, and Sarawak), India and Bangladesh as reported by Van Bressem et al. (2014); this appeared to be an emerging disease that is of concern for the Irrawaddy dolphins populations. Kreb et al. (2020) pointed out that the disappearance of Irrawaddy dolphins in the lower segment of Balikpapan Bay, Indonesia may be caused by increased boat traffic, unsustainable fishing, and underwater noise from piling activities. Conversion of mangroves for shrimp farming also caused high sedimentation rate in Balikpapan Bay, which may have negative impacts on dolphin prey resources and local fisheries (Kreb et al., 2020).

2.2 Matang Mangrove Forest Reserve and its adjacent coastal waters

The Matang Mangrove Forest Reserve Complex (hereafter referred to as the Matang mangroves), is a large expanse of mangrove forest of approximately 400 km^2. Situated along the coast of the Straits of Malacca, it is located in the state of Perak, Peninsular Malaysia, at latitude 4°15'-5°1'N, and longitude 100°2'-100°45'E. The Matang mangroves have a coastline of approximately 52 km from Kuala Gula in the north to Bagan Panchor in the south (Azahar & Nik Mohd Shah, 2003). The coast is characterized by extensive mangrove forests, estuaries, mudflats and islands (Ariffin & Nik Mohd Shah, 2013). From north to south, the Matang mangroves outline the estuaries of Kuala Gula-Kuala Kelumpang, Kuala Selinsing-Kuala Sangga Besar, Kuala Larut-Kuala Jaha, Kuala Trong and Kuala Jarum Mas [*kuala* = estuary] that are each between two to four km wide (Azahar & Nik Mohd Shah, 2003). The major rivers are Sungai Selinsing, Sungai Sangga, Sungai Larut, Sungai Bukit Gantang, Sungai Trong, Sungai Nibong and Sungai Jarum Mas [*sungai* = river].

Matang has a warm humid climate all year round, with rainfall ranging from 2,000-2,800 mm per year, as the adjacent town of Taiping is the wettest part of the country (Ariffin & Nik Mohd Shah, 2013; Azahar & Nik Mohd Shah, 2003). Average air temperature ranges between a minimum of 22°C at night to a maximum of 33°C during daytime. Heavy rainfall usually occurs in the second and last quarters of the year as brought about by the southwest monsoon and northeast monsoon respectively (Ariffin & Nik Mohd Shah, 2013).

The inshore waters are generally shallow and measure less than six meters deep (Teoh, 2014) and have a semidiurnal tide cycle with a tidal range of 1.60-2.98 m (Goessens et al., 2014; JUPEM, 2004). The mean water temperature in the Matang estuaries is approximately 30°C throughout the year, with a difference of 1°C between the surface and bottom waters (Sasekumar et al., 1994a). Inshore waters are slightly alkaline at pH 8.7, while coastal waters have a lower mean value of pH 7.8. Salinity in the Matang mangroves is highest for inshore waters (32 ppt), followed by coastal mudflats (27 ppt) and the upper reaches of rivers (11 ppt) (Ariffin & Nik Mohd Shah, 2013). The salinity and dissolved oxygen in Matang waters are generally dependent on the tide and rainfall (Ariffin & Nik Mohd Shah, 2013; Sasekumar et al., 1994a).

The Matang mangroves is considered as one of the best managed mangrove forests in the world, with a history of more than a century of systematic forestry management since early 1904 (Okamura et al., 2010; Walters et al., 2008). Sustainable wood production is practiced based on a 30-year rotation cycle with first thinning after 15 years and second thinning after 20 years (Goessens et al., 2014). The productive coastal habitats of the Matang mangroves support diverse wildlife, in which at least 22 species of mammals, 160 species of birds, 163 species of fish, 82 species of crustaceans and 103 species of flora have been recorded (Ariffin & Nik Mohd Shah, 2013).

Human settlements in Sangga Besar and Kuala Sepetang lack proper garbage disposal system, resulting in the mangrove waterways serving as regular dumping sites for solid wastes, including raw sewage (Chong, 2006). Ghaderpour et al. (2014) reported detection of various potentially pathogenic bacteria such as *Escherichia coli*, *Klebsiella pneumoniae*, *Serratia marcescens* and *Enterobacter cloacae* in Matang mangrove estuaries. Tanaka et al. (1998) reported that carbon, nitrogen and phosphorus contents of Sungai Sangga Besar was higher in the upper part of the river compared to the river mouth. Tanaka & Choo (2000) reported higher concentrations of ammonium, silicate and phosphate during spring tides than neap tides, indicating a flush of nutrients from the mangrove area by the inundation and tidal mixing of spring tides. Hypoxic conditions, with dissolved oxygen amounting less than 3 mg/L, were observed during spring tides throughout the estuary, while hypoxia was restricted to the upper reaches of the estuary during neap tides (Okamura et al., 2010). Dissolved oxygen gradually increased towards the sea (Teoh et al., 2013).

2.2.1 Fisheries and aquaculture

The Matang mangroves and the adjacent mudflats are important nursery and feeding grounds for marine fish and invertebrates, serving one of the most important fishing grounds in Malaysia (Chong et al., 2012; Tanaka et al., 2011). The Perak state yields an annual fisheries harvest of more than 300,000 tonnes, which is approximately one-fifth of total marine fish landings in Malaysia (Department of Fisheries Malaysia, 2016). In 2011, the combined fish and prawn landings in Matang was estimated to be 151,382 tonnes, with a total economic value of RM981.47 million (Ariffin & Nik Mohd Shah, 2013).

Forty-six families of teleost fish have been recorded thus far in the waterways and coastal mudflats of Matang (Ariffin & Nik Mohd Shah, 2013). A total of 163 species of fish, 37 species of prawns and shrimps, and 45 species of crabs were recorded in Matang, of which 112 species of fish (69%), 27 species of prawns (73%) and 6 species of crabs (13%) are commercially exploited (Ariffin & Nik Mohd Shah, 2013; Ashton, 1999; Chong, 2005; Chong et al., 1994, 2012; Hanamura et al., 2012; Hayase & Muhd Fadzil, 1999; Low et al., 1999; Sasekumar et al., 1994a; Tanaka et al., 2011; Then, 2008).

Since June 2014, fishers in four states on the west coast of Peninsular Malaysia, including the state of Perak (where Matang is located), were required by the Department of Fisheries Malaysia to comply with new fishing zoning regulations that replaced the old zoning system that was used for the past three decades. In the new zoning, the area of 1 n.m. from the shore is assigned as the 'conservation zone', where only aquaculture and blood cockle cultures are allowed (Department of Fisheries Malaysia, 2015). Subsequently, Zone A is the area between 1 and 8 n.m. from the shore, where traditional fishers and traditional anchovy purse seiners with vessels less than 40 gross registered tonnage (GRT) are allowed to fish. Vessels such as trawlers and purse seiners that are less than 40 GRT are allowed to operate between 8 and 15 n.m. from the shore in Zone B. Zone C is the area between 15 n.m. from the shore and the boundary of Malaysia's Exclusive Economic Zone (EEZ) where trawlers and purse seiners between 40 and 70 GRT and above 70 GRT are allowed to fish. Zone C3 is for vessels such as tuna longliners and tuna purse seiners above 70 GRT that are allowed to operate in the Indian Ocean.

The main traditional fishing gear used in Matang is the gillnet, whereas the main commercial gear is the trawl net. Traditional fishing methods in Matang include gillnet, trammel net, bag net, push net, hook-and-line, longlines, and crab trap that are mostly operated within the mangrove channels and within 8 km from the shore. Both gillnets and trammel nets are kept vertically in the water column with floats on the top line rope. Gillnets are single layer monofilament nets that comes in different mesh sizes to target fish that are slightly too large to swim through the respective meshes. Trammel nets consist of three walls of netting, with two outer walls with larger mesh size than the central mesh that entangle fish trying to pass the inner wall. Bag nets are nets that are set in between two stationary poles at or off the river mouths, and are mostly operated during spring tide to target fish that follow tidal movement. Push nets, which are illegal and banned, are triangular nets framed with two long poles at the sides that are pushed in front of the fishing boat and are mostly used at night to target prawns inside the estuaries. Hook-and-line are pole-fishing or hand lines with a single baited hook. Longlines have multiple baited hooks and ganglions on mainlines. Crab traps are made of wire rings and nylon rope, with a bait holder inside the trap and entrance doors and are usually set to lure mud crabs (*Scylla* spp.).

Commercial fishing gears operating in Matang include trawl nets and purse seine nets (Ariffin & Nik Mohd Shah, 2013). Trawl nets are funnel-shaped nets with a horizontal opening and towed behind one or two boats at midwater or on the bottom with catch accumulating in the cod-end. Purse seine nets are large deep water nets set in a circle and the catch is hauled when the purse line is pulled to form a bowl, and are usually used to target oceanic schooling fishes. These mechanized commercial fishing gears are only permissible by law to operate further from the shore (> 8 n.m., or equivalent to 15 km) according to the fishing zones in Malaysia due to their potential destructiveness to the fish stock and environment (Ariffin & Nik Mohd Shah, 2013).

The Matang mangroves support an estimated 8,849 fishers operating 4,053 licensed vessels (Perak Fisheries Department, 2012). Out of the total 3,577 fishing gears operating in the waters of Matang, registered fishers operate a total of 2,490 traditional fishing gears (70%) and 1,087 commercial fishing gears (30%) (Perak Fishery Department, 2012). The combined fish and prawn landings by fishers from the coastal districts of Kerian, Larut-

Matang and Manjung North were 151,382 tonnes in 2011. The total catch attributable to the Matang mangroves was estimated at 88,887 tonnes, and the total economic value of Matang fisheries was estimated at RM 580 million based on the 2011 average value of RM 6,526 per tonne for all the marine fish landed in Perak (Ariffin & Nik Mohd Shah, 2013; Department of Fisheries Malaysia, 2016).

Cockle culture and net cage fish culture are permitted in the Matang mangroves. On-bottom culture of blood cockles *(Tegillarca granosa*) covered a total area of 38.91 km^2 in 2011 (Perak Fisheries Department, 2012). The main culture beds are at Kuala Sungai Gula, Kuala Sungai Selinsing, Kuala Sungai Sangga Besar, Kuala Sungai Larut, Kuala Sungai Trong and Kuala Sungai Jarum Mas. Cockle spats are collected from the wild to seed culture sites on the mudflats. The total cockle production from Matang was 17,615 tonnes in 2011 (Perak Fisheries Department, 2012). The total number of net cages for fish aquaculture in the Matang mangroves was reported to be 8,706, and are mainly located in the main river channels (Perak Fisheries Department, 2012). Each cage farm comprises a cluster of interconnecting floating cage units, usually 2.5 × 2.5 m in surface area and 1.5-2.5 m in depth (Ariffin & Nik Mohd Shah, 2013). The main cultured fish species are Asian seabass (*Lates calcarifer*), mangrove snapper (*Lutjanus johnii*), red snapper (*Lutjanus argentimaculatus*) and groupers (*Epinephelus* spp.) (Perak Fisheries Department, 2012).

2.2.2 Tourism

In the last decade, tourism began to gain traction in Kuala Sepetang, the main fishing village within the Matang mangroves. Tourism visits to the Matang mangroves focused mainly on visits to the nature education centre in Kuala Sepetang, charcoal kiln, river cruise of Sungai Sepetang, Kuala Sangga fishing village, seafood restaurants, wildlife-watching, firefly-watching in Kampung Dew, and bird-watching in Kuala Gula (Mahmud et al., 2015). Mahmud et al. (2015) also reported that the main activities of Matang tourists were visiting charcoal factory (20%), bird watching (20%) and dolphin watching (15%). Local communities who are involved in tourism mainly run seafood restaurants, provide transportation and rental facilities such as boats, guided tours and homestay facilities. Weekends and public holidays are the usual peak periods for tourists to Matang all-year round.

2.2.3 Records of cetaceans in Matang

Prior to 2013, no comprehensive research on cetaceans had been conducted in Matang, and little was known about their ecology prior to the commencement of this study. Records of cetaceans in Matang were captured in literature as early as the 18th century, whereby three stuffed cetacean specimens were reported to be caught off Matang and kept in a museum in Taiping, Perak (Flower, 1900). These three stuffed specimens were recorded as "Little Indian Porpoise", "Larger Indian Porpoise" and "Plumbeous Dolphin" (Flower, 1900), currently known as the Indo-Pacific finless porpoise (*Neophocaena phocaenoides*), Irrawaddy dolphin, and Indo-Pacific humpback dolphin, respectively. Abdul (1986) reported that the "ridge-backed dolphin", a vernacular name for Indo-Pacific humpback dolphins, can be found at Kuala Gula. Sightings of humpback dolphins have been reported in the estuaries of the Matang mangroves from anecdotal accounts since 1960s, and were covered in newspaper reports since 2011 ("A Sign Our Seas Are Full of Life," 2011; "Lady Luck, Dolphins Smile on Us," 2011; "Major Gains from Wild Dolphin Sightings in Kuala Sepetang," 2011; Tan, 2016) as well as in recent publications (Kuit et al., 2019a, 2014; Ponnampalam, 2013). The current day presence of Irrawaddy dolphins in Matang was confirmed by Ponnampalam (2013) in March 2012 during an assessment survey for the sixth revision of the working plan for the Matang Mangrove Forest Reserve published by the Perak State Department of Forestry (see Ariffin & Nik Mohd Shah, 2013). Collectively, these sources confirm that Indo-Pacific humpback dolphins, Irrawaddy dolphins and Indo-Pacific finless porpoises (hereafter referred to as finless porpoises) are the three commonly found cetaceans in the coastal and estuarine waters of Matang.

CHAPTER 3: METHODOLOGY

3.1 Study site

The Matang mangroves and adjacent mudflats are located in Perak state, on the north-western coast of Peninsular Malaysia. The extensive stretch of mangrove-fringed brackish riverine waterways and coastline are important nursery and feeding grounds for marine fish and invertebrates (Chong et al., 2012; Tanaka et al., 2011). The coastal waters of Matang are one of Malaysia's most productive fishery grounds with annual marine fishery landings of more than 300,000 tonnes (Department of Fisheries Malaysia, 2016). Matang experiences a semi-diurnal tidal cycle, with tidal heights ranging from 1.60 to 2.98 m (Goessens et al., 2014). The mean water temperature taken at 0.5 m depth is between 30 and 31°C and the mean salinity ranged from 20.4 ± 3.7 ppt in the upper estuary to 30.5 ± 1.2 ppt in offshore waters (Chew & Chong, 2011).

The size of the study site is approximately 1152 km^2 and stretches 56 km along the coastline from Kuala Gula in the north to Kuala Jarum Mas in the south, and extends up to 24 km from the coastline. The study area was divided into coastal and estuarine strata which were further subdivided into the northern and southern survey blocks (Figure 3.1). This stratification allowed higher systematic search effort to be allocated to the estuarine survey blocks that were presumed to have higher density of coastal cetaceans based on reconnaissance surveys in July 2013. The north estuarine survey block includes the estuarine areas of Kuala Gula, Kuala Sangga and Kuala Larut whereas the south estuarine survey block encompasses the estuarine areas of Kuala Trong and Kuala Jarum Mas. The water depth in estuarine stratum is greatly influenced by the tides, but is generally shallow (≤ 5 m deep) even when up to 8 km away from the coastline. Some nearshore areas are inaccessible by boat during low tide when mudflats are exposed. The coastal stratum is mostly 5-15 m deep and is up to 27 m deep.

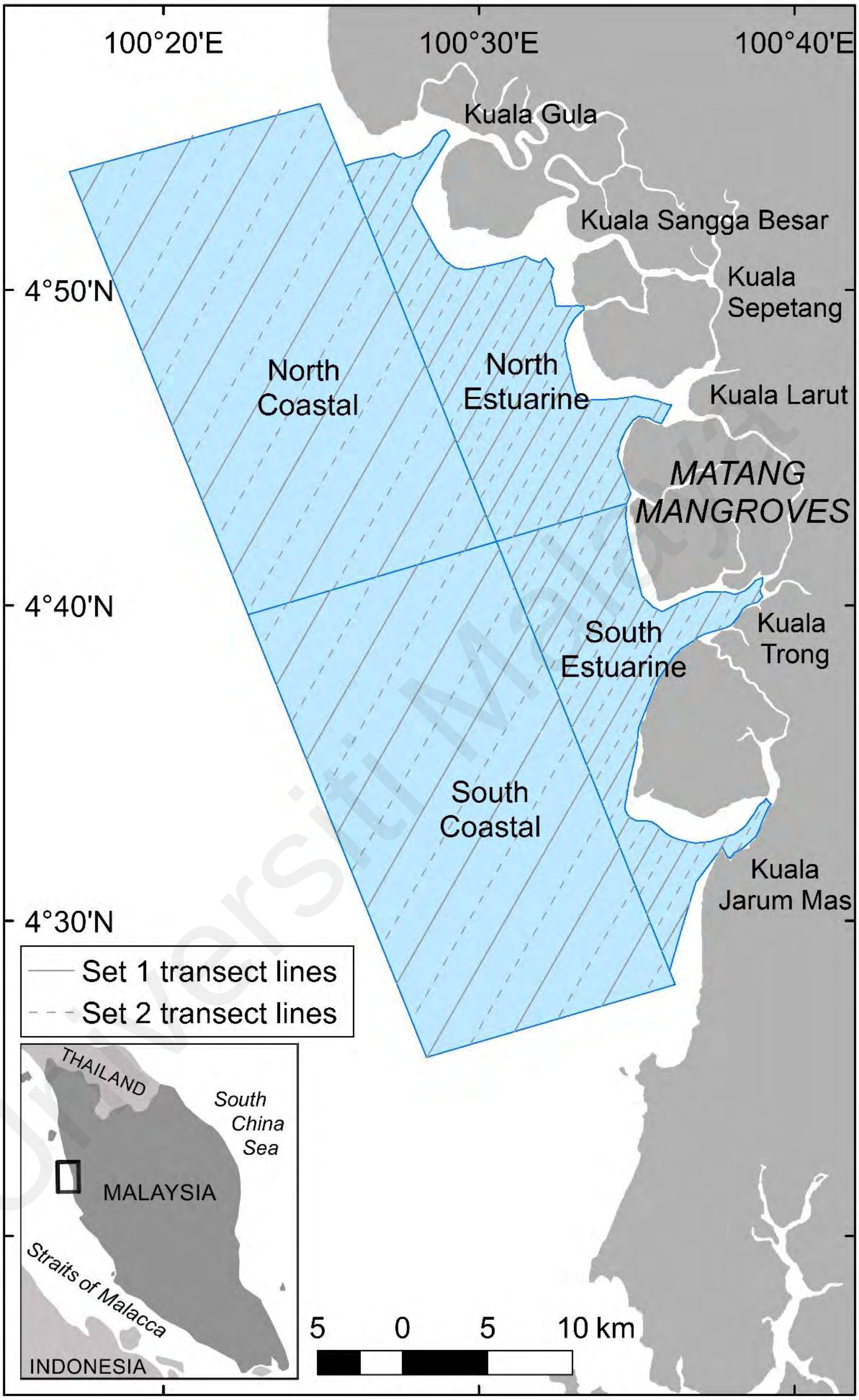

Figure 3.1: The study area with two sets of parallel line transects (solid and dashed grey lines) in the coastal and estuarine strata that were alternated between surveys

3.2 Data collection

3.2.1 Line-transect boat-based surveys

Eleven 10-day line-transect surveys were conducted almost bimonthly between November 2013 and July 2016, except for months with unfavourable weather (i.e., May & November 2014, January & November 2015, March & May 2016). Each full survey was 10 days in duration to ensure that all the line transects were completed. Surveys were carried out on a 8 to 10 m long fiberglass-hulled boat that was powered by either a 100 or 115 HP single outboard engine. The elevated platform on the boat enabled two primary observers to search for dolphins at a height of approximately 2.5 m above deck level along the pre-determined transect lines. The design of the transect lines was randomly generated using DISTANCE 6.0 software (Thomas et al., 2010) for a stratified study with transect lines spaced 1.85 km (1 n.m.) apart in the estuarine strata and 3.70 km (2 n.m.) apart in the coastal strata. The estuarine strata were adjusted to exclude areas that were difficult for vessel navigation, such as shallow depths (< 0.5 m), narrow waterways and places with dense cockle-farming poles. The transect lines were designed to run approximately 45° to the coast to allow detection of dolphin density gradients alongshore and onshore/offshore (Dawson et al., 2008). Two sets of transect lines of the same design were created, and each set of lines was used alternately between surveys (Figure 3.1).

Search effort was separated into two categories. Active searching for dolphins, termed as ‘on effort’, was conducted along the pre-determined transect lines with the research vessel speed maintained at $\leq$ 15 km h^{-1}, while ‘off effort’ was defined as when the research vessel was not travelling on the transect lines. When the survey was ‘on effort’, two experienced primary observers were seated on an elevated platform at a height of 2.5 m above deck level and scanned the area forward of the bow from 10˚ of the port/starboard side to 90˚ of the starboard/port side respectively. Both observers alternated between using unaided eyes and 7 × 50 marine binoculars with built-in compass. The third experienced observer scanned the area forward of the bow to reduce the chance of missing dolphins on the transect line. Observers were rotated to either rest or take up other positions such as data recording approximately every hour to avoid observation fatigue. Observations were made during daylight hours in workable weather conditions (i.e., no heavy rain, swell height not more than 1 m, sea state less than 4 on the Beaufort scale). Sea state and swell height were logged at the start of each transect line, and whenever the data recorder observed a change in conditions during search effort on the line.

Prior to actual surveys, observers were trained to estimate distances to static objects first on land, then to relatively static objects on the water. The estimations were then compared against the readings taken from rangefinder. This was repeated until the difference between observer estimated distances and rangefinder estimated distances were not more than 5 m. During actual surveys, when a sighting cue of cetaceans was detected, the research vessel was stopped and the observer immediately noted the initial bearing to the sighting and bearing of transect line and estimated the distance of the sighting from the research vessel by eye before observers went 'off effort' to approach the group. A waypoint was immediately marked using a handheld GPS (Garmin GPSMAP 78s; Garmin, Olathe, KS) before the research vessel went off-effort and digressed from the transect line to approach the dolphin group and confirm the sighting. Another waypoint was marked when the research vessel was near to the dolphin group. Information from each sighting was recorded into the 'Matang Cetacean Sighting Recording Form' (Appendix A), which include standard sighting data such as date, time, GPS location, species, estimated group size (minimum, maximum and best estimate), group composition, group behaviour, effort level (on-effort or off-effort), sea state (measured on the Beaufort scale), swell height (m), and human activities (e.g., vessels, nets and fishing activity) present within a radius of 500 m.

For each sighting, observations of the behaviour of the dolphin group were made for a minimum of 10 minutes upon encounter, in order to ascertain the predominant behavioural activity. The dolphins' behavioural states were assigned to nine categories (as defined in Table 3.1), which were adapted from Karczmarski et al. (1997), Parra (2005), Peter (2012) and Ponnampalam et al. (2013), or recorded as undetermined if the sighting was too brief to ascertain the behaviour.

Table 3.1: Dolphins' behavioural states and definitions

Behavioural state	Definition
Feeding	High energy, frequent and asynchronous dives with various direction changes. Long, fluke-up dives. Frequent forward lunges to chase prey. Prey species was seen leaping out of the water or in the dolphin's mouth. Collection of fresh, floating catfish head that was partially consumed by dolphins. Mud on dolphin's body part (e.g., rostrum, head, dorsal fin, flank, fluke). Mud plumes were seen, indicative of dolphin stirring up the mud on the bottom while in search of prey.
Foraging	Lower level of energy compared to feeding. Frequent direction changes, with long dive intervals between fluke-up dives. Mud on dolphin's body part (e.g., rostrum, head, dorsal fin, flank, fluke). Mud plumes were seen, indicative of dolphin stirring up the mud on the bottom while in search of prey.
Socializing	High and gregarious levels of activity. Prolonged and close body contact, with synchronized swimming or surfacing. High level of interaction, such as body-rubbing, nudging or touching each other.
Mating	High and gregarious levels of activity. Observation of protruding penis from a male dolphin. Belly-to-belly contact, twisting dives and close body contact.
Herding	Only applicable for Irrawaddy dolphins. High energy levels, intense body contacts that exhibited signs of aggression associated with mating. Twisting dives, with possible gregarious water splashing and synchronized surfacing after prolonged dives. Loud exhalations on the surface.
Resting	Very low level of activity. Slow movement or almost stationary at the surface. Logging on the surface for 5-20 seconds before submerging. Group does not travel anywhere and remains in the general vicinity.
Milling	Low level of activity. Slow swimming back and forth without any apparent purpose and direction.
Travelling	Animals moving in the same direction with regular surfacing and diving pattern. Grasping or chasing of fish not seen.
Evasive	Animals actively swimming away from research vessel and taking prolonged dives. Difficult to be approached and photographed.

Once all necessary data had been collected from the on-effort sighting, the research vessel navigated back to the sighting waypoint on the transect line from which it had previously digressed to continue on-effort observations on the line, weather, time and fuel permitting.

3.2.2 Mark-recapture photo-identification

Photo-identification data were concurrently collected during 12 boat-based surveys between September 2013 and July 2016 from on-effort and off-effort sightings. During each dolphin sighting, conscious efforts were made to approach the animals within 20 m of the group, at a slow speed (<5 km h^{-1}) so as to minimize disturbances to their behaviour as much as possible. Attempts were made to photograph both the left and right sides of the dorsal fins of each dolphin individual in the group, regardless of their distinctiveness and behaviour. Efforts were made to orientate and position the research boat that allowed for the photographs to taken perpendicular to the lateral view of the animals and to avoid backlighting. The photographs of the left and right sides of the dolphins' dorsal fins were taken with digital single lens reflex (SLR) cameras (Canon EOS 60D or 70D) fitted with 70–300 mm telephoto zoom lens.

3.2.3 Sampling of water parameters

During boat-based line transect surveys, water parameters were recorded at the start and end of each transect line and at the sighting locations. Water depths were recorded using a handheld depth sounder (Speedtech Instruments, Great Falls, VA), whereas sea surface temperature (SST), salinity, pH, dissolved oxygen (DO) and total dissolved solids (TDS) were measured using a handheld multi-parameter meter (YSI Professional Plus or YSI 556 MPS; YSI; Yellow Springs, OH).

3.2.4 Interview surveys with local fishers

Interview surveys with local fishers in fishing villages along Matang's coast were conducted between February 2014 and February 2017. The interview questionnaire was adapted from Pilcher & Kwan (2012), and covered a wide range of topics from the fishers' background, fishing as livelihood, fisheries trends, fishing vessel used, frequency of fishing, fishing areas, fishing gears used, target catch, previous cetacean sightings and strandings, local ecological knowledge and perception about cetaceans, and occurrences of cetacean bycatch (Appendix B). Pilot studies were carried out to improve the flow and minimize possible misunderstandings of the questions, and were practised with a social scientist.

According to Krejcie & Morgan (1970), the target sample size required to achieve a 95% confidence interval that is representative of the population size of 2,763 local fishers that were registered in Larut and Matang (Perak Fisheries Department, 2012) was 338 interviews. Efforts were made to conduct the interviews with samples of each major fishing gear types in each fishing village.

Fishing villages were visited to conduct face-to-face interviews with local fishers who fish within the study area. Each respondent was interviewed individually in either the Malay language or Chinese dialect (e.g., Mandarin, Cantonese or Hokkien), according to the preference of the respondent. For sightings, entanglements and stranding incidents, information that were collected include species, number of individuals, size, presence of mother-calf pair, year and month of occurrences. A custom-designed species identification guide was shown to help respondents identify the cetacean species (Appendix C). Respondents could provide more than one response for open-ended questions. Respondents were also asked to mark the locations of fishing areas, dolphin areas, entanglements, and strandings on the map. At the end of each interview, the reliability of the respondents were separately rated for their openness in answering bycatch questions, their level of interest, their level of certainty in numerical questions, and their ability to discriminate between the cetacean species. Responses with the lowest scores (i.e., rated as not honest, not interested, unsure with numerical questions, and not comfortable with respondents' ability to discriminate species) were excluded from analyses.

3.3 Data processing and analyses

3.3.1 Data processing and estimation of abundance of Irrawaddy dolphins using line-transect distance sampling

At the end of each survey day, dolphin sighting locations and survey tracks downloaded and saved using the Garmin MapSource® 6.16.3 software. For on-effort sightings, the perpendicular distance from the dolphin sighting to the transect line was calculated based on the angle to sighting (i.e., angle difference between line bearing and bearing to sighting) and distance to sighting. Survey effort and all associated sightings at Beaufort > 3 were excluded from the analysis (Jefferson et al., 2002).

Line-transect data (i.e., perpendicular distance, best estimate of group size, length of transect line and survey block area) of Irrawaddy dolphins were imported for analysis using program DISTANCE 7.2 (Thomas et al., 2010). The abundance of Irrawaddy dolphins was estimated with the program DISTANCE 7.2 using the following equation (Buckland et al., 2001):

$$N = \frac{n\, f(0) E(s) A}{2\, L\, g(0)} \qquad (3.1)$$

where N is the abundance of individuals, n is the number of on-effort sightings, $f(0)$ is the value of the probability density function at zero perpendicular distance, $E(s)$ is the unbiased mean group size, A is the area of region for which abundance is estimated, L is the length of transect line surveyed, and $g(0)$ is the trackline detection probability.

The four survey blocks were used as the stratum definition. Right truncation of perpendicular distances was explored to investigate whether this improved the fit of the detection function, assessed using goodness-of-fit tests, visual inspection of QQ plots and, all other things being equal, the CV of estimated abundance. Combinations of key functions and series expansions that were considered to model the detection function were half-normal key with cosine or hermite polynomial adjustment, and hazard rate key with cosine or simple polynomial adjustment. Beaufort scale, swell height and group size were included in detection function models to investigate whether they improved model fit. The best fitting detection function model was selected based on the lowest Akaike's Information Criterion (AIC) score. The natural logarithm of group size was regressed against perpendicular distance to test for group size estimation bias; group size estimated from the regression was used if the slope was significant at the 0.15 probability level (the default in DISTANCE).

3.3.2 Photograph processing and estimation of humpback dolphin abundance using mark-recapture analyses

Photographs of the humpback dolphins were sorted into left or right sides of dorsal fins and the best photograph of each individual dolphin in every sighting was cropped around the dorsal fin and entered into a custom-designed Microsoft Access database. Attempts were not made to match the left side of dorsal fins (LDFs) and right side of dorsal fins (RDFs) of individuals. Instead, photographs of LDFs and RDFs were treated as two separate databases. Photographs of dorsal fins were scored manually for quality, Q and distinctiveness, D on a scale of 1 to 4 (with 4 indicating highest quality or highest distinctiveness and 1 indicating very low photo quality or non-distinct individual with a very clean dorsal fin of a standard size and shape) (Minton et al., 2013). Criteria for photo quality evaluation were sharpness, exposure, angle of the dorsal fin, proportion of the dorsal fin that was visible, and presence of water splashes or glare. All dorsal fin photographs were examined for identifiable features (i.e., pigmentation patterns, nicks, notches, dorsal fin shape, scars and mutilations) (Urian et al., 2015) and matched by eye on the computer screen. A marked individual that did not have a match with previously catalogued individuals was considered to be a new individual and was assigned a unique identification code. Individuals were also categorized into whether they were seen in the coastal or estuarine strata.

To minimize bias, the sighting histories used for mark-recapture analysis were filtered to only include dorsal fin photographs with a photo quality score of Q ≥ 2 and distinctiveness score of D ≥ 3. The side of the dorsal fin with more recaptures was used for analysis. Sighting histories were generated for all marked individuals seen in the coastal or estuarine strata, and for marked individuals seen only in the estuarine strata. Data were analyzed using program MARK version 9.0 (White & Burnham, 1999).

Pollock's closed robust design model (Pollock, 1982) was used to estimate the abundance of marked (distinctive) humpback dolphins ($\widehat{N}_m$). Each survey period (ca. 10 days) was treated as a secondary sampling occasion. Four consecutive secondary sampling occasions were pooled to form three non-overlapping primary periods corresponding to one year (i.e., 2013-2014, 2014-2015, 2015-2016), within each of which the population was assumed to be closed. Temporary emigration between primary periods (years) was modeled as the probability that an individual would be unavailable for capture during a primary period, given that it was available (γ") or unavailable (γ') in the previous primary period. Three models considering varying temporary emigration models were considered: (1) Markovian movement, (γ" ≠ γ') where the probability of an individual being present in the study is conditional on whether it was present in the study area in the previous primary period; (2) random movement (γ" = γ') where the probability of an individual being present in the study area is not dependent on whether it was present in the study area in the previous primary period; and (3) no movement, (γ" = γ' = 0) where there is no temporary emigration (Kendall et al., 1997). Annual apparent survival probability was kept constant. Capture and recapture probabilities were assumed equal and were allowed to be either constant within years or time-varying.

The best fitting model was selected based on the lowest score of the small sample size corrected Akaike's Information Criterion (AICc). If overdispersion in the data was apparent, indicated by the variation inflation factor, Fletcher's $\hat{c} > 1$, $\hat{c}$ was adjusted within program MARK and the best fitting model was chosen based on the lowest corrected quasi-AIC (QAICc). To account for model uncertainty, weighted model averaging of the candidate models, based on their AICc/QAICc weights, was applied to obtain estimates of model parameters, including the estimate of the number of distinctive dolphins ($\widehat{N}_m$).

The average proportion of distinctive humpback dolphin individuals (with distinctiveness score of 3 or 4) in the population was estimated using a binomial generalized linear model (GLM) with logit link function fitted in R (R Core Team, 2020) to the number of distinctive and non-distinctive dolphins in each group encountered. Models were fitted with and without primary period as a potential explanatory covariate, and the model with lowest AIC was chosen. This proportion ($\hat{\theta}$) was used as a correction factor to estimate the total population size $\left(\widehat{N}_T\right)$ of humpback dolphins occurring in the study area, as follows:

$$\widehat{N}_T = \frac{\widehat{N}_m}{\hat{\theta}} \quad (3.2)$$

where $\widehat{N}_T$ is the total population size, $\widehat{N}_m$ is the mark-recapture population estimate, and $\hat{\theta}$ is the proportion of distinctive individuals.

The standard error (SE) for the population size, $\hat{N}_T$ was derived using the following formula (Peng et al., 2020):

$$SE(\hat{N}_T) = \sqrt{\hat{N}_T{}^2 \left(\frac{SE(\hat{N}_m)^2}{\hat{N}_m{}^2} + \frac{\text{var}(\hat{\theta})}{\hat{\theta}^2}\right)} \quad (3.3)$$

Log-normal 95% confidence intervals (CI) around total population size were calculated according to Burnham et al. (1987), with the lower limit of $\hat{N}_T^{lower} = \hat{N}_T / C$ and the upper limit of $\hat{N}_T^{upper} = \hat{N}_T \times C$, where:

$$C = \exp\left[1.96\sqrt{ln\left(1 + \left(\frac{SE(\hat{N}_T)}{\hat{N}_T}\right)^2\right)}\right] \quad (3.4)$$

3.3.3 Distribution patterns and encounter rates

Locations of on-effort and off-effort cetacean sightings and survey tracks were plotted using program ARCMAP 10.3.1 (ESRI, Redlands, CA). Only on-effort sightings for each species were used to calculate encounter rates, which were calculated in relation to distance (sightings per 100 km) and hours of effort (sightings per hour). The sum of the best estimates of group size for all on-effort sightings were used to calculate encounter rates of dolphin individuals in relation to distance (individuals per 100 km) and hours of effort (individuals per hour). Encounter rates by survey block were calculated as the total number of on-effort sightings in the survey block per total effort in distance and hours of effort in the survey block. Encounter rates by season were analyzed by pooling surveys into two monsoon seasons: Northeast Monsoon from November-April and Southwest Monsoon from May-October.

In order to visualize the dolphin encounter rates on the map, grid cell analysis was conducted in program ARCMAP 10.3.1, following methods described in Peter (2012). The 2 km × 2 km grid cells of the study area were overlaid and intersected with on-effort survey tracks using program ARCMAP 10.3.1. The encounter rate for each grid cell was calculated by taking the number of on-effort sightings for each species in each grid cell and divided by the sum length of on-effort survey tracks in the grid cell. The best estimates of group size for all sightings including off-effort sightings were used for group size analyses. Spatial distribution of group size and behaviour for all sightings were plotted using program ARCMAP 10.3.1.

All statistical analyses were performed using the SPSS 23.0 (IBM Corp., Armonk, NY). Statistical tests used included chi-square goodness of fit test (for encounter rates in the four survey blocks), chi-square test of independence (for the relationship between species and survey blocks), and Mann-Whitney U test (for encounter rates between two monsoon seasons). For the chi-square goodness of fit test, the expected encounter rates in each survey block was calculated based on the null hypothesis of no difference between survey blocks. For the chi-square test of independence, the expected number of sightings in each cell of the contingency table was calculated by multiplying its row and column totals and dividing by the total number of observations. An alpha-value of 0.05 was used as the significance level.

3.3.4 Habitat characteristics, group size and behaviour

The environmental parameters selected for habitat characteristics analysis in this study were distance to river mouth (km), water depth (m), salinity (ppt), sea surface temperature (SST, °C) and tidal states (high, ebb, low, flood). Sighting locations were imported into Google Earth Pro and distances to river mouth (the shortest distance to the fixed midpoint in the nearest river mouth) were measured to the nearest 0.1 km using the "ruler" function, following methods described in Minton et al. (2011). Sightings located upriver of the fixed midpoint were assigned a value of '0'. Environmental parameters were analyzed using all sightings (on-effort and off-effort). Sightings were categorized into four tidal states according to the classification adapted from Wang et al. (2015) based on the sighting time. The hourly tide heights at the nearest port of Lumut, published by the National Hydrography Centre (Tide Tables Malaysia, 2013, 2014, 2015, 2016), were used to determine the time of high and low water. High and low tides were defined as the 1.5 h before and 1.5 h after the time of high and low water, respectively. The ebb tide was defined as the 3 h period after high tide or before low tide, whereas flood tide was defined as the 3 h period after low tide or before high tide.

Data were checked for normality using a Shapiro-Wilk test and the homogeneity of variances was tested using Levene's test. Non-parametric tests were used for environmental variables that did not meet the assumptions of normality and homoscedasticity. The Kruskal–Wallis H test (for group size and environmental parameters of the two species) and Dunn's test (for comparison of environmental parameters and behavioural states) were performed using SPSS 23.0.

3.3.5 Habitat use

The positions of all humpback dolphin and Irrawaddy dolphin sightings that were categorized as feeding or foraging were plotted on program ARCMAP 10.3.1 for analysis of feeding ground, whereas positions of sightings with presence of mother-calf pairs were plotted for analysis of nursery ground. The feeding and nursery grounds of humpback dolphins and Irrawaddy dolphins were identified using kernel density estimate (KDE) based on methods described in MacLeod (2013). The 'Kernel interpolation with barriers' tool in program ARCMAP 10.3.1 was used to generate the 50% and 95% kernel range polygons. The polygons of the 50% kernel range were used to represent the core areas of feeding and nursery groups.

The percentage of dolphin sightings with presence of mother-calf pairs was calculated by dividing the number of sightings with mother-calf pairs of the species by the total number of sightings of the species. The percentage of sightings with mother-calf pairs by month was calculated by dividing the total number of sightings with mother-calf pairs in the survey month (i.e., January, March, May, July, September, November) by all sightings of the species in that survey month.

3.3.6 Movement and ranging patterns

Resightings of distinctive individuals with quality score, Q ≥ 2 and distinctiveness score, D ≥ 3 were analyzed by calculating the number of times a particular individual was resighted in each survey and each survey year. If an individual was resighted more than once in a single survey day, only the first sighting of the day was used. Resident individuals were defined as distinctive individuals with more than 10 resightings on different survey days on ≥ 50% of bimonthly surveys. Individual ranges were calculated using Minimum Convex Polygons (MCPs) for resident humpback dolphin individuals that had more than 10 resightings. The dorsal fin side with more resightings was used for analysis. The sighting locations of humpback dolphin individuals that were sighted more than 10 times on the LDFs were plotted using the program ARCMAP 10.3.1. The Minimum Bounding Geometry tool in program ARCMAP 10.3.1 was used to create the MCP ranges, and areas that fall on land were removed following the protocols by MacLeod (2013) to more accurately represent the areas that were actually used by the individual dolphin individuals. The MCP area was calculated by adding a field in the attribute table of the shapefile and using the 'Calculate Geometry' function in program ARCMAP 10.3.1.

Using all sightings of each species, the core areas and ranging areas of humpback dolphins and Irrawaddy dolphins were identified using kernel density estimate (KDE) based on methods described in MacLeod (2013). The 'Kernel interpolation with barriers' tool in program ARCMAP 10.3.1 was used to generate the 50% percentage volume contours (PVCs) to represent the core areas) and 95% PVCs to represent the ranging areas. The 50% and 95% kernel range area were calculated by adding a field in the attribute table and using the 'Calculate Geometry' function in program ARCMAP 10.3.1.

3.3.7 Interviews with local fishers

The answers of questionnaires were entered into an Excel database. The responses of interviewed local fishers in Matang such as fishers' perception of dolphins (whether dolphins are important, reasons of dolphin importance/unimportance, whether fishers like dolphins, whether it is illegal to kill cetaceans intentionally and unintentionally) and occurrences of dolphin bycatch were analyzed quantitatively to understand their general perception of dolphins and to identify the occurrence of bycatch in Matang. Responses to open-ended questions were coded to standardized categories, similar to Whitty (2014). Responses related to years of experience, number of fishing days per month, soak times of gears, boat length and horsepower of outboard boat engines were sorted into three to four bins. Since respondents could provide more than one answer per question and some respondents did not provide an answer for certain questions, the percentages for the number of answers in each answer category were calculated by using the total number of answers per question, similar to Kreb et al. (2020). Fishing areas of respondents by gear type, dolphin areas where respondents frequently encountered dolphins, and dolphin bycatch locations were plotted using the program ARCMAP 10.3.1. Fishing gears involved in bycatch of humpback dolphins and Irrawaddy dolphins were also noted for bycatch risk assessment in Chapter 7.

3.3.8 Prevalence of injuries from interactions with human activities and intraspecific interactions

The presence of permanent injuries and disfigurements were assessed in dorsal fin photographs of all distinct photo-identified individuals of both humpback dolphins and Irrawaddy dolphins that were catalogued on the RDFs in which more individuals were catalogued. Non-permanent injuries from aggressive interactions such as superficial tooth rakes and multiple tooth rakes that penetrated the dermis of the dorsal fins (Brown et al., 2016) and injuries from shark bites were omitted from analysis. Photographs were examined for confirmed and potential wounds, scars and disfigurements associated with interactions with fisheries and injuries from intraspecific social interactions. Other major injuries photographed on other parts of the body such as back, fluke and caudal peduncle were also noted. Anthropogenic-related injuries and injuries from intraspecific interactions were classified into twelve types following definitions that were modified from Kügler & Orbach (2014), Luksenburg (2014), Slooten et al. (2013) and Wang et al. (2017a), which were given as follows:

1. Permanent injuries that are confirmed to be from anthropogenic activities such as fishing gear, marine debris or propeller cuts:
   (a) Single, deep indentation on body or dorsal fin: possibly as a result of entanglement in fishing line, net, rope or other marine debris
   (b) Propeller cuts: multiple incisions, cuts or slashes that are typically parallel and evenly spaced as a result of a turning propeller hit
2. Permanent injuries that are probably associated with anthropogenic activities:
   (a) Linear severed dorsal fin: cleanly severed dorsal fin that could be attributed to interaction with fishing gear such as fishing line or net, or a propeller
   (b) Straight, deep cut on dorsal fin: wound characterized by deep-pointed notches
   (c) Short blunt cut on dorsal fin: wound characterized by blunt cut-like indentation
3. Injuries that are probably combination of anthropogenic injuries and intraspecific injuries
   (a) Curved cut on the leading edge of dorsal fin: severed with a curved cut on the leading edge of dorsal fin
4. Injuries that are most likely as the result of intraspecific interactions:

(a) Non-linear severed dorsal fin: non-cleanly severed dorsal fin with irregular dorsal fin profile, probably from intraspecific interaction

(b) Round indentation on the trailing edge and/or leading edge of dorsal fin: half round or oval shaped cut on the trailing edge or leading edge of dorsal fin

(c) Irregular dorsal fin trailing edge: jagged nicks and notches on the trailing edge of dorsal fin

(d) Rounded dorsal fin profile: dorsal fins that are rounded, possibly as a result of nibbles from other individuals

5. Other injuries:

(a) Shark bite injury: jagged, crescent-shaped or widely spaced dental impression

(b) Unidentified: other injuries that could not be assigned to any of these injury types and possible causes could not be determined

3.3.9 Bycatch risk assessment (ByRA)

The Bycatch Risk Assessment (ByRA) toolkit was used to evaluate the spatial risk of bycatch of humpback dolphins and Irrawaddy dolphins. This open-source GIS toolkit was first developed to assess marine megafauna bycatch risk in developing countries by using a combination of field survey data on animal and fishing gear distributions, secondary data from fisher interviews, and assessment of species life history as well as fishing gear criteria (Verutes et al., 2020). The toolkit was applied successfully to estimate bycatch risk for Irrawaddy dolphins and dugongs in four pilot sites in Southeast Asia (Hines et al., 2020). The risk of fisheries bycatch was calculated in the ByRA toolkit in program InVEST 3.6.0 based on the likelihood of exposure (interaction between marine mammals and the fishery) and the consequence to the species (Verutes et al., 2020). Positions of all humpback dolphin and Irrawaddy dolphin sightings and fishing activities observed during boat surveys in July 2013 to July 2016 were plotted and overlaid on a map using the program ARCMAP 10.3.1. Information on fishing gears (stressors) that were collected from interview surveys with local fishers (in Chapter 7) were then organized into four distinct categories: (1) nets, (2) trawls, (3) bag nets, and (4) push net. The 'nets' category included gillnets, driftnets and trammel nets, whereas the 'trawls' category included fish trawl nets and shrimp trawl nets.

Kernel density estimation (KDE) was used to map the intensity of fishing activity and dolphin sightings needed to generate the corresponding shapefiles. Polygon kernel density shapefiles of the two dolphin species, and the four stressors in Matang were then reclassified into three rating scores using Jenks natural breaks for the rating field (3 for high, 2 for medium, and 1 for low). For the management shapefiles, the exposure scores were scored as "1" if management strategies are identified and implemented, "2" if management strategies are identified but not implemented, and "3" for areas where no management strategies was identified (Verutes et al., 2020). For the subregion shapefiles, the area of interest in the study area was divided into four subregions following the survey strata (i.e., North Coastal, North Estuarine, South Coastal, and South Estuarine). The Habitat Risk Assessment Preprocessor in InVEST 3.6.0 was run and the ratings, data quality and weight for the species and stressors were scored as guided by field observations, results of interview with local fishers and literature review, following the criteria defined in Verutes et al. (2020). The evaluation of fishing gear ratings were based on frequency of bycatch gears reported in interview surveys with local fishers in Matang, and literature review (Hines et al., 2015a; Slooten et al., 2013). The ByRA Pre-processor was then run in the software QGIS 3.8.0, followed by the Habitat Risk Assessment in InVEST 3.6.0 to generate the modeled ByRA outputs such as the bycatch risk maps and plots of species-gear interactions. To quantify bycatch risk in ByRA, exposure scores are calculated based on the overlap between species distribution and the extent of human activity in space and time, whereas consequence scores are calculated based on assessment of how a population will respond to an impact (Hines et al., 2020; Verutes et al., 2020). The stoplight approach in Hines et al. (2020) was used to characterize levels of uncertainty and to visualize data quality for ByRA data categories in Matang. Data were characterized as either green (data with high certainty from robust methodologies), yellow (data with medium certainty that were collected opportunistically) or red (data with low certainty with insufficient data or effort) (Hines et al., 2020).

CHAPTER 4: ABUNDANCE ESTIMATES

4.1 Results

4.1.1 Abundance estimates of humpback dolphins

There were 119 sightings of humpback dolphins across 120 survey days, of which 28 sightings were encountered on-effort and 91 sightings were encountered off-effort (Figure 4.1). The sighting histories by survey that met the filtering criteria of photo quality score, $Q \geq 2$ and distinctiveness score, $D \geq 3$ represented 406 LDF captures from 148 individuals (Table 4.1) and 414 RDF captures from 161 individuals. The LDF dataset had a higher number of individual recaptures than the RDF dataset, hence LDF data were used for the mark-recapture analyses. Of these 406 LDF captures by survey, 319 captures were from 76 individuals seen in the estuarine blocks (hereafter inshore individuals) and 87 captures were from 72 individuals seen in the coastal blocks (hereafter offshore individuals). No individuals were seen in both estuarine and coastal blocks. Based on individuals identified using LDF, 60 (83%) of the distinctive offshore individuals and 22 (29%) of the distinctive inshore individuals were sighted in only one out of the 12 surveys. The cumulative number of photo-identified humpback dolphin individuals increased throughout the study period (Figure 4.2a). Inshore individuals (Figure 4.2b) were recaptured more than offshore individuals (Figure 4.2c), which were mostly new individuals that were not subsequently resighted. There were sightings of inshore humpback dolphins in the estuarine strata in all 12 surveys, but there were no sightings in the coastal strata during the last four surveys (Table 4.1).

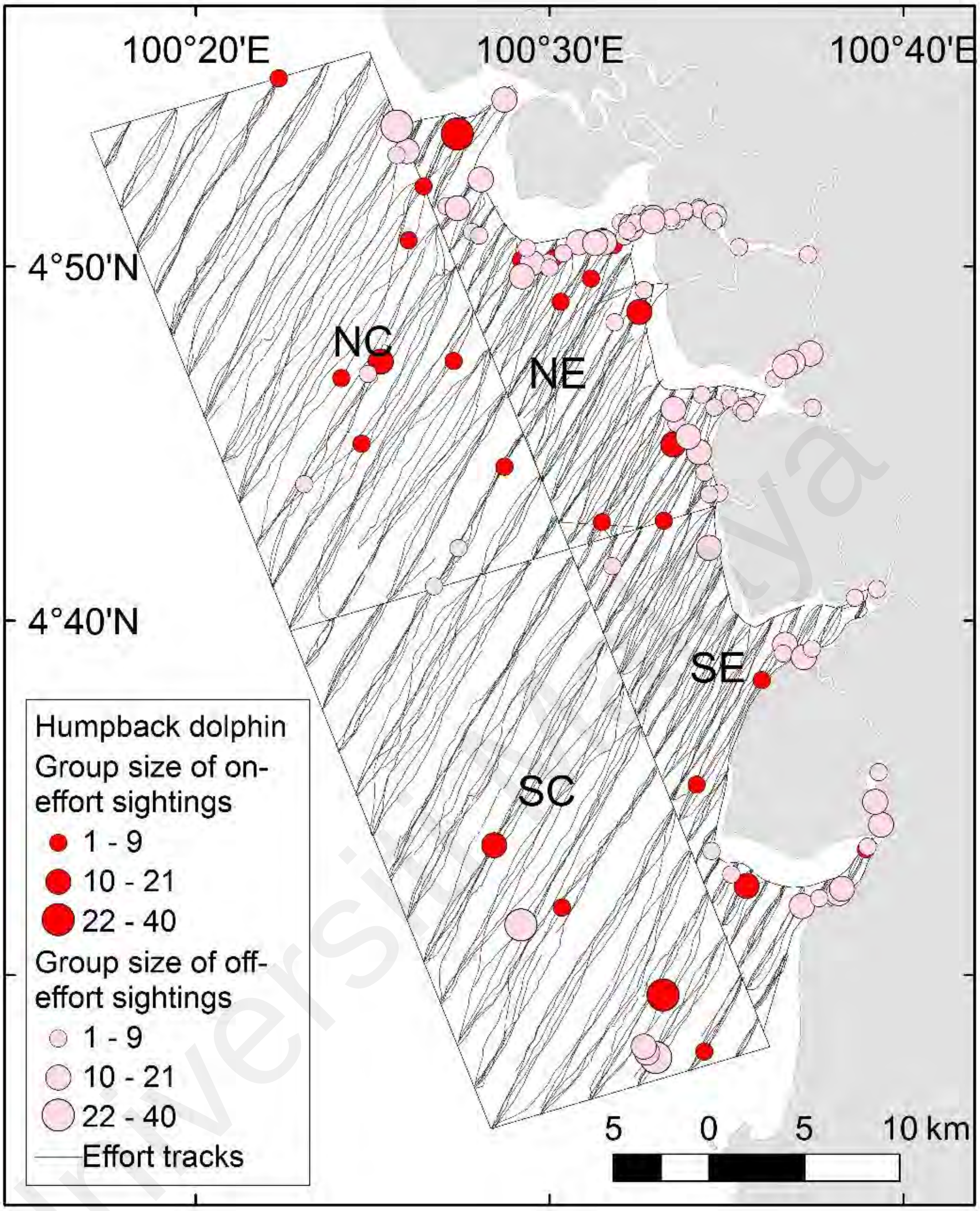

Figure 4.1: The survey effort tracks and group size of humpback dolphin on-effort and off-effort sightings in the north coastal (NC), north estuarine (NE), south coastal (SC) and south estuarine (SE) survey blocks during line-transect surveys between November 2013 and July 2016

Table 4.1: Total survey days, total sightings, total number of distinct individuals (with quality score of $Q \geq 2$ and distinctiveness score of $D \geq 3$), distinct inshore individuals and offshore individuals photo-identified from the left side of dorsal fins (LDFs) during three primary periods used in robust design analysis in MARK

Primary period (P)	Secondary period	Days	Total sightings	Total distinct individuals identified (LDF)	Distinct inshore individuals identified (LDF)	Distinct offshore individuals identified (LDF)
P1 (2013-2014)	18-27 Sep 2013	10	20	52	28	24
	8-17 Nov 2013	10	10	35	28	7
	19-28 Jan 2014	10	13	37	32	5
	6-15 Mar 2014	10	10	31	30	1
P1 Total		**40**	**53**	**85**	**47**	**38**
P2 (2014-2015)	2-11 Jul 2014	10	6	27	24	3
	9-18 Sep 2014	10	7	10	7	3
	3-12 Mar 2015	10	9	28	28	0
	8-17 May 2015	10	14	84	44	40
P2 Total		**40**	**36**	**101**	**56**	**45**
P3 (2015-2016)	30 Jun-9 Jul 2015	10	6	16	16	0
	12-21 Sep 2015	10	7	26	26	0
	12-21 Jan 2016	10	6	27	27	0
	22-31 Jul 2016	10	11	27	27	0
P3 Total		**40**	**30**	**51**	**51**	**0**
Total for 2013-2016		**120**	**119**	**148**	**76**	**72**

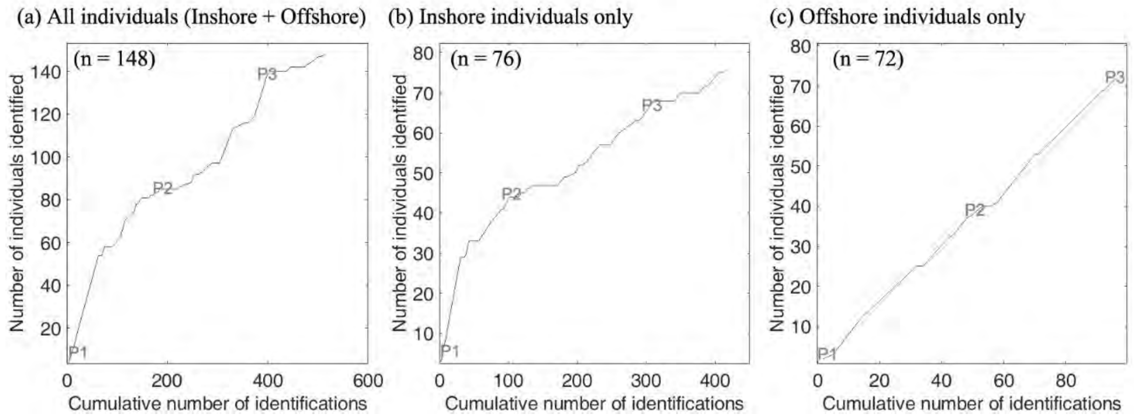

Figure 4.2: Discovery curves of the cumulative number of distinctive humpback dolphin individuals identified against the cumulative number of identifications using photographs of left side of dorsal fins (LDFs) between September 2013 and July 2016 for (a) all individuals, (b) inshore individuals only and (c) offshore individuals only. The start of each primary period was indicated by P1: Primary period 1 (2013-2014), P2: Primary period 2 (2014-2015), and P3: Primary period 3 (2015-2016).

Two mark-capture analyses were conducted; (1) for combined offshore and inshore individuals in the coastal and estuarine strata, and (2) for solely inshore individuals in the estuarine strata. The variance inflation factor, $\hat{c}$ values of 3.025 for combined offshore and inshore humpback dolphins data, and 1.373 for inshore–only data were used to correct the degree of overdispersion prior to model selection (Tables 4.2, 4.3). The Markovian model could not be fitted for either dataset. The best-fitting model for combined offshore and inshore humpback dolphins included random temporary emigration with time-varying capture/recapture probabilities (Table 4.2). The weighted average estimates of the annual number of distinctive offshore and inshore humpback dolphins ($\widehat{N}_m$) varied from 95 (in 2013-2014) to 118 (in 2014-2015) and 56 (in 2015-2016) (Table 4.4). The proportion of marked individuals in the population modelled without primary period as a covariate had a lower AIC than using primary period as a covariate, and hence the overall average of theta = 0.689 was used as the correction factor to calculate total population size. The total number of humpback dolphins in the study area after correction varied from 138 (in 2013-2014) to 171 (in 2014-2015), to 81 (in 2015-2016) (Table 4.4). Estimated capture/recapture probabilities varied between 0.319

and 0.437. The apparent survival probability was estimated as 0.64 (SE = 0.11, 95% CI = 0.41-0.82).

The best fitting model for only inshore humpback dolphins in the estuarine strata included random temporary emigration with time-varying capture/recapture probabilities (Table 4.3). The weighted average estimates of the annual number of distinctive inshore humpback dolphins ($\widehat{N}_m$) varied from 47 (in 2013-2014) to 60 (in 2014-2015), to 56 (in 2015-2016) (Table 4.4). The proportion of marked inshore individuals in the population modelled without primary period as a covariate had a lower AIC than using primary period as a covariate, and hence the overall average of theta = 0.692 was used as the correction factor to calculate total population size of inshore humpback dolphins. The total number of inshore humpback dolphins in the estuarine strata after correction varied from 68 (in 2013-2014) to 87 (in 2014-2015), to 81 (in 2015-2016) (Table 4.4). Estimated capture/recapture probabilities varied between 0.430 and 0.622. The apparent survival probability was estimated as 0.84 (SE = 0.06, 95% CI = 0.67-0.93).

Table 4.2: Pollock's robust design candidate models for abundance estimation of marked humpback dolphins in the coastal and estuarine strata of Matang arranged in corrected quasi Akaike's Information Criterion ($QAIC_c$) values, with the lowest $QAIC_c$ value representing the most parsimonious model. Model notation: *S*: apparent survival probability; *p*: probability of capture; *c*: probability of recapture; (.): constant parameter; (*t*): parameter varies with time. Variance inflation factor, $\hat{c}$ = 3.025.

#	Model	QAICc	Delta QAICc	QAICc weight	Model likelihood	No. of parameters	QDeviance
1	{*S*(.)*p*(*t*)=*c*(*t*)random(*t*)}	-53.74	0	0.907	1.000	18	114.62
2	{*S*(.)*p*(t)=*c*(t)no-movement(*t*)}	-49.19	4.5491	0.093	0.103	19	116.97
3	{*S*(.)*p*(.)=*c*(.)random(*t*)}	-27.87	25.8652	0.000	0.000	9	159.80
4	{*S*(.)*p*(.)=*c*(.)random(.)}	-26.52	27.214	0.000	0.000	8	163.24

Table 4.3: Pollock's robust design candidate models for abundance estimation of marked humpback dolphins in the estuarine strata of Matang arranged in corrected Akaike's Information Criterion ($QAIC_c$) values, with the lowest $QAIC_c$ value representing the most parsimonious model. Model notation: *S*: apparent survival probability; *p*: probability of capture; *c*: probability of recapture; (.): constant parameter; (*t*): parameter varies with time. Variance inflation factor, $\hat{c}$ = 1.373.

#	Model	QAICc	Delta QAICc	QAICc weight	Model likelihood	No. of parameters	QDeviance
1	{*S*(.)*p*(*t*)=*c*(*t*)random(*t*)}	18.36	0.00	0.823	1.000	18	205.47
2	{*S*(.)*p*(t)=*c*(t)no-movement(*t*)}	21.42	3.07	0.177	0.216	19	206.27
3	{*S*(.)*p*(.)=*c*(.)random(.)}	40.60	22.24	0.000	0.000	8	249.53
4	{*S*(.)*p*(.)=*c*(.)random(*t*)}	41.77	23.41	0.000	0.000	9	248.58

Table 4.4: Weighted average estimates of abundance of marked inshore humpback dolphins $(\hat{N}_m)$ in the coastal and estuarine strata, and estuarine strata only of Matang based on the four candidate models, and the estimates of total population $(\hat{N}_T)$ within survey interval year, corrected by the proportion of marked inshore individuals $(\hat{\theta})$ in the population from 2013-2016 photo-identification data. Coefficient of variation (CV), lower and upper log-normal 95% confidence interval (CI) of the estimates are also shown.

Strata	Survey interval	Robust Design abundance estimates			Proportion of marked humpback dolphins		Corrected abundance estimates		
		$\hat{N}_m$	CV $(\hat{N}_m)$	95% CI $(\hat{N}_m)$	$\hat{\theta}$	SE $(\hat{\theta})$	$\hat{N}_T$	CV $(\hat{N}_T)$	95% CI $(\hat{N}_T)$
Coastal and estuarine	2013-2014	95	0.079	80-110	0.689	0.016	138	0.082	118-162
	2014-2015	118	0.098	96-141			171	0.101	148-208
	2015-2016	56	0.095	45-66			81	0.098	67-98
Estuarine only	2013-2014	47	0.027	45-50	0.692	0.018	68	0.038	63-73
	2014-2015	60	0.052	54-66			87	0.058	78-97
	2015-2016	56	0.064	49-63			81	0.069	71-93

4.1.2 Abundance estimates of Irrawaddy dolphins

Approximately 96% of search effort was conducted in sea states of 3 or less on the Beaufort scale. Over 110 survey days, a total of 285 h was spent on effort, which yielded 161 sightings of Irrawaddy dolphins (Table 4.5). The realized transect lines, geographic distribution and group size of on-effort sightings of Irrawaddy dolphins sighted during the study period are presented in Figure 4.3.

Table 4.5: Survey effort and on-effort sightings in Beaufort 3 or less for Irrawaddy dolphins during 11 line-transect surveys between November 2013 and July 2016

Survey period	Effort (km)	Effort (h)	On-effort sightings of Irrawaddy dolphins in Beaufort scale ≤ 3
8-17 Nov 2013	386.1	27.8	14
19-28 Jan 2014	396.7	27.8	15
6-15 Mar 2014	377.1	26.9	12
2-11 Jul 2014	377.7	24.1	15
9-18 Sep 2014	377.3	25.9	20
3-12 Mar 2015	364.8	25.6	9
8-17 May 2015	380.4	25.4	7
30 Jun-9 Jul 2015	380.8	28.2	17
12-21 Sep 2015	352.5	24.5	22
12-21 Jan 2016	349.9	23.0	6
22-31 Jul 2016	364.3	25.8	24
Total	4,107.6	285.0	161

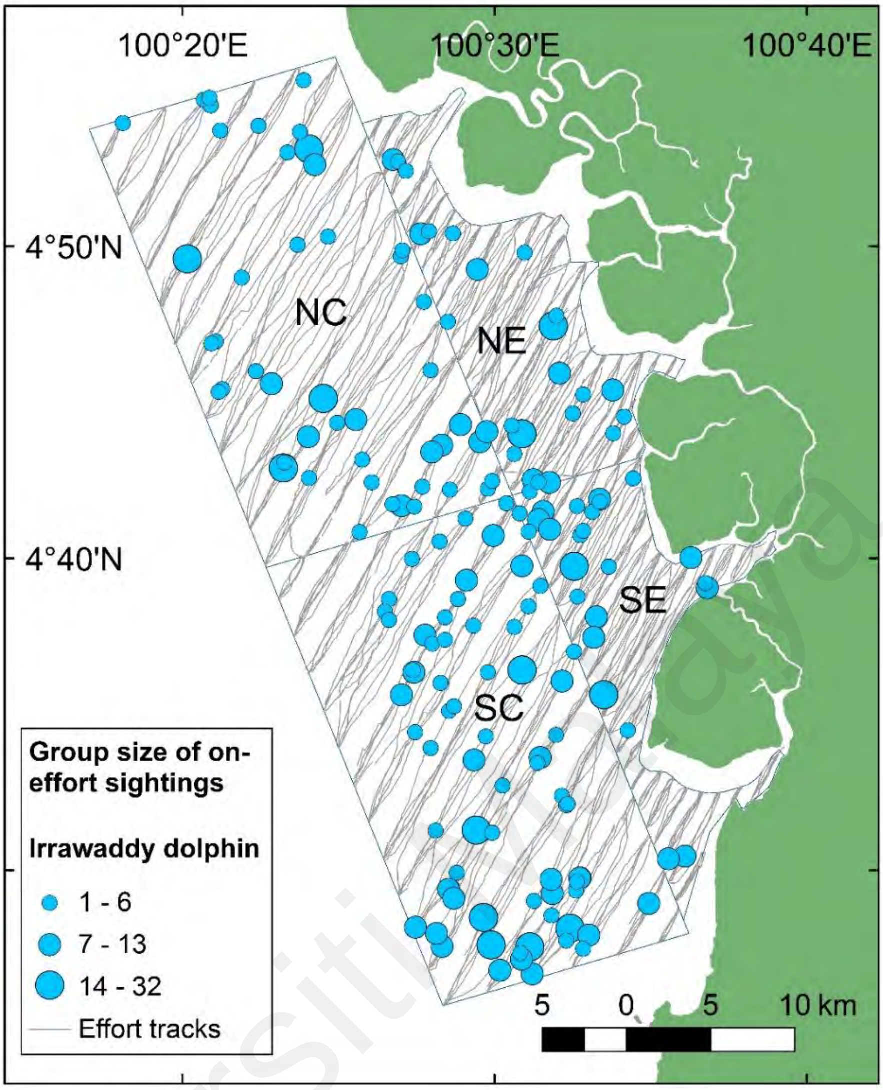

Figure 4.3: The survey effort tracks and group size of Irrawaddy dolphin on-effort sightings in the north coastal (NC), north estuarine (NE), south coastal (SC) and south estuarine (SE) survey blocks during line-transect surveys between November 2013 and July 2016

The selected detection function model for Irrawaddy dolphins was a half-normal key with no adjustment terms, with right truncation at 350 m (Figure 4.4). Inclusion of Beaufort, swell height or group size as covariates did not improve the model fit. The Kolmogorov-Smirnov goodness-of-fit test probability was 0.166, indicating an adequate fit of the model to the data. Estimated average probability of detection within the truncation distance was 0.476 and the effective strip half-width was 166.7 m (CV = 7%). The best estimate of the average abundance of Irrawaddy dolphins in the entire study area between 2013 and 2016 was 763 individuals (CV = 13.3%; 95% CI = 588-990). Estimates for each block are detailed in Table 4.6. The average density of Irrawaddy dolphins in the study area was 0.66 individuals per km^2, with the highest density in the south coastal block at 0.92 individuals per km^2. The average group size of Irrawaddy dolphins was 6.4 individuals (CV = 6.4%, 95% CI = 5.6-7.2).

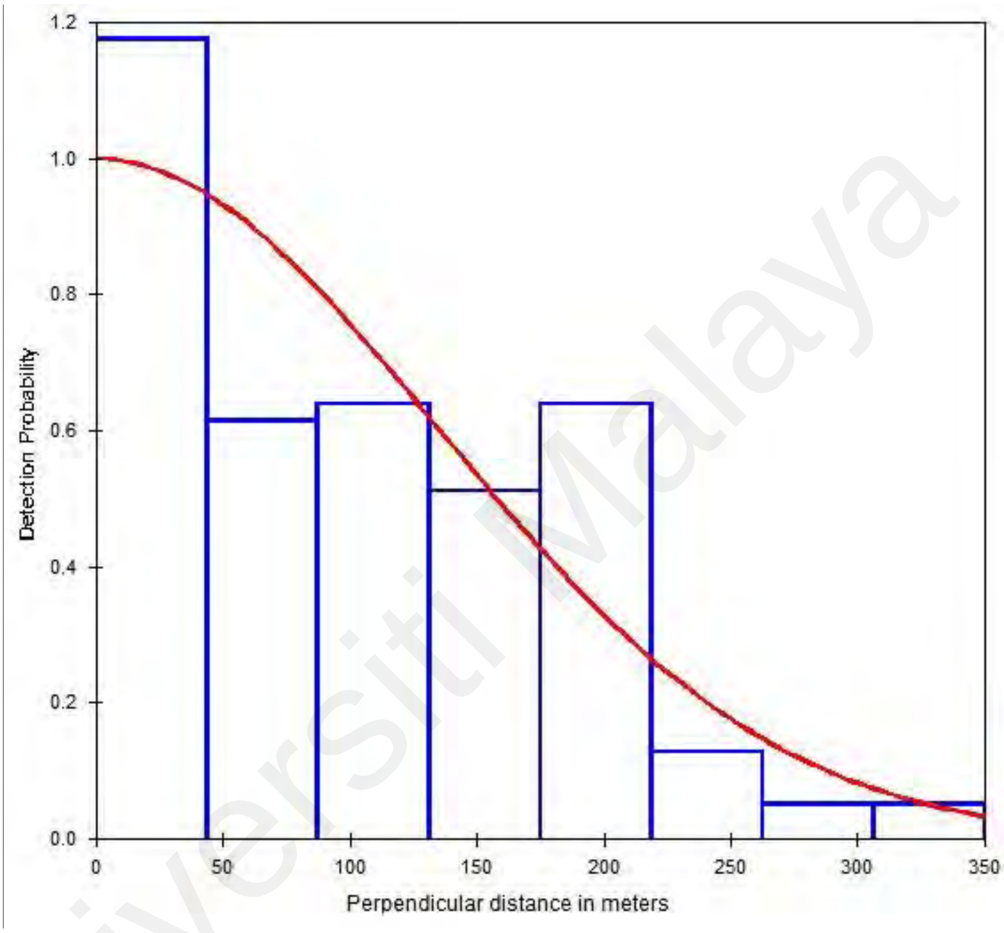

Figure 4.4: Detection probability fitted to the perpendicular distance of Irrawaddy dolphin sightings (n = 149) truncated to 350 m

Table 4.6: Abundance estimates for Irrawaddy dolphins for each survey block. The overall total differs from the sum of the blocks because of rounding error. *N* = estimated abundance, %CV = percent coefficient of variation, 95% CI = 95% confidence interval.

Survey block	Area (km^2)	Density (per km^2)	*N*	% CV	95% CI
North Estuarine	167.42	0.38	64	24.12	40-102
North Coastal	423.71	0.56	238	18.20	167-340
South Estuarine	136.85	0.52	72	22.81	46-112
South Coastal	423.74	0.92	390	16.68	281-540
Total	1151.72	0.66	763	13.31	588-990

4.2 Discussion

4.2.1 Annual mark-recapture of humpback dolphins

The assumptions of the mark-recapture method related to the data are that (1) marks are unique, correctly recorded and not lost during the study period. For the simplest models, it is assumed that (2) future survival or catchability are not affected by marking and (3) animals have an equal probability of being captured or recaptured within each sampling occasion (Hammond, 2018). Closed robust design also assumes that (4) the population remains closed within primary periods. For assumption (1), adult humpback dolphins can be reliably marked with the photographic capture of their long-lasting and unique pigmentation patterns of their dorsal fin. For assumptions (2), apparent survival and capture probability should not have been affected by marking by photo-identification. However, regarding assumption (3), it is not known whether capture probability varied among individuals within sampling occasions because the data were not sufficiently extensive to allow this to be modelled. If individual heterogeneity were present, this would lead to a negative bias in estimated abundance. For assumption (4), births, deaths and emigration may occur within the primary periods of six months to one year but unlikely to cause more than a small bias.

The estimates of abundance relate to the animals that used the area during the study period. Random temporary emigration out of the area between years was found for the whole study area and the estuarine area only (Tables 4.2, 4.3). The results indicate the presence of an inshore humpback dolphin group in the estuarine strata that remained relatively stable across the three years, and an offshore group that occasionally traversed the coastal strata; further population structure study is needed to clarify if these groups belong to the same or separate populations. The annual abundances of inshore humpback dolphins in the estuarine strata across the three years were similar at around 68 to 87 individuals, whereas the total number of humpback dolphins in the whole study area fluctuated between 81 to 171 individuals (Table 4.4). The apparent survival rate of inshore humpback dolphins in the estuarine strata at 0.84 was also higher than the rate of 0.64 for all humpback dolphins in the whole study area. Both variability in annual estimates and the low apparent survival rate in the whole study area is likely a reflection of the occurrence of wide-ranging individuals from outside the study area.

Inshore resident humpback dolphins regularly moved between the five estuaries of Matang (Kuit et al., (2019b), but there were no matches of individuals between the estuarine and coastal strata. This may be linked to the preference of inshore individuals for estuarine prey that are more abundant in the estuaries relative to the coastal waters, which in turn translates to stable use of the estuaries as feeding grounds by the inshore individuals with higher site fidelity within the estuaries and fewer movements in and out of the study area (Kuit et al., 2019a). In contrast, the offshore individuals appear to be range more widely beyond the study area along the wider coastline. The general lack of resightings of individuals from offshore groups, coupled with zero sightings of such groups in the final primary occasion (2015-2016), suggest that those individuals observed in the coastal strata are likely to be occasional visitors to the coastal study area.

4.2.2 Line transect abundance estimates of Irrawaddy dolphins

The assumptions of line-transect sampling include (1) representative sampling of the study area, (2) detection of all animals that are close to the line, (3) animals are detected prior to their response to the observers, and (4) distances are measured accurately (Buckland & York, 1993). In the present study, the study area was sampled systematically with the design of the transect lines placed in four strata. However, Irrawaddy dolphins are elusive animals with inconspicuous surfacing behaviour (Minton et al., 2013) so detection probability is highly likely to be less than one on the transect line due to availability and perception biases, and thus the estimates are negatively biased to an unknown extent. Availability bias arises when animals on the transect line are submerged and thus unavailable for detection, while perception bias arises when surfaced animals are missed by observers due to factors such as poor weather conditions and observer fatigue. Observers were rotated hourly to minimize fatigue, and only sightings in sea states of 0 to 3 on the Beaufort scale were included in the analyses in order to minimize perception bias from missing the animals in higher sea states, as suggested by Jefferson et al. (2002). Whether Irrawaddy dolphins reacted to the observers before detection or not could not be determined, but if the animals did react to the survey vessel prior to detection by swimming away because of their evasive nature this would result in underestimation of abundance. During surveys, the use of rangefinders to measure distance to sighted groups of cetaceans was impractical, however all observers were trained on distance estimation to minimize the bias from the violation of assumption (4).

4.2.3 Comparison with other studies

The largest estimates of humpback dolphins in the Pearl River Estuary, China (Chen et al., 2010) appeared to have a homogeneous distribution in the estuarine waters, hence line-transect distance sampling was a suitable method for abundance estimation there. However, mark-recapture may provide abundance estimates that have a much higher precision than line-transect estimates for study site with less than 100 humpback dolphins (Wang et al., 2012). With the lack of on-effort sightings of humpback dolphins in Matang throughout the survey area, the mark-recapture method was chosen as the most suitable approach taken in this study for the species.

The abundance of Irrawaddy dolphins estimated from this study in Matang appears to be the largest abundance estimated for the species in the Southeast Asian region, and second only to the largest estimates in Bangladesh in a huge study area that is 14.6 times larger than Matang (Smith et al., 2008). Other abundance studies on Irrawaddy dolphin that utilised the same line-transect methods and expended similar extensive survey effort include the two-year survey in Kuching Bay, Sarawak by Minton et al. (2013), and the five-year survey in the Trat Province, Gulf of Thailand by Hines et al. (2015b). However, the size of the survey area in Matang is approximately 2.5 to 2.7 times larger than those two other sites. The approximate density (derived from abundance over survey area size) of 0.66 Irrawaddy dolphin individuals per km^2 in Matang was lower than the approximate density in Trat Province, Gulf of Thailand of 0.98 individual per km^2, but higher than the estimates in Kuching Bay which were 0.32 to 0.50 individual per km^2. However, direct comparisons of abundance estimates and densities across different study sites must be made with caution because of variations in the methodology used, study area size and survey effort (Haughey et al., 2020).

CHAPTER 5: DISTRIBUTION AND HABITAT CHARACTERISTICS

5.1 Results

5.1.1 Sightings and encounter rates

A total of 254 sightings of Irrawaddy dolphins and 124 sightings of humpback dolphins were recorded during the 3-year study (Table 5.1). Sixty-five percent (n = 165) of Irrawaddy dolphin sightings and 23% (n = 28) of humpback dolphin sightings were encountered during on-effort line-transect surveys, while the rest were encountered during off-effort search (Table 5.1). The group encounter rate was higher for Irrawaddy dolphins at 3.87 sightings per 100 km, and lower for humpback dolphins at 0.66 sightings per 100 km (Table 5.1). The encounter rate (by numbers) was also higher for Irrawaddy dolphins at 25.2 individuals per 100 km or 3.6 individuals per hour, whereas humpback dolphins was 5.3 individuals per 100 km or 0.8 individuals per hour.

Comparison of sightings encounter rates across the four survey blocks using on-effort sightings revealed that the encounter rate of Irrawaddy dolphins was highest in the south coastal survey block at 5.22 sightings per 100 km or 0.76 sighting per hour (Figure 5.1). The encounter rate of humpback dolphins was highest in the north estuarine survey block at 1.35 sightings per 100 km or 0.19 sighting per hour (Figure 5.1).

Table 5.1: Survey effort and number of sightings according to effort for humpback dolphins and Irrawaddy dolphins

			Humpback dolphin				Irrawaddy dolphin			
Survey dates	**Effort (km)**	**Effort (h)**	Total sightings	On-effort sightings	Encounter rate (sightings/ 100 km)	Encounter rate (sightings/ hour)	Total sightings	On-effort sightings	Encounter rate (sightings/ 100 km)	Encounter rate (sightings/ hour)
2013										
16-18 Jul	-	-	3	-	-	-	5	-	-	-
18-27 Sep	-	-	20	-	-	-	18	-	-	-
8-17 Nov	386.02	27.82	10	4	1.04	0.14	16	14	3.63	0.50
2014										
19-28 Jan	392.42	27.82	13	4	1.02	0.14	30	15	3.82	0.54
6-15 Mar	390.99	27.75	10	4	1.02	0.14	18	12	3.07	0.43
2-11 Jul	395.83	25.31	6	2	0.51	0.08	19	16	4.04	0.63
9-18 Sep	385.28	26.27	7	1	0.26	0.04	26	20	5.19	0.76
6-7 Nov	-	-	2	-	-	-	5	-	-	-
2015										
3-12 Mar	379.82	27.43	9	3	0.79	0.11	17	9	2.37	0.33
8-17 May	388.52	25.86	14	5	1.29	0.19	15	7	1.80	0.27
30 Jun-9 Jul	397.40	29.37	6	0	0.00	0.00	24	18	4.53	0.61
12-21 Sep	387.87	26.55	7	1	0.26	0.04	24	23	5.93	0.87
2016										
12-21 Jan	378.09	25.47	6	2	0.53	0.08	9	7	1.85	0.27
22-31 Jul	381.45	26.25	11	2	0.52	0.08	28	24	6.29	0.91
Total	**4263.69**	**295.90**	**124**	**28**	**0.66**	**0.09**	**254**	**165**	**3.87**	**0.56**

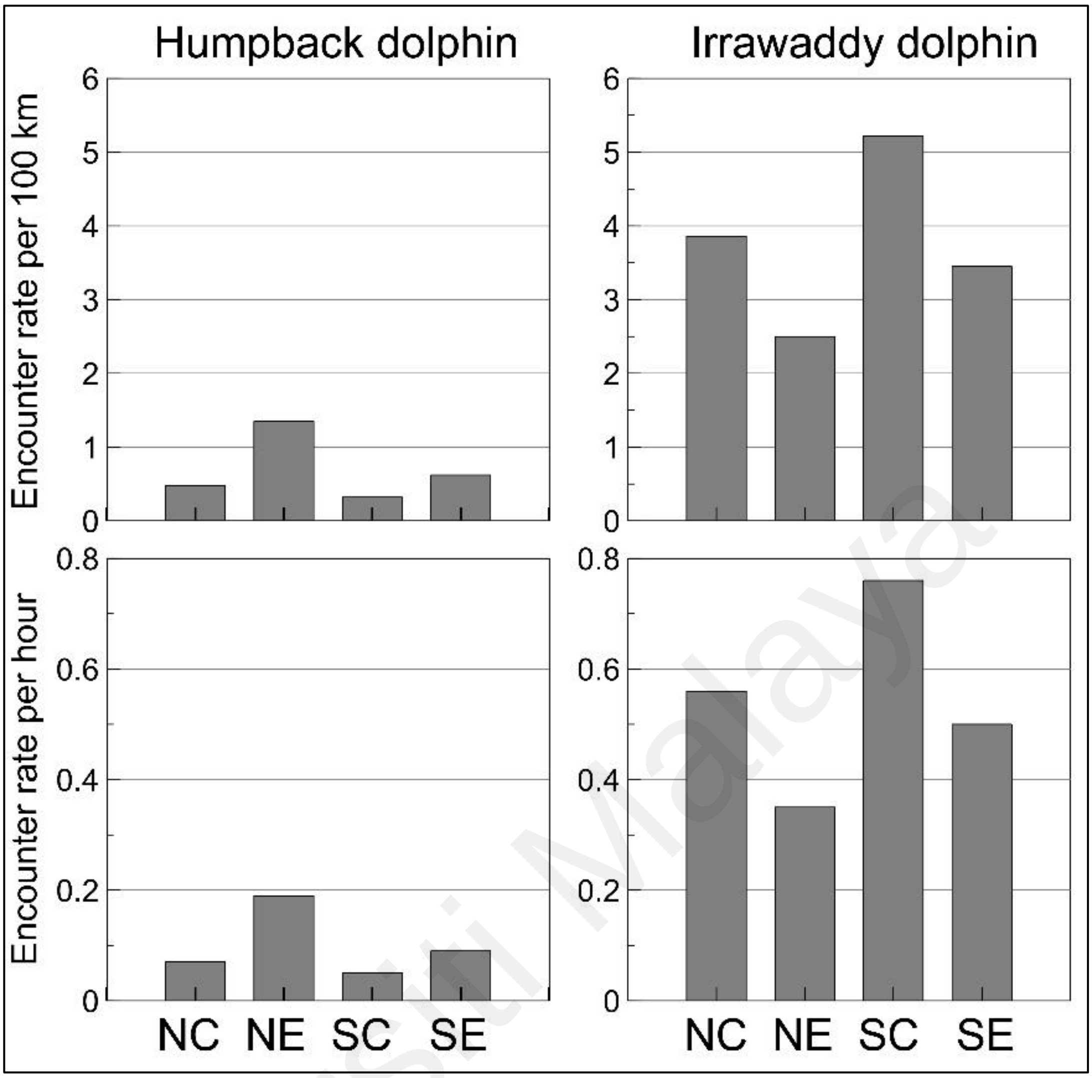

Figure 5.1: The encounter rate per 100 km (top row) and encounter rate per hour (bottom) of humpback dolphins and Irrawaddy dolphins in the north coastal (NC), north estuarine (NE), south coastal (SC) and south estuarine (SE) survey blocks

The chi-square goodness of fit test, comparing the occurrences of on-effort sightings with the expected occurrences based on effort in each survey block, showed significant deviation from the hypothesized values for humpback dolphins (χ^2 (3) = 9.78, P = 0.02) and Irrawaddy dolphins (χ^2 (3) = 12.40, $P < 0.01$). The chi-square test of independence showed that there was a significant relation between species and survey block (χ^2 (6) = 117.98, $P < 0.001$). The encounter rates did not vary significantly between the two monsoon seasons for both humpback dolphins (2-tailed Mann-Whitney U test, U = 5.00, P = 0.100) and Irrawaddy dolphins (U = 5.00, P = 0.068).

5.1.2 Distribution patterns

Most of the humpback dolphin sightings occurred in the shallow estuaries that were less than 10 m depth (Figure 5.2a), whereas Irrawaddy dolphins showed a more ubiquitous distribution in the coastal waters that were up to 15 m depth (Figure 5.2b). On-effort sightings of humpback dolphins were patchily distributed off the river mouths and in the coastal waters of Matang, but most of the off-effort sightings were in the estuaries and rivers where transect lines were not present (Figure 5.2a). There were fewer sightings of humpback dolphins within the 5 m isobath off Kuala Larut and Kuala Trong (Figure 5.2a). Irrawaddy dolphins were generally distributed throughout the coastal waters of Matang, but with fewer sightings within the 5 -10 m isobaths off Kuala Sangga Besar and Kuala Jarum Mas (Figure 5.2b).

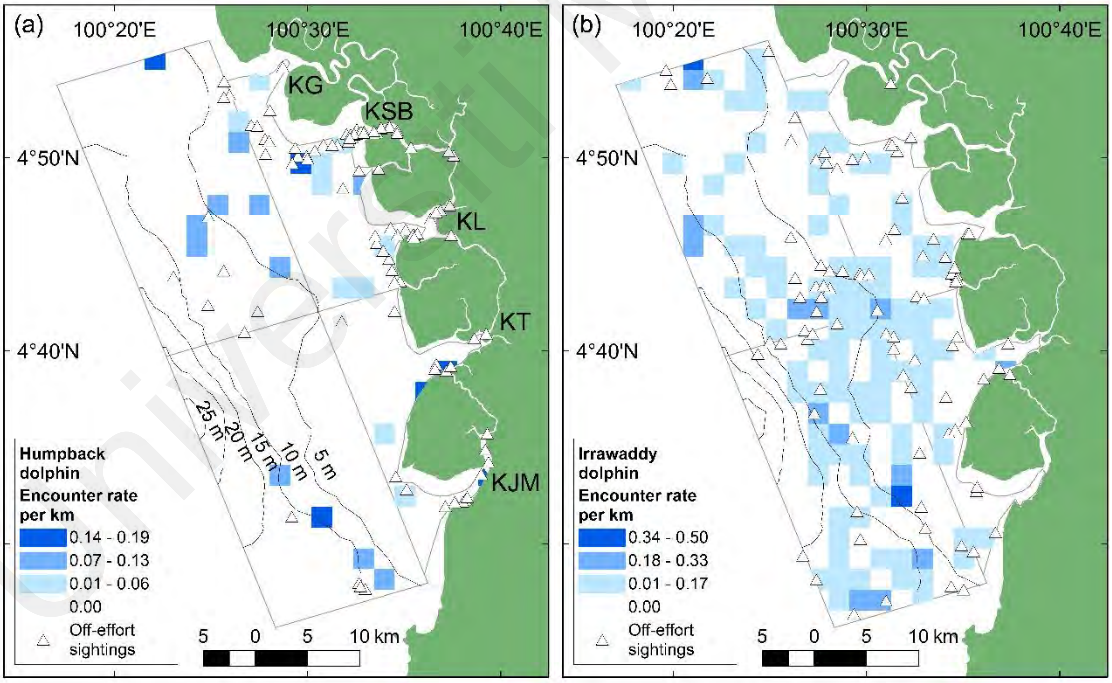

Figure 5.2: The distribution of (a) humpback dolphins and (b) Irrawaddy dolphins in 4 km² grid cells and locations of off-effort sightings within the study area. Mouth of major estuaries: KG: Kuala Gula; KSB: Kuala Sangga Besar; KL: Kuala Larut; KT: Kuala Trong; KJM: Kuala Jarum Mas

5.1.3 Habitat characteristics

There were significant differences between species distribution in relation to distance to river mouth (Kruskal-Wallis, $H = 175.85$, $P < 0.001$), water depth (Kruskal-Wallis, $H = 178.76$, $P < 0.001$), and salinity (Kruskal-Wallis, $H = 85.22$, $P < 0.001$), but not for sea surface temperature (SST) (one-way ANOVA, $F = 2.956$, $P = 0.053$). Dunn's pairwise tests showed significant differences ($P < 0.001$) in distance to river mouth, depth and salinity between humpback dolphins and Irrawaddy dolphins. Humpback dolphins were sighted closest to the river mouth with mean distance of 4.5 ± 5.5 km and with sightings inside the estuaries, whereas Irrawaddy dolphin sightings were farther from river mouths with a mean distance of 10.8 ± 5.4 km (Figure 5.3).

Humpback dolphins were mostly sighted in shallow waters with a mean depth of 3.6 ± 2.23 m and ranging from 0.6 to 11.2 m, whereas Irrawaddy dolphins were sighted in mean water depth of 5.7 ± 3.4 m and ranging from 0.9 to 17.2 m (Figure 5.3b). In terms of salinity, humpback dolphins were found in the lower salinity than Irrawaddy dolphins, ranging from 15.0 ppt in the rivers and up to 34.8 ppt in the coastal waters with a mean salinity of 26.17 ± 3.64 ppt (Figure 5.3c). Irrawaddy dolphins were found in waters with salinity ranging from 20.0 in the river mouths to 34.8 ppt in the coastal waters with a mean of 29.3 ± 3.0 ppt (Figure 5.3c). Sea surface temperature for sightings of both dolphin species in Matang ranged from 27.7 to 32.7°C (Figure 5.3d).

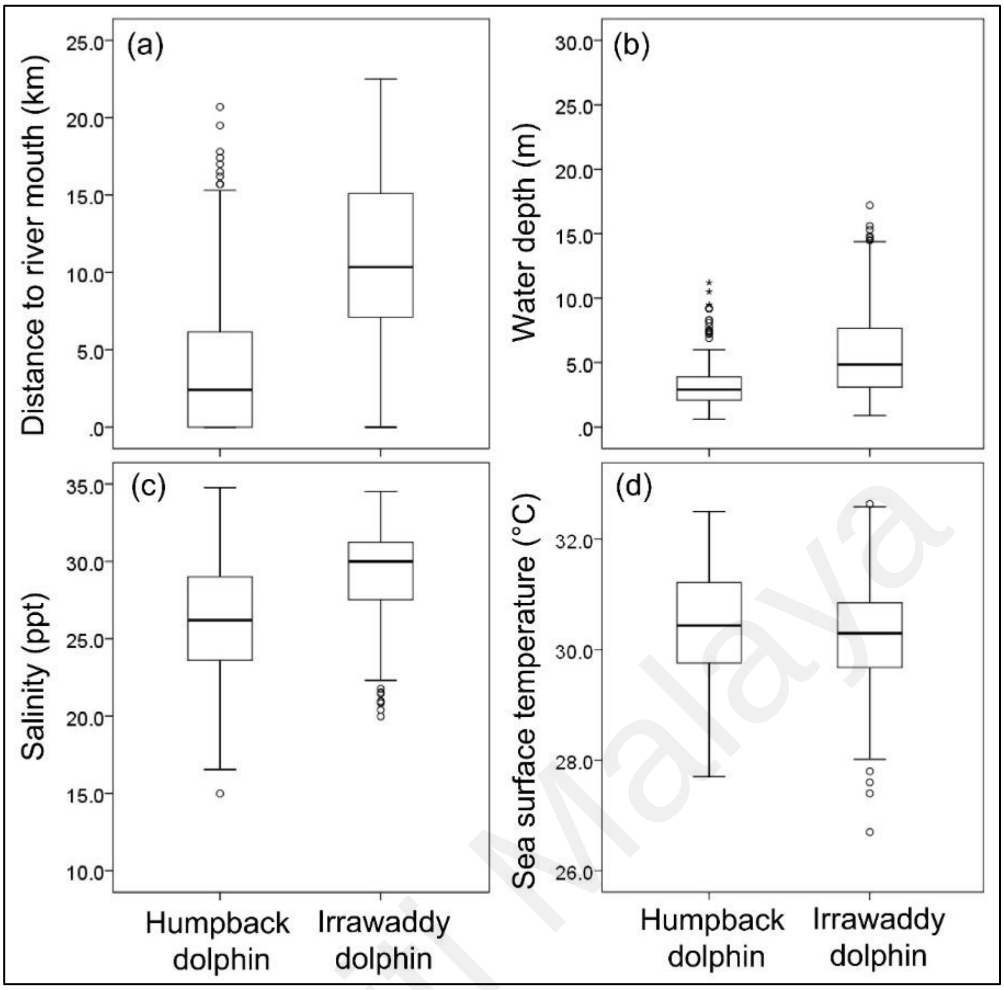

Figure 5.3: Boxplots of the habitat characteristics of the humpback dolphins and Irrawaddy dolphins sighted in Matang waters during the survey periods in terms of (a) distance to river mouth, (b) water depth, (c) salinity and (d) sea surface temperature. The middle line in the boxplot shows the median, the box indicates upper and lower quartiles, and the whiskers show the lowest and highest values within 1.5 times the inter-quartile range. Outliers are marked with small circles

Distance to river mouth across four tidal states were significantly different for humpback dolphins (Kruskal-Wallis, H = 8.21, P = 0.04) and Irrawaddy dolphins (Kruskal-Wallis, H = 19.05, P < 0.001). Humpback dolphins and Irrawaddy dolphins were found to be closest to river mouths during high tide and farthest during low tide (Figure 5.4). For humpback dolphins, median distance to river mouth was 0 km (inside the estuaries) during high tide, 1.5 km during ebb tide, 3.1 km during flood tide, and 5.0 km during low tide (Figure 5.4). For Irrawaddy dolphins, median distance to river mouth was 8.4 km during high tide, 9.9 km during ebb tide, 10.2 km during flood tide, and 13.4 km during low tide (Figure 5.4).

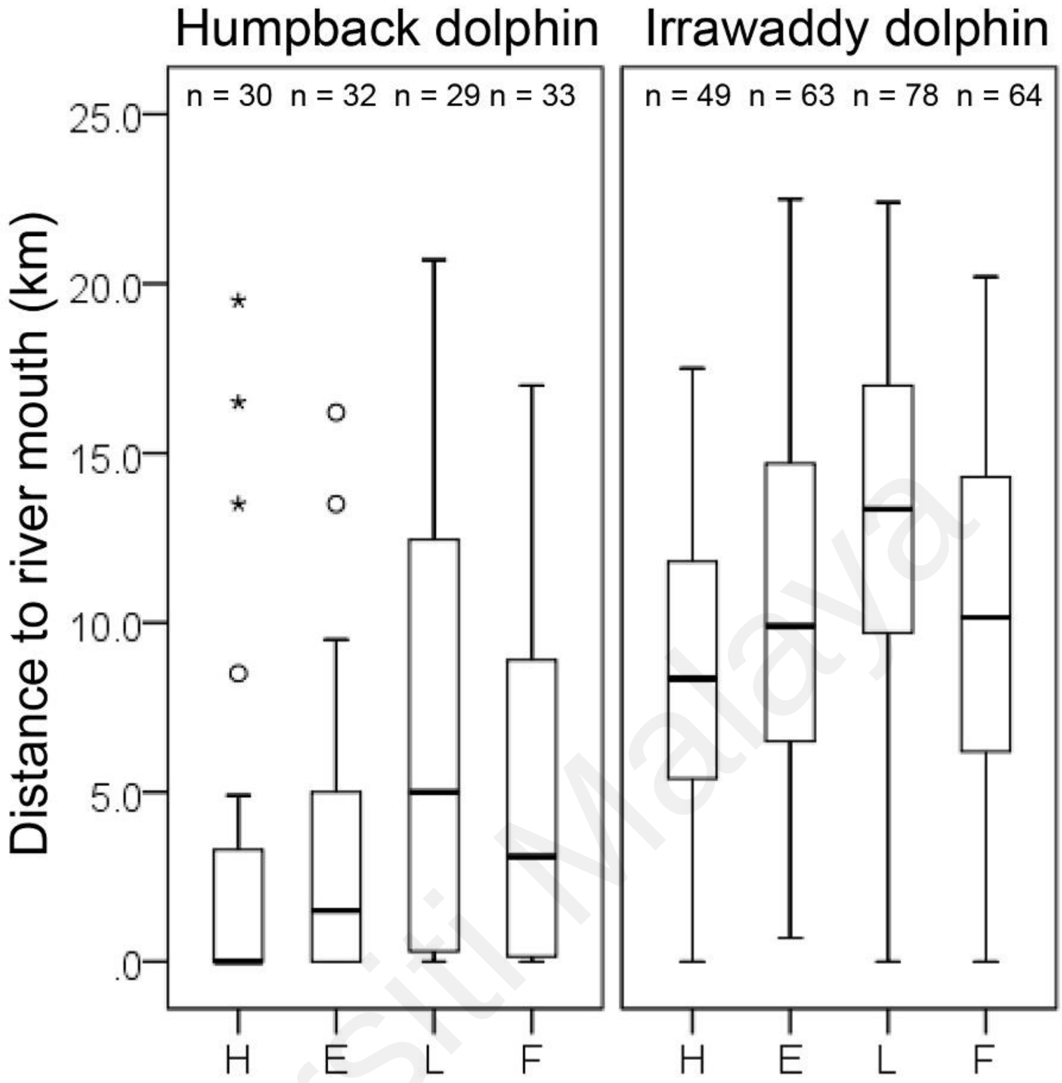

Figure 5.4: Boxplot of distance to river mouth by high (H), ebb (E), low (L) and flood (F) tidal states of all sightings of humpback dolphins and Irrawaddy dolphins, with sample sizes for each tidal state during each species' sightings. The middle line in the boxplot shows the median, the box indicates upper and lower quartiles, and the whiskers show the lowest and highest values within 1.5 times the inter-quartile range. Outliers and extreme values are marked with small circles and stars, respectively

5.1.4 Group size and behaviour

Humpback dolphins had larger mean group size of 8.4 individuals (SE = 0.7; range = 1 – 40; n = 124), whereas Irrawaddy dolphins had smaller mean group size of 6.4 individuals (SE = 0.3, range = 1 – 32; n = 254). The modal group size was two individuals for both humpback dolphins (12% of sightings) and Irrawaddy dolphins (11%). Humpback dolphin groups with mother-calf pairs had a larger mean group size of 10.6 individuals (SE = 0.9; range = 2 – 40, n = 72) than groups without mother-calf pairs (mean

= 5.3; SE = 0.8; range: 1 – 29). Similarly, Irrawaddy dolphin groups with mother-calf pairs had a larger mean group size of 9.4 individuals (SE = 0.6, range= 3 – 32, n = 69), as compared to groups without mother calf pairs that had a mean group size of 5.3 individuals (SE = 0.3; range = 1-19; n = 185).

The most prevalent behaviour of humpback dolphin sightings was feeding (42%), followed by foraging (36%) and socializing (5%). However, for Irrawaddy dolphins, the behaviour of 39% of the sightings were undetermined, mostly due to brief sightings as a result of their evasive and elusive behaviour. The most prevalent behaviour that could be determined for Irrawaddy dolphin sightings were foraging (38%), followed by feeding (9%) and herding (4%). Irrawaddy dolphin sightings with herding behaviour were observed in nine sightings in surveys between the months of March and September.

Humpback dolphins were observed to form large groups (≥ 10 individuals; 28% of sightings) which were predominantly feeding and foraging in the estuarine survey blocks, and were observed to be socializing, feeding and foraging in large groups in the south coastal survey block (Figure 5.5a). Selective feeding of the posterior part of ariid catfishes (i.e., Sagor catfish (*Hexanematichthys sagor*) and Engraved catfish (*Nemapteryx caelata*)) by humpback dolphins, whereby the animals left behind decapitated catfish heads with hard head plates and rigid spines that would float on the water surface, were observed in 18 sightings (16.5%) in all five estuaries in Matang. Seven of these sightings with feeding of catfish (39%) occurred in Kuala Larut and five sightings (28%) occurred in Kuala Sangga Besar. Most of these sightings where dolphins were feeding on catfish body (83%, n = 15) had mother-calf pairs.

Irrawaddy dolphins were mostly observed to be foraging, and there were large aggregations of Irrawaddy dolphins (≥ 10 individuals; 19% of sightings) particularly in the south coastal survey block where herding behaviour was observed (Figure 5.5b).

There were significant variations in group size between behaviours of humpback dolphins (Kruskal-Wallis test, $H = 18.21$, $P = 0.001$ and Irrawaddy dolphins (Kruskal-Wallis test, $H = 28.72$, $P < 0.001$). Dunn's pairwise test showed that humpback dolphin group size was significantly larger when socializing than milling ($P = 0.020$) or foraging ($P = 0.027$). Group size of Irrawaddy dolphins was significantly larger when herding than foraging ($P = 0.001$), milling ($P = 0.003$), or evasive ($P = 0.012$). Irrawaddy dolphins that were feeding also had larger group size than groups that were foraging ($P = 0.039$).

Seventy-eight percent of humpback dolphin (n = 97) and 46% of Irrawaddy dolphin sightings (n = 118) were observed to be either feeding or foraging. Distances to river mouths during the four most commonly encountered behaviour were significantly different for humpback dolphin sightings (Kruskal-Wallis, $H = 14.18$, $P = 0.003$) and Irrawaddy dolphin sightings (Kruskal-Wallis, $H = 10.59$, $P = 0.014$). Dunn's pairwise tests showed significant differences in distance to river mouth of humpback dolphin sightings between feeding and socializing ($P = 0.004$), and between foraging and socializing ($P = 0.018$). Humpback dolphins were feeding and foraging closer to the river mouths as compared to socializing behaviour which occurred farther from the river mouths. For Irrawaddy dolphins, Dunn's posthoc pairwise tests showed significant differences in distance to river mouth between feeding and foraging ($P = 0.023$), and between feeding and herding ($P = 0.04$). The feeding behaviour of Irrawaddy dolphins occurred closer to river mouths compared to foraging and herding behaviours.

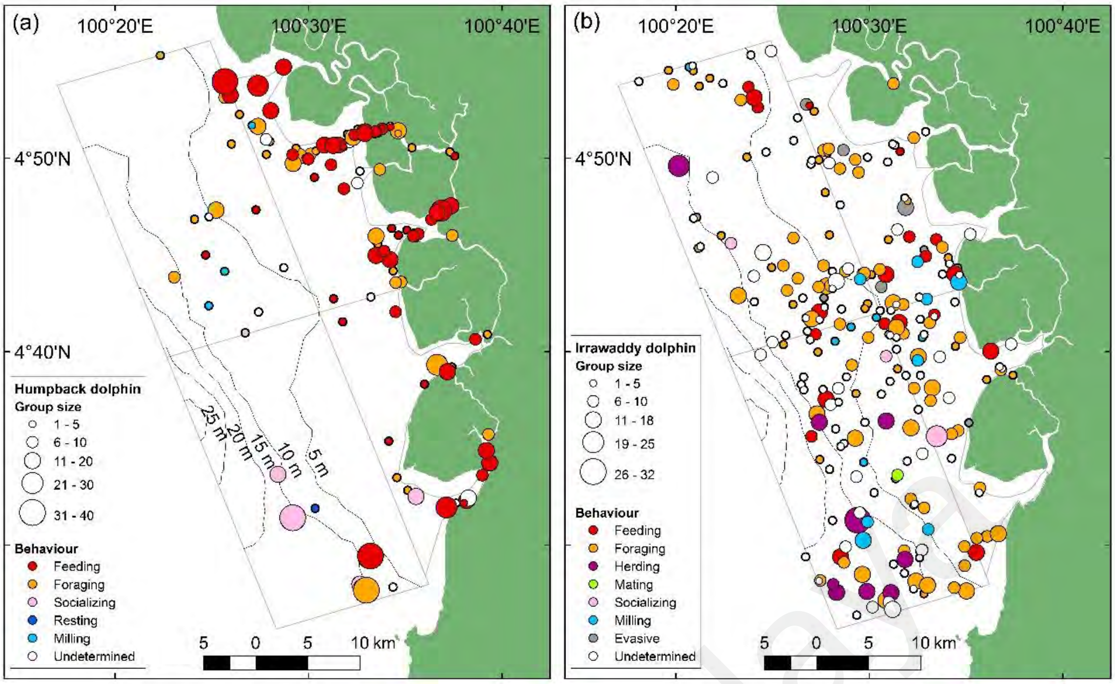

Figure 5.5: Spatial distribution of group size and behaviour of (a) humpback dolphin and (b) Irrawaddy dolphin sightings. Circle size corresponds to group size, and circle colour corresponds to group predominant behaviour

5.1.5 Habitat use

5.1.5.1 Feeding grounds

Feeding and foraging behaviour of humpback dolphins occurred mostly in the estuaries; the core area (50% kernel range) of the animals' feeding grounds were found to be at the estuaries of Kuala Sangga Besar, Kuala Larut, Kuala Trong and Kuala Jarum Mas (Figure 5.6a). Irrawaddy dolphins were recorded to be feeding and foraging throughout the coastal waters of Matang; the animals' 50% kernel range of feeding grounds were found to be around the coastal waters off Kuala Larut and Kuala Trong (Figure 5.6b).

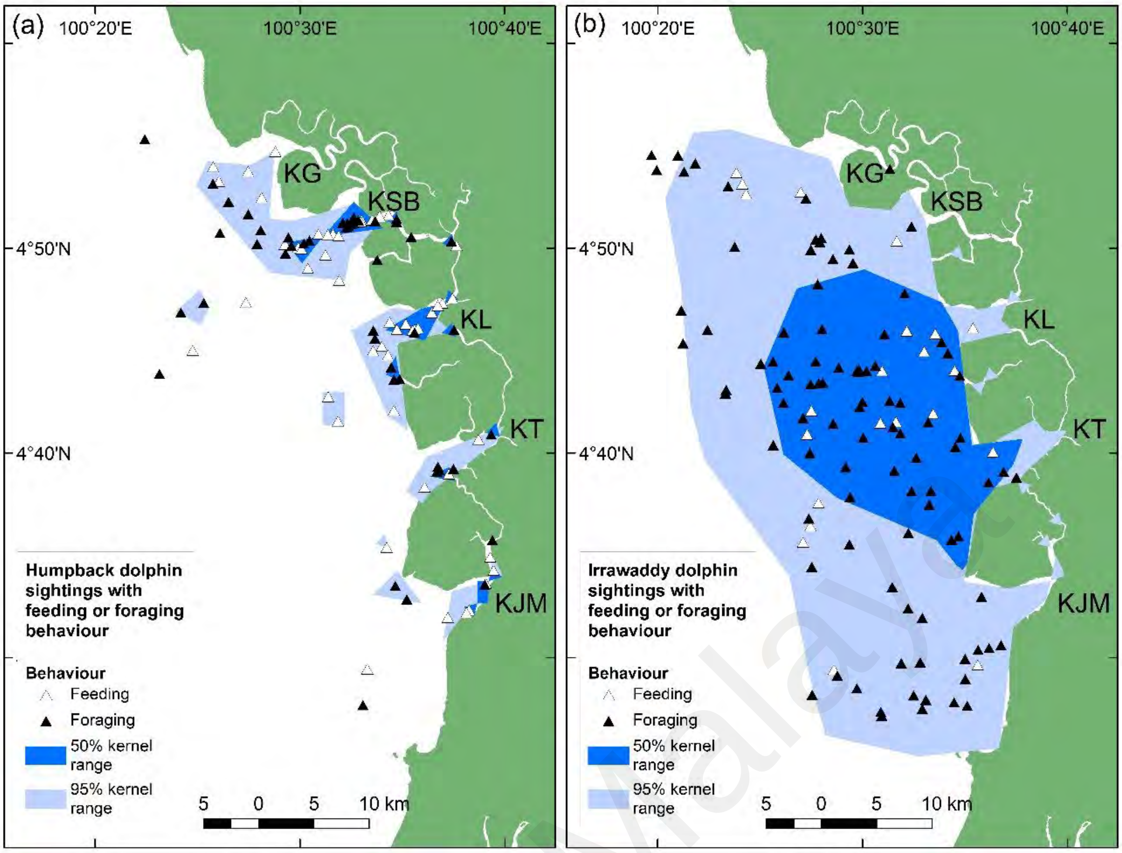

Figure 5.6: Feeding ground of (a) humpback dolphins and (b) Irrawaddy dolphins, as represented by the 50% and 95% kernel range of sightings where feeding or foraging behaviour were observed. KG: Kuala Gula; KSB: Kuala Sangga Besar; KL: Kuala Larut; KT: Kuala Trong; KJM: Kuala Jarum Mas

5.1.5.2 Nursery grounds

Mother-calf pairs were present in 59% (n = 73) of humpback dolphin sightings and 28% (n = 70) of Irrawaddy dolphin sightings. Presence of mother-calf pairs during humpback dolphin sightings was highest in November (75%), January (74%) and May (73%). Presence of mother-calf pairs during Irrawaddy dolphin sightings was highest in May (55%), July (49%) and November (44%). Nursery groups of humpback dolphins with one to four mother-calf pairs were mostly encountered in all five estuaries, and were also occasionally encountered in sightings in the coastal survey blocks (Figure 5.7a). Irrawaddy dolphin sightings with one to two mother-calf pairs were present throughout the coastal waters of Matang (Figure 5.7b). The core areas (50% kernel range) of nursery groups of humpback dolphins were at the estuaries, particularly at Kuala Sangga Besar, Kuala Larut and Kuala Jarum Mas (Figure 5.7a). The core areas (50% kernel range) of nursery groups of Irrawaddy dolphins were at the southern coastal waters, particularly off Kuala Larut, Kuala Trong and Kuala Jarum Mas (Figure 5.7b).

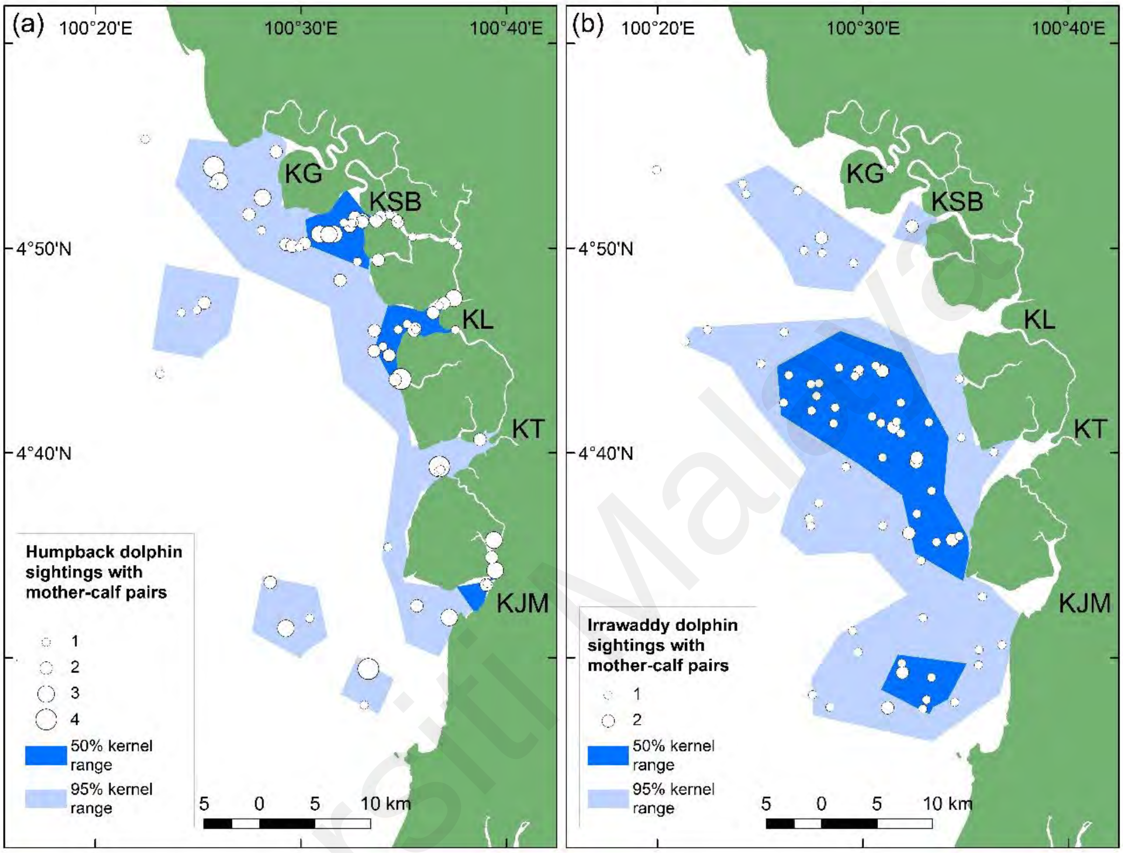

Figure 5.7: Kernel density and sightings of (a) humpback dolphins and (b) Irrawaddy dolphins containing mother-calf pairs. Circle size corresponds to the number of mother-calf pairs in the particular sighting

Humpback dolphin neonates were sighted in May 2015 and January 2016 off Kuala Gula and Kuala Sangga, respectively. Irrawaddy dolphin neonates with very prominent fetal folds were sighted in surveys in May 2015 off Kuala Gula and in July 2015 in the south coastal survey block close to the southernmost boundary of the survey area. However, the Irrawaddy dolphin neonate that was sighted in May 2015 was in fact sighted swimming with a group of humpback dolphins, with no other groups of Irrawaddy dolphins sighted in the immediate vicinity.

5.2 Discussion

5.2.1 Distribution and habitat characteristics

Humpback dolphins and Irrawaddy dolphins in the coastal waters of Matang were present all year round and did not have an identifiable peak in seasonal occurrence. There appears to be spatial partitioning between the two dolphin species in Matang, with the humpback dolphin mostly found closer inshore in the rivers and shallow estuarine waters that are less than 10 m deep, and the Irrawaddy dolphin found mostly farther offshore in waters that are at least 6 m deep but not more than 15 m deep. Despite a high number of sightings in the adjacent river mouths, there were consistently no dolphin sightings in the middle patch of the north estuarine survey block off Kuala Larut. This may be due to the presence of extensive intertidal mudflats with shallow waters (< 2 m) even during the high tide. Most of the humpback dolphin sightings occurred in the north estuarine survey block, whereas the Irrawaddy dolphin sightings occurred mostly in the south coastal survey block. The spatial distribution of the humpback dolphin and the Irrawaddy dolphin overlapped minimally. This is likely due to environment parameters which influence the distribution of preferred prey resources, the dynamics of species interactions, habitat use, their differential responses to anthropogenic activities, and species dominance (Parra, 2005).

Humpback dolphins in Matang were frequently observed to be feeding and foraging in the estuaries and rivers of the Matang mangroves, particularly in the north estuarine stratum that encompasses Kuala Gula, Kuala Sangga Besar and Kuala Larut. Although both humpback dolphins and Irrawaddy dolphins elsewhere were reported to be opportunistic-generalist feeders and prey on a wide variety of coastal and estuarine fishes (Parra, 2005; Parra & Ross, 2009), distance to river mouth appeared to play an important role in determining the distribution of both species of dolphins in Matang, whereby they occurred more inshore during the high tide and farther from river mouths during the low tide. This is similar to observations of Irrawaddy dolphins in Sarawak (Peter et al., 2016) and Taiwanese humpback dolphins (*S. c. taiwanensis*) in western Taiwan, which may be explained by the tidal movement of their epipelagic prey (Lin et al., 2013). Chong (1990) reported that the mudflat fish community including ariids, sciaenids, clupeids, engraulids, cynoglossids and mugilids are periodic wanderers that utilize the mudflats and coastal mangroves during flood tides and return to the creek-inlets and subtidal habitats during ebb tides. The estuaries of Matang appear to be specifically important feeding grounds for humpback dolphins, likely linked to the dolphins' preference for estuarine prey species. Humpback dolphins in Matang were observed to frequently prey on fishes such as ariid catfishes (Family Ariidae) and sciaenid croakers (*Johnius* spp.) that are abundant in the estuaries (Kuit et al., 2015). The humpback dolphins in this study were also observed to swim upriver to brackish waters of salinity as low as 15 ppt in the Sangga Besar River, and were able to exploit prey species such as the Sagor catfish (*Hexanematichthys sagor*) that are abundant in the rivers (Kuit et al., 2015).

Humpback dolphins in Matang were also observed to forage near to gillnets in the estuaries. Although the rivers and estuaries of Matang have high boat traffic due to the intensive fishing activity, the humpback dolphins appeared to have higher tolerance to slow-moving fishing boats in the rivers and estuaries and would sometimes bowride, whereas Irrawaddy dolphins were more evasive and would swim away from boats. This evasive behaviour is similar to other observations of Irrawaddy dolphins elsewhere where they were reported generally to show avoidance to nearby passing boats (Hashim & Jaaman, 2011; Jefferson & Hung, 2004). In an acoustic study, humpback dolphins in the Pearl River Estuary in China were reported to more likely occur in areas with high fishing activity than areas with low vessel activity (Pine et al., 2017b). Such differential responses to anthropogenic activities could explain the lack of Irrawaddy dolphin sightings in estuaries and rivers with high boat traffic, whereas the seemingly more tolerant humpback dolphins can forage in these areas of high fish activities.

Another possible explanation for the differences in habitat partitioning may be the local prey distribution and abundance, as shown in many studies for other species of small cetaceans (Benoit-Bird & Au, 2003; Hastie et al., 2003; Heithaus & Dill, 2002). There are 163 species of fish and 82 species of crustaceans recorded in Matang waters (Ariffin & Nik Mohd Shah, 2013), and Perak state has the highest catch of fish, shrimps and cephalopods in Malaysia (Department of Fisheries Malaysia, 2016). The dominant fish species in Matang's mudflats include fishes from the genera *Johnius*, *Arius* and *Thryssa* (Chong et al., 2012), which were reported to be prey groups of humpback dolphins in Hong Kong (Barros et al., 2004; Jefferson, 2000). Humpback dolphins in Matang estuaries frequently consumed the body of the Sagor catfish, but avoided ingesting the catfish's head that has thick and sharp dorsal and pectoral spines (Kuit et al., 2015). In the northern Gulf of Mexico, eight individuals of common bottlenose dolphins were also reported to have similar prey handling technique of decapitating marine catfish in order to avoid injuries from ingesting the spines that could be fatal (Ronje et al., 2017). However, individuals that failed to decapitate the catfish with sharp spines and swallowed them in whole may be in risk of puncture wounds from catfish spines that were embedded in various tissues and organs that could result in death (Ronje et al., 2017).

It has been hypothesized that humpback dolphins in the Pearl River Estuary used passive listening when foraging and to explore the acoustic cues of their soniferous prey species in the estuaries (Barros et al., 2004; Pine, Wang, Porter, & Wang, 2017; Wang et al., 2017). Ariids and croakers are soniferous fishes that produce sound (Mazlan et al., 2008; Mok et al., 2011), and this suggests that passive listening for soniferous estuarine prey may provide an advantage for the foraging efficiency of humpback dolphins in

Matang's turbid waters. However, specific studies on the dolphins' foraging behaviour in response to the sounds made by prey species are needed for verification of the above.

In contrast, the more evasive Irrawaddy dolphins displayed a relatively homogeneous distribution in all four survey blocks, but were not observed to swim in rivers with heavy boat traffic. Irrawaddy dolphins were dominant in the coastal waters of Matang within 15 km from the coastline and were mostly seen foraging and herding in the south coastal stratum. Compared to humpback dolphins, Irrawaddy dolphins were found in areas of higher salinity, similar to the study in Kuching Bay, Sarawak by Minton et al. (2016). Irrawaddy dolphins in Matang were most frequently observed to be foraging, but little is known about the diet of coastal Irrawaddy dolphins, and within this study's period, prey remains were absent in the stomachs of carcasses that were encountered. Most of the dietary studies of *Orcaella* dolphins have been limited to either the freshwater populations of the Irrawaddy dolphin (Adulyanukosol, 1999; Baird & Mounsouphom, 1997; Marsh et al., 1989; Smith et al., 2009b) or the Australian snubfin dolphin, *O. heinsohni* (Parra, 2005; Parra & Jedensjö, 2014). However, Ponnampalam et al. (2013) observed Irrawaddy dolphins in the eastern Gulf of Thailand foraging for cephalopods as indicated by the presence of squid ink and detached squid tentacles at the water surface. Results from a stable isotope study by Jackson-Ricketts et al. (2018) indicated that Irrawaddy dolphins in the eastern Gulf of Thailand primarily consumed ponyfish (*Nuchequula* sp.), mackerels (*Rastrelliger* spp.), gizzardshad (*Anodontostoma* sp.), scad (*Alepes* sp.), shrimp (*Metapenaeus* sp.), and cephalopods (*Sepiella* sp. and *Amphioctopus* sp.). Cephalopods and small pelagic fishes such as mackerels and scads dominate the demersal and pelagic fisheries in the coastal waters off Matang (Abu-Talib et al., 2000; Chee, 2000). Assuming similar feeding habits for Irrawaddy dolphins in Matang, their wide distribution throughout the study area can be explained by the availability and abundance of a wide selection of prey species in both coastal and estuarine waters (Chong, 2007; Chong et al., 2010a; Then, 2008).

Apart from diet partitioning, Parra (2006) suggested interspecific aggression as one of the main factors of habitat choice between two sympatric species, the Australian humpback dolphin (*S. sahulensis*) and snubfin dolphins in northern Queensland, Australia, with the humpback dolphin dominating the snubfin dolphin. On a few occasions during surveys in Matang, humpback dolphins and Irrawaddy dolphins were observed in the same area at the same time without apparent interaction above the water surface. In the company of humpback dolphins that were feeding or foraging, Irrawaddy dolphins were observed to swim away and leave the area. In a captive tank in Thailand, Leatherwood (as cited in Stacey & Leatherwood, 1997, p. 202), observed that Irrawaddy dolphins dived for 5 min when chased and harassed by humpback dolphins. Behavioural observations of the dolphins suggest that Irrawaddy dolphins in Matang may also avoid areas where the presumably more dominant humpback dolphins are present. However, more research into the behavioural and acoustical ecology of both species is needed before any further discernment is possible.

5.2.2 Group size and behaviour

Larger cetacean groups were reported to have higher hunting success, easier access to mates and better ability to perform information transfer and social learning, but may also suffer from more intra-group aggression (Gygax, 2002a). Dolphin calves may also be raised in larger nursery groups to evade aggressive harassment from male conspecifics seeking mating opportunities and higher boat traffic in shallow waters (Weir et al., 2008). Group size of humpback dolphins with mother-calf pairs in Matang were generally larger and concentrated in the estuaries (Figure 5.7a). This is similar to the Taiwanese humpback dolphin which had about 12 individuals and vary to over 40 individuals (Wang et al., 2015a). Large groups of dolphins (> 10 individuals) engaging in specific behaviours were observed in particular areas in the present study. The frequent observations of large groups of humpback dolphins feeding and foraging especially in the estuaries may reflect a strategy to optimize exploitation of the aggregations of their prey species at the river mouths. The partial consumption of the body of the ariid catfishes by dolphins to avoid hazard from swallowing the head with rigid and sharp spines and hard head plates requires specific prey handling technique (Ronje et al., 2017).

The southern stratum, particularly the south coastal survey block, appeared to be the area where most large group sightings of both species of dolphins were observed to be socializing, or Irrawaddy dolphins were observed to be herding. The sightings of those large groups engaging in feeding, foraging and socializing in the coastal strata, particularly the south coastal stratum, may be attributed to the more open and deeper habitat near the southern boundary of this study's area, where it may be more advantageous to congregate in larger groups (Gygax, 2002b). Similar to Irrawaddy dolphins in Brunei Bay, larger group size was observed during socializing behaviour, where larger group size may provide a higher chance to engage in multiple social relationships (Mahmud et al., 2018a). The herding behaviour of Irrawaddy dolphins in Matang appeared to be intense socializing that exhibited signs of aggression associated with mating, as the individuals in such groups had more tooth rakes on their bodies (Kuit et al., 2019a). This herding behaviour was similarly observed in the eastern Gulf of Thailand (Ponnampalam et al., 2013), and in Kuching, Sarawak (Minton et al., 2013). There was one sighting of mating Irrawaddy dolphins in Matang during the January 2014 survey, as indicated by observations of a dolphin with a protruded penis (Figure 5.8), intense body contacts, high energy levels, gregarious water splashing and twisting dives by individuals in the group of seven dolphins. These social behaviour observations showed that Matang's coastal waters are important socializing and mating grounds especially for Irrawaddy dolphins.

Figure 5.8: Photograph of Irrawaddy dolphin surfacing with a protruded penis observed on 23 January 2014

5.2.3 Habitat use

The high percentage of humpback dolphins seen feeding or foraging (78%) at the estuarine habitats of the study site, along with high percentage of mother-calf pairs in the groups (59%) suggest that the estuaries of Matang, particularly Kuala Sangga Besar, Kuala Larut and Kuala Jarum Mas are important feeding and nursery grounds for humpback dolphins (Figure 5.6a & Figure 5.7a). This may be linked to the prey preference of certain humpback dolphin individuals that are able to exploit abundant estuarine prey species such as ariid catfishes and sciaenid croakers that are important preys of humpback dolphins (Barros et al., 2004). The productive estuaries of Matang may also be preferred by the nursing females that need to meet their higher energetic demands by exploiting the estuarine preys that are concentrated in estuaries. Humpback dolphins that inhabit the sheltered estuarine habitat may also reduce predation risk by large carcharhinid sharks that were known to occur in the offshore waters (Abd. Haris Hilmi et al., 2017).

The frequent observations of feeding and foraging behaviour and presence of mother-calf pairs of Irrawaddy dolphins in the coastal waters also support the importance of Matang's coast as feeding and nursery grounds (Figure 5.6b & Figure 5.7b). Irrawaddy dolphin neonates with very prominent fetal folds were sighted in May and July 2015 surveys. This is broadly similar to reports by Smith (2018) that Irrawaddy dolphin births are believed to peak in April to June during the pre-monsoon season, but births may occur year-round. Presence of mother-calf pairs in Irrawaddy dolphin sightings was highest in May, which is similar to observations by Rodríguez-Vargas et al. (2019) in Penang which is approximately 85 km north of Matang. However, as only one survey was conducted in the month of May within the three-year period of this study, more surveys in the month of May is needed to ascertain whether there is a peak in calving season of Irrawaddy dolphins in Matang. The observations of an Irrawaddy dolphin neonate swimming with humpback dolphins on 11 and 14 May 2015 off Kuala Gula and Kuala Sangga appeared to be alloparenting (Riedman, 1982), similar to observations of an Irrawaddy dolphin calf associating with adult humpback dolphins in Cowie Bay, Sabah (Kamaruzzan & Jaaman, 2013) and separately in Kuching Bay, Sarawak (Minton et al., 2016) in East Malaysia, as well as a finless porpoise calf being assisted by humpback dolphins in Xiamen, China (Wang et al., 2013). The whereabouts of the mother of the Irrawaddy neonate in Matang were unknown. However, having been sighted without its mother on two different days could mean that the neonate had somehow separated from her and was then "adopted" by the humpback dolphins. Wang et al. (2013) postulated the same of the finless porpoise calf amongst the humpback dolphins. The sightings of alloparental care observed in Matang are contrary to the competitive habitat use and behaviour between the Irrawaddy dolphins and humpback dolphins as discussed in Section 5.2.1. Reasons for such alloparental care interactions between the two species remain underreported in the literature and poorly understood, rendering the need for further ethological and behavioural investigations to better comprehend mixed species interactions in sympatry.

Humpback dolphin neonates with less prominent fetal folds were sighted in May 2015 and January 2016. Similar to Irrawaddy dolphins, births of humpback dolphins in Hong

Kong and the Pearl River Estuary in China were presumed to occur throughout the year, but with peak calving occurring in March to June during spring to the early summer months (Jefferson, 2000; Jefferson & Rosenbaum, 2014). However, the average calving interval of humpback dolphins is 5 years (Jefferson & Rosenbaum, 2014), which is longer than the present study's sampling duration. Coupled with the absence of seasonality in Malaysia's hot and humid year-round climate, and boat-based surveys that were only conducted in odd-numbered months, the detailed determination of the calving season of humpback dolphins in Matang could not be carried out within the present study.

5.2.4 Comparison with other studies in the region

The general distribution patterns of both dolphin species in shallow coastal waters (less than 15 m deep) are consistent with findings of other studies throughout their ranges (Hines et al., 2015b; Jefferson & Smith, 2016; Kreb & Rahadi, 2004). Although spatial partitioning of these two sympatric species has been observed elsewhere as well, species-specific distribution patterns in relation to distance from the coastline in Matang differ from other studies. In contrast to Matang, Irrawaddy dolphins in Kuching Bay, Sarawak, Malaysia were mostly found inside the rivers and inshore, whereas humpback dolphins were primarily sighted in the coastal waters (Minton et al., 2013). In the central Gulf of Thailand, Irrawaddy dolphins occurred closer to shore, whereas humpback dolphins had a wider distribution (Jutapruet et al., 2017). Similar to Thailand, Irrawaddy dolphins in the Bay of Bengal, Bangladesh mostly occurred in nearshore waters, whereas humpback dolphins occurred in slightly deeper waters (Smith et al., 2008). Local differences in the intensity of anthropogenic activities, physical environments, prey distribution and abundance may have contributed to these differences in distribution patterns.

CHAPTER 6: MOVEMENT AND RANGING PATTERNS

6.1 Results

6.1.1 Resightings of distinctive dolphin individuals

6.1.1.1 Resightings of humpback dolphins

Based on left dorsal fins (LDFs), a total of 76 distinctive humpback dolphin individuals were sighted in 109 sightings in the inshore waters (<7 km from shore), and 72 individuals were sighted in 19 sightings solely offshore (between 7 and 21 km from shore). There were no matches between the individuals sighted inshore and offshore. Of the 76 inshore individuals, 13 resident individuals (defined as having more than 10 resightings on different survey days on ≥ 50% of surveys) were encountered with 11-17 resightings each. In terms of annual resight rate, almost half of the inshore humpback dolphin individuals (42.1%, n = 32) were sighted consecutively for three years. The other 14 inshore individuals (18.4%) were sighted in two calendar years. Of the remaining 30 inshore individuals (39.5%) that were encountered in one out of the three survey years, eight, 12 and 10 individuals were sighted in the first, second and third years, respectively. A total of 19 inshore individuals (25.0%) were only sighted once throughout the survey duration.

Of the 72 offshore individuals that were less frequently resighted, most of the offshore individuals (80.6%, n = 58) were only encountered once throughout the survey duration. In terms of annual resight rate, most of the offshore individuals (84.7%, n = 61) were encountered in only one out of the three survey years, and the remaining eleven individuals were encountered in two out of three years (15.3%, n = 11). None of the offshore individuals were encountered three years consecutively. Four individuals were sighted three to five times solely in the north coastal stratum, and three individuals were sighted three times solely in the south coastal stratum.

The maximum number of resightings of an offshore individual was of individual LDF-011 that was sighted five times between September 2013 and September 2014 (Figure 6.1). Based on RDFs, another offshore individual (individual RDF-010) was sighted four times between September 2013 and January 2014. Individual RDF-010 was recorded travelling 26 km from the north coastal survey block to the south coastal survey block within a period of three days in September 2013 and was subsequently sighted two more times in the north coastal survey block in November 2013 and January 2014 before not being encountered again (Figure 6.1). There were not enough resightings to determine individual ranging patterns for offshore individuals, and hence individual ranging patterns were only reported for inshore humpback dolphins with > 10 resightings (Section 6.1.2).

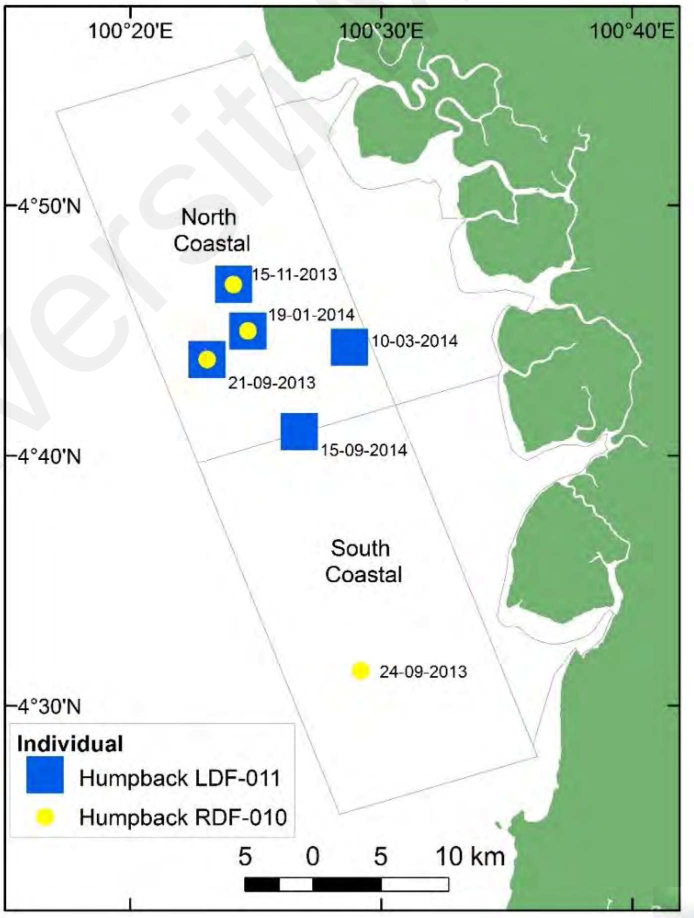

Figure 6.1: Sighting locations and date of two offshore humpback dolphin individuals. Individual LDF-011 was sighted five times and individual RDF-010 was sighted four times

6.1.1.2 Resightings of Irrawaddy dolphins

Based on RDFs, most of the distinctive Irrawaddy dolphin individuals were only sighted in one of the three years (92.4%, n = 353). This was followed by sightings in two out of three years (6.0%, n = 23), and sightings in all three survey years (1.3%, n = 5). The maximum number of resightings of distinctive Irrawaddy dolphins was of one individual (RDF-049) that was sighted five times between November 2013 and July 2016 (Figure 6.2). Some of the Irrawaddy dolphins (i.e., RDF-049 and LDF-061) were observed to move between estuarine and coastal survey blocks (Figure 6.2). As the resightings of Irrawaddy dolphins were not enough to fulfill the minimum requirement of > 10 resightings for a representative individual ranging pattern analysis, the individual Minimum Convex Polygon (MCP) ranges of Irrawaddy dolphins were not reported.

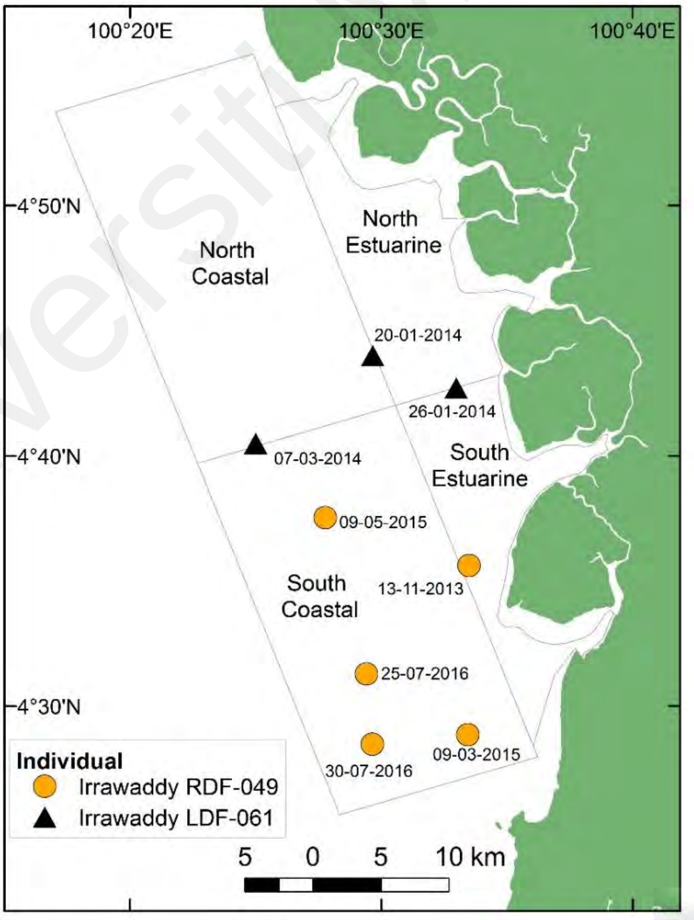

Figure 6.2: Sighting locations and date of two Irrawaddy dolphin individuals. Individual RDF-049 was sighted five times and individual LDF-061 was sighted three times.

6.1.2 Individual ranges of inshore humpback dolphins via Minimum Convex Polygon (MCP)

There were 12 adult dolphins and one sub-adult humpback dolphin that were sighted 11 to 17 times on different survey days in ≥ 50% of surveys, and identified as residents. All these 13 resident individuals ranged inshore and were not recorded to range beyond 7 km into the offshore waters. The MCP ranges of the inshore resident humpback dolphins were similar and overlapped considerably (Figure 6.3), encompassing between three to all five major estuaries (Table 6.1). Six individuals were recorded to utilize all five major estuaries from Kuala Gula to Kuala Jarum Mas (Table 6.1). The Minimum Convex Polygon (MCP) ranges of these resident inshore humpback dolphin individuals sighted were between 133.8 km^2 and 300.6 km^2. (Table 6.1). The mean MCP range of these 13 resident humpback dolphin individuals was 217.4 ± 65.2 km^2. The mean linear distance between two most extreme sighting locations of humpback dolphin individual within the study area was 39.5 km (SD = 4.9, range = 32.1 - 46.1) (Table 6.1). The individual that was most frequently sighted was individual LDF-096 that were sighted 17 times between July 2013 and July 2016, and had the largest linear distance of 46.1 km and the third largest MCP range of 286.7 km^2 (Table 6.1). Individual LDF-045 that was sighted 12 times had the largest MCP range of 300.6 km^2 (Table 6.1). The largest linear distance of two sightings within the same survey was recorded for LDF-002 and LDF-045 that travelled 44.5 km from Kuala Jarum Mas to Kuala Gula within 6 days in March 2014 (Table 6.1).

Table 6.1: **Number of sightings, Minimum Convex Polygon (MCP) range, age class and presence in estuaries of 13 resident inshore humpback dolphin individuals resighted more than 10 times based on left side of dorsal fins (LDFs). Mouth of major estuaries: KG: Kuala Gula; KSB: Kuala Sangga Besar; KL: Kuala Larut; KT: Kuala Trong; KJM: Kuala Jarum Mas.**

Dolphin ID	Age class	No. of sightings	MCP range (km^2)	Linear distance (km)	Presence in estuaries				
					KG	KSB	KL	KT	KJM
LDF-002	Adult	11	214.5	44.5	✓	✓		✓	✓
LDF-003	Adult	12	143.4	36.5		✓	✓		✓
LDF-004	Adult	12	162.8	36.3		✓	✓	✓	✓
LDF-005	Adult	12	234.5	35.5	✓	✓	✓	✓	✓
LDF-014	Adult	11	133.8	38.3	✓	✓	✓		✓
LDF-039	Adult	13	268.0	39.5	✓	✓	✓	✓	✓
LDF-045	Adult	12	300.6	44.5	✓	✓	✓	✓	✓
LDF-048	Adult	12	266.2	46.0	✓	✓	✓	✓	✓
LDF-096	Adult	17	286.7	46.1	✓	✓	✓	✓	✓
LDF-097	Sub-adult	11	247.4	37.7	✓	✓	✓		✓
LDF-099	Adult	16	135.8	33.1	✓	✓	✓	✓	
LDF-119	Adult	11	141.8	32.1	✓	✓		✓	
LDF-159	Adult	13	290.1	43.7	✓	✓	✓	✓	✓

Figure 6.3: Minimum Convex Polygons (MCP) of 12 adult resident humpback dolphins sighted on more than 10 occasions. Text in top left corner indicates the humpback dolphin's identification number based on left dorsal fin, number of sightings and the area of the MCP

On 22 January 2017, the carcass of individual LDF-039 was encountered by fishers off Kuala Sangga and subsequently towed to shore. The dolphin was later found by

MareCet team members to be a pregnant female with a full-term fetus. At the time of examination, external injuries and scarring were not evident on the carcass which was already in an advanced state of decomposition. The actual cause of death could not be confirmed without a full necropsy by veterinarians, but a clean linear cut was found on the right lobe of its tail fluke and its stomach was found to be empty.

6.1.3 Core areas and ranging areas via kernel density estimate (KDE)

6.1.3.1 Core areas and ranging areas of humpback dolphins

As there were no matches between inshore and offshore humpback dolphin individuals, the kernel density estimates were separated for these two groups. The ranging area (95% kernel range) and core area (50% kernel range) of humpback dolphins are shown in Figure 6.4. The ranging area of inshore humpback dolphins in the estuarine survey blocks was estimated to be 190.3 km^2, which included all five major estuaries (Figure 6.4). The core area of inshore humpback dolphins was estimated to be 30.7 km^2, and encompassed the estuaries of Kuala Sangga Besar, Kuala Larut and Kuala Jarum Mas (Figure 6.4).

As for offshore humpback dolphins, the ranging area was estimated to be 348.9 km^2, whereas the core area was estimated to be 100.9 km^2 (Figure 6.4). The core areas of the offshore humpback dolphins were comprised of a northern area of 81.6 km^2 approximately 16 km off Kuala Larut, and 19.3 km^2 in the south that was approximately 8 km off Pantai Remis (Figure 6.4).

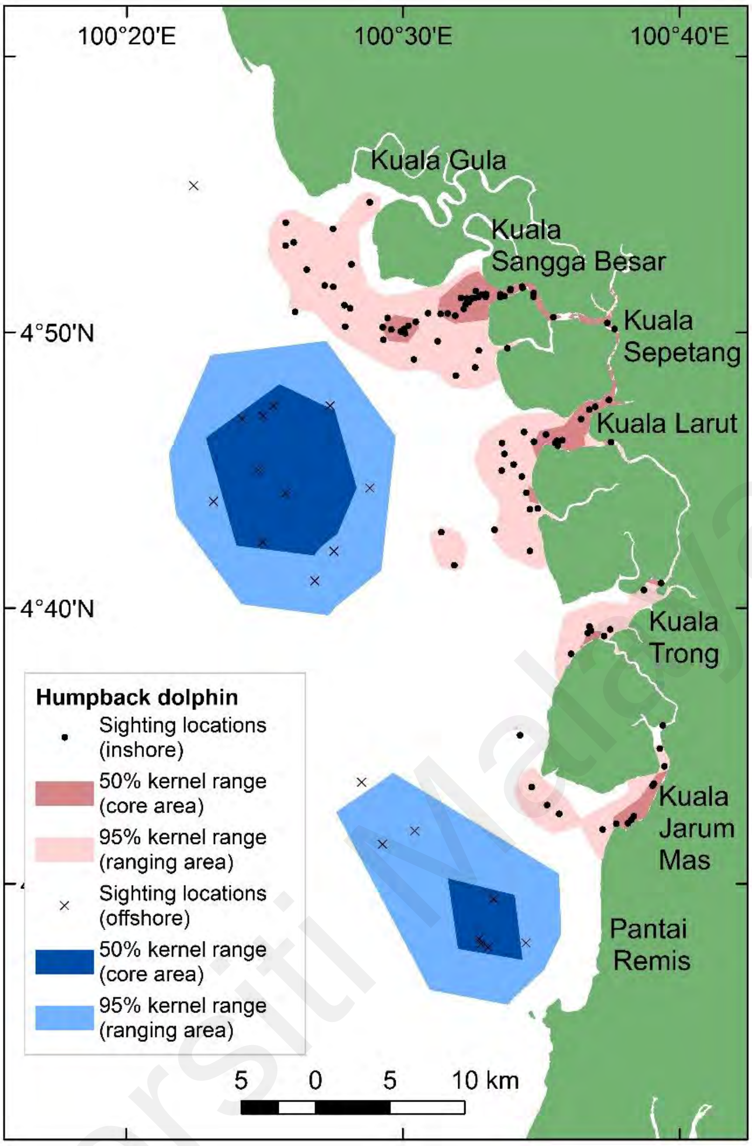

Figure 6.4: Locations of inshore and offshore sightings of humpback dolphins, and the ranging patterns with core areas (50% kernel range) and ranging area (95% kernel range.

6.1.3.2 Core areas and ranging areas of Irrawaddy dolphins

The ranging area (95% kernel range) of Irrawaddy dolphins was estimated to be 940.2 km^2, which encompassed most of the study area, particularly the central and southern sections of the study area (Figure 6.5). The core area (50% kernel range) of Irrawaddy dolphins was estimated to be 313.6 km^2, which encompassed 270 km^2 of the central section of the study area which was up to 18 km off Kuala Larut and Kuala Trong, and the smaller area of 43.6 km^2 in the southern section approximately 10 km off Pantai Remis (Figure 6.5).

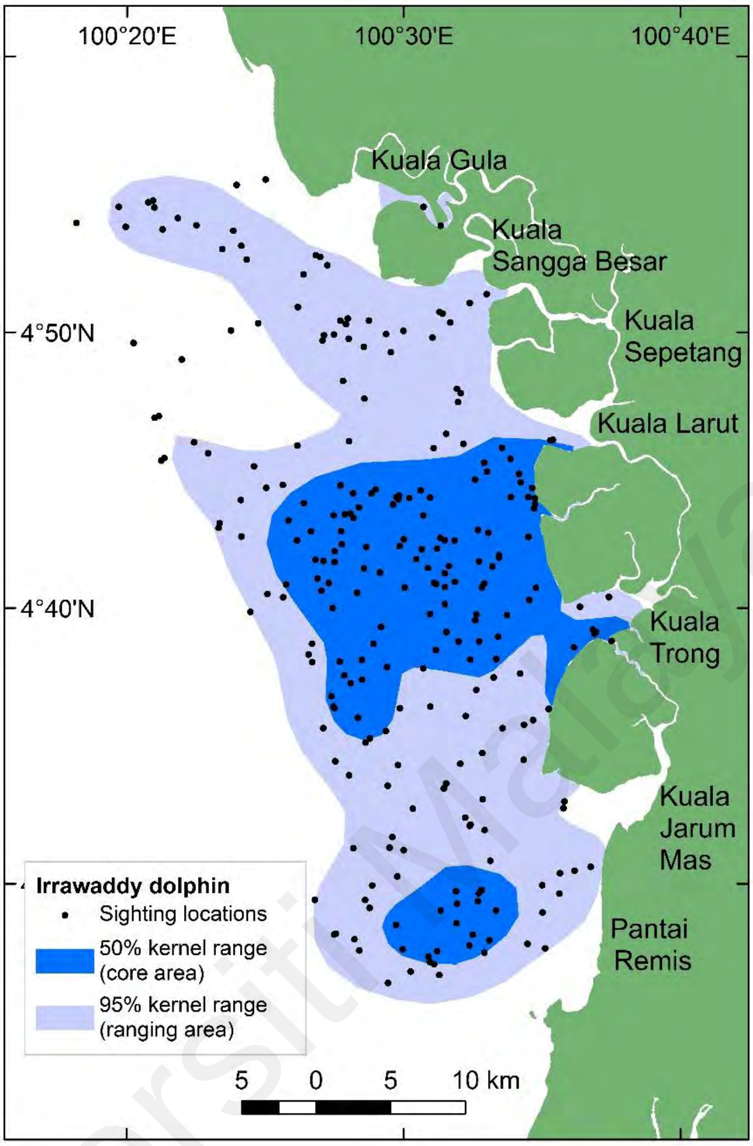

Figure 6.5: Locations of inshore and offshore sightings of Irrawaddy dolphins, and the ranging pattern with core area (50% kernel range) and ranging area (95% kernel range)

6.1.4 Spatial range overlap of humpback dolphins and Irrawaddy dolphins

Although there was considerable spatial overlap of ranging areas between humpback dolphins and Irrawaddy dolphins, their core areas overlapped minimally (Figure 6.6). The total overlap ranging area of Irrawaddy dolphins and offshore humpback dolphins was 283.6 km^2, of which 153.3 km^2 was in the north and 130.3 km^2 was in the south (Figure 6.6). The core areas overlapped minimally at 38.7 km^2, of which 22.6 km^2 was approximately 15 km off Kuala Larut and 16.1 km^2 was approximately 8 km off Pantai Remis (Figure 6.6).

Compared to offshore humpback dolphins, the spatial overlap of ranging areas of Irrawaddy dolphins and inshore humpback dolphins was lower at 146.5 km^2, and encompassed patches of estuarine waters off the estuaries (Figure 6.6). There was very little overlap of the core areas of Irrawaddy dolphins and inshore humpback dolphins off Kuala Larut and Kuala Trong, which totaled 2.1 km^2 (Figure 6.6).

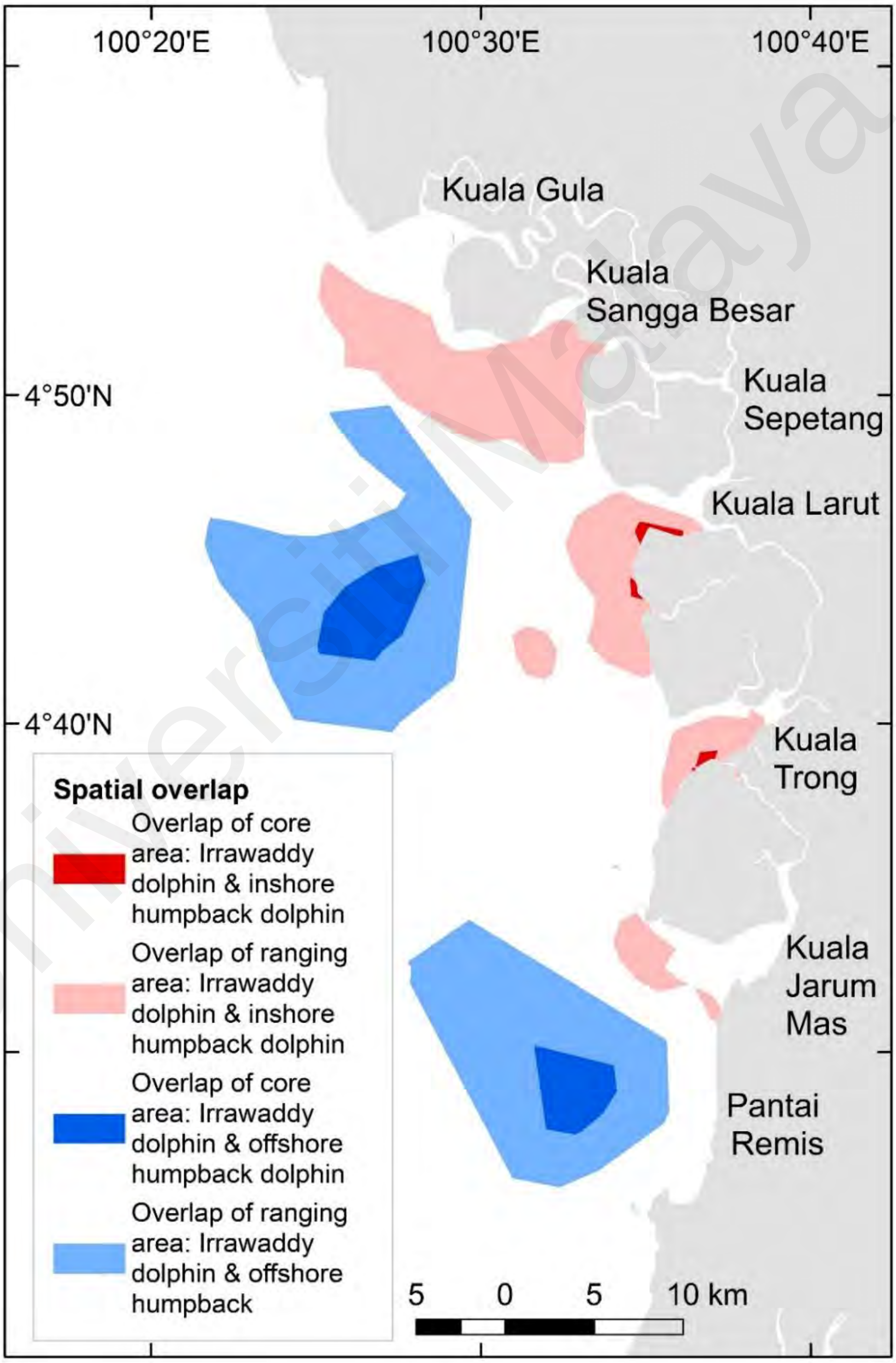

Figure 6.6: Spatial overlap of core areas and ranging areas of Irrawaddy dolphins with inshore and offshore humpback dolphins in Matang

6.2 Discussion

6.2.1 Resightings and ranging patterns of humpback dolphins

The 32 inshore humpback dolphin individuals that were sighted in all three years appeared to be year-round residents that remained within the inshore waters (< 7 km from shore) of the study area. This is similar to multi-year site fidelity of humpback dolphins that were reported in the Pearl River Estuary, Zhanjiang and Beibu Gulf in China (Chen et al., 2011a; Hung & Jefferson, 2004; Xu et al., 2015). The Matang inshore resident humpback dolphins had similar and overlapping MCP ranges that mostly encompassed the five major estuaries, suggesting that these individuals regularly moved alongshore within 7 km from shore between Kuala Gula to Kuala Jarum Mas. The core areas of inshore humpback dolphins in the estuaries of Matang are most likely linked to their use of the productive estuarine habitats as their feeding grounds by optimizing the exploitation of their prey aggregations. Chong et al. (2012) reported that during high tide, Sagor catfish and *Johnius* spp. croakers were among the top 10 most abundant fish that ingressed into the Matang mudflats that extend 2-5 km offshore. Inshore humpback dolphins were confirmed to prey on abundant estuarine fishes such as ariid catfishes (particularly Sagor catfish, *Hexanematichthys sagor*) and sciaenid croakers (*Johnius* spp.) (Kuit et al., 2015). All 13 resident humpback dolphin individuals were observed in one to seven sightings with catfish head remains in the vicinity, whereby the animals had been observed eating only the fish's body, avoiding ingestion of the fish's head containing thick and sharp spines and hard head plates. These inshore humpback dolphins in Matang may develop familiarity with the predictability of food resources in the estuaries and develop social bonds with other individuals using the same area, which may facilitate information transfer among members of the same community (Passadore et al., 2018). In Hong Kong, humpback dolphins were also reported to exploit demersal and shoaling fish found in productive estuaries, including bottom-dwelling species such as catfish and sciaenid croakers (Barros et al., 2004).

Although humpback dolphins in Matang did not appear to exhibit sexual dimorphism and confirmation of the sex of the observed individuals was not possible without genetic confirmation, it was found that most of the sightings of adult dolphins, presumed to be females with calves present, were observed in the estuaries (see Figure 5.7 in Chapter 5). Thus it appears that these estuaries are used by female dolphins as nursery grounds. Additionally, humpback dolphins in Matang appeared to exhibit allomaternal care whereby some calves were observed to associate with different adult individuals within a sighting, which were presumed to be females, similar to reports of allomaternal care in humpback dolphins in South Africa (Karczmarski et al., 1997; Parsons, 2004) and humpback dolphins in Taiwan (Dungan et al., 2016). Personal observations and results thus suggest that the inshore humpback dolphins in Matang may largely be females. Home ranges of female dolphins are primarily determined by food availability and shelter, whereby females tend to show high site fidelity and stay in sheltered waters for protection from predation (Hung, 2008; Methion & Díaz López, 2018). Humpback dolphins that inhabit the sheltered estuarine habitats in Matang may reduce predation risk by tiger shark (*Galeocerdo cuvier*) and bull shark (*Carcharhinus leucas*) that are known to occur in the offshore waters (Abd. Haris Hilmi et al., 2017). The high affinity of nursing females to sheltered estuaries with high concentrations of prey is likely linked to fulfilling their high metabolic demands of lactation while seeking protection from predation (Gubbins, 2002; McCluskey et al., 2016; Piwetz et al., 2015). However, the death of the pregnant and commonly encountered resident inshore dolphin, LDF-039 in January 2017 suggests that while these inshore individuals may have lower predation risks, they may be exposed to higher bycatch risks due to their high fidelity to areas with intense rates of fishing activities (see Chapter 7). Deaths of breeding individuals in a small population would take a long time for population recovery, as the generation length (the turnover rate of breeding individuals) for humpback dolphins are 25 years (Jefferson et al., 2017).

Other than the more frequently resighted inshore humpback dolphins, the present study also revealed the presence of offshore humpback dolphins in Matang which were less frequently resighted and likely to have wide ranging patterns. This non-overlapping ranges between inshore and offshore communities have not been reported elsewhere in humpback dolphins in the Southeast Asian region. In the Pearl River Estuary near Lantau Island, Hong Kong, the presence of two social communities of humpback dolphins were reported, whereby the northern community and western community had its own region of core use, but with partially overlapping overall ranges (95% utilization distribution) at the northwest of the island (Dungan et al., 2012). This is in contrast to the present study in Matang, whereby the 95% kernel ranges of the inshore and offshore individuals did not overlap (Figure 6.4). Some populations of bottlenose dolphins in the western and northeast Atlantic Ocean were reported to show similar patterns of communities of inshore residents and offshore non-residents that do not associate with each other (Gubbins, 2002; Oudejans et al., 2015). Preliminary social structure study on inshore humpback dolphins in Matang showed that they have a fission-fusion social structure, with weak social bonds amongst individuals (Teoh et al., 2019). This fluid social structure in the inshore humpback dolphins, coupled with a lack of photo-identification matches with offshore individuals further suggests that inshore and offshore humpback dolphins utilize Matang's waters rather differently.

Approximately 81% of offshore humpback dolphins in Matang were only sighted once, which was higher than the 41% of Australian humpback dolphins (*S. sahulensis*) in Cleveland Bay that were observed only once (Parra et al., 2006). Parra et al. (2006) reported that the high number of Australian humpback dolphin individuals that were only observed once may either spend most of their time outside their study area or have died. Several possible explanations for the low number of resightings of offshore humpback dolphin individuals in Matang include: 1) some offshore individuals (especially those sighted close to the boundaries of the study area) may be occasional visitors with wide ranging area and frequently moved in and out of the study area and thus less likely to be encountered during surveys; 2) some individuals (especially those sighted a few times) ranged extensively within the offshore waters and stayed for a period of time (e.g., approximately one year) before moving out of the study area and thus not seen in subsequent years; and 3) offshore individuals (especially those that were sighted only once) were probably transient individuals that travelled passed the study area, with Matang being only a transit point within their wider range in the Strait of Malacca.

With no apparent physical barrier that could impede the movement of humpback dolphins inshore/offshore in Matang, but with different habitat characteristics (i.e., depth, salinity, distance to river mouth) (Chapter 5) that influences prey distribution, the non-overlap between the two communities may be explained by differences in habitat use, prey preferences and behavioral adaptations. The apparent wide range and low site fidelity of offshore humpback dolphins suggest that the offshore waters may not be the preferred feeding ground for these individuals, similar to the study by Or (2017) in the Pearl River Estuary, Hong Kong. This stipulation is supported by personal field observations whereby feeding and foraging behaviours were less frequently observed in the offshore humpback dolphins, and larger groups of 17 to 32 individuals were sighted to be socializing in the south coastal survey block (see Chapter 5). These large groups of offshore humpback dolphins that were observed to be socializing may be similar to the temporary breeding aggregations of Indian Ocean humpback dolphins (*S. plumbea*) in the Arabian region (Baldwin et al., 2004). The density of fish and shrimp in Matang's waters are reported to decrease as the distance from shore increased (Chong, 2007; Chong et al., 1994; Sasekumar et al., 1994b). Due to lower prey biomass in the offshore waters, the feeding opportunities appear to be lower and less concentrated compared to the estuaries, and these offshore humpback dolphins may need to range more extensively to other areas in search of their relatively scarce prey. Squid ink had been observed during a sighting of a large group of 40 humpback dolphins in the south coastal survey block which suggests that cephalopods may be part of the prey species of offshore humpback dolphins. As observations in the present study were limited to daytime, it was impossible to ascertain whether these individuals were feeding at night in the offshore or inshore waters.

Sighting locations and patterns of offshore individuals LDF-011 and RDF-010 that were sighted five times before they were no longer seen again in the subsequent years (Figure 6.1) suggest that some of the offshore individuals may move between the north coastal and south coastal survey blocks but remained mainly in the north coastal survey block before they either moved out of the study area or in a less likely scenario, died in the subsequent years. Additionally, based on the distance travelled averaged by the number of days between two most extreme sighting locations within the same survey of offshore humpback dolphin individual RDF-010 and inshore humpback dolphin individual LDF-045, humpback dolphins appear to be able to travel linear distance of approximately 8 km a day on average. Individuals with extensive ranging patterns may be less likely to be encountered in the surveyed area during the surveys (e.g., moving to the southern coastal survey block when the northern coastal block was surveyed).

According to Hung & Jefferson (2004), ranging patterns of humpback dolphins are likely to be shaped by their habitats. The inshore resident humpback dolphins in Matang have a rather linear range with the relatively straight coastline with five interconnected major estuaries, as opposed to the polygonal range of humpback dolphins in Xiamen and Pearl River Estuary that have convoluted coastlines with many bays and inshore islands

(Chen et al., 2011a). The mean individual MCP range of inshore humpback dolphins in Matang (217 km^2) appeared to be larger than the mean individual MCP ranges of humpback dolphins in Hong Kong and China that ranged between 84 to 135 km^2 (Hung & Jefferson, 2004; Hung, 2008; Liu et al., 2015). However, the range sizes were not directly comparable due to differences in study area size, length of study and the minimum number of identifications used to construct individual home ranges (e.g., Nekolny et al., 2017; Seaman et al., 2007). A minimum of 10 sightings were mostly used to construct individual MCP ranges of humpback dolphins in Hong Kong, Xiamen and Zhanjiang (Chen et al., 2011a; Hung & Jefferson, 2004; Xu et al., 2015). However, a study by Hung (2008) with a 12-year dataset used a minimum of 30 sightings which generated a more representative and larger MCP range estimates for the humpback dolphins in Hong Kong than when minimum of 10 sightings were used (Hung & Jefferson, 2004). Additionally, the range sizes reported in these studies refer to the area where the individual was sighted within the study area for a specific time interval, and should not be interpreted as its lifetime home range (Hung & Jefferson, 2004; Powell & Mitchell, 2012). The actual home range size of humpback dolphins in Matang is likely to be larger, as estimated range sizes are limited by the size of the study area and this study had only three years of observations. As funding and time constraints often limit the size of the survey area that can be covered by research teams (Nekolny et al., 2017), it is likely that the present study area did not cover the entire range of these long-living and wide-ranging dolphins (Huang et al., 2012).

6.2.2 Resightings and ranging patterns of Irrawaddy dolphins

The resightings of Irrawaddy dolphins were low and may be insufficient (< 10 sightings) for reliable estimation of their MCP ranges. The possible reasons for low resightings of Irrawaddy dolphin individuals in the present study were: (1) the difficulty in photographing the dorsal fin of all individuals due to their evasive behaviour, (2) the combination of high abundance of Irrawaddy dolphins coupled with wide ranging patterns in the large study area may result in less frequent resightings, (3) the dorsal fin of Irrawaddy dolphins is generally less distinctive and smaller than that of humpback dolphins, thus any injuries that happened after initial sightings may affect the profile of the dorsal fin which in turn can result in the individual being mistakenly identified as new individual.

The range patterns in other studies on coastal Irrawaddy dolphins were mostly generated using all the sightings of the species instead of individual ranges (de la Paz et al., 2020; Jutapruet et al., 2017; Peter et al., 2016), perhaps similarly due to lack of individual resights. Individual recaptures of Irrawaddy dolphin may be higher for studies with intensive survey effort in a smaller population and confined study area, such as the freshwater Irrawaddy dolphin population in the enclosed Chilika Lagoon, which enabled the individual ranges to be calculated for dolphins sighted more than eight times (Sutaria, 2009). The study by Sutaria (2009) had 441 identifications of 80 distinct individuals, in contrast to the present study which had 419 identifications of 382 distinct individuals.

Based on the limited number of resightings of Irrawaddy dolphins, it appears that some Irrawaddy dolphin individuals moved between the estuarine and coastal survey blocks (Figure 6.2), unlike the humpback dolphin individuals. The sightings of Irrawaddy dolphins in Matang appeared to be less clustered in the estuaries and were more evenly distributed in the coastal waters, with ranging area encompassing most of the study area (Figure 6.5). This may be attributed to adaptations to minimize intraspecific competition with other Irrawaddy dolphins in the study area by spreading out in smaller groups throughout the coastal waters, and avoidance of both the boat traffic in the estuaries and of the presumably more dominant inshore humpback dolphins that frequently move between the five major estuaries.

Using only the five resightings of the individual RDF-049 (Figure 6.2) would have resulted in a MCP range of at least 128 km^2 and linear distance of 19 km. It is important to note that this estimation of 19 km of linear distance based on only five sightings is very likely to be underestimated. Elsewhere, the furthest linear distance between resights of coastal Irrawaddy dolphins was 26 km in the Kuching Bay, Sarawak (Peter, 2012) and 16 km in Penang Island (Rodríguez-Vargas, 2015). Accuracy of range size estimates is closely linked to having adequate sample size, and the estimated range size increases with sample size (Anderson, 1982; Hung, 2008).

6.2.3 Spatial range overlap of humpback dolphins and Irrawaddy dolphins

The core areas and ranging areas of offshore humpback dolphins appear to be spatially separated into north coastal and south coastal (Figure 6.4), with the main core area of Irrawaddy dolphins in the central section (Figure 6.5). Overlap of core areas of humpback dolphins and Irrawaddy dolphins appear to be minimal (Figure 6.6), which may be a form of niche differentiation to reduce interspecific competition. This is supported by field observations whereby Irrawaddy dolphins were observed to swim away and leave the area when humpback dolphins entered to feed or forage (Kuit et al., 2019a).

The main core area of Irrawaddy dolphins in the central section of the study area (Figure 6.5) that stretches from the estuaries of Kuala Larut and Kuala Trong to 18 km offshore coincides with areas where foraging behaviour was observed (see Figure 5.6b in Chapter 5). Irrawaddy dolphins were less frequently encountered inside the estuaries (see Figure 5.5 in Chapter 5) and at least two individuals appeared to move between the areas off the estuaries to offshore (Figure 6.2). This may also be linked to avoidance of higher boat traffic in the estuaries where fishing boats frequently moved in and out of the fishing villages to their fishing grounds. Elsewhere, Irrawaddy dolphins were also reported to show avoidance to boats (Hashim & Jaaman, 2011; Kreb & Rahadi, 2004).

Little is known about the prey species of Irrawaddy dolphins in Matang, as prey remains were absent in the stomachs of dolphin carcasses that were encountered during boat surveys. Additionally, prey items were not brought to the turbid water's surface during sightings. Overall there was only one sighting of Irrawaddy dolphin whereby the remains of catfish heads were seen in the vicinity, off Kuala Gula, suggesting that the dolphins may not selectively prey on ariid catfishes as much as the inshore humpback dolphins. It is possible that Irrawaddy dolphins preyed opportunistically on coastal prey species such as cephalopods, mackerels and scads that were reported to dominate the demersal and pelagic fisheries in the coastal waters off Matang (Abu-Talib et al., 2000; Chee, 2000). Such costal fish assemblages were reported to be prey of coastal Irrawaddy dolphins in Trat, Thailand (Jackson-Ricketts et al., 2018) that were also mainly found within 12 km from shore (Hines et al., 2015b).

The results from this chapter have provided important insights for better understanding of ranging patterns of humpback dolphins and coastal Irrawaddy dolphins, as well as identified core areas in Matang that should be prioritized for conservation. Inshore humpback dolphins reside in areas of high bycatch risks particularly from gillnets, and the core areas of Irrawaddy dolphins overlap with areas of fishing activities (see Chapter 7). The results also highlight the challenge of sampling highly mobile offshore humpback dolphins that may travel extensively over wide areas, and emphasizes the importance of considering inter-state conservation and management strategies. The results of range sizes and linear distances should be treated as minimum estimates, as increased sample sizes and expansion of study area in the future are likely to generate more accurate estimates for these evasive and wide ranging delphinids.

CHAPTER 7: HUMAN-DOLPHIN INTERACTIONS AND PREVALENCE OF INJURIES ON DOLPHINS

7.1 Results

7.1.1 Interviews with local fishers

A total of 198 respondents were interviewed over 21 days between February 2014 and February 2017 in 17 fishing villages in Matang. As the questionnaire was targeted at those who have the highest likelihood of interacting with cetaceans, 97% of the respondents (n = 193) were fishers and the remaining 3% (n = 5) of the respondents worked at net cage fish culture farms.

7.1.1.1 Background of respondents, fishing gear, boat and effort

The average age of respondents was 48 years old (SD = 13; Range: 20 – 80). The respondents mostly had 16 to 30 years of fishing experience (37%, n = 73), followed by 31 to 50 years of experience (33%, n = 65), one to 15 years of experience (24%, n = 47) and 50 to 60 years of experience (6%, n = 11). The common gears used by respondents were gillnet, driftnet and trammel net (25%, n = 58), followed by push net (24%, n = 56), trawl net (21%, n = 48), crab trap (14%, n = 32), bag net (8%, n = 19), cockle collection (4%, n = 9), hook and line (3%, n = 6), longline (0.9%, n = 2) and purse seine (0.4%, n = 1) (Figure 7.1).

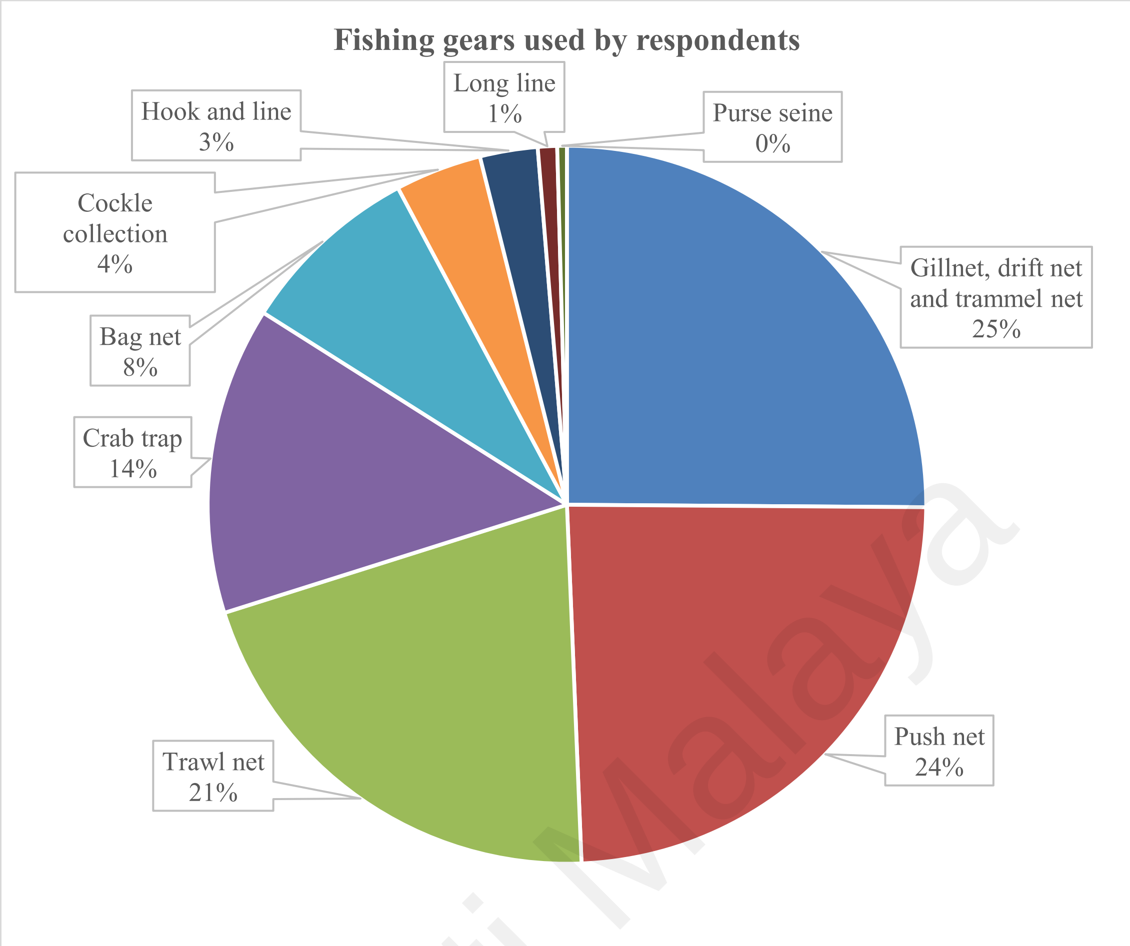

Figure 7.1: Fishing gears used by respondents in Matang

The fishing areas of respondents by gear type are presented in Figure 7.2. Among respondents who used gillnet, driftnet, trammel net, or trawl nets, most of them (81%, n = 42) relied on these gears only, whereas the remaining 19% (n = 10) also used other gears. Trawl nets was the only fishing gear used in the offshore waters, whereas other gears (i.e., crab trap, cockle collection, push net, gillnet, driftnet, trammel nets, bag net, and hook and line were used inshore (Figure 7.2).

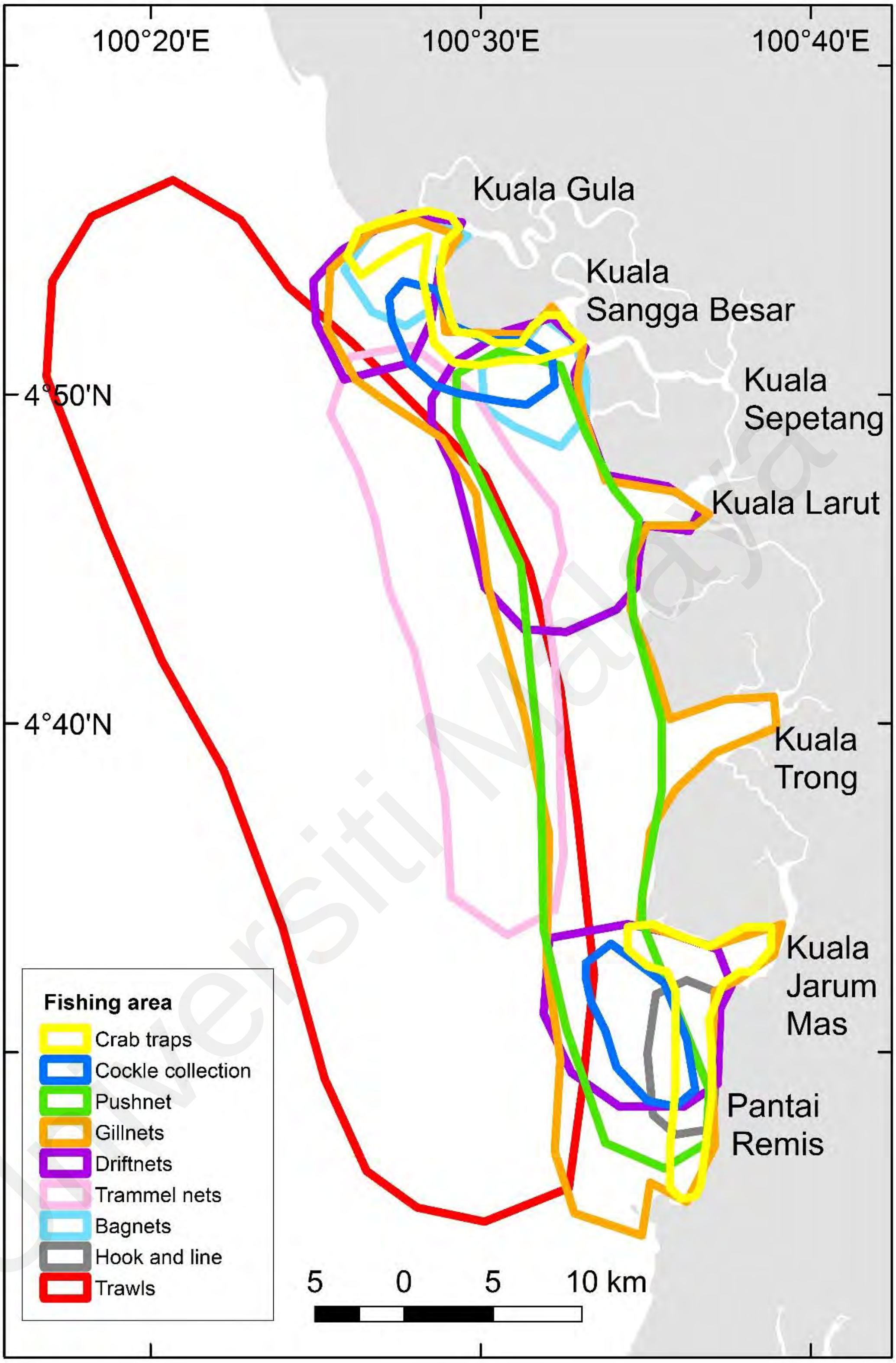

Figure 7.2: Fishing areas of respondents by gear type

Most of the fishers using gillnets, driftnets and trammel nets (96%, n = 43) tended their gears. When asked about soak times of their gears, gillnets were mostly left up to 4 hours (31%, n = 11), followed by up to 2 hours (26%, n = 9). Trammel nets were mostly left up to 1 hour (50%, n = 3). Bag nets were mostly left in the water for up to 4 hours (65%, n = 11). Push nets were mostly operated up to 1 (27.3%, n = 3) or 2 hours (27.3%, n = 3). Crab traps were mostly left for up to 1 hour (41%, n = 7). Trawl nets were mostly trawled up to 2 hours (52%, n = 12), followed by up to 4 hours (39%, n = 9).

Most of the respondents (68%, n = 128) reported that there were two fishers including themselves working on the boat. Most of the respondents were boat captains (76%, n = 146), whereas the remaining 22% (n = 41) were crew members, and 2% (n = 4) of the respondents did not have fixed positions on boat. When asked about how their catches were sold, most of the respondents (77%, n = 156) sold to dealers, and the remaining 23% (n = 47) sold their own catch by themselves.

The boat lengths of respondents were mostly between seven to 10 meters (35%, n = 64), followed by three to six meters (32%, n = 58); 11-16 meters (32%, n = 57) and two respondents (1%) had boats that were longer than 17 meters. Fifty-five percent (n = 104) of the respondents' boats were fitted with inboard engines, whereas the remaining 45% (n = 85) were boats fitted with outboard engines. The horsepower (HP) of the engines on outboard boats were mostly up to 15 HP (37%, n = 38), followed by 16 to 40 HP (26%, n = 27), 41 to 100 HP (20%, n = 21) and 101 to 400 HP (17%, n = 18).

When asked whether the present time spent for fishing had increased, decreased or remained the same as compared to when they started fishing, most of the respondents (38%, n = 72) reported that they had decreased their time spent for fishing and 34% (n = 65) of the respondents spent more time fishing, while the remaining respondents (28%, n = 53) reportedly spent the same amount of time for fishing. During low fishing season, most of the fishers in Matang (48%, n = 66) spent 15 to 21 days per month fishing, followed by 8 to 14 days per month (25%, n = 34). During high fishing season, most of the fishers spent 15 to 21 days per month fishing (47%, n = 64), followed by 22 to 31 days per month (39%, n = 53).

Fishing was the main source of income for 93% of the respondents (n = 185), and was the only source of income for 76% of the respondents (n = 150). Most of the respondents had parents who were fishers (85%, n = 169) and grandparents who were also fishers (68%, n = 135). However, most of them (72%, n = 140) did not want their children to become fishers. The main reasons cited for not wanting their children to become fishers were that fishing is a tough job (44%, n = 61), there is no future in being fishers or there are better opportunities elsewhere (23%, n = 32), low or unstable income (17%, n = 24) and that fishing is a dangerous job (6%, n = 8). Respondents who wanted their children to fish mostly wanted their children to inherit their business or follow their footsteps (58%, n = 11).

7.1.1.2 Local knowledge and perception about cetaceans

All 198 respondents (100%) had sighted cetaceans in Matang. The majority of the respondents (60%, n = 119) had only sighted humpback dolphins, whereas 20% (n = 40) had sighted both humpback dolphins and Irrawaddy dolphins (Table 7.1). Only 4% of the respondents (n = 7) had sighted all three species of cetaceans (humpback dolphins, Irrawaddy dolphins and finless porpoises) that were found in Matang.

Table 7.1: Species of cetaceans seen by respondents in Matang

Cetacean species seen in Matang		
N	*198*	
Seen humpback dolphin only	119	60.1%
Seen humpback dolphin & Irrawaddy dolphin	40	20.2%
Seen humpback dolphin & finless porpoise	19	9.6%
Seen humpback dolphin, Irrawaddy dolphin & finless porpoise	8	4.0%
Seen Irrawaddy dolphin only	7	3.6%
Seen finless porpoise only	3	1.5%
Seen Irrawaddy dolphin & finless porpoise	2	1.0%

The areas where respondents were reported to frequently encounter dolphins are presented in Figure 7.3. Most of the respondents encountered dolphins in the inshore waters, particularly in the five major estuaries and inside Sungai Sangga Besar and Sungai Sangga Kecil that lead to Kuala Sepetang (Figure 7.3). When asked if the fishers see more cetaceans in certain areas, 33% (n = 67) of the respondents observed more cetaceans in Kuala Sangga Besar, followed by Kuala Gula (17%, n = 34).

While most of the respondents did not observe different distribution patterns among the different cetacean species in Matang, 13% (n = 23) of the respondents reported seeing different species in different areas, with the general description that humpback dolphins were most frequently seen closest to the shore, Irrawaddy dolphins being farther from shore and finless porpoises being farthest from shore. Most of the respondents encountered cetaceans while travelling to fishing areas (54%, n = 168), and while fishing (44%, n = 135). In terms of encounter frequency, 111 respondents (58%) reported that they have encountered cetaceans frequently (almost every year) in the last five years, with 35% of the respondents (n = 57) encountering cetaceans monthly in the past one year.

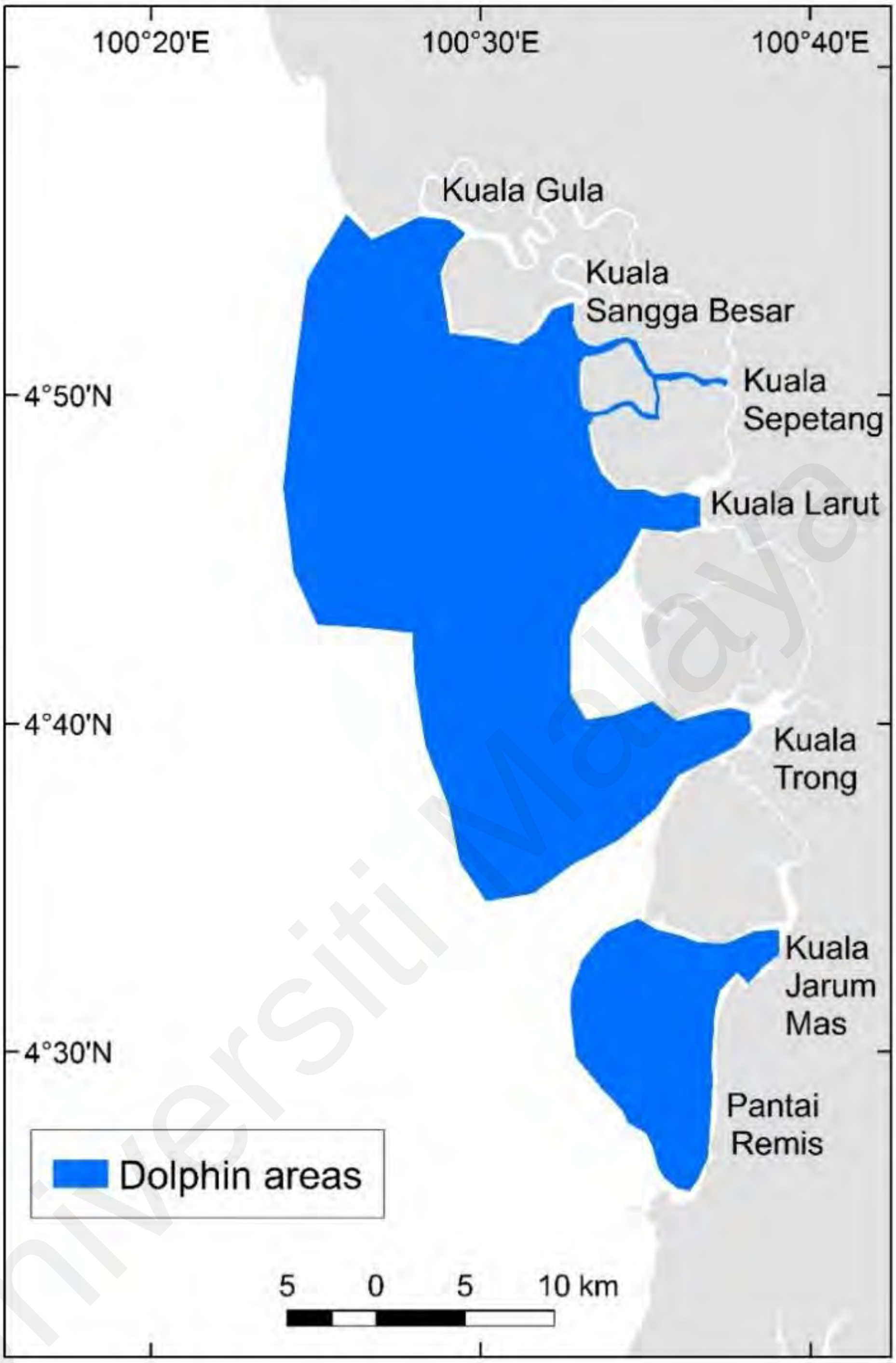

Figure 7.3: The areas where fishers reported they frequently encountered dolphins

Most of the respondents (42%, n = 77) did not observe any difference in cetacean sightings during different tidal conditions. For respondents who observed differences, 31% (n = 57) of the respondents observed cetaceans more frequently during the incoming tide, whereas 14% (n = 25) observed more cetaceans during neap tide. Thirty-three respondents (16%) did not observe tidal differences in cetacean density in Matang.

When asked if respondents had found or heard of any cetacean strandings at sea or on the shores of Matang, 27% (n = 49) had encountered the former and 11% (n = 20) had found or heard of the latter. Respondents had mostly seen or heard of a cetacean stranding in the past 2-5 years (31%, n = 13). When asked about what the respondents thought could be the cause of the strandings, the most common cause was believed to be entanglement (52%, n = 15), followed by 34.5% of the respondents (n = 10) who said they did not know the cause of strandings. The other reasons were propeller strike (7%, n = 2), oil spill (3%, n = 1) and natural/old age (3%, n = 1). When respondents were asked about what they would do in the event of a stranding, most of the respondents (53%, n = 100) said that they would help to push back the cetacean to the sea, whereas 45% (n = 86) would do nothing. The remaining 2% of the respondents (n = 4) said that they would report the stranding to the Department of Fisheries Malaysia or Malaysian Fisheries Development Board (Lembaga Kemajuan Ikan Malaysia, LKIM). When asked about their interest in attending a stranding workshop, 50% (n = 96) were interested, 41% (n = 79) were not interested, and 8% (n = 16) indicated possibility if they have the time.

When asked about their perceived trend in cetacean abundance, 46% (n = 91) of the respondents felt that cetacean abundance in Matang had decreased, 21% (n = 42) felt that the abundance was the same, 20% (n = 39) felt that the cetacean abundance had increased, and 13% (n = 26) said that they did not know (Table 7.2). The main reasons for perceived decrease in cetacean abundance were that Matang's waters are getting shallower (23%, n = 12), there are more fishing activities now (14%, n = 7), pollution (14%, n = 7), and that the cetaceans have moved to other places (10%, n = 5) (Table 7.2). The main reason for respondents who reported perceived increase in cetacean abundance was because they were of the opinion that cetaceans are not caught or harmed in Matang (67%, n = 10) (Table 7.2).

Table 7.2: Perceptions regarding the number of cetaceans now compared to when respondents started fishing. For those who responded that the number of cetaceans had decreased or increased, the reasons provided are shown.

Perceived trend in cetacean abundance		*N*	*198*	
	Decreased		91	46.0%
	Same		42	21.2%
	Increased		39	19.7%
	Don't know		26	13.1%
Reason for perceived decrease		*N*	*52*	
	Shallow water		12	23.1%
	Environmental degradation		11	21.2%
	Don't know		10	19.2%
	More fishing now		7	13.5%
	Cetaceans moved to other place		5	9.6%
	Others		4	7.7%
	Bycatch		2	3.8%
	Prey depletion		1	1.9%
Reason for perceived increase		*N*	*15*	
	Not caught/harmed		10	66.7%
	Sees more		2	13.3%
	Cetaceans reproduced		2	13.3%
	Conservation effective		1	6.7%

When asked if the respondents thought whether there will always be cetaceans in Matang, most of the respondents (81%, n = 158) said “yes”. The main reasons for believing so was due to the mindset that cetaceans will not be extinct (50%, n = 54) and that cetaceans are not hunted, disturbed or killed in Matang (36%, n = 39). However, 7% (n = 14) of the respondents felt there will not always be cetaceans in the sea, due to decreasing water depths in Matang (50%, n = 3), fishing (33%, n = 2) and pollution (17%, n = 1).

When asked whether they like cetaceans, most of the respondents responded positively (71%, n = 140), 21% (n = 41) were neutral, and 8% (n = 15) did not like cetaceans. Common reasons for liking cetaceans were that cetaceans were enjoyable to be observed at sea (60%, n = 73) and that cetaceans are playful animals that would interact with their fishing boats (12%, n = 15). The main reasons for disliking cetaceans were that the animals compete with fishers for fish (56%, n = 5) and that cetaceans damage their nets (44%, n = 4).

When asked if they felt that cetaceans are important, most respondents (69%, n = 137) felt that dolphins are important, 22% (n = 44) were neutral and 9% (n = 17) felt that cetaceans were not important. Positive perceptions about cetacean importance were mainly because cetaceans are enjoyable to observe (38.3%, n = 64), are a potential tourist attraction (28%, n = 46), are part of the ecosystem (14%, n = 23), and are indicator of fish presence (9%, n = 15). Most of the respondents (72%, n = 142) felt that there is potential for dolphin-watching tourism in Matang. However, respondents who felt that cetaceans are unimportant viewed cetaceans as competition with fishers for fish (59%, n = 10) and having no economic value (35%, n = 6).

When asked whether it is illegal to kill cetaceans intentionally, 81% (n = 158) answered "yes", whereas 22% (n = 43) answered "no" and the remaining 7% (n = 13) said they did not know. However, when subsequently asked if it is illegal to kill cetaceans unintentionally (e.g., bycatch), the majority of respondents (77%, n = 149) felt that it was not illegal, whereas 12% (n = 24) still felt that it was illegal even though the catch was accidental.

When asked if the respondents knew or heard of any beliefs regarding cetaceans, only 26% (n = 51) had some beliefs. Respondents mostly said that dolphins would rescue humans in a distress situation (33%, n = 17), that entangling or killing cetaceans brings bad luck (22%, n = 11), cetaceans are smart animals (14%, n = 7) and cetaceans would mourn the death of their calf (10%, n = 5).

7.1.1.3 Bycatch of cetaceans in Matang

Regarding perceptions about the current trend in cetacean bycatch in Matang compared to when the respondents started fishing, most of them (60%, n = 108) said they did not know or never had bycatch, and 23% (n = 41) thought it had decreased. Eighteen respondents (10%) thought that the bycatch rate was the same and 8% (n = 14) thought that it had increased. When asked about the reason for perceived decrease in cetacean bycatch, 73% (n = 8) of the respondents said because there were less cetaceans now, 18% (n = 2) said because cetaceans are clever or smart animals and would not be easily caught, and 9% (n = 1) said because the present day's fishing technology is better. When asked about the reason for perceived increase in cetacean bycatch, most of the respondents (75%, n = 3) said because of the increased fishing effort or increase in size of nets deployed.

When asked whether cetaceans had ever damaged their fishing gears, 11% (n = 22) of the respondents reported that their gears had been damaged by cetaceans. The majority of the respondents with fishing gear damaged by cetaceans were using gillnets (55%, n = 12), followed by trawl nets (27%, n = 6), trammel nets (9%, n = 2) and driftnets (9%, n = 2) (Table 7.3). Most of these respondents' target fish catches were threadfins (family Polynemidae), ariid catfishes (family Ariidae), eel-catfishes (family Plotosidae), mullets (family Mugilidae), seabasses (family Latidae), and pomfrets (family Stromateidae).

When asked whether cetaceans were previously caught in their gears, 28 respondents (14%) said that they had bycatch (Table 7.3). Of these 28 respondents with bycatch, most of them were using gillnets (39%, n = 11), followed by trawl nets (36%, n = 10), driftnets (11%, n = 3), trammel nets (11%, n = 3) and bag nets (4%, n = 1) (Table 7.3). Entanglements in gillnet, driftnet and trammel net encompassed 61% of the cetacean bycatch. When asked if they had bycatch in the last calendar year, most of them reported that they did not have bycatch (58%, n = 15), but nine respondents (35%) reported that they had between one to two bycatch incidents, and two respondents (8%) reported that they had three or more bycatch incidents. The total bycatch incidents of these 11 respondents in the last calendar year was between 14 and 22. Throughout their fishing experience (from when they started fishing to the interview date), most of the respondents (77%, n = 20) reported that they had one to two bycatch incidents, and 12% (n = 3) had more than 10 bycatch incidents. Respondents using gillnets, driftnets and trammel nets that had bycatch mostly had mesh sizes of 1.5 to 4 inches and their target catches were mostly ariid catfishes, eel-catfishes, threadfins, mullets, seabasses, pomfrets, mackerels, and shrimps/prawns (Table 7.4).

Table 7.3: Percentage of respondents who reported about cetaceans damaging fishing gear and cetaceans caught in fishing gear

Cetacean ever damaged your gear?		*N*	193	
	No		171	88.6%
	Yes		22	11.4%
Fishing gears damaged by cetaceans	Gillnet		12	54.5%
	Trawl net		6	27.3%
	Driftnet		2	9.1%
	Trammel net		2	9.1%
Cetacean ever caught in your gear?		*N*	198	
	No		170	85.9%
	Yes		28	14.1%
Fishing gears with cetacean bycatch	Gillnet		11	39.3%
	Trawl net		10	35.7%
	Driftnet		3	10.7%
	Trammel net		3	10.7%
	Bag nets		1	3.6%

When asked about their actions when bycatch occurs (there could be more than one response per respondent), 57% (n = 172) of the responses were that they would release the animal if it was still alive and 36% (n = 108) would discard if the animal was dead.

Eight responses (3%) were that they would report to the Department of Fisheries Malaysia, Department of Wildlife and National Parks Peninsular Malaysia (PERHILITAN), or Taiping Zoo. Four respondents (1%) said that they would eat the bycaught animal. Three responses (1%) were to bury the animal if dead and three respondents (1%) would bring the carcass back to show to other villagers. Two respondents (0.7%) would kill the animal if it was entangled in their gears, and one respondent (0.3%) said that he would sell it.

When asked to provide further details of the bycatch event that they could remember, only 19 respondents (67%) provided further details (Table 7.5). Of these 19 respondents, 10 fishers used gillnets, four fishers used trawl nets, three fishers used driftnets, one fisher used trammel net and one fisher used bag nets (Table 7.5). The most commonly bycaught cetacean species was humpback dolphins (n = 11), followed by Irrawaddy dolphins (n = 3), and finless porpoises (n = 2). The most common number of animals entangled at any given time was one individual (n = 17), followed by three individuals (n = 2). Humpback dolphins and Irrawaddy dolphins were more commonly entangled in gillnets, driftnets, trammel nets and bag nets. When asked about the fate of the bycatch incidents, all four respondents that had bycatch in trawl nets reported that the cetaceans caught died (100%, n = 4). Fifty percent of the entanglements in gillnets, driftnets and trammel nets (n = 7) were reported to be dead, whereas the remaining 50% (n = 7) of the entanglements were reported to be alive and released. Six respondents had entanglements in gillnets/driftnets/trammel nets off Kuala Gula, Kuala Sangga Besar and Kuala Larut (Table 7.5).

Eight out of 19 respondents marked the locations of their bycatch on the map (Figure 7.4). Most of these bycatch locations were either within or in close proximity to core areas of the four main types of fishing gear (especially for nets and trawls) that were identified as bycatch risk gears in the bycatch risk assessment (see Section 7.1.3). Locations of cetacean entanglements in trawl nets could not be recalled by the respondents. When asked if these bycatch were reported, all of these 19 bycatch cases were not reported to the authorities by the fishers (Table 7.5).

Table 7.4: Reported main types of catch by fishing gears in Matang

Types of catch	Type of fishing gears: Gillnet	Driftnet	Trammel net	Trawls	Bag net	Push net	Cockle collection	Crab traps	Hook & line	Longline	Purse seine
Eel-catfishes	✓✓	✓	✓	✓	✓	✓			✓✓	✓✓	
Ariid catfishes	✓✓		✓			✓			✓	✓	
Mullets	✓✓	✓✓		✓	✓	✓			✓		
Threadfins	✓	✓✓	✓	✓	✓	✓					✓
Pomfrets			✓✓	✓✓	✓	✓					
Seabasses	✓✓					✓				✓	✓
Mackerels	✓	✓	✓✓	✓							
Croakers	✓✓				✓	✓					
Sharks	✓	✓	✓								
Stingrays		✓							✓	✓	
Groupers	✓	✓									
Snappers	✓										
Ponyfishes						✓					
Scads			✓								
Prawns and shrimps			✓✓	✓✓	✓✓	✓✓					✓✓
Crabs						✓		✓✓			✓
Cockles						✓	✓✓				
Squids											✓

✓✓: more commonly reported ; ✓: reported

Table 7.5: Further information about bycatch cases encountered by fishers in Matang

No.	Species	Number of animal(s)	Size of the animal(s)	Year	Fate	Fishing gear	Location
1	Humpback dolphin	3	Small	2004	Dead	Trawl net	N/A
2	Finless porpoise	1	Large	2012	Dead	Trawl net	N/A
3	N/A	1	Small	2012	Dead	Trawl net	N/A
4	Finless porpoise	1	Small	N/A	Dead	Trawl net	N/A
5	Humpback dolphin	1	Large	2002	Alive	Gillnet	Kuala Jarum Mas
6	Irrawaddy dolphin	1	Medium	2005	Dead	Gillnet	N/A
7	Humpback dolphin	1	Large	2007	Alive	Gillnet	Off Kuala Gula
8	Irrawaddy dolphin	1	Large	2008	Alive	Gillnet	N/A
9	Humpback dolphin	1	Small	2012	Dead	Gillnet	Off Kuala Larut
10	Humpback dolphin	1	Large	2016	Dead	Gillnet	N/A
11	Humpback dolphin	3	Small	N/A	Alive	Gillnet	N/A
12	Humpback dolphin	1	Large	N/A	Alive	Gillnet	N/A
13	Humpback dolphin	1	Large	N/A	Dead	Gillnet	5nm off Kuala Larut
14	Humpback dolphin	1	Large	N/A	Dead	Gillnet	N/A
15	Humpback dolphin	1	Large	1970s	Alive	Driftnet	Kuala Gula
16	Humpback dolphin	1	Large	2009	Alive	Driftnet	Kuala Jarum Mas
17	Humpback dolphin	1	Small	2013	Dead	Driftnet	N/A
18	Irrawaddy dolphin	1	Large	1970s	Dead	Trammel net	Off Kuala Gula
19	Humpback dolphin	1	Large	2007	Alive	Bag net	Kuala Gula

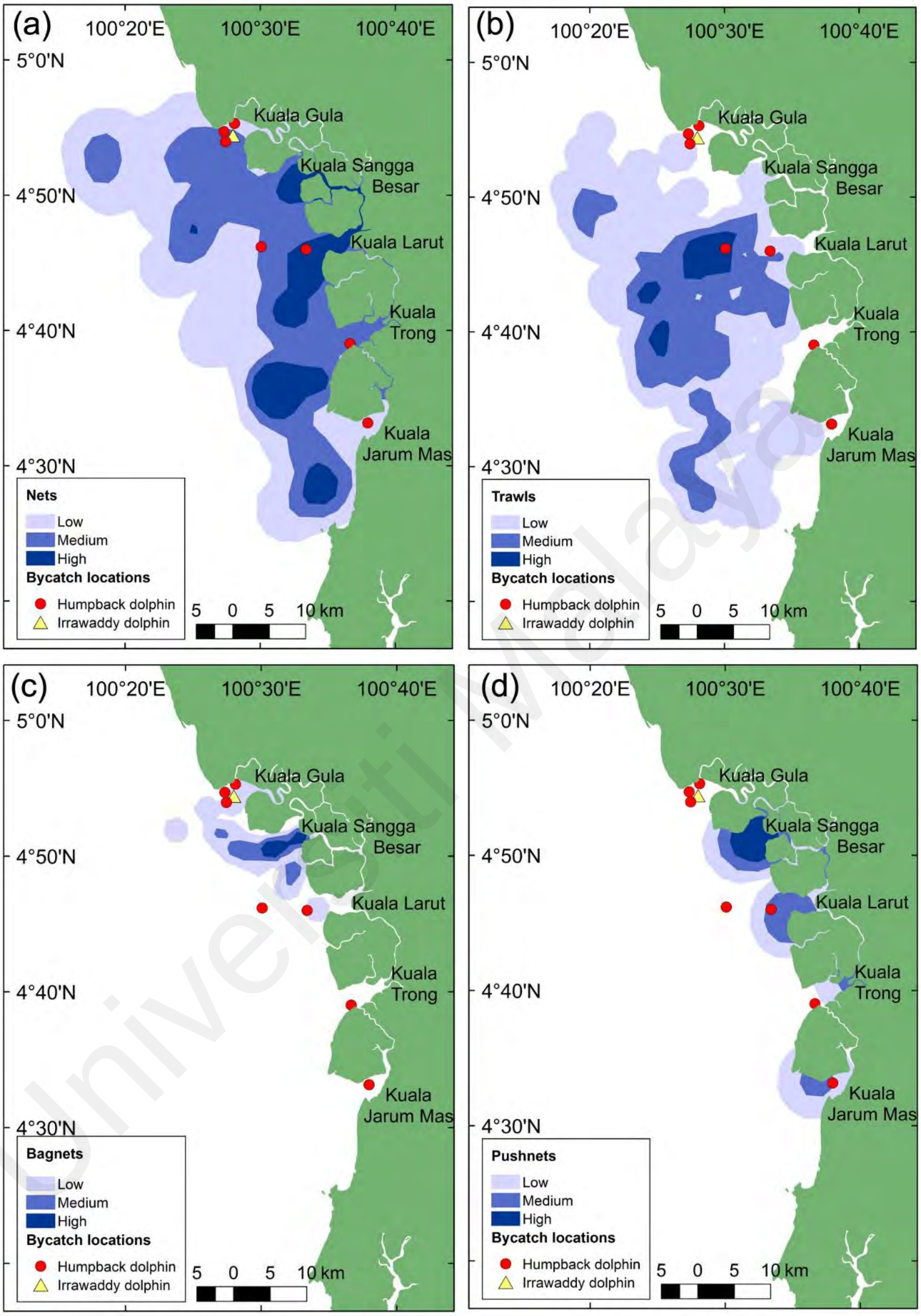

Figure 7.4: Locations of bycatch as reported by interview respondents, overlaid with kernel densities of (a) nets, (b) trawls, (c) bag nets and (d) push nets that were recorded during boat-based surveys

7.1.1.4 Perceptions related to fishing, earnings and resources

When asked whether respondents felt the number of fishers in Matang had increased, decreased or remained the same, most of the respondents felt that the number of fishers had increased (55%, n = 108). When asked about current earnings from fishing compared to when they started fishing, most of the respondents (44%, n = 86) reported that their earnings have decreased. Fifty-six respondents (29%) reported that their earnings have increased, whereas 28% (n = 54) had maintained the same earnings.

When asked about their current fisheries catch compared to when they started fishing, 61% of the respondents (n = 117) reported that their catch decreased, 21% (n = 41) of the respondents had increased catch, and 18% (n = 35) had the same amounts of catch as when they started fishing. For respondents who said that their catch had decreased, the main reasons given were that there was too much fishing or that there are more fishers now (26%, n = 24), followed by change in the environment/shallow water/seabed destruction (25%, n = 23), pollution (15%, n = 14), and competition with modern fishing technology (15%, n = 14). Respondents who reported increase in their catch cited the main reason to be due to better fishing technology (34%, n = 8), seasonality (21%, n = 5) and blessings from God (17%, n = 4).

When asked about the water quality in Matang, 51% of the respondents (n = 85) felt that the water quality in Matang is generally good, whereas 42% (n = 71) felt that the water quality is bad. When asked about the types of pollution in Matang, 31% (n = 48) of the respondents mentioned marine debris or trash, followed by aquaculture (22%, n = 34), fuel (20%, n = 31) and runoffs from oil palm plantations (16%, n = 25).

7.1.2 Prevalence of injuries on dolphins

Of all individuals catalogued on the right dorsal fin (RDF) with quality score, $Q \geq 2$ and distinctiveness score, $D \geq 3$, 83.7% (n = 139) of humpback dolphins and 77.4% (n =

308) of Irrawaddy dolphins had healed and/or existing wounds/injuries (Table 7.6). While the majority of these injuries probably resulted from intraspecific interactions, 23 humpback dolphins (16.5%) and 88 Irrawaddy dolphins (28.5%) had either confirmed or probable anthropogenic injuries from interactions with fishing gear, propeller strike or marine debris, representing six injury types (Table 7.6, Figure 7.5a-f).

Two humpback dolphin (1.5%) that were sighted offshore and 10 Irrawaddy dolphins (3.2%) (Figure 7.5c) each had a single, deep indentation that was most likely caused by fishing line, fishing rope, or marine debris on their body or dorsal fin (Table 7.6). Possible propeller cuts were observed posterior to the dorsal fin on the body of an Irrawaddy dolphin (0.3%) (Figure 7.5b). The most prevalent injury that was probably the result of interactions with human activities was linear severed dorsal fin, as observed on 11 humpback dolphins (7.9%) and 39 Irrawaddy dolphins (12.6%). Almost all of those individuals had linear severed dorsal fins before they were first catalogued in the database, whereas only one humpback dolphin (individual RDF-138) acquired a horizontal linear mutilation within 14 months (Figure 7.6).

Straight, deep cuts on dorsal fins were observed on two humpback dolphins (1.4%) and 16 Irrawaddy dolphins (5.2%). Short, blunt cuts on dorsal fins were observed in two humpback dolphins (1.4%) and five Irrawaddy dolphins (1.6%). There were also six humpback dolphins (4.3%) and 18 Irrawaddy dolphins (5.8%) with a curved cut on the leading edge of the dorsal fin, where those could be due to a combination of anthropogenic and intraspecific injuries.

A total of 116 humpback dolphins (83.5%) and 216 Irrawaddy dolphins (69.7%) were recorded with injuries that were possibly the result of intraspecific interactions (Figure 7.7). The most prevalent injury type for Irrawaddy dolphins in Matang was non-linear severed dorsal fins, with 123 Irrawaddy dolphins (39.7%) observed (Table 7.6). The most common prevalent injury type for humpback dolphins in Matang was irregular dorsal fin trailing edge, with 80 humpback dolphins (57.6%) observed with this injury type (Table 7.6). Round indentation on dorsal fins were recorded in 11 humpback dolphins (7.9%) and 67 Irrawaddy dolphins (21.6%). Nine humpback dolphins (6.5%) and 13 Irrawaddy dolphins (4.2%) had rounded dorsal fin profiles. Shark bite injuries were recorded in three Irrawaddy dolphins (1.0%) but not observed in humpback dolphins in Matang. One humpback dolphin (0.7%) and two Irrawaddy dolphins had unidentified injuries (0.6%).

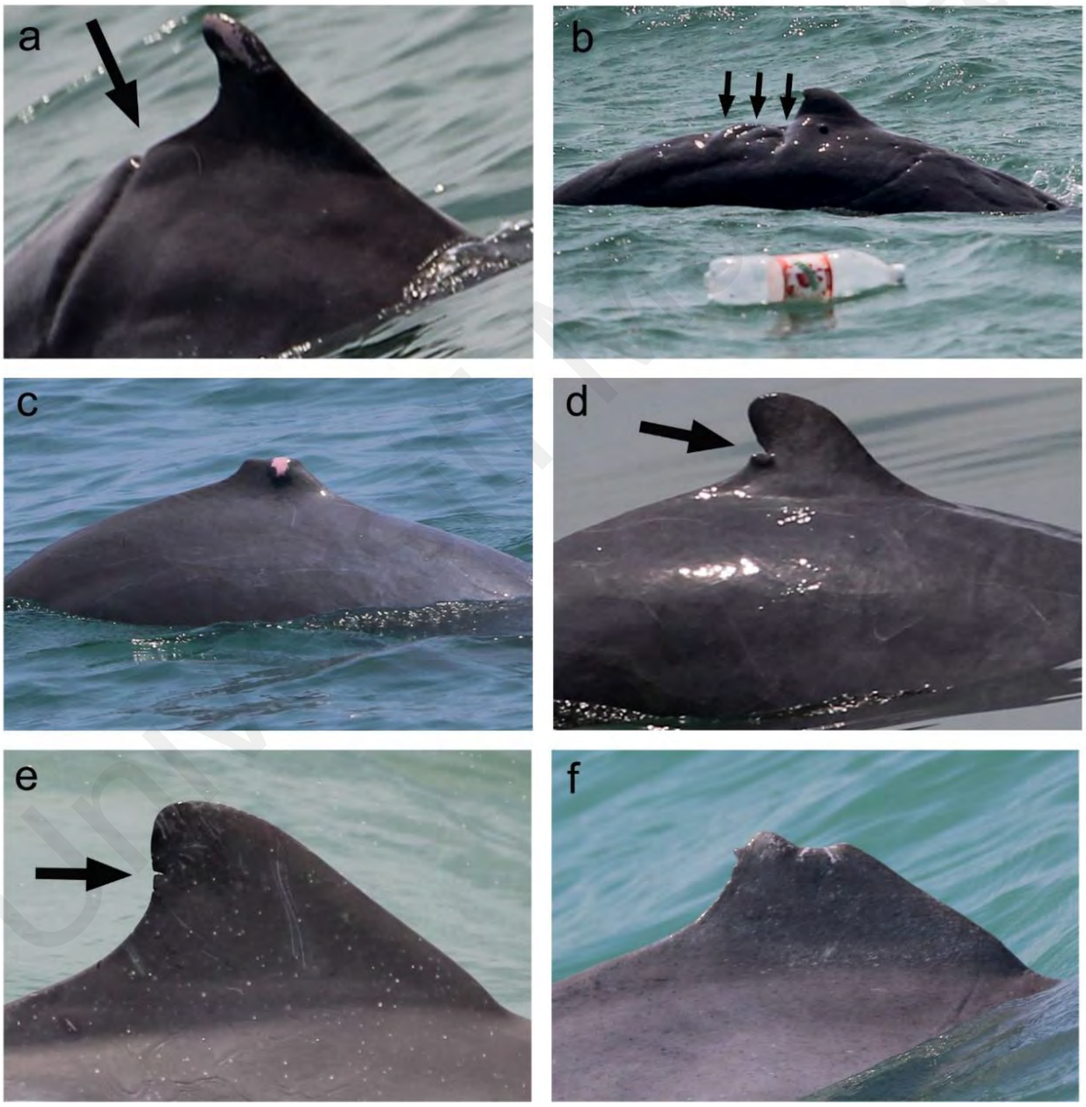

Figure 7.5: Confirmed and probable anthropogenic injuries in humpback dolphins and Irrawaddy dolphins in Matang. Injuries include: (a) Single, deep indentation on the mid-flank of a humpback dolphin, (b) Propeller cuts posterior to the dorsal fin of an Irrawaddy dolphin, (c) Linear severed dorsal fin of an Irrawaddy dolphin with pink scar tissue, (d) Straight, deep cut on the dorsal fin of an Irrawaddy dolphin, (e) Short, blunt cut on the dorsal fin of a humpback dolphin, (f) Curved cut on the leading edge of the dorsal fin of a humpback dolphin

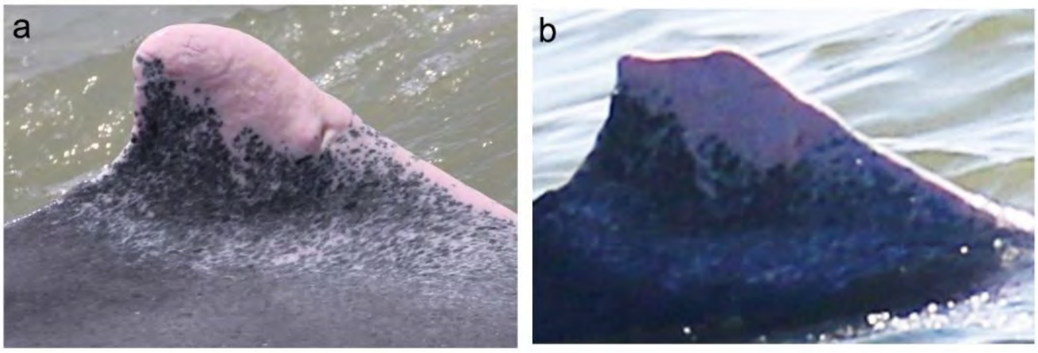

Figure 7.6: A humpback dolphin individual RDF-138 that was observed to have acquired horizontal linear mutilation within 14 months; (a) Individual was first seen without linear mutilation on 7 November 2014 and (b) Seen with linear mutilation on 12 January 2016

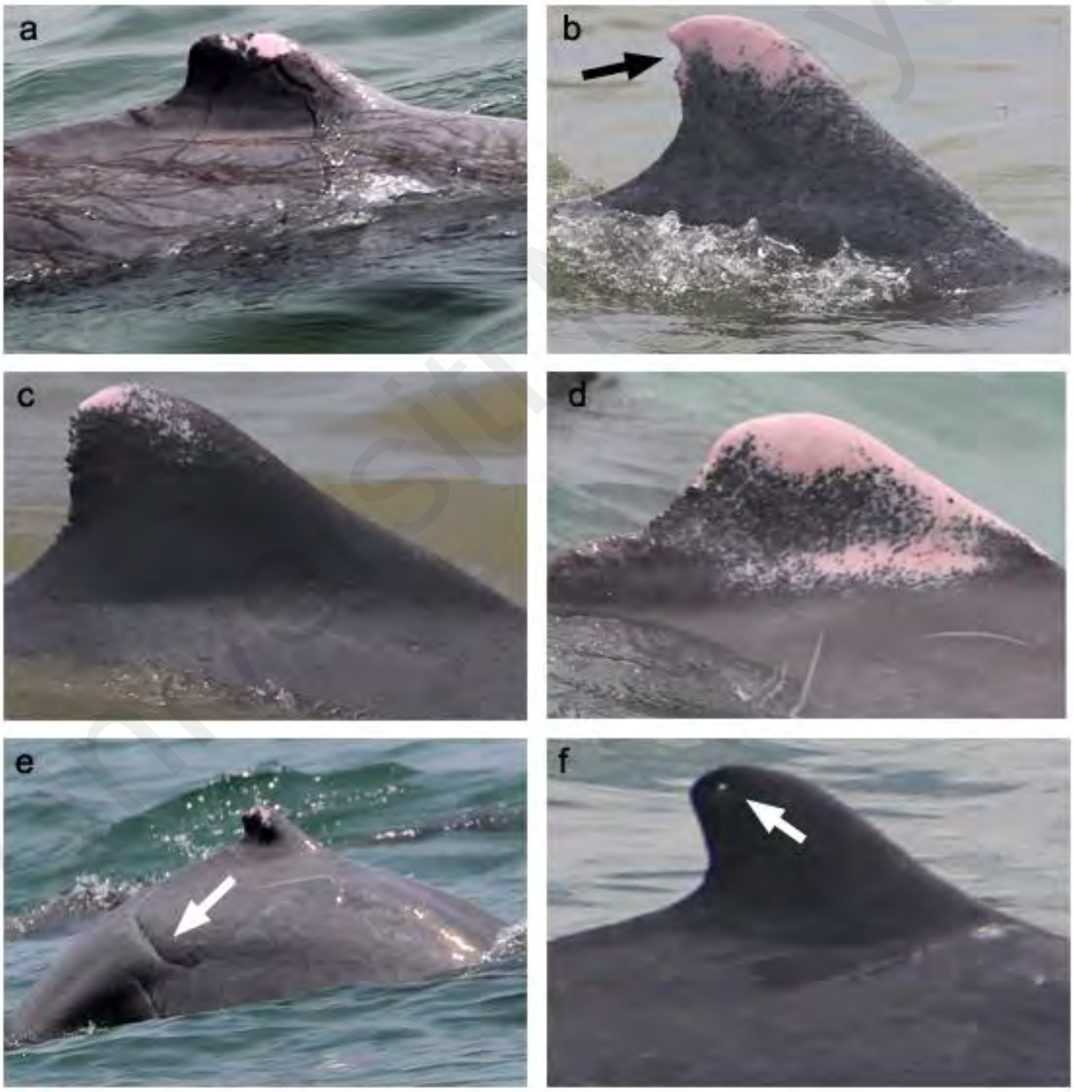

Figure 7.7: Intraspecific injuries, shark bites and unidentified injuries in humpback dolphins and Irrawaddy dolphins in Matang. Intraspecific injuries include: (a) Non-linear severed dorsal fin of an Irrawaddy dolphin, (b) Round indentation on dorsal fin of a humpback dolphin, c) Irregular dorsal fin trailing edge of a humpback dolphin, d) Rounded dorsal fin profile of a humpback dolphin. Other injuries include: e) Shark bite injuries on the body of an Irrawaddy dolphin, f) Example of an unidentified injury: a hole on the dorsal fin of an Irrawaddy dolphin

Table 7.6: Prevalence of injury types in humpback dolphin and Irrawaddy dolphin individuals in Matang in 2013-2016, based on right side of dorsal fin (RDF) images of quality score, Q ≥ 2 and distinctiveness score, D ≥ 3

	Humpback dolphin (n = 166)		Irrawaddy dolphin (n = 398)	
Injury type	*n*	Percentage	*n*	Percentage
No injury	27	16.3%	88	22.1%
≥ 1 injury	139	83.7%	310	77.9%
With confirmed anthropogenic injuries				
Single, deep indentation on body or dorsal fin	2	1.5%	10	3.2%
Propeller cuts	-	-	1	0.3%
With probable anthropogenic injuries				
Linear severed dorsal fin	11	7.9%	39	12.6%
Straight deep cut on dorsal fin	2	1.4%	16	5.2%
Short blunt cut on dorsal fin	2	1.4%	5	1.6%
With probable combination of anthropogenic and intraspecific injuries				
Curved cut on the leading edge of dorsal fin	6	4.3%	18	5.8%
With probable intraspecific injuries				
Non-linear severed dorsal fin	15	10.8%	123	39.7%
Round indentation on dorsal fin	11	7.9%	67	21.6%
Irregular dorsal fin trailing edge	80	57.6%	13	4.2%
Rounded dorsal fin profile	9	6.5%	13	4.2%
Other injuries				
Shark bite injuries	-	-	3	1.0%
Unidentified injuries	1	0.7%	2	0.6%

7.1.3 Bycatch risk assessment (ByRA)

The ByRA outputs revealed that a large proportion of the survey area in Matang posed medium to high bycatch risk to both humpback and Irrawaddy dolphins (Figure 7.8a,b). Among the four research subregions in Matang, the bycatch risk of humpback dolphins was intermediate throughout the five main estuaries, and was highest in the North Estuarine subregion, particularly off the estuaries of Kuala Sangga Besar, Kuala Larut and Kuala Gula, and inside the riverine waterways (Figure 7.8a). These estuaries were areas where high density of gillnets, driftnets, and trammel nets posed bycatch risk to humpback dolphins. Intermediate and highest bycatch risk to Irrawaddy dolphins were widely distributed across the four subregions, with trawls posing highest bycatch risk in large proportions of the South Coastal and North Coastal subregions (Figure 7.8b).

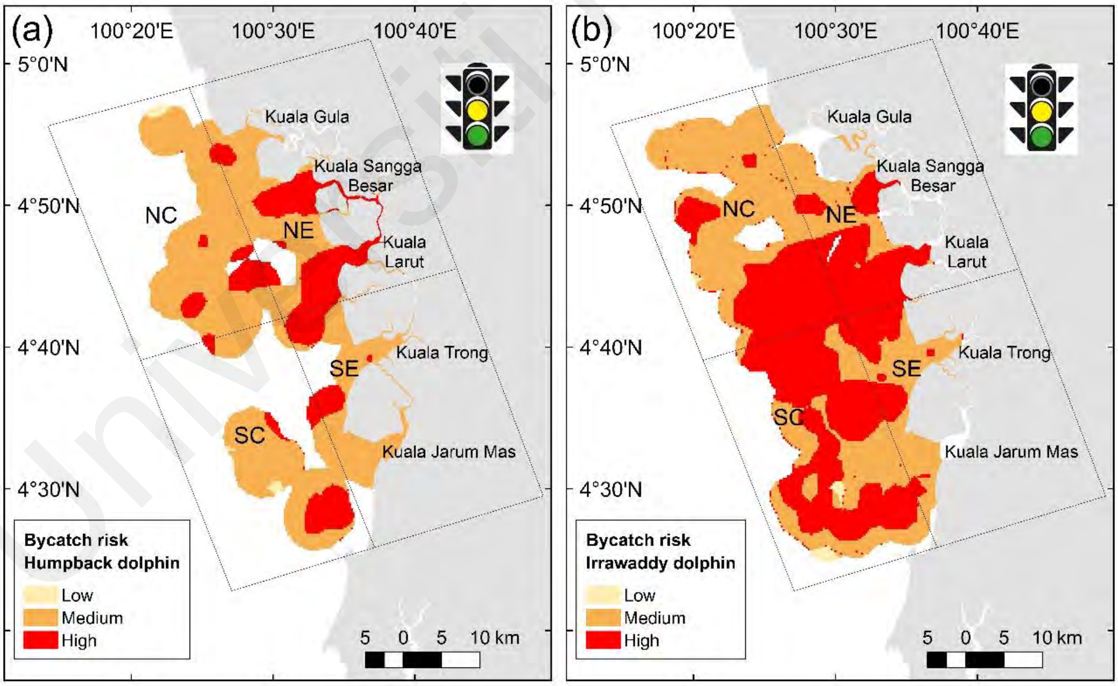

Figure 7.8: Estimated bycatch risk for (a) humpback dolphins and (b) Irrawaddy dolphins in Matang. Darker red indicates higher bycatch risk. Stoplight colours indicate level of uncertainty of ByRA data inputs. ByRA subregions: NC: North Coastal; NE: North Estuarine; SC: South Coastal; SE: South Estuarine

The North Estuarine subregion had the highest cumulative exposure and consequence scores from four stressors, followed by the North Coastal and South Estuarine which had similar levels of cumulative exposure and consequence scores from three stressors. The South Coastal had the lowest scores from only two stressors. The fishing gears that posed the highest bycatch risk for humpback dolphins were nets (i.e., gillnets, driftnets and trammel nets). By percentage, in the North Estuarine it was 31.6%, and in the South Estuarine it was 40.4%. Bycatch risk from trawls in the North Coastal subregion was 37.2% and 50.8% in the South Coastal subregion. Similarly for Irrawaddy dolphins, the fishing gears that posed the highest bycatch risk were nets deployed in the North Estuarine (28.6%) and South Estuarine (40.4%), and trawls in the North Coastal (38.6%) and South Coastal (53.5%). Gillnets, driftnets and trammel nets had the highest exposure scores, whereas trawls had the highest consequence scores to humpback dolphins (Figure 7.9) and Irrawaddy dolphins (Figure 7.10). Bag nets were not present in the South Coastal and South Estuarine subregions, whereas push nets were not present in the North Coastal and South Coastal subregions (Figures 7.9, 7.10).

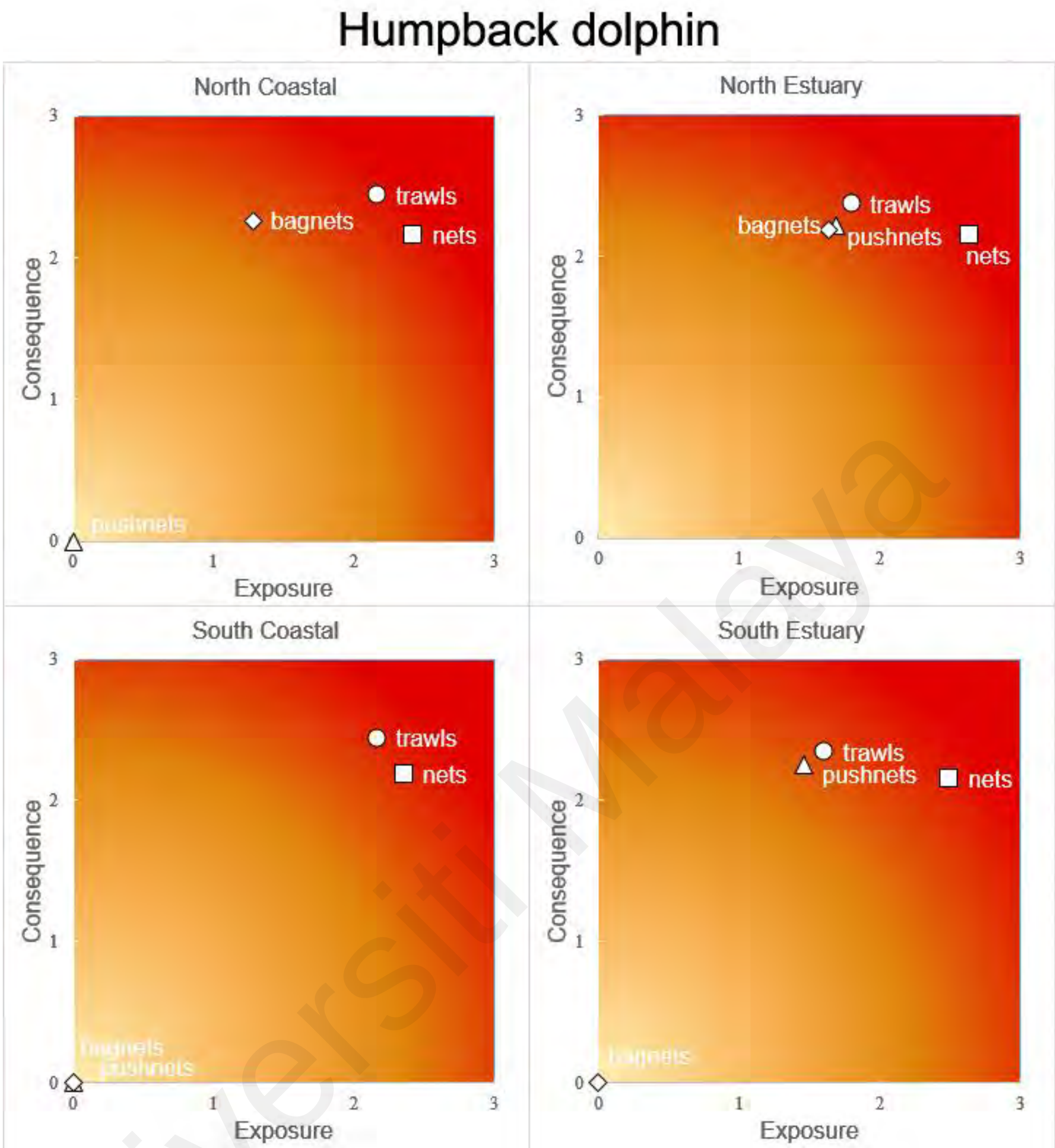

Figure 7.9: Bycatch risk plots showing consequence and exposure scores of nets (i.e., gillnets, driftnets and trammel nets), trawls, bag nets and push nets to humpback dolphins in four subregions. Darker red region (higher exposure and consequence) indicates higher risk of bycatch

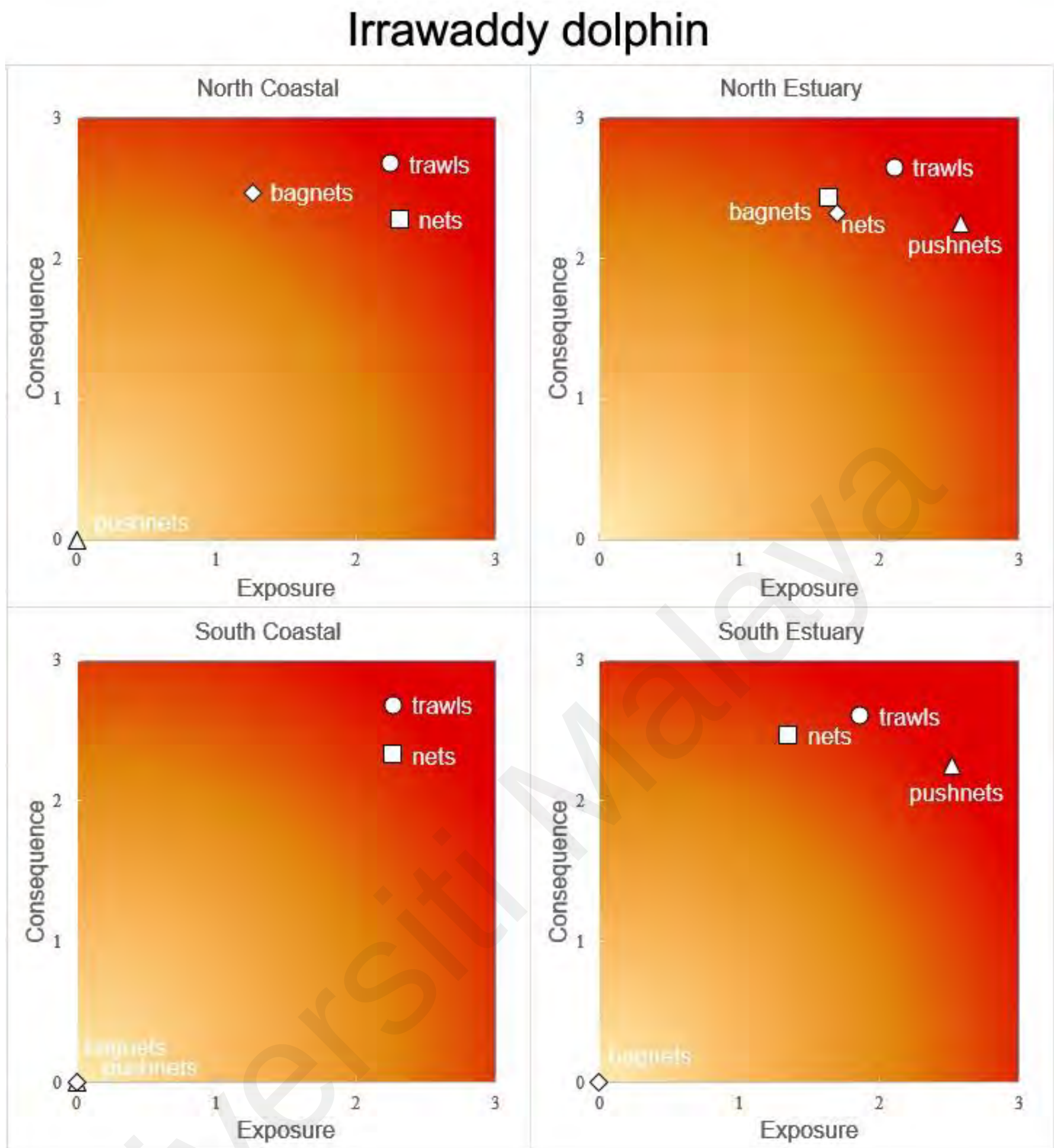

Figure 7.10: Bycatch risk plots showing consequence and exposure scores of nets (i.e., gillnets, driftnets and trammel nets), trawls, bag nets and push nets to Irrawaddy dolphins in four subregions. Darker red region (higher exposure and consequence) indicates higher risk of bycatch

The spatial data layers used in the ByRA analysis were from sightings of dolphins and fishing activities collected during line transect surveys between 2013 and 2016. Four stressors were chosen based on the number of fishing gear records and the reported bycatch gears from interview data (Table 7.7). Crab traps in Matang were unlikely to have cetacean bycatch, while there were not enough records of hook-and-line and longlines, thus those gears were not assessed for bycatch risk to cetaceans. The level of uncertainty for each ByRA data category are shown in Table 7.8. Data in Matang showed a combination of green (high certainty) and yellow (medium certainty).

Table 7.7: Summary of spatial data layers (species and stressors) used in bycatch risk assessment (ByRA)

Spatial data layer	Type	n
Species (sightings)	Humpback dolphin	124
	Irrawaddy dolphin	254
Stressors (fishing gear records)	Nets	199
	Trawls	303
	Bag nets	78
	Push nets	11

Table 7.8: Characterization of uncertainty for bycatch risk assessment (ByRA) data category in Matang. Green: high certainty; Yellow: medium certainty; Red: low certainty

ByRA data category	Data source and type collected in Matang
Dolphin distribution	Systematic line transect boat and photo-ID survey
Fishing occurrence	Collected during line transect survey and data from interviews
Bycatch data	Presence/absence of bycatch from interviews

7.2 Discussion

7.2.1 Interviews with local fishers

7.2.1.1 Local knowledge and perception of local fishers

All respondents had sighted cetaceans in Matang but only 4% of the respondents had sighted all three species of cetaceans in Matang. Humpback dolphins were more frequently sighted by fishers, probably due to their inshore distribution and were relatively more surface active compared to Irrawaddy dolphins and finless porpoises. Adult humpback dolphins have bigger dorsal fins and light/pink patches from loss of skin pigmentation, hence are relatively easier to be spotted than Irrawaddy dolphins and finless porpoises. Fishers who deploy bag nets or push nets mostly remained inshore and were less likely to encounter finless porpoises and Irrawaddy dolphins that were distributed much farther from the coast (Kuit et al. 2019). Finless porpoises were least sighted by fishers in Matang, probably due to their evasiveness, offshore distribution, and smaller group size. It was found during the interviews that the slight physical differences between Irrawaddy dolphins and finless porpoises (i.e., absence of dorsal fin in finless porpoise, smaller in size and darker) were not easily distinguishable by fishers during brief sightings, similar to Jefferson et al. (1993). This highlights the challenge of using interviews to collect information about cetacean species that are physically similar and are elusive, evasive and distributed farther offshore.

The fishing areas as indicated on the map by interview survey respondents (Figure 7.2) were consistent with the distribution of fishing activities as observed during boat-based surveys in 2013 - 2016 (Figure 7.4). Although there are typically data validity issues associated with interview surveys, fishers' knowledge appear to provide accurate information to map spatial distribution of fishing areas for coastal fisheries, similar to Léopold et al. (2014). Most of the fishers sighted cetaceans frequently, especially while travelling to fishing areas. Humpback dolphins were likely to be the species that surfaced in the rivers or estuaries while the fishers' boats passed and moved out of the estuaries to their fishing locations. The relative distribution patterns of the cetaceans described by the respondents were consistent with findings from boat-based surveys in the present study (Kuit et al. 2019; see Chapter 4). This suggests the usefulness of using interviews to collect low resolution data on cetacean distribution and to identify cetacean hotspots in data deficient areas (Braulik et al., 2017), which could be useful for assessments for conservation initiatives such as Important Marine Mammal Areas (IMMA), especially in locations where resources are limited.

Most of the respondents perceived a decline in cetacean abundance, citing reasons that the inshore waters of Matang are getting shallower, increased fishing activities and pollution occurrences. In particular, fishers in the northern estuaries (i.e., Kuala Gula, Kuala Sangga Besar, Kuala Sepetang) perceived that the estuaries and rivers were getting shallower. Some of the older fishers revealed that humpback dolphins used to swim upriver right in front of their fishing villages, but have rarely been observed in the last decade due to shallower rivers. Coastal erosion of mangrove-fringed river banks in the Sungai Sangga Besar, likely due to wave action by large boats where boat traffic is heavy (Chong, 2006), may be a contributor to shallower river. Some of the fishers also felt that mangrove swamps that were destroyed for shrimp farms in the area contributed to the erosion and subsequent decreased water depths in Matang. For context, the development of aquaculture farms represents 11.1% of total land conversion area in Matang's mangroves (Ibharim et al., 2015). Shrimp farming which accounts for 38% of global mangrove loss had been reported to cause soil erosion that leads to increased sedimentation (Barbier et al., 2011; Hossain & Hasan, 2017). Shallower depths could increase underwater noise from boats, and may also pose higher risks of propeller cuts and boat strikes to dolphins (Dey et al., 2019).

Fishers' knowledge can be an invaluable source of data to identify patterns in fishing pressure (Hallwass et al., 2019), which are important to understand links to bycatch patterns. Increased fishing activities especially involving bycatch gears may increase bycatch risks to dolphins, prey depletion and increased risk of injuries or deaths from high boat traffic (Bearzi et al., 2006; Leaper & Calderan, 2017; Slooten, 2013; Wang et al., 2015a; Zanardo et al., 2016). Some fishers in Matang recognized the joint roles of increased fishing pressure and environmental change (discussed below) on both declining cetacean abundance and on fish catch. Similarly in Mahakam River, Indonesia, most of the fishers with previous exposure to marine resource activities also reported that their catch decreased due to overfishing (Whitty, 2014). This suggests that any future efforts to regulate fishing activities and to address cetacean bycatch may be perceived positively by fishers with environmental awareness due to possible benefits of increased fish catch in the long run. However, more effort is still needed to raise the majority of local fishers' understanding of the long-term benefits of properly managed fishing activities.

The fishers' main perceived sources of pollution in Matang were runoffs from palm oil plantations, discharge of effluents from shrimp farms and fish cages, fuel leakage, marine litter, and untreated sewage. Mangrove waterways in Sangga Besar and Kuala Sepetang were reportedly used as dumping sites for solid wastes and sewage, as a result of poor garbage disposal and waste management system, and are believed to be polluted by pesticides and herbicides (Chong, 2006; Ghaderpour et al., 2014). Environmental degradation was perceived by fishers as the reason why cetaceans would move to other places, and thus, the perceived decrease in relative abundance observed by fishers in Matang.

Entanglements in fishing gears like trawl nets and gillnets were thought by fishers in Matang to be the main probable causes of mortality of cetaceans found dead at sea. The fishers' perception on the matter aligns with information reported in Slooten et al. (2013) that suggested the primary gears to cause mortality of humpback dolphins are gill or trammel nets and trawls. This may be related to the fishers' knowledge of bycatch cases of their own fishing gears or of their peers. One of the fishers commented that he saw gillnet marks on a dolphin carcass that was found to be stranded. Some gillnet and trawl fishers interviewed either did not like cetaceans or were neutral about them. These fishers also perceived cetaceans as competitors for fish resources, as a threat due to potential damage to their fishing gears and as having no economic value, as they cannot be sold. Depredation, or removal of fish captured in fishing gear by marine mammals, reduces the value of fishers' catch and may lead to higher risk of entanglement (Read, 2008). Humpback dolphins in India were known to depredate and cause damage to fishing gears (Sutaria et al., 2015). In one occasion in Matang during boat-based surveys, humpback dolphins were observed depredating untended gillnets, whereby half a croaker that was still moving floated to the water's surface. Reeves et al. (2003) reported that beliefs that cetaceans compete for resources and damage fishing gears has prompted deliberate kills by fishers as retaliation in some parts of the world. Despite some fishers' negative experiences of their interactions with cetaceans, it was unlikely that Matang fishers would intentionally kill the animals. Most fishers in Matang who perceived an increase in cetacean abundance said that cetaceans were not purposely harmed in Matang. Most of the fishers were aware that it is illegal to kill cetaceans intentionally. Some of the fishers believed that intentionally killing cetaceans would bring bad luck, even if they did not appreciate the net depredation behaviour of the animals. This is similar to the beliefs of villagers in Laos and Cambodia who believe that killing Irrawaddy dolphins results in bad luck (Baird et al., 1994). Cetaceans were also viewed as being important as they are enjoyable to be observed and dolphins are a potential local tourism attraction. Such views held by some fishers may be linked to the behaviour of humpback dolphins that would occasionally leap, breach or bowride.

Some of the local beliefs held by Matang fishers aligned well with information available from scientific studies. For instance, five fishers mentioned that cetaceans mourned the death of their calves, which is consistent with nurturant epimeletic behaviour documented in dolphins in various parts of the world (Bearzi et al., 2018; Reggente et al., 2016). Matang fishers who were aware of such behaviour must have observed it themselves before; a fisher I interviewed recalled a gillnet entanglement incident of a dolphin calf in his net years ago. He related that an adult dolphin present (presumably the mother) prevented him from taking the dead calf out of the water. The mother dolphin pulled the calf away from the water's surface and into the mid-water column, but it eventually floated back to the surface. The fisher explained that he then managed to pick up the dead calf and place it on his boat.

7.2.1.2 Bycatch of dolphins by fishers in Matang

Based on interview data, the most common fishing gears that had cetacean bycatch were gillnets, driftnets, trammel nets and trawl nets, and were identified as the primary gears that would obtain cetacean bycatch in Matang. Humpback dolphins and Irrawaddy dolphins in Matang appeared to be most commonly entangled in gillnets. Humpback dolphins and Irrawaddy dolphins were also documented to be bycaught in gillnets and driftnets elsewhere (Chen et al., 2016; Hines et al., 2015a; Jaaman et al., 2009; Junchumpoo et al., 2014; Reeves et al., 2013; Slooten et al., 2013; Smith et al., 2008). This may be due to the overlap of the distribution of the fishing areas and the cetaceans. The relatively inshore distribution of humpback dolphins and Irrawaddy dolphins in Matang mostly overlapped with the distribution of gillnets, driftnets and trammel nets.

Entanglement in gillnets, driftnets and trammel nets that were tended by fishers may not be as fatal as in trawls, as almost half of the entanglements in non-trawl gears in Matang were reported to be alive and released. Cetaceans caught in nets set near the surface are able to surface to breathe for some time despite their entanglements until they become too weakened (Soulsbury et al., 2008). As most of the gillnet, driftnets and trammel nets were tended by fishers, entanglements in these nets were perhaps more likely to create movement on the water surface and more likely to be noticed by these fishers who would then able to release the individual, as opposed to a midwater or bottom trawl entanglement that is below the water surface and behind a trawler. However, similar to Pilcher et al. (2017), the reliability of high claims of live releases could not be assessed. There may be possible bias that the entanglements found alive in gillnets may have been over-reported by fishers, as fishers might have chosen mostly to report the entanglements that were alive when released and did not disclose the ones that were found to be dead. One fisher had reported more than 10 bycatch of humpback dolphins in gillnets targeting Sagor catfish in his 47 years of fishing. He admitted to hitting some of the entangled humpback dolphins on their rostrum to kill them, for fear of being bitten. According to the fisher, he had only released one individual, which was entangled on the fluke. Bycaught cetaceans that were released alive or escaped may suffer a variety of injuries that are likely to contribute to pre-mortem stress and affect subsequent long-term survival (Soulsbury et al., 2008).

Section 27 (3) of the Malaysian Fisheries Act 1985 states that marine mammals found to be caught alive must be released immediately, whereas if dead when found, must be reported to a fisheries officer without any penalty imposed (Rahman et al., 2018). However, the reporting of bycatch in Matang to fisheries officers appeared to be extremely low, as only 3% of the respondents said that they would report to the authorities if they had a bycatch. None of the 19 bycatch cases listed in Table 7.5 were reported to the authorities by fishers. Most of the dead entanglements in Matang were most likely discarded at sea, probably due to the fishers' fear of legal actions and to avoid bringing any trouble on themselves. Bycatch or damaged gears would cost fishers more money and time to disentangle the animals, and to repair or replace the damaged gears (Fertl & Leatherwood, 1997; Zollett & Rosenberg, 2005). Additionally, it was deemed bad luck to entangle and eat dolphins especially among Chinese fishers, as there were beliefs that nets that have entangled cetaceans would subsequently have poor catch. Based on a reported anecdote, a fisher in Kuala Sepetang village who once brought back an entangled dolphin for consumption had a boat accident a month after that.

The number of cetacean bycatch by 11 respondents in the last calendar year at the time of interview surveys were between 14 and 22 cetaceans, and should be treated as the minimum cetacean bycatch rate in Matang. The actual number of bycatch is likely to be higher than this number, as this number was not extrapolated according to the proportion of fishers that have not been interviewed, and bycatch cases are likely to be underreported by fishers. The intensity of marine mammal and fisheries interaction largely depends on the extent of overlap in space and time with their shared target species (Matthiopoulos et al., 2008). Occurrence of bycatch and gear damage by humpback dolphins appeared to be more likely to occur in gillnets that were targeting ariid catfishes, threadfins, eel-catfishes and pomfrets that are likely the animals' prey species. Otoliths of ariid catfishes and croakers, and spines of eel-catfish and ariid catfishes were found in the stomach content of a dead stranded humpback dolphin in Matang (Kuit et al., 2015). Depredation and bycatch of Irrawaddy dolphins during this study is less understood as fishers mostly reported about bycatch of humpback dolphins. However, Irrawaddy dolphins were sighted near to gillnets and trawl nets that were being hauled up on a few occasions during boat-based surveys. Irrawaddy dolphins in Chilika Lagoon, India were reported to forage close to stake nets with high catch of mullets (D'Lima et al., 2014).

According to Pilcher et al. (2017), a perceived decreasing trend of cetaceans being bycaught in fishing gears could indicate either a decrease in entanglements (positive) or a decrease in cetacean abundance (negative). Most of the respondents in Matang felt that the cetacean bycatch rate in Matang has reduced due to decreasing number of cetaceans. This implies that the number of bycaught cetaceans may be higher in the past, and as more cetaceans died from entanglements, the decreased abundance of cetaceans in Matang has thus led to lower probability of entanglement presently. While there were no comprehensive studies on cetacean abundance estimates in Matang for comparison with the past (see Chapter 5), the results of this study is cause for major concern as there has been high mortality of cetaceans from entanglements due to the high level overlap of human-dolphin interactions (Figure 7.8).

7.2.1.3 Limitations and bias of interview surveys

Despite best efforts to interview as many fishers as possible, the recommended sample size of 338 was not reached. The dataset of 198 interviews in this study might not be statistically representative but remain useful for qualitative and descriptive purposes to assess cetacean bycatch levels and conservation perceptions in Matang. While there were 2,763 local fishers that were registered in Larut and Matang (Perak Fisheries Department, 2012), the actual number of fishers that are actively fishing is unknown.

There were insufficient interviews of purse seiners, as those vessels are now mostly crewed by foreign crew and thus there were language barriers. There was also reluctance for the owners of the purse seine vessels to allow their workers to be interviewed by myself and my volunteers, hence presence of cetacean bycatch in purse seines were undetermined. The only local purse seine fisher interviewed in this study used purse seines in the 1960s. It was also difficult to assess the reliability of data from interviews, as the data may be incomplete or inaccurate from memory decay and biased responses of the respondents (e.g., Whitty, 2016). Bycatch of protected species are often under-reported, as there may be fear that accurate reporting will result in negative consequences such as punitive actions or lead to conservation actions that would threaten the fishers' livelihoods (Moore et al., 2010; Whitty, 2014). However, interview-based approach with questionnaires used in the present study serves as a comprehensive and low-cost method to study fishing pressures on marine mammals (Pilcher et al., 2017).

7.2.2 Prevalence of injuries on dolphins

There are at least three types of fishery interactions, namely bycatch, chronic entanglements and fishers aggression (Puig-Lozano et al., 2020). It is important to note that the focus of the injury assessment on the dolphins' dorsal fin and mid flank area in this study are limited to interactions that resulted in external injuries on this mid-section in individuals that survived such interactions, and did not take into account the possibility of immediate fatalities from such injuries. Prevalence of anthropogenic injuries appeared to be higher in Irrawaddy dolphins (28.7%) than humpback dolphins (16.5%) in Matang. Those results were surprising, given behavioural observations during boat-based surveys whereby humpback dolphins appeared to approach boats and depredate nets more and were thus presumed to have more interactions with anthropogenic activities, whereas Irrawaddy dolphins appeared to be evasive and stayed away from boats. However, the lesser prevalence of anthropogenic injuries observed in humpback dolphins could be due to the fatality of severe injuries, hence individuals that did not survive such interactions were not observable. The prevalence of anthropogenic injuries reported in the present study serves as a conservative indicator level of the individuals that have survived anthropogenic interactions.

In this study, only the photographs of the mid-flank (i.e., dorsal fin and the flank area ventral to the dorsal fin) was used for injuries analysis as these areas were most visible when the animals surfaced, enabling the photographs of the dorsal fin to be taken for photo-identification purposes. However, it is acknowledged that anthropogenic injuries may occur on other sections of the body such as the tail flukes, head and caudal peduncle (Van Bressem et al., 2018; Wang et al., 2018). As there were not enough photographs of other body sections particularly for Irrawaddy dolphins due to their surfacing behaviour, only dorsal fin photographs were analyzed in the present study and are likely to have underestimated the prevalence of external anthropogenic injuries on those animals.

The two offshore humpback dolphins with single, deep indentation on their bodies or dorsal fin that were sighted once in 2013 in the South Coastal survey block in Matang were first catalogued in 2011 in Langkawi, which is another cetacean research project site approximately 200 km north of Matang. Both dolphins are known to be females with offspring (L. Ponnampalam & Z.Y. Teoh, unpublished data). The dolphins' injuries were already healed when the photographs were first taken in Langkawi. Due to the movement of some offshore humpback dolphin individuals in and out of the study area in Matang, it is uncertain where these two individuals acquired the injuries from anthropogenic interactions. These offshore individuals may have been exposed to higher risk of anthropogenic interactions due to their long range movement in the busy Strait of Malacca. Both dolphins were subsequently recorded in Langkawi waters again in 2016 and 2018, respectively (L. Ponnampalam & Z.Y. Teoh, unpublished data). This suggests that such major injuries are survivable by some individuals. According to Wells et al. (2008), propeller injuries that only affect the soft tissue were often survivable and some dolphins with the amputations of the distal ends of fins were observed to survive and continue to reproduce. Out of all the humpback dolphins catalogued in Matang, only one individual sighted inshore was observed to have acquired new linear dorsal fin mutilation within the study period (Figure 7.3). The exact cause of the injury and the location where the injury was acquired could not be determined, as the individual was not sighted with unhealed injury at any time between the before and after the mutilation. This linear mutilation appears to be likely from interaction with either fishing line, fishing net or a single propeller cut (Luksenburg, 2014). The healing appeared to have happened fairly quickly, as the injury and full healing of the injury occurred within the span of 14 months between the two sightings. A study on common bottlenose dolphins in Sarasota Bay, Florida by Greenfield et al., (2021) found that dolphins had fewer preferred associates immediately after the anthropogenic injuries, and started to return to normal association levels after two years. Long-term research is needed to ascertain if these mutilations could affect subsequent dolphin ranging patterns, social structure and behavioural responses to human activities in Matang.

While humpback dolphin studies elsewhere reported higher prevalence of possible anthropogenic injuries, direct comparison could not be made as there were differences in the criteria of injuries evaluation and also in the number of body sections that were taken into account for analyses (e.g., Smith et al., 2015; Wang et al., 2017a). In Bangladesh, 15.0% (n = 61) of humpback dolphins had injuries that were almost certainly resultant from fishing gear entanglement and 8.6% (n = 35) of the individuals there had marks that were possibly caused by fishing gear entanglement (Smith et al., 2015). The study on small population of Taiwanese humpback dolphin individuals (*S. c. taiwanensis*) by Wang et al. (2017a) which examined injuries on the head, mid- and tail body sections and on both sides of body, reported the highest proportion of humpback dolphin with injuries at 57.7% of the individuals (n = 45). In the Pearl River Estuary, Hong Kong, at least 8.9% of humpback dolphins survived anthropogenic interactions, whereby 2.3% of the animals (n = 5) bore net scars and 2.8% (n = 6) had propeller cuts on their bodies (Jefferson, 2000). The prevalence of significant fishery-related injuries on the rostrum, dorsal fin and body of humpback dolphins in Xiamen, China was reported to be 11.7% (n = 7) by Wang et al. (2018).

While the prevalence of injuries in dolphins in Matang that survived may appear to be lower than the prevalence in other populations, other more severe anthropogenic interactions that lead to fatal injuries in the dolphins here could not be determined in the present study. Additionally, the exact type of fishing gears that caused these injuries could not be determined, as there was no direct observation of attached fishing gear on the injured dolphins throughout this study. Direct observations of the fishing gears that have caused the injuries in these survivors are very rare, especially for small populations that are declining (Wang & Araújo-Wang, 2017). To date, only a few cases of some fishing gears that were still attached on affected humpback dolphin individuals in Taiwan and Thailand are known and reported in literature (Jutapruet et al., 2015; Wang & Araújo-Wang, 2017).

The prevalence of anthropogenic injuries in coastal Irrawaddy dolphins is less understood than humpback dolphins, as there appears to be very limited published studies on the subject matter. Dorsal fin disfigurements were recorded in some of the coastal populations of Irrawaddy dolphins such as in Bangpakong Estuary, Thailand and Banten Bay, Indonesia, but the prevalence rates and the source of injuries were not investigated (Khalifa et al., 2014; Tongnunui et al., 2011). Injury assessments were conducted by Thiele (2010) on photographs of Australian snubfin dolphins (*O. heinsohni*) in Roebuck Bay. In that study, 41.9% of snubfin dolphins had injuries indicative of fishing gear, 9.6% with injuries indicative of vessel strikes, and 11.2% with both fishing gears and vessel strike injuries. Thirty-nine Irrawaddy dolphin individuals in Matang had linear mutilation injuries (see Table 7.6), similar to fishing gear interaction injuries reported in Thiele (2010).

Anthropogenic injuries in dolphins that survived may have reduced the animals' health, survivorship or reproductive capabilities to a certain extent (Wang et al., 2017a). Vessel collision and propeller strike have been reported to cause mortalities of some Irrawaddy dolphins in Indonesia, Laos and India (Van Waerebeek et al., 2007). At least two juvenile Irrawaddy dolphins were reported to die as a result of injuries due to vessel collision in Mahakam River, Indonesia (Kreb & Rahadi, 2004). In Hong Kong, vessel collisions, propeller strike and net entanglement was reported as major causes of death for humpback dolphins in Hong Kong (Jefferson, 2000; Parsons & Jefferson, 2000; Würsig et al., 2016). For riverine populations of Irrawaddy dolphins, Kreb & Budiono

(2005b) reported that 74% of dolphin deaths (n = 38) between 1995 and 2001 in the Mahakam River, Indonesia were due to entanglement in gillnets with large mesh sizes of 7.5-17.5 cm, but that there were also reports of fishers successfully releasing the Irrawaddy dolphins from the gillnet entanglement. In Matang, one humpback dolphin carcass and three Irrawaddy dolphin carcasses were encountered during the study period, but the presence of external pre-mortem injuries could not be determined due to the carcasses' advanced stages of decomposition. Additionally, cause of death could not be determined due to lack of post-mortem investigation by marine veterinarians. Long-term and systematic frequent collection of cetacean carcasses and post-mortem by experienced veterinarians are recommended to further investigate the causes of deaths in cetaceans in Matang.

In Matang, the prevalence of probable intraspecific injuries appeared to be high at 82.8% for humpback dolphins and 69.7% for Irrawaddy dolphins. This is expected, as they are group-living animals and occasionally display aggression behaviour that could result in injuries. In particular, Irrawaddy dolphin individuals that display herding behaviour had more tooth rakes. Multiple tooth-rake injuries on Australian humpback dolphins also result in open wounds than penetrate the dermis but would eventually heal (Brown et al., 2016).

Shark bite injuries were also observed in Irrawaddy dolphins. In Australia, Australian humpback and snubfin dolphins have high prevalence of shark bites that were mostly from tiger shark (Smith et al., 2018) and other large carcharhinid sharks. Bull shark attacks that result in mortalities were recorded in this freshwater subpopulation of Irrawaddy dolphins in Chilika Lagoon, India, whereby most of the shark bites targetted the ventral side of the dolphins (Khan et al., 2011). Large carcharhinid sharks that could cause such injuries to dolphins and were recorded in the trawling zone in Larut Matang, Perak are Tiger shark (*Galeocerdo cuvier*) and Bull shark (*Carcharhinus leucas*) (Abd. Haris Hilmi et al., 2017).

7.2.3 Bycatch risk assessment

Bycatch risk assessment allows identification of locations to be prioritized for bycatch mitigation efforts based on currently available data. By integrating data from interviews with local fishers and boat-based surveys, these ByRA outputs can identify particular species, fishing gears and locations with high interaction rates (Verutes et al., 2020) and can be used to guide fisheries management planning and enforcement. The estuarine waters particularly the Northern Estuarine subregion off Kuala Sangga Besar and Kuala Larut were identified to have highest bycatch risk to humpback dolphins (Figure 7.5). Additionally, the South Coastal subregion and the estuarine and coastal waters off Kuala Larut are areas with the highest bycatch risk to Irrawaddy dolphins.

These identified areas of concern for bycatch were mostly due to the intensity of operating nets (i.e., gillnets, driftnets and trammel nets) that were associated with greater exposure, and trawl nets that were associated with greater consequences for mortality. The North Estuarine subregion encompassing the waters off Kuala Gula, Kuala Sangga Besar and Kuala Larut also have the presence of four stressors (i.e., nets, trawls, bag nets, push nets) which are used throughout the year in Matang. While new fishing zoning effective from June 2014 regulated that trawlers in Perak can only operate beyond eight nautical miles from shore (Department of Fisheries Malaysia, 2015), there were single and paired trawlers that were observed to be operating less than eight nautical miles from shore, causing exposure and thus bycatch risk of inshore dolphins to trawling activity. The exposure of dolphins to bycatch is also increased due to lack of cetacean bycatch management strategies during the survey period. Bycatch mitigation efforts in Matang should focus on strategies to reduce entanglement in gillnets and trawls nets in the highest bycatch risk areas that target the prey species of dolphins.

In order to improve data quality used in ByRA particularly on bycatch/stranding data (Table 7.8), mapping habitat suitability using maximum entropy modelling, improving interview survey effort and establishment of an effective stranding network to retrieve dolphin carcasses and necropsies of stranded animals in Matang by qualified veterinarians to determine the causes of death would be helpful to reduce the uncertainty level. This can also be complemented by having electronic monitoring systems or onboard observers to monitor marine mammal bycatch occurrences. Nevertheless, ByRA is a useful tool to raise concerns and prioritize bycatch mitigation efforts, especially when direct bycatch observation are hard to come by.

CHAPTER 8: GENERAL DISCUSSION

8.1 General ecology of coastal delphinids in Matang

Prior to this study, very little was known about the ecology of coastal delphinids in Matang, with only the presence of dolphins recorded from historical field observations and anecdotal accounts. Studying wild cetaceans in their natural environment can be inherently difficult as they spend a substantial amount of time underwater beneath the water surface and they are highly mobile, ranging over large distances (Ballance, 2018). This is especially true for coastal delphinids in Matang's waters, where Irrawaddy dolphins are generally evasive and less frequently seen even by local fishers (Chapter 7), and some humpback dolphin individuals are likely to range over large distances and move in and out of the study area (Chapter 6). With boat-based surveys conducted between 2013 and 2016 and interview surveys conducted between 2014 and 2017, this study has improved our understanding about the ecology of humpback dolphins and Irrawaddy dolphins in Matang, and established some important baseline information that could be used to prioritize conservation and management efforts.

Differences in habitat use and dietary divergence are some of the most widely adopted strategies by sympatric delphinids (Bearzi, 2005; Loizaga de Castro et al., 2017). The core areas of Irrawaddy dolphins and humpback dolphins overlapped minimally (Chapter 6), suggesting some degree of spatial separation between the two species. Habitat partitioning between Irrawaddy dolphins and humpback dolphins are likely attributed to several factors, including (but not limited to) the distribution and abundance of preferred prey resources, the dynamics of species interactions, differential responses to anthropogenic activities, and species dominance.

Coastal delphinids are also known to exhibit behavioural plasticity by employing different ethological adaptations such as feeding strategies to optimize acquisition of the types of prey found in their local environments (dos Santos et al., 2007; Finn et al., 2009; Wilson et al., 2017). In the present study, the inshore humpback dolphins primarily preyed on estuarine species such as sciaenid croakers and ariid catfishes (particularly Sagor catfish, *Hexanematichthys sagor*), similar to bottom-dwelling species reported to be prey of humpback dolphins in Hong Kong (Barros et al., 2004). While the prey species of offshore humpback dolphins were not confirmed in the present study due to lack of feeding observations and stomach contents, these offshore individuals were not observed to visit the estuaries and thus are likely to either prey on other species (possibly cephalopods based on presence of squid ink) that are abundant in the farther coastal waters, or not actively using the offshore waters of Matang as feeding grounds. The diet of common bottlenose dolphins (*Tursiops truncatus*) that occur farther offshore off Hong Kong were reported to include cephalopods, and are not likely to compete with resident humpback dolphins that occur more inshore (Barros et al., 2000). Stable isotope studies may reveal if there are significant differences in isotopic ratios between inshore and offshore dolphins (Díaz-Gamboa et al., 2018).

The inshore humpback dolphins exhibit higher inter-annual site fidelity and utilize the estuaries as feeding and nursery grounds (Chapter 5), which may be attributed to the proximity to productive estuaries that provide shelter and higher feeding opportunities. Food availability is one of the key drivers that influence the choice of foraging habitat by humpback dolphins (Jefferson, 2000; Lin et al., 2020). The inshore individuals are likely to maximize their feeding opportunities by exploiting the tidal movement of their abundant estuarine prey. The movement of inshore individuals closer to river mouths particularly during high tide indicate possible familiarity of the resident individuals with the aggregation of their estuarine prey in their habitat (Parsons, 2004). Passive listening for soniferous prey has also been hypothesized as a beneficial foraging strategy employed by some delphinids elsewhere, such as humpback dolphins in Hong Kong and South

Africa (Barros et al., 2004; Barros & Cockroft, 1999) and bottlenose dolphins (Barros & Wells, 1998; McCabe et al., 2010). Passive listening may also be employed by inshore humpback dolphins in Matang when foraging for sciaenid croakers and ariid catfishes, that are known to be soniferous and abundant in Matang (Kuit et al., 2019a). Bottlenose dolphins in Sarasota Bay, Florida are reported to change their travel direction significantly towards the source of the fish sounds that were played, which may enable them to identify the type, number, size and location of the soniferous prey, before subsequently tracking the prey by using echolocation (Gannon et al., 2005).

Female dolphins may prefer to raise calves in larger nursery groups in the shallow estuaries to avoid harassment from males seeking mating opportunities (Weir et al., 2008). The sheltered estuaries also reduce predation risk from large carcharhinid sharks such as tiger sharks and bull sharks in the offshore waters (Abd. Haris Hilmi et al., 2017) that were presumed to cause shark bite injuries in two Irrawaddy dolphins observed during surveys (Chapter 8). Besides predator avoidance, coastal delphinids may also adapt their foraging techniques to avoid potentially lethal injuries while hunting for prey that are armed with defense mechanisms such as sharp spines and barbs (Parra, 2007; Ronje et al., 2017). The decapitation of catfishes by inshore humpback dolphins, and to a smaller degree by Irrawaddy dolphins in the present study, appear to be a foraging technique to hunt for the abundant catfish while avoiding injuries from ingesting the thick and sharp spines. This prey handling technique of decapitating catfish heads was also reported in humpback dolphins in Kuala Perlis (Teoh, 2018) and in common bottlenose dolphins (*Tursiops truncatus*) in the northern Gulf of Mexico (Ronje et al., 2017). In northeast Queensland, Australian humpback dolphins (*S. sahulensis*) were observed carrying sponge on their rostrum, which may be used as protection when foraging in the sea bottom for bottom-dwelling species that may have spines or barbs (Parra, 2007). Remains of catfish spines were also retrieved from the stomach content of a humpback dolphin carcass in Matang (Kuit et al., 2015). The lengths of the catfish spines found were shorter than what would have been expected from the larger catfishes that were partially consumed by humpback dolphins in Matang (Kuit et al., 2015), but it is undetermined whether the spines caused perforations that may have led to its death, as the carcass was found in an advanced stage of decomposition. Studies in bottlenose dolphins in Sarasota Bay, Florida have reported that there may be maternal transmission of foraging habits within the community from adult females to calves through social learning (Rossman et al., 2015; Weiss, 2006). Long-term research in Matang may reveal if the calves of the resident inshore individuals eventually share similar ranging patterns as the adults and adopted the practice of decapitation of their prey after becoming independent.

The dominance structure of co-existing delphinid species in inshore waters appears to differ between study sites. For example, Irrawaddy dolphins in Kuching Bay, East Malaysia occur closer to the shore and enter rivers more frequently (Minton et al., 2013), in contrast to the findings of the present study. Irrawaddy dolphins, being the more abundant dolphin species in Matang, appear to spread out in smaller groups throughout the coastal waters, which may be adaptations to minimize intraspecific competition with other Irrawaddy dolphins in the study area, and avoid inshore humpback dolphins that frequently move between the five major estuaries (Chapter 6). This is in accordance with the findings of other studies on coastal delphinids elsewhere (Parra et al., 2011; Wang et al., 2016). There were behavioural observations of Irrawaddy dolphins swimming away and leaving the area when humpback dolphins entered to feed or forage in the same area (Kuit et al., 2019a). Similarly, Australian snubfin dolphins (*O. heinsohni*) were reported to swim away from Australian humpback dolphins that are more dominant (Parra, 2006). Irrawaddy dolphins are known to be an evasive species that generally avoid boats in other study sites (Hashim & Jaaman, 2011; Kreb & Rahadi, 2004; Ponnampalam et al., 2013; Smith, 2018). This may partly explain why Irrawaddy dolphins in Matang appear to occur throughout the coastal waters but avoid the rivers and estuaries (Chapter 5); these are areas with high vessel traffic as fishing boats frequently move in and out of the villages to reach their fishing areas and dolphin-watching tour boats may be present. Hence, these observations indicate that Irrawaddy dolphins may avoid the core areas of humpback dolphins in the estuaries and rivers due to either one or a combination of the following reasons: presence of the presumably more dominant humpback dolphins and of high vessel traffic.

The present study has provided the first estimates of dolphin abundances in Matang, and the largest estimate of coastal Irrawaddy dolphins in the Southeast Asian region, which suggests that Matang holds a significant number of dolphins. This finding may be partially attributed to the large and extensive study area surveyed (c. 1152 km^2) in the present study, compared to other sites in Malaysia with similar intensive survey effort but with smaller survey area that are less than 500 km^2 (Hines et al., 2015b; Minton et al., 2013). Throughout the known ranges of humpback dolphins and Irrawaddy dolphins in Southeast Asia, the coverage of previous research efforts are patchy, and isolated on relatively small coastal areas (Hines et al., 2015a). The present study emphasizes the importance of extending survey areas to the known depth limits of the focal species and covering as much coastline as possible when resources permit, in order to have good coverage and more accurate estimates of abundance and size of ranging areas.

A large proportion of the coastlines in Southeast Asia has not yet been surveyed for cetaceans (Kaschner et al., 2012), and huge gaps remain in understanding the ecology and conservation status of cetaceans. Although abundance estimates are available in some of these study sites in Southeast Asia, most sites have not been surveyed frequently enough to allow estimation of abundance trends, which are fundamental to conservation yet difficult to be achieved with limited capacity and extensive data gaps. In view of this, research and conservation should be undertaken concurrently, especially for threatened marine mammals, as there may be insufficient time to wait for conservation actions to be implemented after collection of comprehensive scientific information (Ponnampalam et al., 2015).

8.2 Threats to humpback dolphins and Irrawaddy dolphins in Matang

As coastal delphinids that live in close proximity to anthropogenic activities, humpback dolphins and Irrawaddy dolphins throughout their range face various threats that could threaten their survival (Jackson-Ricketts, 2017; Jefferson et al., 2017; Minton et al., 2017). While some anthropogenic threats such as entanglements and boat strikes cause direct injuries or even immediate death of cetaceans, others may slowly affect their health or cause changes in behaviour, social structure and distribution that have considerable consequences to their welfare (Hawkins et al., 2008; Nicol et al., 2020).

Although no previous abundance estimates exist for comparison to detect trends in abundance, interview surveys revealed that most fishers in Matang perceived a decline in cetacean abundance (Chapter 7). Mortalities of cetaceans have been recorded every year during the surveys in 2013-2016, and the death of a resident inshore female individual (LDF-039) that was pregnant with a full-term fetus was recorded in 2017 (Chapter 6). Deaths of breeding individuals in a small population would take a long time for population recovery, due to the long generation length (the turnover rate of breeding individuals) of 25 years for humpback dolphins (Jefferson et al., 2017) and 20 years for Irrawaddy dolphins (Minton et al., 2017). Approximately 17% of humpback dolphins and 29% of Irrawaddy dolphins had anthropogenic-related injuries that are possibly caused by interactions with fishing gear, propeller strike or marine debris (Chapter 7). Individuals with anthropogenic injuries on certain parts of their body may also have higher risks of future entanglements (Wang et al., 2017a).

While inshore humpback dolphins in Matang's estuarine habitats may have increased foraging opportunities from the aggregation of estuarine prey, these dolphins are also exposed to increasing threats from anthropogenic activities such as risk of entanglement in fishing gears that target similar species, competition for prey resources, high vessel traffic from fishing vessels and tour boats from the fishing villages, pollution and habitat degradation. Similarly, humpback dolphins in Zhanjiang Estuary and Pearl River Estuary in China were reported to prefer areas with higher fish abundance, even if it is riskier with higher vessel traffic, noisier and highly polluted (Lin et al., 2020; Pine et al., 2017b). However, the preference of humpback dolphins for estuarine habitats is also disadvantageous due to greater exposure to anthropogenic threats which are great concern for long term viability of the dolphins (discussed further below).

This study showed that bycatch in nets and trawl nets are highly likely to be one of the main threats to dolphins in Matang. The bycatch risk assessment revealed that a large proportion of the study area posed intermediate to high bycatch risk to both species particularly from gillnets/driftnets/trammel nets operating inshore and trawl nets operating offshore (Chapter 7). Observation of gillnet depredation by humpback dolphins and gillnet fishers reporting gear damage by cetaceans (Chapter 7) indicate competition for the same food resources between the two parties in Matang, which increases the dolphins' risks of entanglements, cause fisheries-related injuries or even deaths from suffocation (Chapter 7). With intensive fishing activities in Matang, the issue of overfishing, which is evident in Malaysia (Ahmad et al., 2003; Chong et al., 2010b), can cause prey depletion that would only increase competition and fisheries interactions between fishers and dolphins. Poor body conditions which indicates nutritional stress, similar to observations in humpback dolphins in Taiwan by Slooten et al. (2013), were observed in some humpback dolphins in Matang. Compared to threats such as bycatch and boat strikes that usually garner more attention, such indicators of poor health from competition with humans represents a pervasive yet frequently overlooked issue that deserves further attention.

Habitat degradation, particularly the rivers that are getting shallower, was the reason cited by fishers to explain why humpback dolphins no longer swim upriver right in front of their fishing villages (Chapter 7). During the first boat reconnaissance surveys in July 2013, humpback dolphins were observed once upriver in front of the fishing village in Kuala Sepetang, and were less frequently observed upriver in the following years. This decline in upriver occurrences may be due to increased fishing boats near to fishing villages, causing increased underwater noise particularly in shallower depths (Dey et al., 2019). Dolphins in Matang may also be threatened by untrained tour operators conducting dolphin-watching tourism that approached these animals abruptly and did not maintain a safe distance. Dolphin-watching in developing countries is often unregulated and poses high risks of propeller cuts and boat strikes to cetaceans (Mustika et al., 2015, 2016)

Coastal water pollution may also pose threats to dolphins that occur closer inshore. Runoffs from palm oil plantations, discharge of effluents from shrimp farms and fish cages, fuel leakage, marine litter, and untreated sewage were cited as major pollution sources by fishers in Matang (Chapter 7). These fisher observations were supported by studies showing that the Matang mangrove waterways are reportedly used as dumping sites for solid wastes and sewage in addition to being polluted by pesticides and herbicides (Chong, 2006; Ghaderpour et al., 2014). Cutaneous nodules that was reported by Van Bressem et al. (2014) as an emerging skin disease in other populations of Irrawaddy dolphins, have been observed in Matang (Kuit et al., 2019a). Presence of skin diseases suggests that dolphins in Matang may be living in a compromised environment. Some skin diseases in dolphins were reported to be possibly linked to prophylactic antibiotics that are heavily used in aquaculture such as shrimp farms (Van Bressem et al., 2009). Given that the estuaries of Kuala Sangga and Kuala Gula are crowded with fish and shrimp farms, future studies should look for the presence of such antibiotics and other chemicals that may have impacts on the health of the delphinids.

From the synthesis of the findings of the present study, the distribution and interactions of Irrawaddy dolphins and humpback dolphins with their habitat in Matang are summarized in a schematic diagram in Figure 8.1. Although Matang is internationally designated as an IUCN Important Marine Mammal Area (IMMA), Matang is currently not afforded protection as a marine protected area, as existing marine parks in Malaysia are mostly established to conserve islands with coral reefs. With the current fishing within zone A (equivalent to approximately 1.8 to 14.8 km from the shore) in the state of Perak that allows gillnets, driftnets and trammel nets to operate, coupled with the lack of specific mitigation measures to significantly reduce cetacean bycatch in Malaysia, these fishing gears continue to pose deadly entanglement risks to coastal delphinids in Matang and throughout Malaysia. As such, priority for dolphin conservation should be given especially to the smaller number of inshore humpback dolphins that have high reliance on the estuaries of Matang, which are frequently exposed to high bycatch risks and vessel traffic. Bycatch mitigation efforts should target working with gillnet/driftnet/trammel net fishers who fish in areas with highest bycatch risk, particularly off Kuala Sangga Besar and Kuala Larut (Chapter 7).

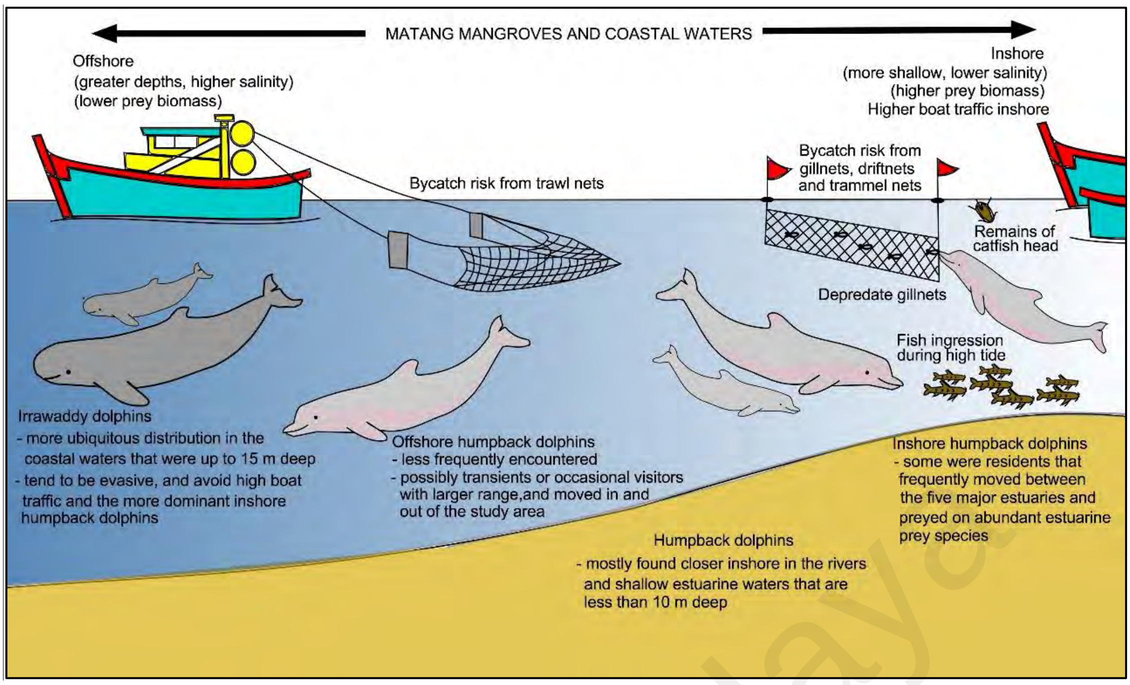

Figure 8.1: Schematic diagram (not to scale) of distribution and interactions between Irrawaddy dolphins and humpback dolphins (both inshore and offshore) with their habitat, and bycatch risk from fishing activities in Matang's waters

8.3 Limitations of the present study and suggestions for improvement

Although valuable ecological information has been revealed about the abundance estimates, distribution, habitat characteristics, habitat use, movement, ranging patterns, and human-dolphin interactions of humpback dolphins and Irrawaddy dolphins in Matang, there were constraints and limitations in this study that serve to provide suggestions for future improvement. The limitations of this study and suggestions for improvement are elaborated as follow:

1. Due to logistical constraints, the visual observations on boat-based surveys were limited to daylight hours (mostly between 0800h to 1800h). The nocturnal habitat use of dolphins in Matang was not investigated in the present study, and I could not determine if there are intraspecific and interspecific temporal partitioning (e.g., foraging in the estuaries at night). While visual observation at night would be difficult to detect dolphins and probably unsafe to navigate in offshore waters,

passive acoustics could be considered by attaching acoustic recorders on the cockle poles on the river mouths to detect the presence of dolphins at night.

2. Photo-identification recaptures of Irrawaddy dolphins were insufficient for robust mark-recapture estimates and individual ranging patterns. Due to their evasive behaviour and unpredictable surfacing patterns, Irrawaddy dolphins were difficult to photograph (i.e., not every individual in the group can be captured) and only a small percentage of photographs of dorsal fins of Irrawaddy dolphins met the filtering criteria for photo quality and distinctiveness. With the lack of distinctiveness in their dorsal fin (i.e., not as distinct as humpback dolphins with pigmentation patterns to match) and a relatively large number of individuals (~763) in a considerably large study area, there were many similar-looking dorsal fins that could not be distinguished from one other especially in lower photo quality when taken from a far distance. Line-transect distance sampling was used instead to estimate the abundance of Irrawaddy dolphins. Attempts to have enough photo-identification recaptures of these generally evasive Irrawaddy dolphins in the whole study area in Matang would require more funding to have more surveys and extend the survey duration to follow the groups longer and attempt to photograph them when they are less evasive, such as during herding and socializing behaviour.
3. Robust abundance estimation of humpback dolphins via line-transect distance sampling could not be conducted for comparison with mark-recapture due to the insufficient on-effort sightings as a result of their distribution patterns in the estuaries. Photo-identification was used instead to estimate the abundance of humpback dolphins via mark-recapture.
4. Despite best efforts to photograph both sides of dorsal fins of every individual, photo-identification of some of the humpback dolphin individuals in the group

may have been missed. Recaptures of distinctive humpback dolphins individuals were slightly higher on the LDFs, compared to the RDFs. The success of capturing good photographs of dorsal fins depends on many factors such as the behaviour of the dolphins (e.g., travelling group with regular surfacing are easier to be photographed than evasive groups), the group size (e.g., larger groups are more difficult), the tightness of the group (e.g., widely spread out groups are more difficult), the time spent with the dolphin groups (e.g., longer time spent with the group results in more photographs), the weather conditions (e.g., backlit photographs and choppy sea are not ideal), the photographic equipment, the level of experience of the photographer to anticipate dolphins surfacing and quick reflex, and the ability of the boat skippers to navigate around the dolphin group and position the research vessel in the best spots. Attempts were made to photograph both sides of dorsal fins as much as possible to allow the dorsal fin side with higher recaptures of distinctive individuals to be used for individual movement analysis, and complemented with the other side if needed.

5. It is likely that the present study area, despite being considerably large at 1152 km^2, did not cover the entire home range of these long-living and wide-ranging dolphins in Matang. As funding and time constraints often limits the size of the survey area that can be covered by research teams (Nekolny et al., 2017), the estimation of the range of dolphins in Matang could be improved by expanding the northern and southern boundary of the present study (e.g., Kuala Kurau to Lumut), if resources permit.
6. Due to the limitation in resources, the transect lines in the large coastal survey blocks were spaced at 3.7 km to allow completion of all transect lines within 10 days during each survey. This study could have benefited with spacing of transect lines similar to those in the estuarine survey blocks (i.e., spaced at 1.85 km), but

this would have required more resources and longer survey period which are beyond the financial support of this study. Future research with more resources could consider allocating higher search effort in the coastal survey blocks by adding more transect lines.

7. Although the initial plan was to have boat-based surveys every two months, there were three surveys that were spaced between four to six months due to unfavourable weather and a capsize incident. I recognize there may be some important observations that were not captured in months when surveys were not able to be conducted.
8. The sex differences in habitat use of humpback dolphins was not examined in the present study due to the difficulty in determining the sex of the individuals without genetic confirmation, lack of sexual dimorphism and possible allomaternal care by certain dolphins. Given enough funding and the permit to conduct biopsy sampling is obtained, biopsy to confirm the sex of individuals is recommended.
9. The number of interviews conducted with fishers did not reach the recommended sample size of 338 for statistically representative data due to difficulty in getting enough fishers who were willing to be interviewed. There were also insufficient interviews for purse seiners that are mostly manned by foreign crew, due to language barriers and reluctance of the purse seine vessel owners to allow their crew to be interviewed. Hence, bycatch in purse seines could not be determined. Future interview survey efforts should focus on purse seine vessel owners using a shorter and concise interview, and arrange for translators who are well-versed in Southeast Asian languages.
10. The reliability of bycatch data from interviews is subjected to biased responses and memory decay, thus bycatch rates were likely under-reported in this study. It is recommended for the authorities to establish a dedicated observer programme

to monitor cetacean bycatch. If possible, a dedicated observer programme to monitor bycatch is recommended. Fishers should also be encouraged to report their bycatch with the assurance by relevant government officers that there will not be any negative consequences or lawful actions taken against them.

11. The prevalence of anthropogenic injuries in the present study was limited to the analysis of photographs of the mid-flank (i.e., dorsal fin and the flank area below the dorsal fin) as these areas were most visible when the dolphins surfaced.

8.4 Recommendations for future studies

The present ecological study has improved our understanding of the ecology of humpback dolphins and Irrawaddy dolphins in Matang, but has also opened up a vast scope for further investigation. Further research to enhance our ecological knowledge and for conservation dolphins in Matang are as follows:

1) Long-term monitoring surveys should be conducted to measure population trends, to allow better estimation of survival rates, to determine if their survival is being negatively impacted by anthropogenic activities, and to detect possible shifts in habitat use. Continued line transect distance sampling for Irrawaddy dolphins and photo-identification mark-recapture for humpback dolphins are recommended to assess annual abundance, where resources permit.
2) Passive acoustic monitoring (PAM) methods may also be considered for future population monitoring efforts of both species, and to investigate the movement of dolphins at night when visual surveys are not feasible.
3) Photo-identification surveys should be expanded beyond the southern boundary of the study area (to approximately 30 km south to Lumut) to catalogue more individuals and determine if they remain in that area or move in and out of the present study area. The photo-identification database should also be thoroughly

matched across different study sites in the Strait of Malacca with active ongoing research (e.g., Langkawi, Kuala Perlis) to shed light on the extent of the range of these offshore humpback dolphin individuals.

4) Feeding ecology studies are recommended for the coastal delphinids in Matang. This includes the recovery of stomach contents from carcasses of humpback dolphins and Irrawaddy dolphins to allow identification of prey items, and stable isotope analysis on dolphin skin and teeth samples to determine the isotopic signatures of prey of dolphins in Matang. Detailed studies on the diversity, distribution and abundance of fish, cephalopods and shrimps particularly in the offshore waters are also recommended to elucidate availability of potential prey in the coastal waters of Matang and to better understand niche separation in the two sympatric species of coastal delphinids.
5) Biopsy sampling for genetic studies and determination of sex, if permission to collect skin biopsy samples was obtained. This will enable better understanding of possible influence of sex and kinship on ranging patterns of dolphins in Matang. This may be further complemented with social structure study to better understand the social organization of both species.
6) Exploration of the efficiency of low-cost bycatch mitigation methods particularly in gillnets, driftnets and trammel nets, in reducing bycatch of dolphins without significantly affecting the catch of fishers.

8.5 Recommendations for conservation management

Since Matang is recognized as an IUCN IMMA and anthropogenic threats continue unabated, the call to conservation actions such as mitigating bycatch, reducing pollution, regulating dolphin-watching tourism, water quality monitoring and cetacean health assessments are justified (Kuit et al., 2019a). Taking into consideration the local socio-cultural and legal contexts of the study area, and by working with relevant local stakeholders such as the local management authorities, fishers and tour operators, the following conservation actions are recommended.

1. The government and private developers should avoid large-scale coastal modification near identified core habitats of cetaceans particularly in Kuala Sangga Besar and Kuala Larut (north strata). Such coastal modifications include coastal shrimp farming, coastal reclamation, and clearing of fringing mangrove forests in Matang;
2. The government to implement and enforce fisheries regulation to restrict the use of high risk bycatch gears especially in areas of high bycatch risk. ByRA has identified highest bycatch risk of dolphins in gillnets, driftnets and trammel nets particularly off Kuala Sangga Besar, Kuala Larut and Kuala Gula, and inside the riverine waterways, and in trawls in the farther coastal waters. While prohibited areas for fishing may be most effective for bycatch mitigation, such approach may be least popular to local fishers since fishing may be their only source of livelihood. Gear prohibition in high bycatch risk areas may be refined with restrictions on mesh size, net length and net soak time;
3. The government in collaboration with relevant research institutions and fishers to explore the use of cost-effective bycatch mitigation methods such as the use of recycled bottles as reported in FAO (2018) or acrylic glass spheres as reported in Kratzer et al. (2020) to increase the acoustic reflectivity of gillnets that are deployed inshore in the cetacean hotspot areas. Some gillnetters in Matang who had dolphin entanglements in the past expressed interest in participating in inexpensive bycatch mitigation as long as their catch will not be greatly affected;
4. The government in collaboration with NGOs to lead the initiatives to regulate dolphin-watching tourism among tour operators and implement slow zones in cetacean hotspot areas particularly in the Sangga Besar River, to reduce the risk

of injuries and deaths of cetaceans from boat collision. Tour operators need to be trained on how to approach dolphins carefully without disrupting the natural behaviour of the animals;

5. The government in collaboration with scientists must continue to diligently and systematically monitor water quality in cetacean habitat and the prevalence of skin diseases among cetaceans in Matang. Wherever possible, tissue samples from dolphin carcasses with skin diseases should be analyzed for histopathology to identify possible sources of toxic contaminants such as from the sewage, agricultural run-offs and finfish culture, of which those issues should be managed accordingly; and
6. The government in collaboration with NGOs should increase public awareness among local villagers (especially fishers) to reduce the use of single-use/disposable plastics and promote proper disposal of wastes to reduce habitat pollution and the risk of accidental ingestion of marine debris by cetaceans.

8.6 Conclusions

This study is the first ecological study on the Indo-Pacific humpback dolphins and Irrawaddy dolphins in the coastal waters of Matang, Perak, Peninsular Malaysia. The present study has achieved all four objectives that were set, and has also provided important ecological baseline data for species protection and habitat management. The study has provided the first estimates of abundance of coastal delphinids in Matang. Estimates of abundance totaled 763 Irrawaddy dolphins (CV = 13.3%; 95% CI = 588-990) via line-transect distance sampling from four sampling strata. The annual abundance estimates of humpback dolphins via mark-recapture fluctuated from 138 (95% CI = 118-162) in year 2013-2014 to 171 (95% CI = 148-208) in 2014-2015, to 81 (95% CI = 67-98) in 2015-2016, likely due to the presence of offshore individuals that moved in and out of the study area. The estuarine strata were inhabited by 68 (95% CI = 63-73) inshore humpback dolphins in 2013-2014 to 87 (95% CI = 78-97) dolphins in 2014-2015, and to 81 (95% CI = 71-93) dolphins in 2015-2016. The humpback dolphins exhibited a clustered distribution and were mostly found closer inshore in the rivers and shallow estuarine waters that are less than 10 m deep. The Irrawaddy dolphin had a relatively homogenous distribution and were mostly found in farther coastal waters that are less than 15 m deep. The core areas of feeding and nursery grounds of humpback dolphins were mainly in the estuaries of Kuala Sangga Besar, Kuala Larut and Kuala Jarum Mas. As for Irrawaddy dolphins, the core areas of feeding and nursery grounds were mainly around the coastal waters off Kuala Larut and Kuala Trong. The inshore resident humpback dolphin individuals (occurring within 7 km from shore) frequently moved between the five major estuaries and foraged for abundant estuarine prey such as sciaenid croakers and ariid catfishes, especially when fish ingress into the mudflats during high tide. The study also revealed the presence of offshore humpback dolphin groups (possibly occasional visitors or transients) between 7 and 21 km from shore that were less frequently encountered. The offshore humpback dolphins were likely to have a wide range and moved in and out of the study area. The individual MCP ranges of 13 inshore resident humpback dolphins overlapped considerably in the major estuaries, with mean MCP range of 217.4 ± 65.2 km^2. This ranging pattern in the estuaries was most likely linked to their use of the productive estuarine habitats by mostly nursing females for feeding by optimizing the exploitation of their estuarine prey aggregations that is tidal-driven. The ranging area of inshore humpback dolphins included all five major estuaries, with core area encompassing the estuaries of Kuala Sangga Besar, Kuala Larut and Kuala Jarum Mas. The ranging area and core areas of offshore humpback dolphins were comprised of the area approximately 16 km off Kuala Larut and 8 km off Pantai Remis. The ranging area of Irrawaddy dolphins encompassed most of the study area, with core areas in the central and southern sections of the study area. Approximately 17% of humpback dolphins and 29% of Irrawaddy dolphins were found to have anthropogenic-related injuries. Based on interview surveys with local fishers, bycatch of dolphins mostly occurred in gillnets, driftnets, trammel nets and trawl nets. Bycatch risk assessment (ByRA) revealed that medium to high dolphin bycatch risk in gillnets and trawl nets persist throughout most of the study area, with highest bycatch risk of humpback dolphins occurring particularly off the estuaries of Kuala Sangga Besar and Kuala Larut. The highest bycatch risk of Irrawaddy dolphins occurred in the coastal waters particularly off Kuala Larut. Conservation efforts should focus on the core areas identified in the present study, and future bycatch mitigation efforts should target these areas with high bycatch risks.

REFERENCES

A sign our seas are full of life. (2011, September 12). *New Straits Times*. http://e.nst.com.my/nst/articles/12sep/Article#ixzz1lqcxiFAW

Abd. Haris Hilmi, A. A., Ahmad, A., & Lawrence, K. J. (2017). *Data collection on sharks and rays by species in Malaysia (August 2015 - July 2016)*.

Abdul, J. (1986). A review study of avian and mammals at Kuala Gula Birds Sanctuary Perak. *The Journal of Wildlife and Parks*, *5*, 135–142.

Abu-Talib, A., Mahyam, M.-I., Mohamad-Saupi, & Sharum, Y. (2000). Abundance and distribution of demersal fish resources in the northern part of the Straits of Malacca. In M. Shariff, F. M. Yusoff, N. Gopinath, H. M. Ibrahim, & R. A. Nik Mustapha (Eds.), *Towards Sustainable Management of the Straits of Malacca* (pp. 25–43). Malacca Straits Research and Development Centre (MASDEC), University Putra Malaysia, Serdang, Malaysia.

Acevedo-Gutiérrez, A. (2009). Habitat Use. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals, Second edition,* pp. 524–529. Academic Press, Elsevier, San Diego, CA.

Adulyanukosol, K. (1999). Dugong, dolphin and whale in Thai waters. *Proceedings of the 1st Korea-Thailand Joint Workshop on Comparison of Coastal Environment: Korea-Thailand*, *1*, 1–5.

Ahmad, A. T., Isa, M. M., Ismail, M. S., & Yusof, S. (2003). Status of Demersal Fishery Resources of Malaysia. *Management and Future Directions for Coastal Fisheries in Asian Countries. WorldFish Center Conference Proceedings 67*, 83–136.

Akamatsu, T., Ura, T., Sugimatsu, H., Bahl, R., Behera, S., Panda, S., Khan, M., Kar, S. K., Kar, C. S., Kimura, S., & Sasaki-Yamamoto, Y. (2013). A multimodal detection model of dolphins to estimate abundance validated by field experiments. *The Journal of the Acoustical Society of America*, *134*(3), 2418–2426.

Anderson, D. J. (1982). The Home Range: A New Nonparametric Estimation Technique. *Ecology*, 63(1), 103-112.

Ariffin, R., & Nik Mohd Shah, N. M. (2013). *A Working Plan for The Matang Mangrove Forest Reserve, Perak: The First 10-year Period (2010–2019) of the Third Rotation (Sixth Revision).*

Ashton, E. C. (1999). *Biodiversity and community ecology of mangrove plants : molluscs and crustaceans in two mangrove forests in Peninsular Malaysia in relation to local management practices*. (Doctoral dissertation). University of York, York, UK.

Azahar, M., & Nik Mohd Shah, N. M. (2003). *A Working Plan for The Matang Mangrove Forest Reserve, Perak: The Third 10-year Period (2000–2009) of the Second Rotation (Fifth Revision).*

Baird, I. G., & Beasley, I. L. (2005). Irrawaddy dolphin *Orcaella brevirostris* in the

Cambodian Mekong River: an initial survey. *Oryx*, *39*(3), 301–310.

Baird, I. G., & Mounsouphom, B. (1997). Distribution, mortality, diet and conservation of Irrawaddy dolphins (*Orcaella brevirostris* Gray) in Lao, PDR. *Asian Marine Biology*, *14*, 41–48.

Baird, I. G., Mounsouphom, B., & Stacey, P. J. (1994). Preliminary surveyes of Irrawaddy dolphins (*Orcaella brevirostris*) in Lao PDR and Northeastern Cambodia. *Report of the International Whaling Commission*.

Baldwin, R. M., Collins, M., Van Waerebeek, K., & Minton, G. (2004). The Indo-Pacific Humpback Dolphin of the Arabian Region: A Status Review. *Aquatic Mammals*, *30*(1), 111–124.

Ballance, L. T. (2018). Cetacean Ecology. In B. Wursig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), *Encyclopedia of Marine Mammals* (pp. 172–180). Academic Press, London, UK.

Barbier, E. B., Hacker, S. D., Kennedy, C., Koch, E. W., Stier, A. C., & Silliman, B. R. (2011). The value of estuarine and coastal ecosystem services. In *Ecological Monographs*, *81*(2), 169-193.

Barros, N. B., & Cockroft, V. G. (1999). Prey resource partitioning between Indo-Pacific humpback dolphins (*Sousa chinensis*) and bottlenose dolphins (*Tursiops truncatus*) off South Africa: Competitive exclusion or mutual tolerance. In *13th Biennal Conference on the Biology of Marine Mammals, November 28-December 3, Maui, Hawaii.*

Barros, N. B., Jefferson, T. A., & Parsons, E. C. M. (2004). Feeding Habits of Indo-Pacific Humpback Dolphins (*Sousa chinensis*) Stranded in Hong Kong. *Aquatic Mammals*, *30*(1), 179–188.

Barros, N. B., Parsons, E. C. M., & Jefferson, T. A. (2000). Prey of offshore bottlenose dolphins from the South China Sea. *Aquatic Mammals*, *26*(1), 2–6.

Barros, N. B., & Wells, R. S. (1998). Prey Feeding Patterns of bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Journal of Mammalogy*, *79*(3) 1045-1059.

Bearzi, G., Kerem, D., Furey, N. B., Pitman, R. L., Rendell, L., & Reeves, R. R. (2018). Whale and dolphin behavioural responses to dead conspecifics. *Zoology*, *128*, 1–15.

Bearzi, G., Politi, E., Agazzi, S., & Azzellino, A. (2006). Prey depletion caused by overfishing and the decline of marine megafauna in eastern Ionian Sea coastal waters (central Mediterranean). *Biological Conservation*, *127*(4), 373–382.

Bearzi, M. (2005). Dolphin sympatric ecology. *Marine Biology Research*, *1*(3), 165–175.

Beasley, I., Chooruk, S., & Piwpong, N. (2002). The status of the Irrawaddy dolphin, *Orcaella brevirostris*, in Songkhla Lake, Southern Thailand. *Raffles Bulletin of Zoology*, *10*, 75–83.

Beasley, I., & Jefferson, T. A. (1997). Marine mammals of Borneo: A preliminary checklist. In *the Sarawak Museum Journal, 51,*193-210.

Beasley, I., Robertson, K.M. & Arnold, P. (2005). Description of a new dolphin, the Australian snubfin dolphin *Orcaella heinsohni* sp. n. (Cetacea, Delphinidae). *Marine Mammal Science*, *21*(3), 365–400.

Bejder, L., & Samuels, A. (2003). Evaluating impacts of nature-based tourism on cetaceans. In N. Gales, M. Hindell, & R. Kirkwood (Eds.), *Marine mammals: fisheries, tourism and management issues* (pp. 229–256). CSIRO Publishing.

Benoit-Bird, K. J., & Au, W. W. L. (2003). Prey dynamics affect foraging by a pelagic predator (*Stella longirostris*) over a range of spatial and temporal scales. *Behavioral Ecology and Sociobiology*, *53*(February), 364–373.

Berger-Tal, O., Polak, T., Oron, A., Lubin, Y., Kotler, B. P., & Saltz, D. (2011). Integrating animal behavior and conservation biology: A conceptual framework. *Behavioral Ecology*, *22*(2), 236–239.

Bonizzoni, S., Furey, N. B., Santostasi, N. L., Eddy, L., Valavanis, V. D., & Bearzi, G. (2019). Modelling dolphin distribution within an Important Marine Mammal Area in Greece to support spatial management planning. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *29*(10), 1665–1680.

Bossart, G. D. (2011). Marine mammals as sentinel species for oceans and human health. *Veterinary Pathology*, *48*(3), 676–690.

Braulik, G. T., Kasuga, M., Wittich, A., Kiszka, J. J., MacCaulay, J., Gillespie, D., Gordon, J., Said, S. S., & Hammond, P. S. (2017). Cetacean rapid assessment: An approach to fill knowledge gaps and target conservation across large data deficient areas. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *28*(October 2017), 216–230.

Brown, A. M., Bejder, L., Parra, G. J., Cagnazzi, D., Hunt, T., Smith, J. L., & Allen, S. J. (2016). Sexual dimorphism and geographic variation in dorsal fin features of Australian humpback dolphins, *Sousa sahulensis*. *Advances in Marine Biology*, *73*, 273–314.

Brusa, J. L., Young, R. F., & Swanson, T. (2016). Abundance, ranging patterns, and social behavior of bottlenose dolphins (*Tursiops truncatus*) in an estuarine terminus. *Aquatic Mammals*, *42*(1), 109–121.

Buckland, S. T., Anderson, D. R., Burnham, K. P., Laake, J. L., Borchers, D. L., & Thomas, L. (2001). *Introduction to distance sampling: estimating abundance of biological populations.* Oxford University Press.

Buckland, S. T., Anderson, D. R., Laake, J. L., Burnham, K. P., Borchers, D. L., & Thomas, L. (2004). Advanced distance sampling. *Ecology*, *89*(12), 416.

Buckland, S. T., & York, A. E. (2009). Abundance estimation. In *Encyclopedia of Marine Mammals* (Issue 1, pp. 1–5). Elsevier, Inc., Canada.

Buckland, S. T., & York, A. E. (2018). Abundance Estimation. In B. Würsig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), *Encyclopedia of Marine Mammals (Third Edition)* (pp. 1–6). Academic Press, London, UK.

Burgman, M. A., & Fox, J. C. (2003). Bias in species range estimates from minimum convex polygons: Implications for conservation and options for improved planning. *Animal Conservation*, *6*(1), 19–28.

Burnham, K. P., Anderson, D. R., White, G. C., Brownie, C., & Pollock, K. H. (1987). Design and analysis methods for fish survival experiments based on release-recapture. *American Fisheries Society Monograph*, *5*, 1–437.

Burt, W. H. (1943). Territoriality and Home Range Concepts as Applied to Mammals. *Journal of Mammalogy*, *24*(3), 346.

Cagnazzi, D. (2010). *Conservation status of Australian snubfin dolphin, Orcaella heinsohni, and Indo-Pacific humpback dolphin, Sousa chinensis, in the Capricorn Coast, Central Queensland, Australia*. (Doctoral dissertation). Southern Cross University, Lismore, NSW.

Cañadas, A., & Hammond, P. S. (2008). Abundance and habitat preferences of the short-beaked common dolphin Delphinus delphis in the southwestern Mediterranean: implications for conservation smoothed covariates used in the models for predicting abundance of groups (left side) and group size. *Endangered Species Research*, *4*, 309–331.

Casipe, K. P., Espinosa, K. E. S., Jarabelo, C. J. M. & de la Paz, M. E. L. (2017). Foraging behavior association between Irrawaddy dolphins (*Orcaella brevirostris*) and tidal net fisheries in the coastal waters of Pulupandan, Negros Occidental, Philippines. *Sylvatrop*, *25*(1 & 2), 67–92.

Chan, S. C. Y., & Karczmarski, L. (2017). Indo-Pacific humpback dolphins (*Sousa chinensis*) in Hong Kong : Modelling demographic parameters with mark- recapture techniques. *PLoS ONE*, *12*(3), 1–28.

Chan, S. C. Y., & Karczmarski, L. (2019). Epidermal lesions and injuries of coastal dolphins as indicators of ecological health. *EcoHealth*, *16*(3), 576–582.

Chee, P. E. (2000). The pelagic fishery of the West Coast of Peninsular Malaysia. In M. Shariff, F. M. Yusoff, N. Gopinath, H. M. Ibrahim, & R. A. Nik Mustapha (Eds.), *Towards Sustainable Management of the Straits of Malacca* (pp. 127–143). Malacca Straits Research and Development Centre (MASDEC), University Putra Malaysia, Serdang, Malaysia.

Chen, B.-Y., Zheng, D.-M., Ju, J.-F., Xu, X.-R., Zhou, K.-Y., & Yang, G. (2011a). Range patterns of resident Indo-Pacific humpback dolphins (*Sousa chinensis*, Osbeck 1765) in Xiamen, China: Implications for conservation and management. *Zoological Studies*, *50*(6), 751–762.

Chen, B., Gao, H., Jefferson, T. A., Lu, Y., Wang, L., Li, S., Wang, H., Xu, X., & Yang, G. (2018). Survival rate and population size of Indo-Pacific humpback dolphins (*Sousa chinensis*) in Xiamen Bay, China. *Marine Mammal Science, 34*(4), 1018-

1033.

Chen, B., Xu, X., Jefferson, T. A., Olson, P. A., Qin, Q., Zhang, H., He, L., & Yang, G. (2016). Conservation Status of the Indo-Pacific Humpback Dolphin (*Sousa chinensis*) in the Northern Beibu Gulf, China. *Advances in Marine Biology*, *73*, 119–139.

Chen, T., Hung, S. K. Y., Qiu, Y., Jia, X., & Jefferson, T. A. (2010). Distribution, abundance, and individual movements of Indo-Pacific humpback dolphins (*Sousa chinensis*) in the Pearl River Estuary, China. *Mammalia*, *74*(2), 117–125.

Chen, T., Qiu, Y., Jia, X., Hung, S. K. Y., & Liu, W. (2011b). Distribution and group dynamics of Indo-Pacific humpback dolphins (Sousa chinensis) in the western Pearl River Estuary, China. *Mammalian Biology*, *76*(1), 93–96.

Cherdsukjai, P., & Kittiwattanawong, K. (2013). The population sizes of Indo-Pacific humpback dolphins (*Sousa chinensis*) around Sukon and Sarai Islands, Thailand estimated using photo-identification technique. *Proceedings of the Design Symposium on Conservation of Ecosystem (2013) (The 12th SEASTAR2000 Workshop)*, 51–54. http://hdl.handle.net/2433/176190

Chew, L. L., & Chong, V. C. (2011). Copepod community structure and abundance in a tropical mangrove estuary, with comparisons to coastal waters. *Hydrobiologia*, *666*(1), 127–143.

Chilvers, L. B., Corkeron, P. J., Chilvers, B. L., & Corkeron, P. J. (2001). Trawling and bottlenose dolphins' social structure. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, *268*(1479), 1901–1905.

Chong, V. C. (2005). Fifteen years of fisheries research in Matang mangroves : what have we learnt? In S. M. Ismail, A. Muda, R. Ujang, K. A. Budin, K. L. Lim, & S. Rosli (Eds.), *Sustainable Management of Matang Mangroves: 100 Years and Beyond, 4th Forest biodiversity Series* (pp. 411–429). Forestry Department Peninsular Malaysia.

Chong, V. C. (2006). Sustainable utilization and management of Mangrove ecosystems of Malaysia. *Aquatic Ecosystem Health & Management*, *9*(2), 249–260.

Chong, V. C. (2007). Mangrove-fisheries linkages - the Malaysian perspective. *Bulletin of Marine Science*, *80*(3), 755–772.

Chong, V. C., Jamizan A.R, Yazid, M. Z., Ali, M. S., & Natin, P. (2010a). Diversity and abundance of fish and invertebrates of Semerak estuary and adjacent inshore waters, Kelantan. *Malaysian Journal of Science*, *29*, 95–110.

Chong, V. C., Lee, P. K. Y., & Lau, C. M. (2010b). Diversity, extinction risk and conservation of Malaysian fishes. *Journal of Fish Biology*, *76*(9), 2009–2066.

Chong, V. C., Sasekumar, A., Leh, M. U. C., & D'Cruz, R. (1990). The fish and prawn communities of a Malaysian coastal mangrove system, with comparisons to adjacent mud flats and inshore waters. *Estuarine, Coastal and Shelf Science*, *31*(5), 703–722.

Chong, V. C., Sasekumar, A., & Lim, K. H. (1994). Distribution and abundance of prawns in a Malaysian mangrove system. *Proceedings of the Third ASEAN-Australia Symposium on Living Coastal Resources. Chulalongkorn University), Bangkok, Vol. 2, Research Papers*, 437–445.

Chong, V. C., Teoh, H. W., Ooi, A. L., Jamizan, A. R., & Tanaka, K. (2012). Ingression and feeding habits of fish in Matang coastal mudflats, Malaysia. In *JIRCAS Working Report No. 75* (pp. 15–24). Japan International Research Center for Agricultural Sciences. http://www.jircas.affrc.go.jp/

Cribb, N., Miller, C., & Seuront, L. (2013). Indo-Pacific bottlenose dolphin (*Tursiops aduncus*) habitat preference in a heterogeneous, urban, coastal environment. *Aquatic Biosystems*, *9*(1), 3.

Culik, B. (2010). Odotocetes. The toothed whales: “Orcaella brevirostris.” In *UNEP/CMS Secretariat, Bonn, Germany*.

D’Lima, C., Marsh, H., Hamann, M., Sinha, A., & Arthur, R. (2014). Positive interactions between Irrawaddy dolphins and artisanal fishers in the Chilika Lagoon of Eastern India are driven by ecology, socioeconomics, and culture. *Ambio*, *43*(5), 614–624.

Dai, Y., Chantra, R., Kittiwattanawong, K., Zhao, L., Sakornwimon, W., Aierken, R., … Wang, X. (2021). Genetic structure of the endangered Irrawaddy dolphin (*Orcaella brevirostris*) in the Gulf of Thailand. Genetics and Molecular Biology, *44*(2), e20200365.

Dares, L. E., Hoffman, J. M., Yang, S. C., & Wang, J. Y. (2014). Habitat characteristics of the critically endangered Taiwanese humpback dolphins (*Sousa chinensis*) of the eastern Taiwan Strait. *Aquatic Mammals*, *40*(4), 368–374.

Dawson, S., Wade, P., Slooten, E., & Barlow, J. (2008). Design and field methods for sighting surveys of cetaceans in coastal and riverine habitats. *Mammal Review*, *38*(1), 19–49.

de la Paz, M. E., Palomar-Abesamis, N., Sabater, E., Señoron, J. A., & Dolar, M. L. L. (2020). Habitat use and site fidelity of Irrawaddy dolphins (*Orcaella brevirostris*) in the coastal waters of Bago-Pulupandan, Negros Occidental, Philippines. *Raffles Bulletin of Zoology*, *68*(June), 562–573.

Department of Fisheries Malaysia. (2015). *National Plan of Action for the Management of Fishing Capacity in Malaysia (Plan 2)*. Department of Fisheries Malaysia. http://www.dof.gov.my/dof2/resources/user_1/UploadFile/Penerbitan/Senarai Penerbitan/NPOA.pdf

Department of Fisheries Malaysia. (2016). *Annual Fisheries Statistics 2016*. https://www.dof.gov.my/dof2/resources/user_29/Documents/Perangkaan Perikanan/2016/Landing1.pdf

Dey, M., Krishnaswamy, J., Morisaka, T., & Kelkar, N. (2019). Interacting effects of vessel noise and shallow river depth elevate metabolic stress in Ganges river dolphins. *Scientific Reports*, *9*(1), 1–13.

Díaz-Gamboa, R. E., Gendron, D., & Busquets-Vass, G. (2018). Isotopic niche width differentiation between common bottlenose dolphin ecotypes and sperm whales in the Gulf of California. *Marine Mammal Science*, *34*(2), 440–457.

Dolar, M. L. L., de la Paz, M., & Sabater, E. (2018). Orcaella brevirostris *Iloilo-Guimaras Subpopulation. The IUCN Red List of Threatened Species 2018: e.T123095978A123095988.*

Dolar, M. L. L., Perrin, W. F., Pres Gaudiano, J., Yaptinchay, A. A. S. P., & Tan, J. M. L. (2002). Preliminary report on a small estuarine population of Irrawaddy dolphins Orcaella brevirostris in the Philippines. *Raffles Bulletin of Zoology*, *10*, 155–160.

Dolar, M. L. L., Perrin, W. F., Yaptinchay, A. A. S. P., Jaaman, S. A., Santos, M. B., Alava, M. N., & Suliansa, M. S. (1997). Preliminary investigation of marine mammal distribution, abundance, and interactions with humans in the Southern Sulu Sea. *Asian Marine Biology*, 61–81.

dos Santos, M. E., Coniglione, C., & Louro, S. (2007). Feeding behaviour of the bottlenose dolphin, *Tursiops truncatus* (Montagu, 1821) in the Sado estuary, Portugal, and a review of its prey species. *Revista Brasileira de Zoociências*, *9*(1), 31-39.

Dungan, S. Z., Hung, S. K. Y., Wang, J. Y., & White, B. N. (2012). Two social communities in the Pearl River Estuary population of Indo-Pacific humpback dolphins (*Sousa chinensis*). *Canadian Journal of Zoology*, *90*(June 2015), 1031–1043.

Dungan, S. Z., Riehl, K. N., Wee, A., & Wang, J. Y. (2011). A review of the impacts of anthropogenic activities on the critically endangered eastern Taiwan Strait Indo-Pacific humpback dolphins (*Sousa chinensis*). *Journal of Marine Animals and Their Ecology*, *4*(2), 3–9.

Dungan, S. Z., Wang, J. Y., Araújo, C. C., Yang, S. C., & White, B. N. (2016). Social structure in a critically endangered Indo-Pacific humpback dolphin (*Sousa chinensis*) population. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *26*(3), 517–529.

ERM-Hong Kong. (1998). *Fisheries Resources and Fishing Operations in Hong Kong Waters: Final report for Hong Kong Agriculture, Fisheries and Conservation Department (AFCD). Hong Kong Government.*

Evans, P. G. H., Pierce, G. J., & Wright, A. J. (2012). Marine mammal studies to address future challenges in conservation management. *Journal of the Marine Biological Association of the United Kingdom*, *92*(8), 1639–1644.

FAO. (2018). *Report of the Expert Workshop on Means and Methods for Reducing Marine Mammal Mortality in Fishing and Aquaculture Operations: Vol. FAO Fisher* (Issue March).

Fertl, D., & Leatherwood, S. (1997). Cetacean interactions with trawls: a preliminary review. *Journal of Northwest Atlantic Fishery Science*, *22*, 219–248.

Finn, J., Tregenza, T., & Norman, M. (2009). Preparing the perfect cuttlefish meal:

Complex prey handling by dolphins. *PLoS ONE*, *4*(1), 2007–2009.

Flores, P. a. C., & Bazzalo, M. (2004). Home ranges and movement patterns of the marine tucuxi dolphin, *Sotalia fluviatilis*, in Baía Norte, southern Brazil. *Latin American Journal of Aquatic Mammals*, *3*(1), 37–52.

Flower, S. S. (1900). Mammals of Siam and the Malaya Peninsula. *Proceedings of the Zoological Society of London*, *69*(3), 306–377.

Forcada, J. (2018). Distribution. In B. Wursig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), *Encyclopedia of Marine Mammals, Third edition* (pp. 259–262). Academic Press, London, UK.

Gannon, D. P., Barros, N. B., Nowacek, D. P., Read, A. J., Waples, D. M., & Wells, R. S. (2005). Prey detection by bottlenose dolphins, *Tursiops truncatus*: An experimental test of the passive listening hypothesis. *Animal Behaviour*, *69*(3), 709–720.

Gerrodette, T., Perryman, W. L., & Oedekoven, C. S. (2018). *Accuracy and precision of dolphin group size estimates*. *35*(1), 22–39.

Ghaderpour, A., Mohd Nasori, K. N., Chew, L. L., Chong, V. C., Thong, K. L., & Chai, L. C. (2014). Detection of multiple potentially pathogenic bacteria in Matang mangrove estuaries, Malaysia. *Marine Pollution Bulletin*, *83*(1), 324–330.

Goessens, A., Satyanarayana, B., Van Der Stocken, T., Zuniga, M. Q., Mohd-Lokman, H., Sulong, I., & Dahdouh-Guebas, F. (2014). Is Matang Mangrove Forest in Malaysia sustainably rejuvenating after more than a century of conservation and harvesting management? *PLoS ONE*, *9*(8).

Greenfield, M. R., McHugh, K. A., Wells, R. S., & Rubenstein, D. I. (2021). Anthropogenic injuries disrupt social associations of common bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Marine Mammal Science*, *37,* 29-44.

Griffin, R. B., & Griffin, N. J. (2003). Distribution, habitat partitioning, and abundance of Atlantic spotted dolphins, bottlenose dolphins, and loggerhead sea turtles on the eastern Gulf of Mexico continental shelf. *Gulf of Mexico Science*, *21*(1), 23–34.

Gubbins, C. (2002). Use of Home Ranges By Resident Bottlenose Dolphins (*Tursiops truncatus*) in a South Carolina Estuary. *Journal of Mammalogy*, *83*(1), 178–187.

Gygax, L. (2002a). Evolution of group size in the dolphins and porpoises: interspecific consistency of intraspecific patterns. *Behavioral Ecology*, *13*(5), 583–590.

Gygax, L. (2002b). Evolution of group size in the superfamily Delphinoidea (Delphinidae, Phocoenidae and Monodontidae): a quantitative comparative analysis. *Mammal Review*, *32*(4), 295–314.

Hallwass, G., Schiavetti, A., & Silvano, R. A. M. (2019). Fishers' knowledge indicates temporal changes in composition and abundance of fishing resources in Amazon protected areas. *Animal Conservation*, *23*(1), 36–47.

Hammond, P. S. (2010). Estimating the abundance of marine mammals. In I. L. Boyd, W. D. Bowen, & S. J. Iverson (Eds.), *Marine Mammal Ecology and Conservation : a handbook of techniques* (pp. 42–67). Oxford University Press.

Hammond, P. S. (2018). Mark-Recapture. In B. Wursig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), *Encyclopedia of Marine Mammals, Third edition* (pp. 580-584). Academic Press, London, UK.

Hammond, P. S., Mizroch, S. A., & Donovan, G. P. (1990). Individual recognition of cetaceans: use of photo-identification and other techniques to estimate population parameters. *Report - International Whaling Commission, Special Issue*.

Hanamura, Y., Tanaka, K., Man, A., & Faizul Mohd Kassim. (2012). Ecological characteristics of hyperbenthic crustaceans in mangrove estuaries on the northwest coast of Peninsular Malaysia: An overview. *JIRCAS Working Report*, *75*, 25–34.

Hashim, N. A. N., & Jaaman, S. A. (2011). Boat effects on the behaviour of Indo-Pacific Humpback (*Sousa chinensis*) and Irrawaddy dolphins (*Orcaella brevirostris*) in Cowie Bay, Sabah, Malaysia. *Sains Malaysiana*, *40*(12), 1383–1392.

Hastie, G. D., Wilson, B., & Thompson, P. M. (2003). Fine-scale habitat selection by coastal bottlenose dolphins: application of a new land-based video-montage technique. *Canadian Journal of Zoology*, *81*, 469–478.

Haughey, R., Hunt, T., Hanf, D., Rankin, R. W., & Parra, G. J. (2020). Photographic capture-recapture analysis reveals a large population of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) with low site fidelity off the North West Cape, Western Australia. *Frontiers in Marine Science*, *6,* 1-14.

Hawkins, E. R., Gartside, D. F., & Elizabeth, R. (2008). *Dolphin Tourism: Impact of vessels on the behaviour and acoustics of inshore bottlenose dolphins (Tursiops aduncus)*.

Hayase, S., & Muhd Fadzil, H. (1999). Fish distribution and abundance in Matang and Merbok mangrove waters, west coast of Peninsular Malaysia: preliminary results for 1996-1997. In K. Katsuhiro & P. S. Choo (Eds.), *Proceedings of the Fourth JIRCAS Seminar on Productivity and Sustainable Utilisation of Brackish Water Mangrove Ecosystems.* (pp. 50–91). Japan International Research Centre for Agricultural Sciences (JIRCAS).

Heithaus, M. R., & Dill, L. M. (2002). Food availability and tiger shark predation risk influence bottlenose dolphin habitat use. *Ecology*, *83*(2), 480–491.

Hines, E. M., Ponnampalam, L. S., Fairul Izmal, J. H., Whitty, T. S., Jackson-Ricketts, J., Kuit, S. H., & Acebes, J.-M. (2015a). Report of the Third Southeast Asian Marine Mammal Symposium (SEAMAM III). *CMS Technical Series Publication*, *32*, 1-643.

Hines, E. M., Strindberg, S., Junchumpoo, C., Ponnampalam, L. S., Ilangakoon, A. D., Jackson-Ricketts, J., & Monanunsap, S. (2015b). Line transect estimates of Irrawaddy dolphin abundance along the eastern Gulf Coast of Thailand. *Frontiers in Marine Science*, *2*, 1–10.

Hines, E., Ponnampalam, L., Junchumpoo, C., Peter, C., Vu, L., Huynh, T., Caillat, M., Johnson, A., Minton, G., Lewison, R., & Verutes, G. M. (2020). Getting to the bottom of bycatch: a GIS-based toolbox to assess the risk of marine mammal bycatch. *Endangered Species Research*, *42*, 37–57.

Hooker, S. K., Whitehead, H., Gowans, S., & Baird, R. W. (2002). Fluctuations in distribution and patterns of individual range use of northern bottlenose whales. *Marine Ecology Progress Series*, *225*, 287–297.

Hossain, M. A. R., & Hasan, M. R. (2017). An assessment of impacts from shrimp aquaculture in Bangladesh and prospects for improvement. *FAO Fisheries and Aquaculture Technical Paper No. 618*.

Huang, S.-L., Karczmarski, L., Chen, J., Zhou, R., Lin, W., Zhang, H., Li, H., & Wu, Y. (2012). Demography and population trends of the largest population of Indo-Pacific humpback dolphins. *Biological Conservation*, *147*(1), 234–242.

Hung, S. K., & Jefferson, T. A. (2004). Ranging Patterns of Indo-Pacific Humpback Dolphins (*Sousa chinensis*) in the Pearl River Estuary, People's Republic of China. *Aquatic Mammals*, *30*(1), 16.

Hung, S. K. Y. (2008). *Habitat use of Indo-Pacific humpback dolphins (Sousa chinensis) in Hong Kong*. (Doctoral dissertation). The University of Hong Kong, Hong Kong SAR.

Hung, S. K. Y. (2014). *Monitoring of Marine Mammals in Hong Kong waters (2013-14). Final report (1 April 2013 to 31 March 2014). Report submitted to the Agriculture, Fisheries and Conservation Department of the Hong Kong SAR Government.*

Hung, S. K. Y. (2019). *Monitoring of Marine Mammals in Hong Kong waters (2018-19). Final report (1 April 2018 to 31 March 2019). Report submitted to the Agriculture, Fisheries and Conservation Department of the Hong Kong SAR Government.*

Hupman, K., Stockin, K. A., Pollock, K., Pawley, M. D. M., Dwyer, S. L., Lea, C., & Tezanos-Pinto, G. (2018). Challenges of implementing Mark-recapture studies on poorly marked gregarious delphinids. *PLoS ONE*, *13*(7), 1–27.

Hwang, A., Defran, R. H., Bearzi, M., Maldini, D., & Saylan, C. A. (2014). Coastal range and movements of common bottlenose dolphins (*Tursiops truncatus*) off California and Baja California, Mexico. *Bulletin of the Southern California Academy of Sciences*, *113*(1), 1–13.

Ibharim, N. A., Mustapha, M. A., Lihan, T., & Mazlan, A. G. (2015). Mapping mangrove changes in the Matang Mangrove Forest using multi temporal satellite imageries. *Ocean and Coastal Management*, *114*, 64–76.

Jaaman, S. A., Lah-anyi, Y. U., & Pierce, G. J. (2009). The magnitude and sustainability of marine mammal by-catch in fisheries in East Malaysia. *Journal of the Marine Biological Association of the United Kingdom*, *89*(5), 907–920.

Jackson-Ricketts, J. (2017). *Diet, life history, habitat, and conservation of Irrawaddy dolphins (Orcaella brevirostris) in the Gulf of Thailand*. (Doctoral dissertation).

University of California, Santa Cruz.

Jackson-Ricketts, J., Junchumpoo, C., Hines, E. M., Hazen, E. L., Ponnampalam, L. S., Ilangakoon, A., & Monanunsap, S. (2020). Habitat modeling of Irrawaddy dolphins (*Orcaella brevirostris*) in the Eastern Gulf of Thailand. *Ecology and Evolution*, *August 2019*, ece3.6023.

Jackson-Ricketts, J., Ruiz-Cooley, R. I., Junchumpoo, C., Thongsukdee, S., Intongkham, A., Ninwat, S., Kittiwattanawong, K., Hines, E. M., & Costa, D. P. (2018). Ontogenetic variation in diet and habitat of Irrawaddy dolphins (*Orcaella brevirostris*) in the Gulf of Thailand and the Andaman Sea. *Marine Mammal Science*, *35*(2), 492-521.

Jaroensutasinee, M., Jutapruet, S., & Jaroensutasinee, K. (2010). Population size of Indo-Pacific humpback dolphins (*Sousa chinensis*) at Khanom, Thailand. *Walailak Journal of Science and Technology*, *7*(2), 115–126.

Jayasankar, P., Patel, A., Khan, M., Das, P. & Panda, S. (2011). Mitochondrial DNA diversity and PCR-based sex determination of Irrawaddy dolphin (*Orcaella brevirostris*) from Chilika Lagoon, India. *Molecular Biology Reports*, *38*(3), 1661–1668.

Jefferson, T. A. (2000). Population biology of the Indo-Pacific hump-backed dolphin in Hong Kong waters. *Wildlife Monographs*, *144*, 1–65.

Jefferson, T. A., & Curry, B. E. (2015). Humpback Dolphins: A Brief Introduction to the Genus *Sousa*. *Advances in Marine Biology*, *72*, 1–16.

Jefferson, T. A., & Hung, S. K. Y. (2004). *Neophocaena phocaenoides*. *Mammalian Species*, *746*(1), 1.

Jefferson, T. A., Hung, S. K. Y., Law, L., Torey, M., & Tregenza, N. (2002). Distribution and abundance of finless porpoises in Hong Kong and adjacent waters of China. *Raffles Bulletin of Zoology*, *Suppl. 10*, 43–55.

Jefferson, T. A., & Karczmarski, L. (2001). *Sousa chinensis*. *Mammalian Species*, *655*, 1–9.

Jefferson, T. A., Karczmarski, L., Kreb, D., Laidre, K., O'Corry-Crowe, G., Reeves, R., … Zhou, K. (2008). *Orcaella brevirostris Mahakam River subpopulation* (errata version published in 2016). The IUCN Red List of Threatened Species 2008: e.T39428A98842174.

Jefferson, T. A., Leatherwood, S., & Webber, M. A. (1993). Marine Mammals of the World. In *FAO Species Identification Guide* (Vol. 13, Issue 3). ftp://ftp.fao.org/docrep/fao/009/t0725e/t0725e12.pdf

Jefferson, T. A., & LeDuc, R. (2018). Delphinids, Overview. *In B. Wursig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), Encyclopedia of Marine Mammals, Third edition* (pp. 242–246). Academic Press, London, UK.

Jefferson, T. A., & Rosenbaum, H. C. (2014). Taxonomic revision of the humpback dolphins (*Sousa* spp.), and description of a new species from Australia. *Marine Mammal Science*, *30*(4), 1494–1541.

Jefferson, T. A., & Smith, B. D. (2016). Re-assessment of the conservation status of the Indo-Pacific humpback dolphin (*Sousa chinensis*) using the IUCN Red List Criteria. *Advances in Marine Biology*, *73*, 1–26.

Jefferson, T. A., Smith, B. D., Braulik, G. T., & Perrin, W. (2017). *Sousa chinensis.* The IUCN Red List of Threatened Species 2017: e.T82031425A50372332.

Junchumpoo, C., Monanunsap, S., & Penpein, C. (2014). Population and Conservation Status of Irrawaddy Dolphins (*Orcaella brevirostris*) in Trat Bay, Trat Province, Thailand. *Proceedings of the Design Symposium on Conservation of Ecosystem (The 13th SEASTAR2000 Workshop)*, *2*, 32–38.

JUPEM. (2004). *A hand book on Tide Tables. Malaysia: Department of Survey and Mapping*.

Jutapruet, S., Huang, S.-L., Li, S., Lin, M., Kittiwattanawong, K., & Pradit, S. (2015). Population Size and Habitat Characteristics of the Indo-Pacific Humpback Dolphin (*Sousa chinensis*) Off Donsak, Surat Thani, Thailand. *Aquatic Mammals*, *41*(2), 129–142.

Jutapruet, S., Intongcome, A., Wang, X., Kittiwattanawong, K., & Huang, S.-L. (2017). Distribution of three sympatric cetacean species off the coast of the central-western Gulf of Thailand. *Aquatic Mammals*, *43*(5), 465–473.

Karczmarski, L., Cockcroft, V. G., & McLachlan, A. (2000). Habitat use and preferences of Indo-Pacific humpback dolphins *Sousa chinensis* in Algoa Bay, South Africa. *Marine Mammal Science*, *16*(1), 65–79.

Karczmarski, L., Huang, S.-L., Or, C. K. M., Gui, D., Chan, S. C. Y., Lin, W., … Wu, Y. (2016). Humpback Dolphins in Hong Kong and the Pearl River Delta. *Advances in Marine Biology, 73*, 27–64.

Karczmarski, L., Thornton, M., & Cockcroft, V. G. (1997). Description of selected behaviours of humpback dolphins *Sousa chinensis. Aquatic Mammals*, *23*(3), 127–133.

Kaschner, K., Quick, N. J., Jewell, R., Williams, R., & Harris, C. M. (2012). Global Coverage of Cetacean Line-Transect Surveys: Status Quo, Data Gaps and Future Challenges. *PLoS ONE*, *7*(9): e44075.

Kendall, W. L., Nichols, J. D., & Hines, J. E. (1997). Estimating temporary emigration using capture-recapture data with Pollock's robust design. *Ecology*, *78*(2), 563-578.

Khalifa, M. A., Kamal, M. M., Adiwilaga, E. M., & Sunuddin, A. (2014). Preliminary Study on the Distribution of Irrawaddy Dolphin, Orcaella brevirostris, in Banten Bay. *Open Journal of Marine Science*, *4*, 338–343.

Khan, M., Panda, S., Pattnaik, A. K., Guru, B. C., Kar, C., Subudhi, M., & Samal, R. (2011). Shark attacks on Irrawaddy dolphin in Chilika lagoon, India. *Journal of the*

Marine Biological Association of India, *53*, 27–34.

Kratzer, I. M. F., Schäfer, I., Stoltenberg, A., Chladek, J. C., Kindt-Larsen, L., Larsen, F., & Stepputtis, D. (2020). Determination of Optimal Acoustic Passive Reflectors to Reduce Bycatch of Odontocetes in Gillnets. *Frontiers in Marine Science*, *7*, 1–18.

Kreb, D. (2004). *Facultative river dolphins: conservation and social ecology of freshwater and coastal Irrawaddy dolphins in Indonesia*.

Kreb, D., & Budiono. (2005a). Cetacean diversity and habitat preferences in tropical waters of East Kalimantan, Indonesia. *Raffles Bulletin of Zoology*, *53*(1), 149–155.

Kreb, D., & Budiono. (2005b). Conservation management of small core areas: key to survival of a Critically Endangered population of Irrawaddy river dolphins *Orcaella brevirostris* in Indonesia. *Oryx*, *39*(2), 178–188.

Kreb, D., Lhota, S., Porter, L., Redman, A., Susanti, I., & Lazecky, M. (2020). Long-Term Population and Distribution Dynamics of an Endangered Irrawaddy Dolphin Population in Balikpapan Bay, Indonesia in Response to Coastal Development. *Frontiers in Marine Science*, *7*, 1-22.

Kreb, D., & Lim, I. (2009). *Balikpapan Bay Irrawaddy Dolphin Project 2008. Conservation and diversity of cetaceans in and near Balikpapan Bay, East Kalimantan, Indonesia.*

Kreb, D., & Rahadi, K. D. (2004). Living Under an Aquatic Freeway: Effects of Boats on Irrawaddy Dolphins (Orcaella brevirostris) in a Coastal and Riverine Environment in Indonesia. *Aquatic Mammals*, *30*(3), 363–375.

Krejcie, R. V, & Morgan, D. W. (1970). Determining Sample Size for Research Activities. *Educational and Psychological Measurement*, *30*(3), 607–610.

Krützen, M., Beasley, I., Ackermann, C. Y., Lieckfeldt, D., Ludwig, A., Ryan, G. E., … Spencer, P. B. S. (2018) Demographic collapse and low genetic diversity of the Irrawaddy dolphin population inhabiting the Mekong River. *PLoS ONE*, *13*(1): e0189200.

Kügler, A., & Orbach, D. N. (2014). Sources of notch and scar patterns on the dorsal fins of dusky dolphins (*Lagenorhynchus obscurus*). *Aquatic Mammals*, *40*(3), 260–273.

Kuit, S. H., Ponnampalam, L. S., Fairul Izmal, J. H., & Chong, V. C. (2014). Cetacean research and a precautionary approach in developing dolphin-watching tourism in the coastal waters of the Matang mangroves. *Proceedings of the Matang Mangrove Forest Management Conference*, 27–39.

Kuit, S. H., Ponnampalam, L. S., Ng, J. E., Chong, V. C., & Then, A. Y. H. (2019a). Distribution and habitat characteristics of three sympatric cetacean species in the coastal waters of Matang, Perak, Peninsular Malaysia. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *29*(10), 1681–1696.

Kuit, S. H., Ponnampalam, L. S., Ng, J. E., Fairul Izmal, J. H., & Chong, V. C. (2015).

Selection factors of Sagor catfish (*Hexanematichthys sagor*) as prey by Indo-Pacific humpback dolphins (*Sousa chinensis*) in the estuaries of Matang, Perak, Malaysia. In *Poster presentation at the Society of Marine Mammalogy 21st Biennial Conference, San Francisco, CA, USA. December, 2015.*

Kuit, S. H., Then, A. Y.-H., Ng, J. E., Teoh, Z. Y., & Ponnampalam, L. S. (2019b). Ranging patterns of Indo- Pacific humpback dolphins (*Sousa chinensis*) in the Matang Important Marine Mammal Area in Perak, Peninsular Malaysia. In *Poster presentation at the World Marine Mammal Conference, Barcelona, Spain. December, 2019.*

Kurihara, N., & Oda, S. (2009). Effects of size on the skull shape of the bottlenose dolphin (*Tursiops truncatus*). *Society*, *32*, 19–32.

Lady luck, dolphins smile on us. (2011, August 11). *New Straits Times*.

Leaper, R., & Calderan, S. (2017). *Review of methods used to reduce risks of cetacean bycatch and entanglements. CMS Technical Series No. 38. UNEP/CMS Secretariat, Bonn, Germany*.

Léopold, M., Guillemot, N., Rocklin, D., & Chen, C. (2014). A framework for mapping small-scale coastal fisheries using fishers' knowledge. *ICES Journal of Marine Science*, *71*(7), 1781-1792.

Li, S., Lin, M., Xu, X., Xing, L., Zhang, P., Gozlan, R. E., Huang, S., & Wang, D. (2016). First record of the Indo-Pacific humpback dolphins (*Sousa chinensis*) southwest of Hainan Island, China. *Marine Biodiversity Records*, *9*(1), 1-6.

Lin, M., Caruso, F., Liu, M., Lek, S., Li, K., Gozlan, R. E., & Li, S. (2020). Food risk trade-off in the Indo-Pacific humpback dolphin: An exploratory case study. In *Aquatic Conservation: Marine and Freshwater Ecosystems, 30*(4), 860–867.

Lin, T.-H., Akamatsu, T., & Chou, L.-S. (2013). Tidal influences on the habitat use of Indo-Pacific humpback dolphins in an estuary. *Marine Biology*, *160*(6), 1353–1363.

Lin, T.-H., Akamatsu, T., & Chou, L.-S. (2015). Seasonal Distribution of Indo-Pacific Humpback Dolphins at an Estuarine Habitat: Influences of Upstream Rainfall. *Estuaries and Coasts*, *38*(4), 1376–1384.

Lin, W., Chang, L., Frère, C. H., Zhou, R., Chen, J., Chen, X., & Wu, Y. (2012). Differentiated or not ? An assessment of current knowledge of genetic structure of *Sousa chinensis* in China. *Journal of Experimental Marine Biology and Ecology*, *416–417*, 17–20.

Liu, J. Y., Chou, L. S., & Chen, M. H. (2015). Investigation of trophic level and niche partitioning of 7 cetacean species by stable isotopes, and cadmium and arsenic tissue concentrations in the western Pacific Ocean. *Marine Pollution Bulletin*, *93*(1–2), 270–277.

Liu, M., Lin, M., Dong, L., Xue, T., Zhang, P., Tang, X., & Li, S. (2020). Group sizes of Indo-Pacific dumpback dolphins in waters southwest of Hainan Island, China: Insights into rare records of large groups. *Aquatic Mammals*, *46*(3), 259–265.

Liu, M., Lin, M., Lusseau, D. & Li, S. (2021). Intra-Population Variability in Group Size of Indo-Pacific Humpback Dolphins (*Sousa chinensis*). *Frontiers in Marine Science*, *8*, 1–10.

Loizaga de Castro, R., Saporiti, F., Vales, D. G., Cardona, L., & Crespo, E. A. (2017). Using stable isotopes to assess whether two sympatric dolphin species share trophic resources. *Marine Mammal Science*, *33*(4), 1234–1244.

Low, C. B., Chong, Vi. C., Hayase, S., & Lim, L. H. S. (1999). Prawn production of Matang and Dinding River mangroves: Species distribution and seasonal recruitment. In K. Kiso & P. S. Choo (Eds.), *Production and Sustainable Utilization of Brackish Water Mangrove Ecosystems, Proceedings of the 4th Seminar of Results of 1997/98 Research Projects* (pp. 89–101). Japan International Research Centre for Agricultural Sciences and Ministry of Aqriculture Malaysia, Penang. http://repository.um.edu.my/63169/

Luksenburg, J. A. (2014). Prevalence of external injuries in small cetaceans in aruban waters, Southern Caribbean. *PLoS ONE*, *9*(2), 1–10.

MacLeod, C. D. (2013). *An Introduction To Using GIS In Marine Biology: Supplementary Workbook Four – Investigating Home Ranges Of Individual Animals*. Pictish Beast Publications, Glasgow, UK.

Mahmud, A. I., Emiru, K. T., & Viez, E. R. A. (2015). Ecotourism in Mangroves in Peninsular Malaysia. *World Applied Sciences Journal*, *33*(5), 699–703.

Mahmud, A. I., Jaaman, S. A., Muda, A. M., Muhamad, H. M., Zhang, X., & Scapini, F. (2018a). Factors influencing the behaviour of Irrawaddy dolphins Orcaella brevirostris (Owen in Gray, 1866) in Brunei Bay, Malaysia. *Journal of Ethology*, *36*(2), 169–180.

Mahmud, A. I., Jaaman, S. A., Muda, A. M., Muhamad, H. M., Zhang, X., & Scapini, F. (2018b). Population estimation, distribution, and habitat preference of Irrawaddy dolphins *Orcaella brevirostris* (Owen in Gray, 1866) in the Brunei Bay, Malaysian waters. *Wildlife Biology*, *2018*, 1-14.

Major gains from wild dolphin sightings in Kuala Sepetang. (2011, August 11). *New Straits Times*.

Marsh, H., Lloze, R., Heinsohn, G. E., & Kasuya, T. (1989). Irrawaddy dolphin, *Orcaella brevirostris* (Gray, 1866). In S. H. Ridgway & R. Harrison (Eds.), *Handbook of Marine Mammals* (pp. 101–118). Academic Press, London.

Matthiopoulos, J., Smout, S., Winship, A. J., Thompson, D., Boyd, I. L., & Harwood, J. (2008). Getting beneath the surface of marine mammal - Fisheries competition. *Mammal Review*, *38*(2–3), 167–188.

Mazlan, A. G., Abdullah, S., Sharmina, M. G., & Arshad, A. (2008). On the biology and bioacoustic characteristic of spotted catfish *Arius maculatus* (Thunberg 1792) from the Malaysian estuary. *Research Journal of Fisheries and Hydrobiology*, *3*(2), 63–70.

McCabe, E. J. B., Gannon, D. P., Barros, N. B., & Wells, R. S. (2010). Prey selection by resident common bottlenose dolphins (*Tursiops truncatus*) in Sarasota Bay, Florida. *Marine Biology*, *157*(5), 931–942.

McClellan, C. M., Brereton, T., Amico, F. D., Johns, D. G., Cucknell, A., Patrick, S. C., … Godley, B. J. (2014). *Understanding the Distribution of Marine Megafauna in the English Channel Region : Identifying Key Habitats for Conservation within the Busiest Seaway on Earth*. *9*(2), 1-16.

McCluskey, S. M., Bejder, L., & Loneragan, N. R. (2016). Dolphin prey availability and calorific value in an estuarine and coastal environment. *Frontiers in Marine Science*, *3*, 1–23.

Methion, S., & Díaz López, B. (2018). Abundance and demographic parameters of bottlenose dolphins in a highly affected coastal ecosystem. *Marine and Freshwater Research*, *69*(9), 1355-1364.

Minton, G., Peter, C., Poh, A. N. Z., Ngeian, J., Braulik, G., Hammond, P. S., & Tuen, A. A. (2013). Population estimates and distribution patterns of Irrawaddy dolphins (*Orcaella brevirostris*) and Indo-Pacific finless porpoises (*Neophocaena phocaenoides*) in the Kuching Bay, Sarawak. *The Raffles Bulletin of Zoology*, *61*(2), 877–888.

Minton, G., Peter, C., & Tuen, A. A. (2011). Distribution of small cetaceans in the nearshore waters of Sarawak, East Malaysia. *The Raffles Bulletin of Zoology*, *59*(1), 91–100.

Minton, G., Smith, B. D., Braulik, G. T., Kreb, D., Sutaria, D., & Reeves, R. (2017). *Orcaella brevirostris*. The IUCN Red List of Threatened Species 2017: e.T15419A50367860.

Minton, G., Zulkifli Poh, A. N., Peter, C., Porter, L., & Kreb, D. (2016). Indo-Pacific humpback dolphins in Borneo: a review of current knowledge with emphasis on Sarawak. *Advances in Marine Biology*, *73*, 141–156.

Mok, H.-K., Lin, S.-Y., & Tsai, K.-E. (2011). Underwater ambient biological noise in the waters on the west coast of Taiwan. *Kuroshio Science*, *5*, 51–57.

Moore, J. E., Cox, T. M., Lewison, R. L., Read, A. J., Bjorkland, R., McDonald, S. L., Crowder, L. B., Aruna, E., Ayissi, I., Espeut, P., Joynson-Hicks, C., Pilcher, N., Poonian, C. N. S., Solarin, B., & Kiszka, J. (2010). An interview-based approach to assess marine mammal and sea turtle captures in artisanal fisheries. *Biological Conservation*, *143*(3), 795–805.

Moore, S. E. (2008). Marine mammals as ecosystem sentinels. *Journal of Mammalogy*, *89*(3), 534–540.

Morrison, M. L., Marcot, B. G., & Mannan, R. W. (1999). Wildlife-Habitat Relationships: Concepts and Applications. *Journal of Range Management*, *47*(4), 316.

Morzer Bruyns, W. F. J. (1965). *Some notes on the Irrawaddy Dolphin, Orcaellla* *brevirostris (Owen, 1866)*.

Mustika, P. L. K., Birtles, A., Everingham, Y., & Marsh, H. (2015). Evaluating the potential disturbance from dolphin watching in Lovina, north Bali, Indonesia. *Marine Mammal Science*, *31*(2), 808–817.

Mustika, P. L. K., Welters, R., Ryan, G. E., D'Lima, C., Sorongon-Yap, P., Jutapruet, S., & Peter, C. (2016). A rapid assessment of wildlife tourism risk posed to cetaceans in Asia. *Journal of Sustainable Tourism*, *9582*(December), 1–21.

Nadarajah, C. (2000). Breaking the surface - A study of whales, dolphins, and dugongs in West Malaysia. *European Research on Cetaceans*, *14*, 43.

Nekolny, S. R., Denny, M., Biedenbach, G., Howells, E. M., Mazzoil, M., Durden, W. N., Moreland, L., Lambert, J. D., & Gibson, Q. A. (2017). Effects of study area size on home range estimates of common bottlenose dolphins *Tursiops truncatus*. *Current Zoology*, *63*(6), 693–701.

Ng, S. L., & Leung, S. (2003). Behavioral response of Indo-Pacific humpback dolphin (*Sousa chinensis*) to vessel traffic. *Marine Environmental Research*, *56*(5), 555–567.

Nicol, C., Bejder, L., Green, L., Johnson, C., Keeling, L., Noren, D., Van der Hoop, J., & Simmonds, M. (2020). Anthropogenic Threats to Wild Cetacean Welfare and a Tool to Inform Policy in This Area. *Frontiers in Veterinary Science*, *7*(February), 1–12.

Niu, F. Q., Yang, Y. M., Zhou, Z. M., Wang, X. Y., Monanunsap, S., & Junchumpoo, C. (2019). Echolocation clicks of free-ranging Irrawaddy dolphins (*Orcaella brevirostris*) in Trat Bay, the eastern Gulf of Thailand . *The Journal of the Acoustical Society of America*, *145*(5), 3031–3037.

Notarbartolo di Sciara, G., Hoyt, E., Reeves, R., Ardron, J., Marsh, H., Vongraven, D., & Barr, B. (2016). Place-based approaches to marine mammal conservation. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *26*(February), 85–100.

Ogle, K. M. (2005). *Fine-scale movement patterns of Pacific coast bottlenose dolphins (Tursiops truncatus).* (M.Sc. thesis). San Diego State University, San Diego, CA.

Okamura, K., Tanaka, K., Siow, R., Man, A., Kodama, M., & Ichikawa, T. (2010). Spring tide hypoxia with relation to chemical properties of the sediments in the Matang Mangrove Estuary, Malaysia. *Japan Agricultural Research Quartery, 44*(3), 325-333.

Or, C. K. M. (2017). *Socio-spatial ecology of Indo-Pacific humpback dolphins (Sousa chinensis) in Hong Kong and the Pearl River Estuary*. (Doctoral dissertation). The University of Hong Kong, Hong Kong.

Oshima, J. E. de F., & Santos, M. C. de O. (2016). Guiana dolphin home range analysis based on 11 years of photo-identification research in a tropical estuary. *Journal of Mammalogy*, *97*(2), 599–610.

Oudejans, M. G., Visser, F., Englund, A., Rogan, E., & Ingram, S. N. (2015). Evidence for distinct coastal and offshore communities of bottlenose dolphins in the north east atlantic. *PLoS ONE*, *10*(4), 1–15.

Parra, G. J. (2005). *Behavioural ecology of Irrawaddy, Orcaella brevirostris (Owen in Gray, 1866), and Indo-Pacific humpback dolphins, Sousa chinensis (Osbeck, 1765), in northwest Queensland, Australia: a comparative study*. (Ph.D thesis). James Cook University, Townsville.

Parra, G. J. (2006). Resource partitioning in sympatric delphinids: Space use and habitat preferences of Australian snubfin and Indo-Pacific humpback dolphins. *Journal of Animal Ecology*, *75*(4), 862–874.

Parra, G. J. (2007). Observations of an Indo-Pacific humpback dolphin carrying a sponge: Object play or tool use? *Mammalia*, *71*(3), 147–149.

Parra, G. J., & Corkeron, P. J. (2001). Feasibility of using photo-identification techniques to study the Irrawaddy dolphin, *Orcaella brevirostris* (Owen in Gray 1866). *Aquatic Mammals*, *27*(1), 45–49.

Parra, G. J., Corkeron, P. J., & Arnold, P. (2011). Grouping and fission-fusion dynamics in Australian snubfin and Indo-Pacific humpback dolphins. *Animal Behaviour*, *82*(6), 1423–1433.

Parra, G. J., Corkeron, P. J., & Marsh, H. (2006). Population sizes, site fidelity and residence patterns of Australian snubfin and Indo-Pacific humpback dolphins: Implications for conservation. *Biological Conservation*, *129*(2), 167–180.

Parra, G. J., & Jedensjö, M. (2014). Stomach contents of Australian snubfin (*Orcaella heinsohni*) and Indo-Pacific humpback dolphins (*Sousa chinensis*). *Marine Mammal Science*, *30*(3), 1184–1198.

Parra, G. J., & Jefferson, T. A. (2018). Humpback Dolphins. In B. Wursig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), *Encyclopedia of Marine Mammals, Third edition* (pp. 483–489). Academic Press, London, UK.

Parra, G. J., & Ross, G. J. B. (2009). Humpback Dolphins. In W. F. Perrin, B. Würsig, & J. G. M. Thewissen (Eds.), *Encyclopedia of Marine Mammals, Secondedition, (*pp. 576–582). Academic Press, Elsevier, San Diego, CA.

Parsons, E. C. M. (1998). The behaviour of Hong Kong's resident cetaceans: The Indo-Pacific hump-backed dolphin and the finless porpoise. *Aquatic Mammals, 24*(3), 91-110.

Parsons, E. C. M. (2004). The Behavior and Ecology of the Indo-Pacific Humpback Dolphin (*Sousa chinensis*). *Aquatic Mammals*, *30*(1), 38–55.

Parsons, E. C. M., & Jefferson, T. A. (2000). Post-mortem investigations on stranded dolphins and porpoises from Hong Kong waters. *Journal of Wildlife Diseases*, *36*(2), 342–356.

Passadore, C., Möller, L., Diaz-Aguirre, F., & Parra, G. J. (2018). High site fidelity and restricted ranging patterns in southern Australian bottlenose dolphins. *Ecology and*

Evolution, *8*(1), 242–256.

Peng, C., Wu, H., Wang, X., Zhu, Q., Jefferson, T. A., Wang, C., Xu, Y., Li, J., Huang, H., Chen, M., & Huang, S. (2020). Abundance and residency dynamics of the Indo-Pacific humpback dolphin, *Sousa chinensis*, in the Dafengjiang River Estuary, China. *Marine Mammal Science*, *36*(2), 623–637.

Perak Fisheries Department. (2012). *Annual Fisheries Statistics 2011*. Fisheries Department, Perak.

Perrin, W. F. (2002). Problems of marine mammal conservation in Southeast Asia. *Fisheries Science*, *68*, 238–243.

Peter, C. (2012). *Distribution patterns, habitat characteristics and population estimates of Irrawaddy dolphins Orcaella brevirostris) in Kuching Bay, Sarawak*. (Master's thesis). Universiti Malaysia Sarawak, Kota Samarahan, Malaysia.

Peter, C., Norliza, A., Ngeian, J., Tuen, A. A., & Minton, G. (2016). Identifying habitat characteristics and critical areas for Irrawaddy Dolphin, *Orcaella brevirostris*: implications for conservation. *Topics in Biodiversity and Conservation*, *15*, 225–238.

Pilcher, N. J., Adulyanukosol, K., Das, H., Davis, P., Hines, E., Kwan, D., Marsh, H., Ponnampalam, L. S., & Reynolds, J. (2017). A low-cost solution for documenting distribution and abundance of endangered marine fauna and impacts from fisheries. *PLoS ONE*, *12*(12), 1–15.

Pilcher, N. J., & Kwan, D. (2012). *Dugong questionnaire survey project manual*. *September*, 44.

Pine, M. K., Wang, D., Porter, L., & Wang, K. X. (2017a). Investigating the spatiotemporal variation of fish choruses to help identify important foraging habitat for Indo-Pacific humpback dolphins, *Sousa chinensis*. *ICES Journal of Marine Science*, *75*(2), 510-518.

Pine, M. K., Wang, K., & Wang, D. (2017b). Fine-scale habitat use in Indo-Pacific humpback dolphins, *Sousa chinensis*, may be more influenced by fish rather than vessels in the Pearl River Estuary, China. *Marine Mammal Science*, *33*(1), 291–312.

Piwetz, S., Lundquist, D., & Würsig, B. (2015). Humpback Dolphin (Genus Sousa) Behavioural Responses to Human Activities. *Advances in Marine Biology*, *72*, 17–45.

Pollock, K. (1982). A capture-recapture sampling design robust to unequal catchability. *The Journal of Wildlife Management*, *46*(3), 752–757.

Ponnampalam, L. S. (2012). Opportunistic observations on the distribution of cetaceans in the Malaysian South China, Sulu and Sulawesi Seas and an updated checklist of marine mammals in Malaysia. *The Raffles Bulletin of Zoology*, *60*(1), 221–231.

Ponnampalam, L. S. (2013). The dolphins of the Matang Mangroves. In R. Ariffin & N. M. S. Nik Mustafa (Eds.), *A Working Plan for The Matang Mangrove Forest*

Reserve, Perak: The First 10-year Period (2010–2019) of the Third Rotation (Sixth Revision). State Forestry Department, Perak, Malaysia, (pp. 110–112).

Ponnampalam, L. S., & Fairul Izmal, J. H. (2011). Distribution, ecology, and conservation of cetaceans around the Langkawi Archipelago, with special reference to Indo-Pacific humpback dolphins, *Sousa chinensis*. *Final Report to the Ocean Park Conservation Foundation Hong Kong, August 2011.*, 41 pp.

Ponnampalam, L. S., Fairul Izmal, J. H., Adulyanukosol, K., Ooi, J. L. S. S., & Reynolds, J. E. (2015). Aligning conservation and research priorities for proactive species and habitat management: the case of dugongs *Dugong dugon* in Johor, Malaysia. *Oryx*, *49*(4), 743–749.

Ponnampalam, L. S., Hines, E. M., Monanunsap, S., Ilangakoon, A. D., Junchumpoo, C., Adulyanukosol, K., & Morse, L. J. (2013). Behavioral observations of coastal Irrawaddy dolphins (*Orcaella brevirostris*) in Trat Province, Eastern Gulf of Thailand. *Aquatic Mammals*, *39*(4), 401–408.

Ponnampalam, L. S., Kimura, S., & Fairul Izmal, J. H. (2012). The abundance and conservation management of cetaceans in Langkawi, Malaysia, with special references to the Indo-Pacific finless porpoise (*Neophocaena phocaenoides*) and Indo-Pacific humpback dolphin (*Sousa chinensis*). *Final Report of Project No. IPCF 12/2 Submitted to the Australian Marine Mammal Centre Grants Program, April 2014*, 30 pp.

Ponnampalam, L. S., Kuit, S. H., & Ng, J. E. (2018). Diversity and distribution of marine mammals in Tun Mustapha Park, Kudat, Sabah , during the Tun Mustapha Park Scientific Expedition 2017. *Sabah Parks Nature Journal*, *11*, 35–46.

Powell, R. A., & Mitchell, M. S. (2012). What is a home range? *Journal of Mammalogy*, *93*(4), 948–958.

Puig-Lozano, R., Fernández, A., Sierra, E., Saavedra, P., Suárez-Santana, C. M., De la Fuente, J., … Arbelo, M. (2020). Retrospective Study of Fishery Interactions in Stranded Cetaceans, Canary Islands. *Frontiers in Veterinary Science*, *7*(October), 1–15.

R Core Team. (2020). *R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/* (URL https://www.R-project.org/). URL https://www.R-project.org/.

Rahman, M. A. A., Rusli, M. U., Aziz, N., Rusli, M. H. M., & Talaat, W. (2018). An appraisal of the Malaysian legal framework in conserving the marine endangered species. *Journal of Sustainability Science and Management, 5, 217-224.*

Rajamani, L., Porter, L., Dolar, L., Rodríguez-Vargas, L. H., & Yobe, M. (2018). Marine mammals of coastal Penang Island, Malaysia. *Aquatic Mammals*, *44*(3), 319–327.

Rajamani, L., Rodríguez-Vargas, L. H., & Swee Ling, O. (2014). Local community knowledge of Penang's marine mammals. In N. Esa, L. Rajamani & Z. Yusoff (Eds.), *Re-engineering Local Knowledge: Life Science and Technology* (pp. 73–89). Penang, Malaysia: Penerbit Universiti Sains Malaysia.

Ratnam, L. C. (1982). The Irrawaddy river dolphin in the Bernam River. *The Journal of Wildlife and Parks*, *1*(17).

Read, A. J. (2008). The looming crisis: interactions between marine mammals and fisheries. *Journal of Mammalogy*, *89*(3), 541–548.

Reeves, R., McClellan, K., & Werner, T. (2013). Marine mammal bycatch in gillnet and other entangling net fisheries, 1990 to 2011. *Endangered Species Research*, *20*(1), 71–97.

Reeves, R. R., Smith, B. D., Crespo, E. A., & Notarbartolo di Sciara, G. (2003). Dolphins, whales, and porpoises: 2002–2010 conservation action plan for the world's cetaceans. *IUCN/SSC Cetacean Specialist Group.* IUCN, Gland, Switzerland & Cambridge, UK. 139 pp.

Reggente, M. A. L., Alves, F., Nicolau, C., Freitas, L., Cagnazzi, D., Baird, R. W., & Galli, P. (2016). Nurturant behavior toward dead conspecifics in free-ranging mammals: New records for odontocetes and a general review. *Journal of Mammalogy*, *97*(5), 1428–1434.

Rice, D. W. (1998). *Marine Mammals of the World. Systematics and Distribution*. The Society for Marine Mammalogy.

Riedman, M. L. (1982). The Evolution of Alloparental Care and Adoption in Mammals and Birds. *The Quarterly Review of Biology*, *57*(4), 405–435.

Rodríguez-Vargas, L. H. (2015). *The Distribution of Aquatic Mammals in the Waters of Penang Island, Malaysia, with a Focus on the Ecology and Conservation of the Irrawaddy dolphin Orcaella brevirostris (Owen in Grey, 1866)*. (Master's thesis). Universiti Sains Malaysia, Penang, Malaysia.

Rodríguez-Vargas, L. H., Rajamani, L., Dolar, L., & Porter, L. (2019). Population size, distribution and daylight behaviour of Irrawaddy dolphins (*Orcaella brevirostris*) in Penang Island, Malaysia. *Raffles Bulletin of Zoology*, *67*, 671–683.

Ronje, E. I., Barry, K. P., Sinclair, C., Grace, M. A., Allen, J., Balmer, B., Panike, A., Toms, C., Mullin, K. D., & Wells, S. (2017). *A common bottlenose dolphin (Tursiops truncatus) prey handling technique for marine catfish (Ariidae) in the northern Gulf of Mexico*, *12*(7), e0181179.

Ross, P. S., Dungan, S. Z., Hung, S. K., Jefferson, T. A., Macfarquhar, C., Perrin, W. F., Riehl, K. N., Slooten, E., Tsai, J., Wang, J. Y., White, B. N., Würsig, B., Yang, S. C., & Reeves, R. R. (2010). Averting the baiji syndrome: conserving habitat for critically endangered dolphins in Eastern Taiwan Strait. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *20*(6), 685–694.

Rossman, S., Ostrom, P. H., Stolen, M., Barros, N. B., Gandhi, H., Stricker, C. A., & Wells, R. S. (2015). Individual specialization in the foraging habits of female bottlenose dolphins living in a trophically diverse and habitat rich estuary. *Oecologia*, *178*(2), 415-425.

Sasekumar, A., Chong, V. C., & Harinder, R. S. (1994a). The physical and chemical characteristics of Matang Mangrove waters. *Proceedings of the Third ASEAN-Australia Symposium on Living Coastal Resources, Vol. 2: Research Papers, Chulalongkorn University, Bangkok, Thailand*, 446–453.

Sasekumar, A., Chong, V. C., Lim, K. H., & Singh, H. R. (1994b). The fish community of Matang mangrove waters. *Proceedings of the Third ASEAN-Australia Symposium on Living Coastal Resources, Vol. 2: Research Papers, Chulalongkorn University, Bangkok, Thailand*, 457–464.

Seaman, D. E., Millspaugh, J. J., Kernohan, B. J., Brundige, G. C., Raedeke, K. J., & Gitzen, R. A. (2007). Effects of Sample Size on Kernel Home Range Estimates. *The Journal of Wildlife Management*, *63*(2), 739-747.

Shane, S. H. (1990). Behavior and Ecology of the Bottlenose Dolphin at Sanibel Island, Florida. In Leatherwood, S. & Reeves, R.R., (Eds.), *The Bottlenose Dolphin* (pp. 245-265). San Diego, Academic Press.

Slooten, E. (2013). Effectiveness of area-based management in reducing bycatch of the New Zealand dolphin. *Endangered Species Research*, *20*(2), 121–130.

Slooten, E., Wang, J. Y., Dungan, S. Z., Forney, K. A., Hung, S. K., Jefferson, T. A., … Chen, C. (2013). Impacts of fisheries on the Critically Endangered humpback dolphin *Sousa chinensis* population in the eastern Taiwan Strait. *Endangered Species Research*, *22*(2), 99–114.

Smith, B. D. (2004). *Orcaella brevirostris (Ayeyarwady River subpopulation).* The IUCN Red List of Threatened Species 2004: e.T44556A10919593.

Smith, B. D. (2018). Irrawaddy Dolphin: *Orcaella brevirostris*. In B. Wursig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), *Encyclopedia of Marine Mammals, Third edition* (pp. 525-529). Academic Press, London, UK.

Smith, B. D., Ahmed, B., Mowgli, R. M., & Strindberg, S. (2008). Species occurrence and distributional ecology of nearshore cetaceans in the Bay of Bengal, Bangladesh, with abundance estimates for Irrawaddy dolphins *Orcaella brevirostris* and finless porpoises *Neophocaena phocaenoides*. *Journal of Cetacean Research and Management*, *10*(1), 45–58.

Smith, B. D., & Beasley, I. (2004a). *Orcaella brevirostris Malampaya Sound subpopulation.* The IUCN Red List of Threatened Species 2004: e.T44187A10858619

Smith, B. D., & Beasley, I. (2004b). *Orcaella brevirostris Mekong River subpopulation.* The IUCN Red List of Threatened Species 2004: e.T44555A10919444.

Smith, B. D., & Beasley, I. (2004c). *Orcaella brevirostris Songkhla Lake subpopulation.* The IUCN Red List of Threatened Species 2004: *e.T44557A10919695.*

Smith, B. D., Braulik, G., Jefferson, T. A., Chung, B. D., Vinh, C. T., Van Du, D., Van Hanh, B., Trong, P. D., Ho, D. T., & Van Quang, V. (2003). Notes on two cetacean surveys in the Gulf of Tonkin, Vietnam. *Raffles Bulletin of Zoology*, *51*(1), 165–171.

Smith, B. D., Braulik, G., Strindberg, S., Ahmed, B., & Mansur, R. (2006). Abundance of Irrawaddy dolphins (*Orcaella brevirostris*) and Ganges River dolphins (*Platanista gangetica gangetica*) estimated using concurrent counts made by independent teams in waterways of the sundarbans mangrove forest in Bangladesh. *Marine Mammal Science*, *22*(3), 527–547.

Smith, B. D., Braulik, G., Strindberg, S., Mansur, R., & Ahmed, B. (2009a). Habitat selection of freshwater-dependent cetaceans and the potential effects of declining freshwater flows and sea-level rise in waterways of the Sundarbans mangrove forest, Bangladesh. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *225*, 209–225.

Smith, B. D., Mansur, R., Strindberg, S., Redfern, J., & Moore, T. (2015). Population demographics, habitat selection, and a spatial and photographic analysis of bycatch risk of Indo-Pacific humpback dolphins *Sousa chinensis* and bottlenose dolphins *Tursiops aduncus* in the northern Bay of Bengal, Bangladesh. *International Whaling Commission Scientific Committee Report*, 1–31.

Smith, B. D., Shore, R. G., & Lopez, A. (2007). *Status and conservation of freshwater populations of Irrawaddy dolphins.* (Issue Working Paper No. 31).

Smith, B. D., Sonim, V., Boonchai, R., Cadena, A. J., & Manopawitr, P. (2016). *Final report on dolphin conservation along the coastline of the Thai and Cambodian border.* https://www.iucn.org/sites/dev/files/content/documents/2016/final20report20iucn20cambodia20thailand20dolphin20project_final2028229.pdf

Smith, B. D., Tun, M. T., Chit, A. M., Win, H., & Moe, T. (2009b). Catch composition and conservation management of a human-dolphin cooperative cast-net fishery in the Ayeyarwady River, Myanmar. *Biological Conservation*, *142*(5), 1042–1049.

Smith, F., Allen, S. J., Bejder, L., & Brown, A. M. (2018). Shark bite injuries on three inshore dolphin species in tropical northwestern Australia. *Marine Mammal Science*, *34*(1), 87–99.

Soulsbury, C., Iossa, G., & Harris, S. (2008). The Animal Welfare Implications of Cetacean Deaths in Fisheries. *Whale and Dolphin Conservation Society*, 1–54. http://au.whales.org/sites/default/files/work/wdcs_bycatchreport_2008_full.pdf

Stacey, P. J., & Leatherwood, S. (1997). The Irrawaddy dolphin, *Orcaella brevirostris*: a summary of current knowledge and recommendations for conservation action. *Asian Marine Biology*, *14*, 195–214.

Sutaria, D., & Jefferson, T. A. (2004). Records of Indo-Pacific Humpback Dolphins (Sousa chinensis, Osbeck, 1765) Along the Coasts of India and Sri Lanka: An Overview. *Aquatic Mammals*, *30*(1), 125–136.

Sutaria, D., & Marsh, H. (2011). Abundance estimates of Irrawaddy dolphins in Chilika Lagoon, India, using photo-identification based mark-recapture methods. *Marine Mammal Science*, *27*(4), 338-348.

Sutaria, D. N. (2009). *Species conservation in a complex socio-ecological system :*

Irrawaddy dolphins, Orcaella brevirostris in Chilika Lagoon, India. (Ph.D thesis). James Cook University, Townsville, Australia.

Sutaria, D., Panicker, D., Jog, K., Sule, M., Muralidharan, R., & Bopardikar, I. (2015). Humpback Dolphins (Genus *Sousa*) in India: An Overview of Status and Conservation Issues. *Advances in Marine Biology*, *72*, 229-256.

Symons, J., Sprogis, K. R., & Bejder, L. (2018). Implications of survey effort on estimating demographic parameters of a long-lived marine top predator. *Ecology and Evolution*, *8*(21), 10470–10481.

Tan, C. L. (2016, April 19). *Our rarely seen and little known dolphin species need some care*. https://www.thestar.com.my/lifestyle/living/2016/04/19/our-rarely-seen-and-little-known-dolphin-species-need-some-care

Tanaka, K., & Choo, P. S. (2000). Influences of nutrient outwelling from the Mangrove swamp on the distribution of phytoplankton in the Matang Mangrove Estuary, Malaysia. *Journal of Oceanography*, *56*(1), 69-78.

Tanaka, K., Hanamura, Y., Chong, V. C., Watanabe, S., Man, A., Kassim, F. M., … Ichikawa, T. (2011). Stable isotope analysis reveals ontogenetic migration and the importance of a large mangrove estuary as a feeding ground for juvenile John's snapper *Lutjanus johnii*. *Fisheries Science*, *77*(5), 809–816.

Tanaka, K., Sugahara, K., Ohwaki, Y., & Choo, P. S. (1998). C, N, P composition of suspended matter in Matang Mangrove Estuary, Malaysia. *Japan Agricultural Research Quarterly*, *32*(2), 153–158.

Tarsi, K., & Tuff, T. (2012). Introduction to Population Demographics. *Nature Education Knowledge*, *3*(11), 3.

Temple, A.J., Westmerland, E. & Berggren, P. (2021). By-catch risk for toothed whales in global small-scale fisheries. *Fish and Fisheries*, *2021*(00), 1–5.

Teoh, H. W. (2014). *Ecology of hermit crabs (Family Diogenidae) in Matang mangrove estuary and adjacent coastal waters*. (Doctoral dissertation). University of Malaya, Kuala Lumpur, Malaysia.

Teoh, S. W., Jaaman, S. A., & Palaniappan, P. M. (2013). A preliminary study of population size of Irrawaddy Dolphins (*Orcaella brevirostris*) in Cowie Bay, Sabah, Malaysia. *Journal of Tropical Biology and Conservation*, *10*, 23–26.

Teoh, Z. Y. (2018). *Humpback dolphin social ecology under anthropogenic threats in Langkawi, Malaysia. Final report of project No. 03286416 submitted to the Conservation Leadership Program, September 2018,* 46 pp.

Teoh, Z. Y., Kuit, S. H., & Then, A. Y. (2019). Social Structure of Indo-Pacific Humpback Dolphins (*Sousa chinensis*) in the Matang Important Marine Mammal Area. *Poster Presentation at the World Marine Mammal Conference, Barcelona, Spain. December, 2019.*

Then, A. Y. H. (2008). *The structure and trophodynamics of the fish community in* *estuaries of Matang Mangrove Forest Reserve, Peninsular Malaysia*. (Master's thesis). University of Malaya, Kuala Lumpur, Malaysia.

Thiele, D. (2010). Collision Course: Snubfin dolphin injuries in Roebuck Bay. *Report to the World Wildlife Fund - Australia*, *July*, 15.

Thomas, L., Buckland, S. T., Burnham, K. P., Anderson, D. R., Laake, J. L., Borchers, D. L., & Strindberg, S. (2014). Distance Sampling. In N. Balakrishnan, T. Colton, B. Everitt, W. Piegorsch, F. Ruggeri & J. L. Teugels, *Wiley StatsRef: Statistics Reference Online*, 1–15.

Thomas, L., Buckland, S. T., Rexstad, E. A., Laake, J. L., Strindberg, S., Hedley, S. L., Bishop, J. R. B., Marques, T. A., & Burnham, K. P. (2010). Distance software: Design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology*, *47*(1), 5–14.

Thomas, L., Williams, R., Sandilands, D., Andrews, S., Thomas, L., Williams, R., Sandilands, D., & Andrews, S. (2007). Designing line transect surveys for complex survey regions. *Journal of Cetacean Research and Management*, *9*(1), 1–21.

Tide Tables Malaysia. (2013). *Tide Tables Malaysia 2013*. National Hydrographic Centre, Royal Malaysian Navy.

Tide Tables Malaysia. (2014). *Tide Tables Malaysia 2014*. National Hydrographic Centre, Royal Malaysian Navy.

Tide Tables Malaysia. (2015). *Tide Tables Malaysia 2015*. National Hydrographic Centre, Royal Malaysian Navy.

Tide Tables Malaysia. (2016). *Tide Tables Malaysia 2016*. National Hydrographic Centre, Royal Malaysian Navy.

Tongnunui, S., Wattanakornsiri, A., Pachana, K., Beamish, F. W. H., & Tongsukdee, S. (2011). Preliminary Investigation of Irrawaddy Dolphin (*Orcaella brevirostris*) in the Bangpakong Estuary, Inner Gulf of Thailand. *Environment and Natural Resources Journal*, *9*(2), 48–57.

Tyack, P. L. (2018). Behavior, Overview. *In B. Wursig, J. G. M. Thewissen, & K. M. Kovacs (Eds.), Encyclopedia of Marine Mammals,* Third edition (pp. 86–93). Academic Press, London, UK.

Urian, K., Gorgone, A., Read, A., Balmer, B., Wells, R. S., Berggren, P., … Hammond, P. S. (2015). Recommendations for photo-identification methods used in capture-recapture models with cetaceans. *Marine Mammal Science*, *31*(1), 298–321.

Van Bressem, M. F., Burville, B., Sharpe, M., Berggren, P. & Van Waerebeek, K. (2018). Visual health assessment of white-beaked dolphins off the coast of Northumberland, North Sea, using underwater photography. *Marine Mammal Science*, *34*(4), 1119–1133.

Van Bressem, M.-F., Minton, G., Sutaria, D., Kelkar, N., Peter, C., Zulkarnaen, M., Mansur, R. M., Porter, L., Vargas, L. H. R., & Rajamani, L. (2014). Cutaneous nodules in Irrawaddy dolphins: An emerging disease in vulnerable populations. *Diseases of Aquatic Organisms*, *107*(3), 181–189.

Van Bressem, M. F., Santos, M. C. de O., & Oshima, J. E. de F. (2009). Skin diseases in Guiana dolphins (Sotalia guianensis) from the Paranaguá estuary, Brazil: A possible indicator of a compromised marine environment. *Marine Environmental Research*, *67*(2), 63–68.

Van Waerebeek, K., Baker, A. N., Félix, F., Gedamke, J., Iñiguez, M., Sanino, G. P., Secchi, E., Sutaria, D., Helden, A. van, & Wang, Y. (2007). Vessel collisions with small cetaceans worldwide and with large whales in the Southern Hemisphere, an initial assessment. *Latin American Journal of Aquatic Mammals*, *6*(1), 43–69.

Verutes, G. M., Johnson, A. F., Caillat, M., Ponnampalam, L. S., Peter, C., Vu, L., … Hines, E. M. (2020). Using GIS and stakeholder involvement to innovate marine mammal bycatch risk assessment in data-limited fisheries. *Plos One*, *15*(8), e0237835.

Walters, B. B., Rönnbäck, P., Kovacs, J. M., Crona, B., Hussain, S. A., Badola, R., Primavera, J. H., Barbier, E., & Dahdouh-Guebas, F. (2008). Ethnobiology, socio-economics and management of mangrove forests: A review. *Aquatic Botany*, *89*(2), 220–236.

Wang, J. Y., & Araujo-Wang, C. (2018). *Sousa chinensis ssp. taiwanensis (amended version of 2017 assessment).* The IUCN Red List of Threatened Species 2018: e.T133710A122515524.

Wang, J. Y., & Araújo-Wang, C. (2017). Severe mutilation of a Critically Endangered Taiwanese humpback dolphin *Sousa chinensis taiwanensis* by fishing gear. *Diseases of Aquatic Organisms*, *123*(3), 257–262.

Wang, J. Y., Chu Yang, S., Hung, S. K. Y., & Jefferson, T. A. (2007). Distribution, abundance and conservation status of the eastern Taiwan Strait population of Indo-Pacific humpback dolphins, *Sousa chinensis*. *Mammalia*, *71*(4), 157–165.

Wang, J. Y., Hung, S. K. Y., Yang, C., Jefferson, T. A., Secchi, E. R., Yang, S. C., Jefferson, T. A., Secchi, E. R., & Yang, C. (2008). Population differences in the pigmentation of Indo-Pacific humpback dolphins, *Sousa chinensis*, in Chinese waters. *Mammalia*, *72*(4), 302–308.

Wang, J. Y., Hung, S. K. Y., Yang, S. C., & Swinhoe, R. (2004a). Records of Indo-Pacific Humpback Dolphins, *Sousa chinensis* (Osbeck, 1765), from the Waters of Western Taiwan. *Aquatic Mammals*, *30*(1), 189–196.

Wang, J. Y., Riehl, K. N., Klein, M. N., Javdan, S., Hoffman, J. M., Dungan, S. Z., Dares, L. E., & Araujo-Wang, C. (2015a). Biology and Conservation of the Taiwanese Humpback Dolphin, *Sousa chinensis taiwanensis*. *Advances in Marine Biology*, *73*, 91-117.

Wang, J. Y., Riehl, K. N., Yang, S. C., & Araújo-Wang, C. (2017a). Unsustainable human-induced injuries to the Critically Endangered Taiwanese humpback dolphins (*Sousa chinensis taiwanensis*). *Marine Pollution Bulletin*, *116*(1–2), 167–174.

Wang, J. Y., Yang, S. C., Fruet, P. F., Daura-Jorge, F. G., & Secchi, E. R. (2012). Mark-Recapture Analysis of the Critically Endangered Eastern Taiwan Strait Population of Indo-Pacific Humpback Dolphins (*Sousa chinensis*): Implications for Conservation. *Bulletin of Marine Science*, *88*(4), 885–902.

Wang, J. Y., Yang, S. C., & Reeves, R. R. (2004b). *Report of the First Workshop on Conservation and Research Needs of Indo-Pacific Humpback Dolphins, Sousa chinensis, in the Waters of Taiwan.* National Museum of Marine Biology and Aquarium, Checheng, Pingtung County, Taiwan, 43 pp.

Wang, X., Jutapruet, S., Huang, S., Turvey, S., Wu, F., & Zhu, Q. (2018). External injuries of Indo-Pacific humpback dolphins (*Sousa chinensis*) in Xiamen, China, and its adjacent waters as an indicator of potential fishery interactions. *Aquatic Mammals*, *44*(3), 285–292.

Wang, X., Wu, F., Mou, J., & Zhu, Q. (2013). Indo-Pacific humpback dolphins (*Sousa chinensis*) assist a finless porpoise (*Neophocaena phocaenoides sunameri*) calf: evidence from Xiamen waters in China. *Journal of Mammalogy*, *94*(5), 1123–1130.

Wang, X., Wu, F., Turvey, S. T., Rosso, M., & Zhu, Q. (2016). Seasonal group characteristics and occurrence patterns of Indo-Pacific humpback dolphins (Sousa chinensis) in Xiamen Bay, Fujian Province, China. *Journal of Mammalogy*, *97*(4), 1026–1032.

Wang, Z. T., Nachtigall, P. E., Akamatsu, T., Wang, K. X., Wu, Y. P., Liu, J. C., Duan, G. Q., Cao, H. J., & Wang, D. (2015b). Passive acoustic monitoring the diel, lunar, seasonal and tidal patterns in the biosonar activity of the Indo-Pacific humpback dolphins (*Sousa chinensis*) in the Pearl River Estuary, China. *PLoS ONE*, *10*(11), e0141807.

Wang, Z. T., Nowacek, D. P., Akamatsu, T., Wang, K. X., Liu, J.-C., Duan, G.-Q., Cao, H.-J., & Wang, D. (2017b). Diversity of fish sound types in the Pearl River Estuary, China. *PeerJ*, *5*, e3924.

Wedekin, L. L., Daura-Jorge, F. G., Piacentini, V. Q., & Simões-Lopes, P. C. (2007). Seasonal variations in spatial usage by the estuarine dolphin, *Sotalia guianensis* (van Bénéden, 1864) (Cetacea; Delphinidae) at its southern limit of distribution. *Brazilian Journal of Biology*, *67*(1), 1–8.

Weir, J. S., Duprey, N. M. T., & Würsig, B. (2008). Dusky dolphin (*Lagenorhynchus obscurus*) subgroup distribution: Are shallow waters a refuge for nursery groups? *Canadian Journal of Zoology*, *86*(11), 1225–1234.

Weiss, J. (2006). Foraging Habitats and Associated Preferential Foraging Specializations of Bottlenose Dolphin (*Tursiops truncatus*) Mother-Calf Pairs. *Aquatic Mammals*, *32*(1), 10–19.

Wells, R. S., Allen, J. B., Hofmann, S., Bassos-Hull, K., Fauquier, D. A., Barros, N. B., DeLynn, R. E., Sutton, G., Socha, V., & Scott, M. D. (2008). Consequences of injuries on survival and reproduction of common bottlenose dolphins (*Tursiops truncatus*) along the west coast of Florida. *Marine Mammal Science*, *24*(4), 774–794.

White, G. C., & Burnham, K. P. (1999). Program MARK: Survival estimation from populations of marked animals. *Bird Study*, *46*, S120–S139.

Whitty, T. S. (2014). *Conservation-scapes: An interdisciplinary approach to assessing cetacean bycatch in small-scale fisheries* (Doctoral dissertation, University of California, San Diego). Retrieved from https://escholarship.org/uc/item/2619j4z8

Whitty, T. S. (2016). Multi-methods approach to characterizing the magnitude, impact, and spatial risk of Irrawaddy dolphin (*Orcaella brevirostris*) bycatch in small-scale fisheries in Malampaya Sound, Philippines. *Marine Mammal Science*, *32*(3), 1022–1043.

Wilson, R. M., Tyson, R. B., Nelson, J. A., Balmer, B. C., Chanton, J. P., & Nowacek, D. P. (2017). Niche Differentiation and Prey Selectivity among Common Bottlenose Dolphins (*Tursiops truncatus*) Sighted in St. George Sound, Gulf of Mexico. *Frontiers in Marine Science*, *4*, 1–13.

Worton, B. J. (1989). *Kernel Methods for Estimating the Utilization Distribution in Home-Range Studies*.

Wu, H., & Cheng, Z. (2017). Distribution and habitat characteristics of the Indo-Pacific humpback dolphin *(Sousa chinensis)* in the Northern Beibu Gulf, China. *Aquatic Mammals*, *43*(2), 219–228.

Würsig, B., Parsons, E. C. M., Piwetz, S., & Porter, L. (2016). The Behavioural Ecology of Indo-Pacific Humpback Dolphins in Hong Kong. *Advances in Marine Biology*, *73*, 65–90.

Xu, X., Song, J., Zhang, Z., Li, P., Yang, G., & Zhou, K. (2015). The world's second largest population of humpback dolphins in the waters of Zhanjiang deserves the highest conservation priority. *Scientific Reports*, *5*, 1-9.

Yang, G., Ji, G., Ren, W., Zhou, K., & Wei, F. (2005). Pattern of genetic variation of bottlenose dolphins in Chinese waters. *Raffles Bulletin of Zoology*, *53*(1), 157–164.

Yang, W. C., Chang, W. L., Kwong, K. H., Yao, Y. T., & Chou, L.-S. (2013). Prevalence of Epidermal Conditions in Critically Endangered Indo-Pacific Humpback Dolphins (*Sousa chinensis*) from the Waters of Western Taiwan. *Pakistan Veterinary Journal*, *33*(4), 505–509.

Zanardo, N., Parra, G. J., & Möller, L. M. (2016). Site fidelity, residency, and abundance of bottlenose dolphins (*Tursiops sp.*) in Adelaide's coastal waters, South Australia. *Marine Mammal Science*, *32*(4), 1381–1401.

Zhou, K., Xu, X., & Tian, C. (2007). Distribution and abundance of Indo-Pacific humpback dolphins in Leizhou Bay, China. *New Zealand Journal of Zoology*, *34*(1), 35–42.

Zollett, E. A., & Rosenberg, A. A. (2005). *A Review of Cetacean Bycatch in Trawl Fisheries. Literature Review: prepared for the Northeast Fisheries Science Center, New Hampshire, U.S.A.*

Zulkifli Poh, A. N. (2013). *Habitat characteristics and overlap of small cetaceans in Kuching Bay, Sarawak, Malaysia.* (Master's thesis). Universiti Malaysia Sarawak, Kota Samarahan, Malaysia.

Zulkifli Poh, A. N., Peter, C., Ngeian, J., Tuen, A. A., & Minton, G. (2016). Abundance Estimates of Indo-Pacific Humpback Dolphins (*Sousa chinensis*) in Kuching Bay, East Malaysia. *Aquatic Mammals*, *42*(4), 462–465.