ECOLOGY OF WADERS IN THE JERAM AND REMIS MUDFLATS, SELANGOR DARUL EHSAN

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ABSTRACT

The objectives of this project were to study the distribution and abundance of waders shorebird and water bird species, to study the factors (i.e. tide, time of the day and disturbance) affecting the distribution and behaviour of waders shorebirds and water birds, and to determine the relationships between morphological characteristics and foraging behaviour of waders shorebirds and water birds. The study was conducted in the mudflat area of Jeram and Remis Beaches (in Selangor, Malaysia) from August 2013 to July 2014 using direct observation technique (aided with binoculars and video recorder). Three plots were set-up in Jeram Beach consisted a total of 27 ha meanwhile two plots were set-up in Remis Beach which cover a total area of 28 ha. For abundance study, the birds were counted in four interval periods (i.e. from 0800-1000 hours, 1000-1200 hours, 1400-1600 hours and 1600-1800 hours) in all tidal states. For foraging behaviour study, the actively foraging birds were watched and their foraging activities were recorded for at least 30 seconds up to a maximum of five minutes. A total of 19,041 individuals of waders were recorded during sampling period. No significant differences were found in bird's abundance between Jeram and Remis Beaches (t = 2.96, p = 0.05). Although no difference exist between the sampling sites, a significant difference were detected between the sampling plots in Jeram Beach (S = 16.67, p < 0.001) and also between the sampling plots in Remis Beach (W = 78, p = 0.003). Two samples t-test shows a significant difference in avian abundance between migratory and non-migratory seasons (t = 2.39, p = 0.036). A Spearman Rank Correlation highlighted a significant relationship between bill size and foraging time (R = 0.443, p <0.05), bill size and prey size (R = -0.052, p < 0.05), bill size and probing depth (R = 0.42, p = 0.003), and leg-length and water/mud depth (R = 0.706, p < 0.005). A Mann-Whitney U test showed a significant difference in avian abundance between high and low tides (W = 78.0, p < 0.005). A Friedman's Two-Way ANOVA by rank test proves the significant differences that occurred in bird's distribution between ebbing, low tide peak and rising tide (S = 17.17, p < 0.0001). χ^2 test was used for all behaviours engaged by birds during low tide, and the results show a significant difference between behaviours (χ^2 = 1831.9, p < 0.0001). An ANOVA analysis showed no significant difference in the abundance of birds between interval periods (S = 487.0, p = 0.554). Spearman's rank correlation shows significant relationships between the abundance of bird with the abundance of humans, dogs and vehicles (p < 0.05) in both Jeram and Remis Beaches. Therefore, this study suggests that Jeram and Remis Beaches is important area for waders. Tide and disturbance affect the abundance and behaviours of birds meanwhile time of the day do not affect their abundance and behaviour. The morphological characteristics of bird also influence birds' foraging behavior.

ABSTRAK

Objektif kajian ini adalah untuk mengkaji taburan dan kelimpahan spesies burung-burung air, untuk mengkaji faktor yang mempengaruhi taburan dan tingkah laku burung-burung air (iaitu air pasang, masa dan gangguan), dan juga untuk menentukan hubungan antara ciri morfologi dan tingkah laku mencari makanan burung-burung air. Kajian ini telah dijalankan di kawasan berlumpur di Pantai Jeram dan Pantai Remis (Selangor, Malaysia) dari Ogos 2013 hingga Julai 2014 dengan menggunakan teknik pemerhatian secara langsung (menggunakan teropong dan perakam video). Tiga plot telah dibina di Pantai Jeram yang merangkumi kawasan seluas 27 ha sementara dua plot telah dibina di Pantai Remis yang merangkumi kawasan seluas 28 ha. Untuk kajian kelimpahan, burung dikira dalam empat tempoh fasa (iaitu 0800-1000 jam, 1000-1200 jam, 1400-1600 jam dan 1600-1800 jam) dalam semua keadaan pasang surut. Untuk kajian tingkah laku tabiat pemakanan, burung yang aktif mencari makanan telah diperhati dan aktiviti mencari makanan mereka direkodkan sekurang-kurangnya 30 saat sehingga maksimum 5 minit. Sebanyak 19,041 individu burung-burung air telah dicatatkan sepanjang tempoh pemerhatian. Tiada perbezaan yang signifikan ditemui pada kelimpahan burung antara Pantai Jeram dan Pantai Remis ($t = 2.96$, $p = 0.05$). Walaupun tiada perbezaan wujud di antara kawasan persampelan, perbezaan yang signifikan telah direkodkan di antara plot persampelan di Pantai Jeram ($S = 16.67$, $p < 0.001$) dan juga di antara plot persampelan di Pantai Remis ($W = 78$, $p = 0.003$). Ujian t dua sampel menunjukkan perbezaan signifikan dalam kelimpahan burung di antara musim hijrah dan bukan hijrah ($t = 2.39$, $p = 0.036$). Ujian Kolerasi “Spearman Rank” merekodkan hubungan yang signifikan di antara saiz paruh dan masa mencari makan ($R = 0.443$, $p < 0.05$), saiz paruh dan saiz mangsa ($R = -0.052$, $p < 0.05$), saiz paruh dan kedalaman memasukkan paruh semasa mencari makanan ($R = 0.42$, $p = 0.003$), dan panjang kaki/ kedalaman lumpur ($R = 0.706$, $p < 0.005$). Ujian Mann-Whitney U menunjukkan perbezaan ketara mengenai kelimpahan burung semasa air pasang dan surut ($W = 78.0$, $p < 0.005$). Ujian “Friedman Two-Way ANOVA by rank” membuktikan perbezaan ketara berlaku dalam taburan burung pantai di antara waktu air mula surut, puncak air surut dan air mula pasang ($S = 17.17$, $p < 0.0001$). Ujian χ^2 telah digunakan untuk semua tingkah laku burung-burung air semasa air surut, dan keputusan menunjukkan perbezaan yang signifikan antara tingkah laku ($\chi^2 = 1831.9$, $p < 0.0001$). Analisis ANOVA menunjukkan tiada perbezaan yang signifikan dalam kelimpahan burung antara tempoh selang ($S = 487.0$, $p = 0.554$). Ujian Korelasi Spearman menunjukkan hubungan yang signifikan di antara kelimpahan burung dengan kelimpahan manusia, anjing dan kenderaan ($p < 0.05$) di Pantai Jeram dan Pantai Remis. Justeru, kajian ini merumuskan bahawa Pantai Jeram dan Pantai Remis merupakan kawasan penting untuk burung-burung air. Air pasang dan gangguan menjejaskan kelimpahan dan tingkah laku burung. Sementara itu, masa sepanjang hari tidak memberi kesan kepada kelimpahan dan tingkah laku burung. Ciri-ciri morfologi burung juga mempengaruhi tingkah laku mereka di dalam mencari makanan.

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EAAF	:	East Asian Australian Flyway
km	:	kilometre
IUCN	:	International Union for Conservation of Nature
g	:	gram
m	:	metre
ha	:	hectare
C	:	Celcius
cm	:	centimetre
min	:	minutes
mm	:	millimetre
n	:	Total number of species
SE	:	Standard Error
s	:	second

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CHAPTER 1: GENERAL INTRODUCTION

1.1 The lifestyle of migratory waders

There are many definitions of waders used by ornithologist worldwide. Different region has different meaning of waders. In North America, wader is used to refer to long-legged wading birds such as storks and herons (Beautyofbirds.com 2011). Water bird is defined as any birds species that entirely depend on wetlands for variety of activities such as foraging, nesting, loafing and moulting (Rajpar and Zakaria 2009, 2010). Birdlife Australia (2016) defined wader as those birds which were commonly found on coastal shores, including beaches, rocky shores, mudflats, tidal wetlands and lagoons. Meanwhile Bamford et al. 2008 defined shorebirds as members of the order Charadriifomes. Therefore, in this study, waders were consist of shorebirds and waterbirds were defined as birds species that depend on wetland and carried out various activities there (Lane 1987; Barter 2002, Wikipedia 2015).Waders undergo amongst the most spectacular feats of migration seen in the animal kingdom, with some species travelling in excess of 20,000 km a year during a life span that may exceed 20 years (Bamford et al. 2008). During these long migrations, which may range from 12,000 km to 25, 000 km (Howes and Parish 1989), many waders rely on stopover areas along the migratory route to replenish energy and nutrient reserves.

The stopover areas were usually located along the migratory route or flyway. Flyway is the term used to describe a geographic region that supports a group of population of migratory waders throughout their annual cycle (Bamford et al. 2008). In general, there are eight broad migratory birds flyway in the world including Mississippi American Flyway, Pacific American Flyway, Atlantic American Flyway, East Africa West Asia Flyway, Central Asia Flyway, East-Asian Australian Flyway and Black Sea/

Mediterranean Flyway (Figure 1.1). Birds in their fly oath from north to the south at the East-Asian Australian Flyway (EAAF) pass from Malaysia (Boere and Strout 2006). Thousands of waders annually migrate through the EAAF from the breeding grounds in Alaska and Siberia to tropical wintering areas in South-east Asia and Australia (Pepping et al. 1999). Waders are considered to use the EAAF if their migration takes them through eastern Asia. Countries that are within the EAAF are Alaska, Russia, Mongolia, China, North Korea, South Korea, Japan, Philippines, Vietnam, Laos, Thailand, Cambodia, Myanmar, Bangladesh, India, Malaysia, Singapore, Brunei, Indonesia, Timor, Papua New Guinea, Australia and New Zealand.

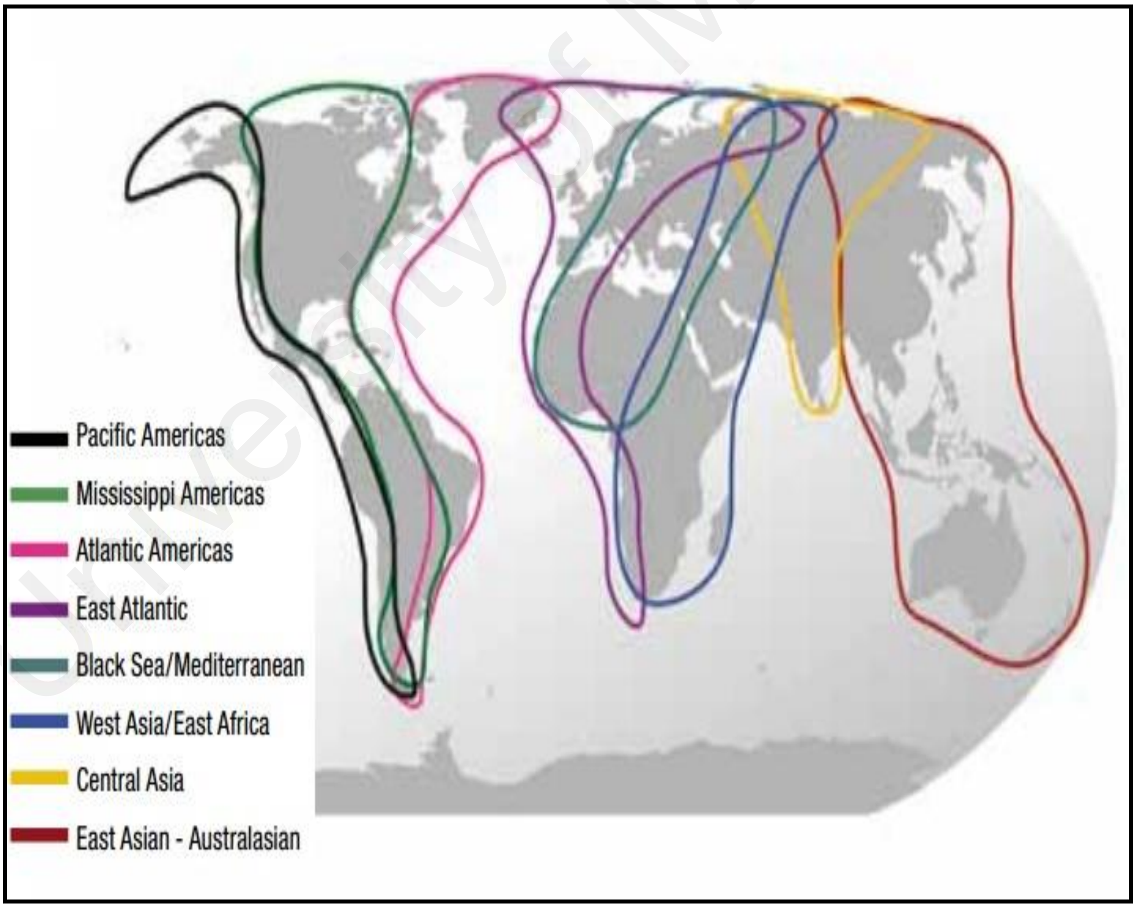


Figure 1.1: The Global Flyway Map.

Source: Mackinnon et al. (2012)

Malaysia is one of the countries situated along the EAAF (Figure 1.2). Malaysia has a tropical climate because it is located near the equator and its position near the South China Sea. It also has abundant of rainfall and a humid climate throughout the year. Malaysia (1-8^{o}N; 100-119^{o}E), comprising of Peninsular Malaysia, Sabah and Sarawak, is located in the Indo-Pacific region that is also includes sea areas surrounding Indonesia and the Philippines. Peninsular Malaysia is bounded by seas on all sides except in the North where it is connected to the Asian Mainland via Thailand. The West Coast of Peninsular Malaysia is bordered by Strait of Malacca with Andaman Sea to the North and Java Sea to the South. Overall, the total coastline for Malaysia is 4,800 km, with 2,100 km for Peninsular Malaysia and 2,700 km for East Malaysia (Burke et al. 2001). The extensive coastline of Malaysia supports a large number of resident and migratory water birds and shorebirds (Li et al. 2007). Previous study by Li et al. (2007), indicated a total of 134 sites were involved in waders counts across the whole of Malaysia in 2004 to 2006. The surveys confirmed that the coast of Malaysia, particularly the coast of Selangor and Sarawak is very important for waders. However, the bird numbers showed a decline of 22.4% in Malaysia between 1983 to 1986 and 2004 to 2006 (Li et al. 2007).

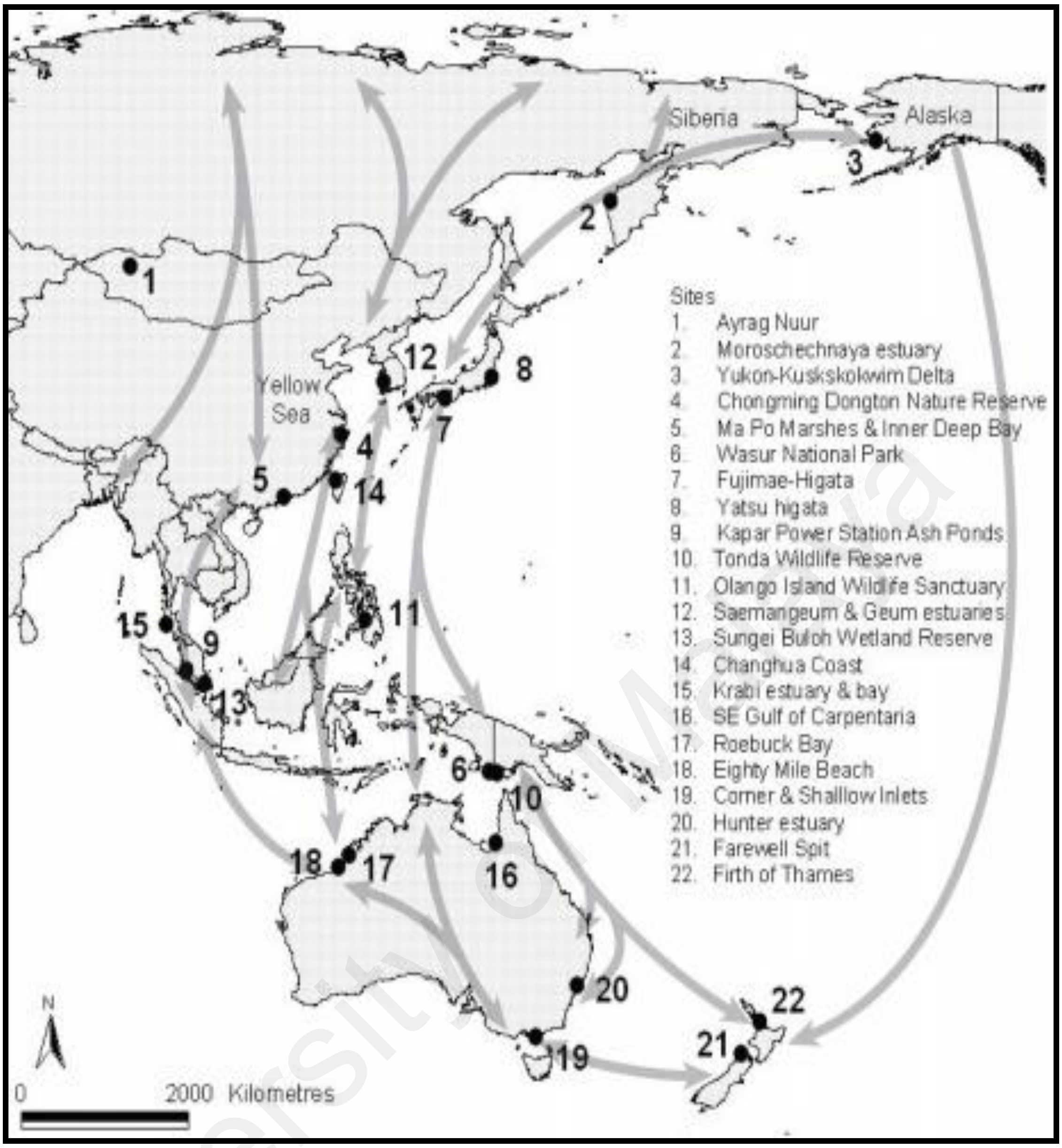


Figure 1.2: The East Asian-Australasian Flyway (EAAF).

Source: Spencer (2010).

1.2 Problem Statement

Birds serve as excellent indicators of environmental health and change. They occupy a wide range of niches, use many types of food and physical resources, and are sensitive to environmental changes (Mackinnon et al. 2012). A declined in birds population indicated that the environmental health were under serious condition. A slight change in environment quality might cause a serious reduction in bird population. Across all avian taxa, populations of migratory waders are among the most uniformly and dramatically in decline (International Wader Study Group 2003). There is increasing evidence that waders populations are declining worldwide (Zöckler et al. 2003; Wetlands-International 2006). Of the 41% of waders populations with known trends (210 populations) in the world, 48% are in decline and only 16% are increasing (Spencer 2010). A higher number and proportion of waders are globally threatened in the EAAF than in any of the other seven major flyways of the world (Kirby 2010) (Figure 1.3). Twenty percent of bird species that use the EAAF are listed as critically endangered or near threatened under International Union for Conservation of Nature (IUCN) risk criteria (Barter 2002). Most of these species are dependent on tidal flats, in particular 24 globally threatened or Near Threatened species of waders, waterfowl, spoonbills, cranes, seabirds and pelicans (IUCN 2011), plus a further nine waders species currently under review which could be classified as threatened or near threatened in the near future (Mackinnon et al. 2012).

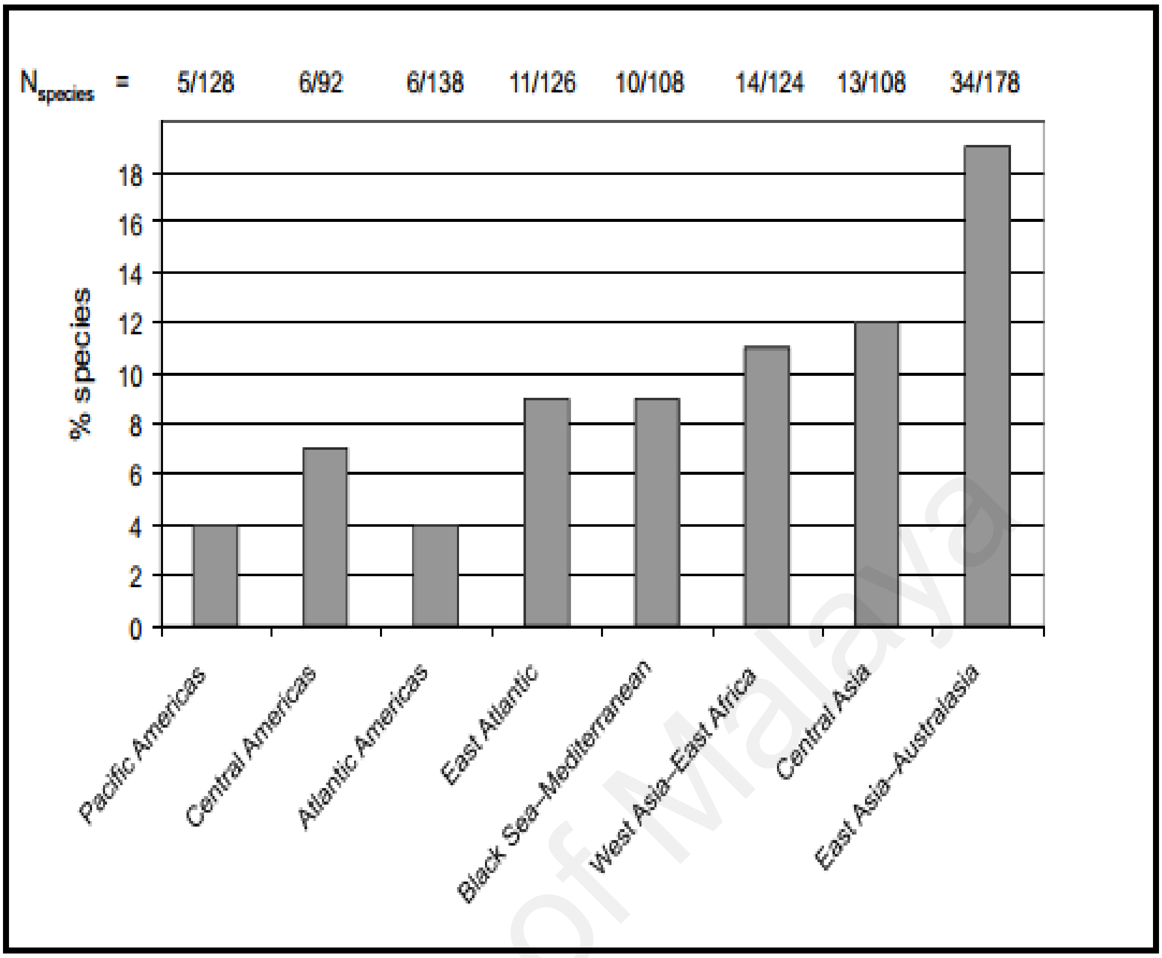


Figure 1.3: Total number and proportion of globally threatened and Near Threatened waders in the flyways of the world.

Sources: Kirby (2010); Mackinnon et al. (2012)

Waders are the most important consumers of the intertidal communities due to their high energetic requirements and efficiency in acquiring food (Goss-Custard 1984). Waders species undergo major physiological changes before their migration to fuel their long-distance flights (Landys-Ciannelli et al. 2003; Battley and Piersma 2005; Spencer 2010). Many birds increase the time they spend feeding before departure to increase their daily mass gains. Red knot, *Calidris canutus,* for example, gained on average 2.84 g per day at stopover sites in the Wadden Sea, in the Netherlands (Nebel et al. 2000) and 2.93 g per day at stopover sites in Iceland but daily mass gains increased steadily from 0.85 g to 7.0 g over a 24 day stopover period (Piersma et al. 1999). A bird's preparation for migration has two stages process. Flight muscles steadily increase in lean mass during the refuelling period and reach their maximum size before departure, while the lean mass of the main fuelling organs, the stomach, liver, kidney and intestines, undergo rapid growth in the early stages of the refuelling process to support flight muscle development (Piersma et al. 1999; Landys-Ciannelli et al. 2003; Spencer 2010). Immediately before departure, non-essentials organs, such as the intestines, may be reduced in size (Landys-Ciannelli et al. 2003; Spencer 2010).

Many factors were involved in determining foraging success of waders and the effects of its spatial distribution on the intertidal mudflats (Figure 1.4). Such factors include prey density, environmental characteristics, human disturbance and morphology of waders. To maximize their food intake, waders engaged varieties of strategies during foraging. The strategies used were greatly influenced by their physical morphology. Moermond (1990) suggested that any subtle differences in morphological traits, such as the length of the wing, tarsus and toes of birds could result in different foraging manoeuvre.

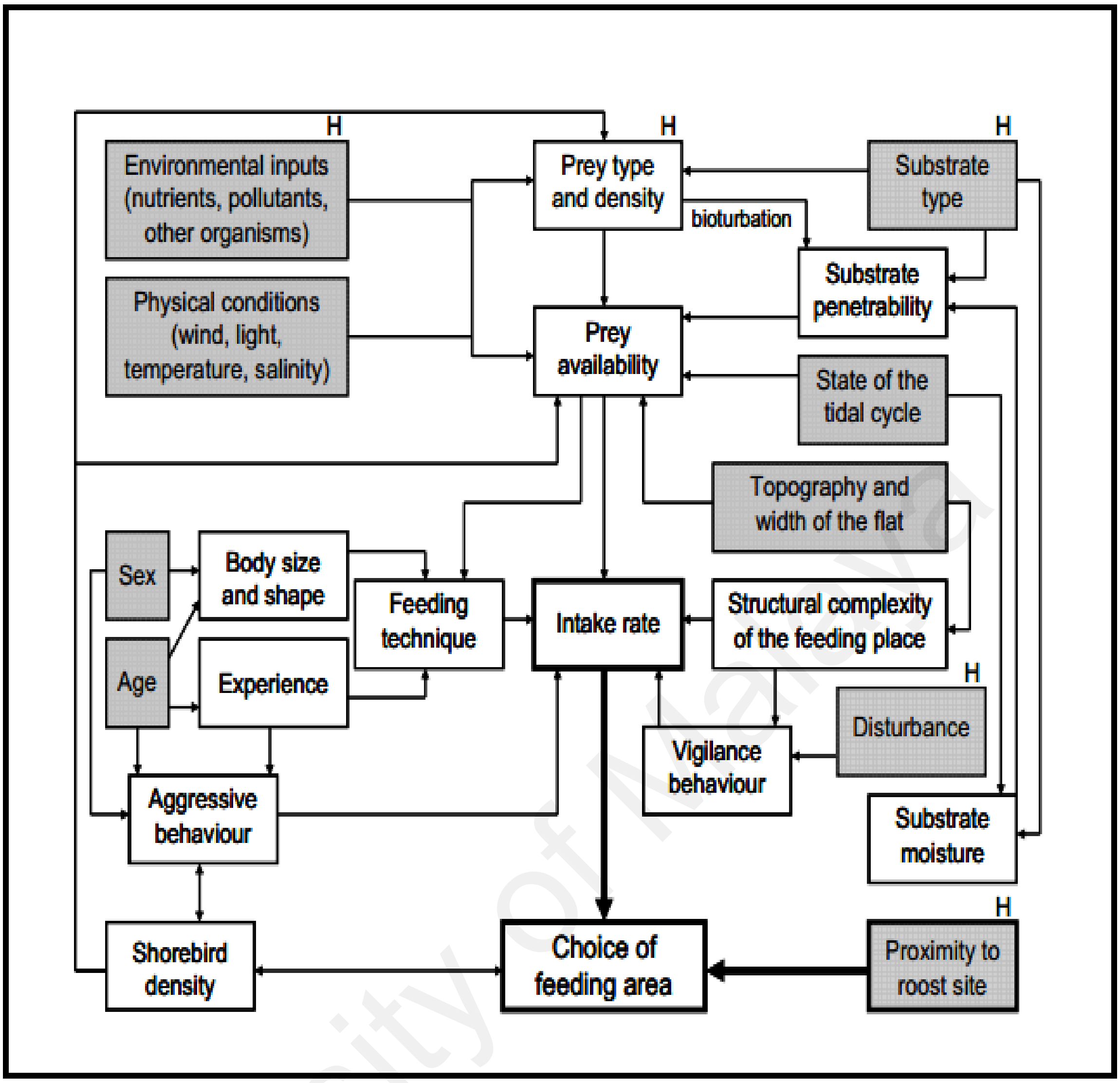


Figure 1.4: Factors that commonly influence the foraging habitat selection by waders. 'H' denotes factors which may be affected by human impacts. Shaded boxes indicate base inputs (i.e. those that do not have any other factor leading into them).

Sources: Spencer (2010)

Waders distribution was strongly affected by the environmental condition. Not only birds, but all organisms belonging to the plant and animal communities are affected by the physical characteristic of the environment (Gillis et al. 2008). Some species are very specialized and only use sites with specific resources (Piersma 2006), or staging sites where they can build up enough weight for long distance journeys (Warnock 2010). Environmental condition such as climate or weather, tidal state and disturbance give an impact towards bird distribution. Moreover, climate variation in the long term period may influence the animals' food sources as food availability can be dictated by the weather (White 2008). Furthermore, variation in tide level changes the immediate environment (Lehmicke et al. 2013) and thus affects both the amount of foraging space and the availability of prey (Evans 1979). In addition, stop over sites that combine an abundance of food with a relatively disturbance-free environment allow birds to maximize foraging time and quickly replenish their energy reserve (Helmers 1992).

In order for waders to gain enough energy to enable them to continue their journey towards their breeding grounds, they need to obtain enough food. The invertebrate populations of estuaries are the main source of food for millions of waders. Fluctuations in these invertebrate populations can potentially result in significant mortality for large numbers of birds (Atkinson et al. 2000; Smart & Gill 2003). The positive correlation between waders and benthic invertebrate populations is common (Colwell and Landrum 1993). However, study have shown that the effects of birds predation on the intertidal communities can be highest depending on bird densities, their feeding rates, and prey population dynamics (Wilson 1991). In some cases, birds control the densities and distribution of their prey (Zwart and Esselink 1989) while in other cases they may only affect the densities of the most abundant species (Wilson 1991).

According to ‘optimal foraging theory’ (MacArthur & Pianka 1966), birds will maximize their food intake rate at all times. As a result, there will be a strong selection for areas that are rich in macrobenthic prey, the distribution of which is considered continuously patchy (Van de Kam et al. 1999).

Many migrating waders usually forage during the nonbreeding season on intertidal habitats. However, massive intertidal habitats alteration in this century has reduced natural foraging areas for migratory waders (Weber and Haig 1996; Davis and Smith 1998; Masero and Pérez-Hurtado 2001). The loss of intertidal areas along migratory pathways, especially staging sites (where birds must replenish their energy stores during migration) can have extreme consequences for bird populations (Myers et al. 1987; Baker et al. 2004; Warnock 2010; Rakhimberdiev et al. 2011). For the millions of birds that migrate through the East Asian-Australasian Flyway, the intertidal areas of Asia are a crucial migratory bottleneck (Barter 2003; Rogers et al. 2010; Yang et al. 2011).

The migratory lifestyle of waders is fascinating but it also presents a major conservation problem which requires various governments to cooperate and coordinate conservation efforts, especially the identification and protection of important sites. The identification of important sites requires information on the numbers of birds at sites and the total size of each waders population (Bamford et al. 2008).

There are several implications for conservation can be taking out from this study. Firstly, the updated population estimates in this study enable some interpretation to identify key areas in which to focus protection and wise use of habitat for either resident or migratory waders. Secondly, behavioural studies underpin a detailed understanding of the habitat requirements of waders species. Significant gaps in knowledges remain for many species that spend their non-breeding seasons in Malaysia, as no detailed studies have investigated wader foraging behaviour in Malaysia. This lack of basic information limits effective management of waders habitat in their non-breeding range particularly in Malaysia.

1.3 Objectives of the Study

The objectives of this study as follows:

a) To study the distribution and abundance of wader species utilizing the mudflats areas of Jeram and Remis Beaches, Selangor, Malaysia. In chapter 3, the objective is further divided into few sub-objectives as follows:

   i) To gather the information about the diversity and abundance of wader species in Jeram Beach and Remis Beach and thus makes the comparison between these sampling sites.
   ii) To determine the wader diversity during migratory and non-migratory seasons and examines the effects of migratory birds on resident population.
   iii) To compare the results of this study with the previous study.

b) To study the factors affecting the distribution and behaviour of wader species in mudflat areas. In chapter 4, this objective was subdivided as follows:

   i) To relate the effect of the tidal cycle on the abundance and behaviour of tropical waders.
   ii) To determine the effect of different interval periods of the day on the abundance of tropical waders.

c) To determine the significance relationships between morphological characteristics and foraging behaviour adapted by waders species utilizing the mudflats area of Jeram Beach and Remis Beach, Selangor, Peninsular Malaysia (Chapter 5).

d) To investigate how disturbance caused by human and dogs are affecting the abundance and behaviour of waders utilizing the coastal mudflats area of Jeram and Remis Beaches, located in Selangor, Peninsular Malaysia (Chapter 6).

CHAPTER 2: LITERATURE REVIEW

2.1 Intertidal Mudflats of Southeast Asia

Mudflat is also known as tidal flat. Tidal flats are intertidal, non-vegetated, soft sediment habitats, found between mean high-water and mean low-water spring tide cycles (Dyer et al. 2000; Smithsonian Institution 2010) and are generally located in estuaries and other low energy marine environment. They are distributed widely along coastline worldwide, accumulating fine grain sediments on gently sloping beds, forming the basic structure upon which coastal wetland build. Although tidal flats comprises only about 7% of total coastal shelf areas (Stutz and Pikey 2002; Smithsonian Institution 2010), they are highly productive components of shelf ecosystems responsible for recycling organic matter and nutrients from both terrestrial and marine sources and also areas of high primary productivity.

Depending on sediment grain size, tidal flats may be generally categorized into mudflats and sand flats. Generally, mudflats are located in the upper part of intertidal zone whereas sand flats are located in the lower part. Mudflats and sand flats in estuaries are vital feeding habitats for resident bird populations and provide important overwintering sites for migratory waders (Goss-Custard and Verboven 1993). Mudflats are highly productive environments and they can be viewed as the 'pasturelands' of the intertidal zone (The University of Sydney 2010). Furthermore, intertidal mudflats are important habitats for a large variety of animal and plant species. They perform many ecological functions by providing spawning grounds for fish, habitats for birds, reptiles and other important fauna as well as protecting the coastal zone from erosion (The University of Sydney 2010). Mudflats and sand flats are often utilized by bait collectors, the activities of whom have been found in some cases to affect shorebird populations

(Townsend and O’Connor 1993; Shepherd and Sherman Boates 1999), or to have no effect on waders density or feeding technique (Navedo and Masero 2008).

The distribution, status and trends of intertidal mudflats are heavily impacted by human influence (Healy et al. 2002; Keddy 2010; Mackinnon et al. 2012). Throughout South-East Asia, mudflats and adjoining mangroves have been greatly reduced due to growing human population and corresponding demand for land. The current estimates of the rate of intertidal habitat loss in Asia are equal to or greater than recorded losses of mangroves (Giri et al. 2011), tropical forest (Achard et al. 2002) and sea grasses (Waycott et al. 2009). For example, over the past 50 years, losses of up to 51% of coastal wetlands have occurred in China (An et al. 2007), 40% in Japan, 60% in the Republic of Korea, and more than 70% in Singapore (Hilton and Manning 1995; Yee et al. 2010). This has reduced the number of refueling or staging points for migratory birds between breeding and wintering grounds.

Mudflats are a distinct feature of West Coast of Peninsular Malaysia which is sheltered from strong wave action, allowing substrate to be deposited along the coastline. This substrate comprises largely of the silt, sand, clay and decomposed organic matter which allows for the prolific growth of mangroves as well as small invertebrates and minute organisms to thrive. When exposed during low tide, mudflats offer good feeding places for a host of migratory shorebirds on ‘refueling’ stops as well as large numbers of herons and egrets as well as gulls and terns which roost in large numbers on the exposed mud (Jeyarajasingam 2012).

2.1.1 The importance of Intertidal Mudflats

Estuarine mudflats are very important for wader population during winter and migration. Many species of waders feed almost exclusively on intertidal benthic invertebrates at low tide. In temperate regions, species diversity of intertidal benthic invertebrates may be relatively low, but sediment that is rich in organic content may support exceedingly high densities – molluscs and polychaete worms can exceed 10,000 individuals per m^2 (Barnes et al. 1997). On the contrary, in tropical regions, the biodiversity of benthic macrofauna on intertidal mudflats is much higher and the productivity rates are ten times higher than in temperate intertidal habitats (Alongi 1989). Therefore, the intertidal mudflats in tropics areas can thus be concluded as more valuable as it comprises of higher content of prey items for bird utilizing these areas. Study in the Inner Gulf of Thailand by Wetland International and the Bird Conservation Society, indicated that the intertidal mudflats, salt pans and abandoned shrimp ponds in this area are visited by an estimated of 80,000 to 100,000 of waders each year (Erftemeijer et al. 1999).

Apart from being vital habitat for the survival of millions of birds of more than a hundred species, intertidal habitats is also critical as nesting beaches for sea turtles, breeding areas for Asia's seals, spawning grounds for important economic fisheries, and home of thousands of species of invertebrates (Mackinnon et al. 2012). Yusoff et al. (2006), reported that intertidal habitat are amongst the most productive ecosystems on earth which provide safe spawning areas and nurseries for countless species of fish and crustacean on which coastal fisheries depend. Similarly, Zulkifli et al. (2014), stated that this area provides important permanent and temporary habitats for a large number and range of marine and terrestrial fauna.

Furthermore, intertidal habitats functions as physical collecting zones of sand, mud, pebbles and fringe vegetation that help slow and break the action of waves. Gentle beaches tame ocean providing safe places for villagers, harbours and towns and the protection for adjacent agricultural areas (Mackinnon et al. 2012). Intertidal mudflats also important for the livelihood of coastal villagers whose collect shellfish and other products from the mudflats at low tide. Nielsen et al. (1998) reported the local exploitation of bivalve molluscs and crabs at the Cua Day Estuary in the Red River Delta in Vietnam, an area habituated by approximately of 39,000 peoples. They estimated that at least 200,000 man days were spent on collecting 1,600 tons of bivalves and 30 tons of crabs from a 3,350 ha area per year. Therefore, the intertidal mudflats area can be classified as crucial areas to generate incomes for people living near the shores.

In addition, healthy strand vegetation, sea grass beds, algal beds and mangroves, provide significant shelter in the face of typhoon and storms against the tsunami that are frequent in a zone prone to devastating earthquakes (Caldecott and Wickremasinghe 2005). Coastal damage seen after the great tsunami in Acheh, Indonesia in 2004 revealed that sites protected by intact healthy coral, mangrove or other coastal vegetation were dramatically less damaged than sites where the same habitats had been destroyed (Chang et al. 2006; Forbes and Broadhead 2007).

2.2 Wader in general

A total of 743 bird species were recorded in Malaysia (Malaysian Nature Society Bird Conservation Council 2015) and occurred in 9 types of habitats (Madoc 1985). The habitat are categorized as open seas, islands within open seas, coastal areas, mangroves, freshwater swamps, rivers, urban or rural types of recreational parks, fields or bushes, forests and highland areas. Waders are an integral part of estuarine systems and are the subject of extensive conservation effort in many places in the world (Hill et al. 1997; Stroud et al. 2004; Durell et al. 2005). Waders depend on coastal and inland wetlands and can occur in large numbers at their non-breeding and staging sites (Lane 1987; Barter 2002).

Birds are found almost everywhere because they are very dynamic, can easily be seen and observed for several purposes (Joshi and Shrivastava 2012). Birds serve as excellent indicators of environmental health and change. They occupy a wide range of niches, use many types of food and physical resources, and are sensitive to environmental changes (Mackinnon et al. 2012). For example, birds have been used in Environmental Impact Assessment (E.I.A) because they are very sensitive to environmental changes (Joshi and Shrivastava 2012). Some birds are generally believed by local people to be both indicators of season and time, and to some extent certain bird species can be used to predict the period of the day and night, e.g., cock crows at dawn. Furthermore, birds are well-adapted to many diverse terrestrial and aquatic habitats. To study an ecosystem, the birds serve as important component as they have the ability to fly away and avoid any obnoxious condition. Hence, they are considered as important health indicators of the ecological conditions and productivity of an ecosystem (Newton 1995; Desai and Shanbhag 2007; Li and Mundkur 2007; Joshi and Shrivastava 2012).

Rapid development of Southeast Asia coastal plains over the last few decades has posed adverse effects on populations of waders through degradation of natural habitats essentials for water birds (Bakewell 2009). Results from Asian Water bird Census between 1987 and 2007 revealed an estimated reduction of over 22% water bird populations visiting Malaysia (Li et al. 2007). In addition, the wader numbers of the

West Coast of Peninsular Malaysia have declined dramatically. This applies particularly to Perak State and Selangor State of which the former has suffered a decline of 80% to 94% and the latter one of 50% over the last twenty years (Li et al. 2007). Based on survey conducted by Li et al. (2006), about 21,390 waders species were recorded in Selangor Coast from November 2004 until April 2005. This count is much lower than the total of 39,034 shorebirds recorded in 1985 until 1986 by Silvius et al. (1987) and indicated a decline of 30% over the last 20 years. The reduction is likely to be even larger as the 2005 survey covered the area from the coast of Sekinchan to Sungai Bernam which Silvius et al. did not covered. It is believed that loss of habitat due to economic development has contributed to the decline of the bird population.

2.2.1 Factors affecting wader's distribution and habitat selection

The migration of animals results in seasonal fluctuations in population densities in a particular area. Most wader species migrate along well defined routes called "flyways" and they often use same stopover wintering sites for decades (Kober 2004). During this long migration, which may range from 12,000 km to 25,000 km (Howes and Parish, 1989), birds rely on strategically located stopover sites characterized by a predictable food supply and nearby habitat for resting when foraging sites are tidally inundated (Brown et al. 2001) to replenish their energy and nutrient reserves. The changes in population size during migration are mainly driven by external factors, of which the quality of stopover habitats is one of the most important factor (Ge et al. 2009). During this long distance migration, lower quality stopover sites may result in poor body condition and affect bird's ability to reach breeding or wintering grounds and reduce adult or juvenile survivorship (Pfister et al. 1998). Thus, Myers (1984 (a)), suggested that such areas are critical for the continuation of migration and ultimately critical for the survival of many birds.

Site selection is especially important for seasonally migrating animals that show drastic shifts in the habitats they use in the course of annual cycle (Piersma 2012). Selecting an area to live is crucial to all animals, as individuals that occupy sites with greater foraging success and lower predation risk potentially have higher reproductive success and survival, and realize higher fitness (Fretwell and Lucas 1970; Stephens and Krebs 1986; Cresswell 1994; Leyler et al. 2012). Some of factors influencing whether the birds will stops along migration routes are wind, tide, competition, predation and microclimatic condition (Ge et al. 2009). The availability of food in migratory stopover areas has been recognized as being crucial to survival of several bird populations (Burger 1986). Additionally, the dependence of large numbers of waders on just a few sites during migration increases species vulnerability because large numbers of individuals can simultaneously be impacted by changes in habitat suitability and availability (Brown et al. 2001).

2.2.1.1 Food Resources

Waders migrate between breeding and non-breeding grounds annually, stopping at several coastal bays or estuaries, or inland wetlands during the journey (Morrison 1984). Non-breeding waders generally seek habitat where resource availability is adequate, stable and predictable (Evans and Dugan 1984). Over small spatial scales, habitat selection when foraging strongly influences the composition and diversity of bird assemblages (MacArthur et al. 1966). Besides that, food density has been used by many authors to explain the differential of habitat use by shorebirds at migratory stopover sites (Colwell and Landrum 1993, Isola et al. 2000, Jing et al. 2007).

To maximize fat deposition at stopover sites rapidly, migratory birds feed on whatever is available to them (Recher 1966). Birds may forage for prey that is locally available at any stopover sites (Botto et al. 1998), mainly selecting preys on the basis of their abundance (Davis and Smith 2001). In addition, several studies had shown that foraging success, and hence survival potential of waders can be limited by interference (Triplet et al. 1999, Van Gils and Piersma 2004) or excessive depletion of their prey (Zharikov and Skiletter 2003).

Wader distributions and densities usually match the distribution of their preferred prey species (Zharikov and Skilleter 2004). Most species segregate themselves in the intertidal habitat according to preferences for sediment penetrability and water depth, as birds prefer to feed in shallow water or wet substrates (Lane 1987). Availability of prey is often determined by the maximum depth at which a bird can insert its bill into the substrate and maximum leg length (Dann 1987). This allows a suite of species to co-exist in the same feeding habitat (Dann 1999).

The influence of food resources on the ecology of nonbreeding waders in coastal environments has been well-studied (Burger and Olla 1984; Kober 2004; Finn 2010; Spencer 2010). Zheng et al. (2015), in their study, found that the relative abundance and density of wader, Hooded Cranes, (*Grus monacha*) were significantly affected by food abundance. Birds interact with prey in two ways, equivalent to functional and numerical responses of predators (Goss-Custard 1977). In the first case, variation in prey abundance may influence foraging behaviour and social interaction of birds, which affects the rate at which prey are consumed additionally, prey abundance may influence spacing of individuals (Goss-Custard 1984; Puttick 1984). Second, variation in prey abundance may affect the distribution of nonbreeding waders within estuaries and among habitats (Evans and Dugan 1984).

2.2.1.2 Environmental Factors

Other than food resources, the abundance and stopover sites selection by waders is also determined by environmental factors such as climate or weather, tidal cycle and salinity of particular habitats. Weather for example can have various biological and ecological impacts on the adults and young birds. Both adults and their nestling were reported to be susceptible to temperature and rainfall particularly during breeding (Sparks and Tryjanowski 2005). Some important examples showed that adults were the first affected by weather during migration and wintering (Saether et al. 2006) and after arrival on the breeding ground (Tryjanowski et al. 2004). Moreover, climate variation in the long term period may influence the animals' food sources as food availability can be dictated by the weather (White 2008). As in the case of the waders colony in Putrajaya, long term monitoring comprising years of surveys and studies may reveal significant roles of climate in dictating their population size, density, survival and other ecological attributes. This is important for the future conservation of the wader communities (Ismail and Rahman 2013). Similarly, Zduniak (2009), reported that rainy and cold weather conditions have also been reported to cause high chick mortality in young storks and significantly reduce their breeding success and survival. Variation in rainfall and temperatures was also found to have adverse effect on the fledging success of White Stork with poorer food resources (Denac 2006).

Weather was varied with respect to the time of the days. Robbins (1981) said that some bird species decrease their activity during times of extreme temperature (>25 ^{o}C). By day, when exposed to direct solar radiation, birds were at risk of heat stress, and only used roost sites with wet substrates or shallow water, where counter-current exchange mechanisms could be used to lower body temperature (Battley et al. 2003). Thermal stress, either because of wind and cold induced rises in maintenance costs

(Wiersma and Piersma 1994) or excessive heat load (Battley et al. 2003), is a function of the geomorphological features of a place, and may also influenced by human disturbance.

Tide is the major factor influencing the distribution, abundance and behaviour of waders (Brennan et al. 1985). Variation in tide level changes the immediate environment (Lehmicke et al. 2013) and thus affects both the amount of foraging space and the availability of prey (Evans 1979, Calle et al. 2016). Burger et al. (1977), found that four of the five species of waders on the mudflat reached peak abundance between 1.5 to 2.5 hours after low tide. Dunlins (*Calidris alpina*) on extensive tidal flats showed peaks for feeding at 1 hour before and 1 hour after low tide (Ehlert 1964). In contrast, fewest numbers were recorded about 1 hour after high tide. Flooding and ebbing tides alternately inundate and expose intertidal habitats, thus alter the wetness of foraging areas. Foraging waders tend to avoid drier substrates (Prater 1972; Smith 1974; Goss-Custard 1977, Grant 1984) and study by Myers et al. (1980) had demonstrated that substrate texture influences the ability of a bird to penetrate the substrate when probing for prey, which results in birds spending less time in areas of coarse substrate. Furthermore, increased substrate wetness, owing to tidal inundation, probably affects prey availability in two ways; (1) it makes substrates easier to penetrate (Grant 1984) and (2) it increases invertebrate activity, rendering prey more susceptible to wader predators (Goss-Custard 1984).

Manipulation of water levels and salinity may play significant roles in determining habitats that waders can successfully exploit (Velasquez and Hockey 1992). Culmen and tarsus length are positively correlated with water depths in which a species forages, indicating that most birds occur in a specific range of water depths (Baker 1979). The importance of salinity, however, is less clear. Velasquez (1992) found that birds using artificial saltpans responded to changes in prey composition caused by fluctuations in salinity rather than manipulation of water levels. Burger (1984) speculated that the distributions of species that forage on a narrow range of prey items are more likely to be influenced by salinity than those that have broad prey base.

2.2.1.3 Disturbance and Predation Risk

The distribution of animals is usually thought to be restricted by the occurrence of good feeding areas, with predators and disease organisms determining the quality of such areas in addition to resource abundance (Newton 1998). Stopover sites that combine an abundance of food with a relatively disturbance-free environment allow waders to maximize foraging time and quickly replenish their energy reserve (Helmers 1992). On contrary, sites with extensive anthropogenic and/or natural disturbance may force waders to spend less time foraging (Thomas et al. 2003), while expending more energy in avoiding disturbance, or abandon the sites (Burger 1986; Harrington 1999). Waders are particular in choice of such roosts (Luís et al. 2001), preferring accessible sites. Accessibility is a function of the risk of predator attack, perhaps in combination with human disturbance (Rosa et al. 2006).

Perceived predation risk is thought to underpin the selection of both feeding and roosting sites by waders (Lawler 1996). Waders will select roosts closest to their low tide intertidal feeding habitat and sites which usually have an open aspect allowing easy detection of prey during high tides (Rogers 2003). Most wader species prefer open roost sites which allow the detection of potential predators. Therefore, most waders will avoid areas with tall vegetation (Rogers et al. 2006) such as mangrove, as this vegetation can provide cover for ambushing birds of prey (Dekker and Ydenberg 2004). Several studies have shown that the predation risk of raptors has obvious effects on the habitat use by birds (Cresswell 1994; Ydenberg et al. 2002). For instance, birds on salt marshes were more likely to be killed by raptors than those on bare flats (open intertidal mudflats) due to difficulties in detecting raptors in vegetated area (Jing et al. 2007).

2.3 Foraging Behaviour of Waders

Waders are a highly mobile group of animals and have sophisticated site-sampling processes that operate at larger spatial scales than most other animals (Quaintenne et al. 2011). Analysis of behaviour can aid in evaluation of wader habitat use and other life history requirement during migration (De Leon and Smith 1999). Behavioural studies should be a method of determining how birds respond to environmental changes and compete for limited resources, such as diminishing habitat (Goss-Custard and Durell 1990). Studied by Rowell-Garvon and Withers (2009), reported that foraging behaviour was the dominant behaviour exhibited by waders and these behaviours seemed to be related to morphological differences among species.

Most of the time spent by a bird during migration is spent at stopover sites (Newton 2008). Habitat requirements for different species and guilds of waders vary in time and space, and this can be detected only by behavioural studies (De Leon and Smith 1999). Documenting behaviour within different types of habitat allows a better understanding of why those habitats are selected (Titman 1981) and provides opportunity to evaluate the significance of regional areas to migratory birds (Streeter et al. 1993; Davis and Smith 1998). Habitat characteristics such as vegetation height and prey abundance could affect foraging behaviour (Holmes and Schultz 1988).

Waders encounter variable and unpredictable food resources (i.e. predominantly invertebrates) at stopover sites (Skagen and Oman 1996; Davis and Smith 1998; Davis and Smith 2001). In response to those unpredictable food resources, waders should forage opportunistically to successfully complete their migration (Skagen 1997). The term ‘opportunistic foraging’ simply refers to waders consuming prey in proportion to availability (Davis and Smith 2001). However, quality (e.g. gross energy, percentage fat, protein) of available prey items should also be considered when examining migrant waders foraging strategies because nutrient reserves are critical for survival and reproduction (Myers et al. 1979; Maron and Myers 1985). Because waders typically dynamic (Fredrickson and Reid 1990, Farmer and Parent 1997), they likely cannot afford to discriminate between profitable prey and unprofitable prey. Consequently, adopting an opportunistic foraging strategy provide migrant wader with a flexible strategy that allows them to increase their probability of being able to replenish energy and nutrient reserves for continuing their migration to breeding and wintering grounds as well as arriving on the breeding grounds in good conditions (Davis and Smith 1998).

Feeding behaviour and habitat selection in waders is heavily influences by their morphology, particularly leg length and bill length and shape (Baker 1979). The morphology of a bird is considered as an important factor in restricting the range of foraging manoeuvre it can perform (Martin and Karr 1990).

Studies of single-dimensional niche segregation among waders have focused on the relationships between the bill length and prey size (Holmes and Pitelka 1968, Baker and Baker 1973, Eldridge 1987), and between tarsal length and water depth of foraging habitats (Baker 1979; Eldridge 1987). Holmes and Pitelka (1968) reported that bird species with long bills consumed larger prey than did bird species with small bills, and Eldridge (1987) reported that large bird species consumed larger prey and foraged in deeper water than small bird species. Similarly, Schoener (1984) noted that for certain birds, larger species consume a larger range of food sizes than smaller species because their preferred food (i.e. larger prey) may be relatively scarce and handling costs may be higher. Furthermore, Davis and Smith (2001) found that American Avocets (*Recuvirostra americana*) and Long-billed Dowitchers (*Limnodromus scolopaceaus*) (the larger species) consumed larger prey and foraged in deeper water than did Least sandpiper (*Calidris minutilla*) and Western sandpipers (*Calidris mauri*) (the smaller species).

The foraging methods of even similar species of birds can differ between areas with different vegetation structure (Maurer and Whitmore 1981). However, there are also other ornithologists who claim that the habitat of the bird can be instrumental in influencing other related foraging behaviours such as the height at which it forages and the substrate from which it obtain its prey (Robinson and Holmes 1982). In addition to prey availability, the habitat use of waders may also be constrained by foraging strategies (Kalejta and Hockey 1994; Barbosa and Moreno 1999). Waders detect prey by visual and tactile sensory mechanisms, exhibiting a wide range of feeding styles such as pecking, probing, stabbing, sweeping, ploughing (Ntiamoa-Baidu et al. 1998), and surface tension (Rubega 1997). Pecking and probing are thought to be the main methods for visual and tactile foraging respectively (Baker and Baker 1973). For example, medium scolopacids foraged significantly more in habitats that had greater amounts of vegetation, less bare shoreline and deeper water, whereas small charadriids used areas with large expanses of shoreline and shallower water. This difference was due to the larger size and longer legs of medium scolopacids, which allow them to exploit a more diverse array of habitats.

Migrating waders provide an opportunity to study behavioural interactions among species for both prey and foraging spaces because they often forage in dense flocks, concentrating along relative narrow tide lines (de Boer and Longamane 1996).

Foraging birds often form groups to reduce risk of predation while decreasing the cost of vigilance (Bednekoff and Lima 1998). Some species show despotic behaviour such as defense of feeding territories (Turpie 1995; Johnson et al. 2001), while in other species tend to live in flocks (Myers 1984 (b)) when interference is absent or cryptic (Bijleveld and Piersma 2012). As group size increases, scanning rates or vigilance decreases (Roberts 1996). However, some species form groups because of resource location; they forage together because the food is clumped or prey densities are higher in some places than others (Burger et al. 2007). When large group of birds foraged in the same place, competition can result, either for the prey itself or for access to the prey (Stillman et al. 2000). Competition occurs when feeding rate is negatively related to competitor density and when the presence of an individual impedes the access of another individual to a resource (Cresswell et al. 2001). Aggression should occur only when individuals can increase their share of resources that are concentrated by being aggressive (Beauchamp 1998). Increasing spatial clumping of resources, such as prey, can lead to increase competition (Schmidt et al. 1998).

2.4 Threats to Wader's population

2.4.1 Habitat Losses/ Degradation

The past century has seen massive alteration and loss of natural intertidal habitats that are prime importance to large numbers of migrant waders during the nonbreeding season (Masero and Pérez-Hurtado 2001). Waders face a number of threats to their populations and habitats in the East Asian-Australasian flyway. A total of 20% of wader species that use this flyway are listed as critically endangered or near threatened under IUCN risk criteria (Barter 2002). Waders can be extremely sites faithful (Dan 1981; Rehfisch and Austin 2006), therefore, habitat loss can directly impact their survival and fitness (Burton et al. 2006).

In their non-breeding range, degradation of habitat and excessive disturbance at roost and feeding habitat are thought to be the main threats to migratory wader populations (Smith 1991; Watkins 1993; Department of Environment and Heritage 2005). The loss of habitat through changes in land use practices is the most severe threat to the conservation of water birds (Asia-Pacific Migratory Water bird Conservation Committee 2001).

The intertidal mudflat is one of the most important habitats chosen by wader species during their non-breeding seasons. This area had been shrinking over the past 20 years by continuous reclamation, and some mudflats were almost covered by seawater during high tide, and no super-tidal mudflats remains. Some results of morphological and behaviour research suggested that the birds could not feed and roost at the high water level areas (Zhenming et al. 2006). In such circumstances, a heavy reclamation resulted in the loss of wader’s habitat and forced the waders to move to the neighbouring artificial field inside the seawall such as fishing ponds and paddies field when the tide rose (Hu and Lu 2000; Tang and Lu 2002).

Global climate change projections suggest that sea level rise and prolonged drought (Bates et al. 2008) may reduce the availability of coastal wetlands for migratory waders (Galbraith et al. 2002; Austin and Rehfisch 2003), and the temperature increases may alter invertebrate prey reproduction (Lawrence and Soame 2004) and potentially cause a pole ward shift in the range of many wader species (Chambers et al. 2005).

2.4.2 Disturbance

Increasing levels of human disturbances in estuaries are exerting pressures on wader populations (Hill et al. 1997). Such disturbance includes walking, driving vehicles, or using powered vessels in or near bird flocks. Domestic animals, especially uncontrolled dogs, can also be a major source of disturbance to waders. Waders are under intense pressure from anthropogenic activities such as land reclamation, habitat destruction, pollution, hunting, and recreation (Tucker and Heath 1994). The general lack of community understanding or education on wader related conservation issues are significant threats to wader survivals.

On their roosting and foraging grounds, waders can suffer high disturbance rates by fishers, watercraft, walkers and dogs (Burger and Gochfeld 1991; Fitzpatrick and Bouchez 1998; Paton et al. 2000; Blumstein et al. 2003) or coastal developments (Burton et al. 2002; Durell et al. 2005). Human-induced disturbance at high tide roost sites (Burton et al. 1996) and low tide feeding sites (Burger 1981; Thomas et al. 2003) can also results in higher energy expenditure and a reduction in food intake for birds at their non-breeding or staging sites (Stillman and Goss-Custard 2002; Coleman et al. 2003), which can impinge on their ability to build fat reserves to fulfil their annual cycle of moult, migration and breeding (Spencer 2010). This has implications for energy conservation as any extra time spent in flight can have significant effects on bird’s body condition and mortality (Durell et al. 2005). Furthermore, high level of disturbance by human activity and avian predators can affect the survival and fitness of birds (Durell et al. 2005; Goss-Custard et al. 2006).

The frequency of disturbance and distance at which waders take flight are often the quantified measures of disturbance (Burger 1981; Blumstein et al. 2003). Human activities can impact on waders more than 200 m away (Thompson 1992). A more subtle measure of disturbance is the level of vigilance and sleep behaviour in roosting individuals. Many bird species sleep with one eye open, so they can respond quickly to perceived threats. Sleep is often accompanied by periods of eye closure interrupted by short periods of eye opening or ‘pecking’ (Landrem 1983; Rattenborg et al. 1999).

Disturbance can cause a reduction in food intake in several ways: the presence of people leads to increased vigilance by foraging waders and to a decrease in the proportion of time devoted to feeding (Burger and Gochfeld 1991), the birds may stop foraging altogether and they may leave the foraging site (Smit and Visser 1993), perhaps changing to a less profitable site at which they have a lower food intake rate (Burger 1988). In addition to this reduction in food intake, energy expenditure can be increased by avoidance behaviour, particularly if the birds fly away. The combination of these effects may produce serious deficits in the daily energy budget of the disturbed birds (Bélanger and Bédard 1990), or necessitate extra compensatory foraging, for example, at night (Riddington et al. 1996). There would be variation between individuals in the effect of disturbance according to their age, feeding method and dominance (Goss-Custard and Durell 1988). Depending on the proximity and type of human activity (walking, fishing, etc), waders may respond either by spending more time watching potential human threat, or by walking away from approaching humans (Fitzpatrick and Bounchez 1998), or by taking flight and moving to a nearby undisturbed section of beach (Smit and Visser 1993). Although these types of reactions have some effect on waders, particularly a reduction in foraging time, a potentially more serious consequence of human and dog activity would be the abandonment of a valuable foraging area by some or all waders. It is generally agreed that disturbance, especially that caused by recreational activities, is a threat to waders, since many recreational activities may increase in intensity and distribution (Cayford 1993).

2.5 The Significance of Study

Effective wader conservation is dependent on a detailed understanding of the distribution of wader populations, their life history and habitat requirements (Spencer 2010). Many studies on waders in Malaysia was focussed on wader's distribution and abundance (Parish and Wells 1984, 1985; Edwards et al. 1986; Hawkins and Howes 1986; Howes et al. 1986, Li et al. 2007; Riak 2004; Lomoljo 2011) only. This study focussed on to improve the data on wader's population in two sampling sites, which are Jeram Beach and Remis Beach which were previously known as important stopover sited for migratory waders.

Some of the species found in this study were listed as Vulnerabe in which if no further action were taken might cause these species were at risk of becoming endangered. For this reasons, the knowledge on abundance and distribution of waders alone is not enough for the conservation efforts of these species to be carried out effectively. Thus, this study focussed on investigating the factors which affecting the distribution, abundance and behaviour of wader species utilizing non-breeding stopover sites such as tide, time of the day, morphological characteristics and disturbance. Therefore, this study also provided new detail information on factor affecting the distribution, abundance and behaviour of waders in Malaysia. This information can be used for more effective conservation of waders in Malaysia. For example, in this study, species of waders which were found to be the most sensitive towards disturbance can be used to set the barrier or buffer zones for mixed-groups of waders at foraging and loafing sites.

CHAPTER 3: THE DISTRIBUTIONS OF WADER SPECIES UTILIZING THE COASTAL MUDFLATS AREAS OF JERAM BEACH AND REMIS BEACH, SELANGOR.

3.1 Introduction

Thousands of waders migrate annually through the East-Australian Flyway from the breeding grounds in Alaska and Siberia to tropical wintering areas in South-east Asia and Australia (Pepping et al. 1999). These species migrate between 12,000 and 25,000 km annually from wintering to breeding grounds (Myers 1984). Skagen and Knopf (1994) hypothesized that migrant waders require a network of intermediate stopover sites between breeding and wintering areas to successfully complete their migration.

Most migratory wader species prefer wetland areas as their stop-over sites. Wetlands are widely recognized as a highly important ecosystem with diverse attributes including a distinctive avifauna (Burger 1985; Rajpar et al. 2010). Malaysia is blessed with a total of 3.5 to 4.0 million ha of natural wetland area which is equal to 10% of the total land area (Aik 2002; Rajpar and Zakaria 2010). Malaysian wetland is divided into nine major types; namely mangroves, mudflats, nipah swamps, freshwater swamp forest, peat swamp forest, lakes, river system (nearly 100 river systems), fresh marshes and paddy fields (Malaysian Wetland Working Group 1986). These wetland areas serve as important habitats and refuges for wide array of migratory and threatened wader species (Asmawi 2007). Some of the studies of waders in wetlands of Southeast Asia include study by Riak (2004) and Lomoljo (2011) in Peninsular Malaysia, Round (2006) in Thailand and Ramakrishnan and Gan (2005) in Singapore.

Estimating population size and population fluctuation of different waders in wetland habitat is highly important to understand the wader community structures and population status of species in the dwelling area (Kaminski et al. 2006). Wetland waders are diverse and often show different behavioural tactics to explore the wetland areas and reflect the ecological conditions of a particular area. Nevertheless, the information on the population parameters and ecology of wetland waders is scarce (De Leon and Smith 1999).

Therefore, the aims of this chapter are (1) to gather the information about the diversity and abundance of wader species in Jeram Beach and Remis Beach and thus makes the comparison between these sampling sites; (2) to determine the wader diversity during migratory and non-migratory seasons and examine the effects of migratory waders on resident population, and lastly; (3) to compare the results of this study with the previous study.

3.2 Literature review

Tidal flats tend to be highly productive and are vital habitat for waders (Velasquez 1992). Tidal flats are intertidal, non-vegetated, soft sediment habitats, found between mean high-water and mean low-water spring tide cycles (Dyer et al. 2000) and are generally located in estuaries and other low energy marine environment. Although tidal flats comprise only about 7% of total coastal shelf areas (Stutz and Pikey 2002), they are highly productive components of shelf ecosystems responsible for recycling organic matter and nutrient from both terrestrial and marine sources and also areas of high primary productivity. Mudflats in estuaries are vital feeding habitats for resident wader populations and provide important overwintering sites for migratory waders (Goss-Custard and Verboven 1993).

In tropical regions, the biodiversity of benthic macrofauna on intertidal mudflats are much higher (Alongi 1990). An equivalent biomass of macrofauna on mudflats in the tropics produces a rate of biomass turn-over (productivity) ten times faster than in temperate intertidal habitats (Alongi 1990). Mudflats are a distinct feature of West Coast of Peninsular Malaysia which was sheltered from strong wave, allowing the substrate to be deposited along the coastline (Jeyarajasingam 2012).

The wader numbers on the West Coast of Peninsular Malaysia have declined dramatically. This applies particularly to the state of Perak and Selangor, of which the former has suffered a decline of 80% to 94% and the latter of 50% over the last twenty years (Li et al. 2006). A survey conducted by Li et al. (2006) on the Selangor Coast indicated a decline of 30% of the number of waders species over the last 20 years compare to study by Silvius et al. (1987).

3.3 Methodology

3.3.1 Study Areas

Jeram and Remis Beaches are located on the Selangor Coast on the West Coast of Peninsular Malaysia (3^{o}13’27”N, 101^{o}18’13”E) (Figure 3.1; Figure 3.2 (a); Figure 3.2 (b)) where semidiurnal tides prevails. The distance between Jeram Beach and Remis Beach is approximately 2 km. Both beaches are located in the southern part of Kuala Selangor district.

At Jeram Beach, the width of the intertidal zone can achieved up to 900 m. The backshore consists of a sand pit fringed by mangroves *Avicennia alba* and *Sonneratia alba*. Three plots were setup in Jeram Beach. Each plot has a size of 100 m width and about 900 m length during low tides when the intertidal zone was exposed. Plot 1 is located near the jetty where there were small stalls near the shore area. Plot 2 is located close to Jeram Seafood Restaurant (‘Aroma Ikan Bakar’ Seafood Restaurant). This plot has mangrove forest consists of *Avicennia* sp. Plot 3 is more isolated and located in front of fish pond operated by local people (Figure 3.3 (a)).

Remis Beach is popular among tourists and has more activities. Only 2 plots were built in these areas due to human activities constraints. Both plots have a size of 200 m in width and 700 m in length when the intertidal areas are fully exposed during low tides. Plot 1 was located close to the marine police post (Figure 3.3(b)). In addition, this area has more rocks situated along the coast compared to plot 2. Meanwhile, plot 2 was located near the stalls where most of the human activities were conducted. This plot was frequently visited by local people for collecting mussels. The selection of these sites was based on past history of wader counts reported by Wetland Internationals in 1999-2004 (Li et al. 2007) which shows that these sites was previously known as important stopover sites for waders.

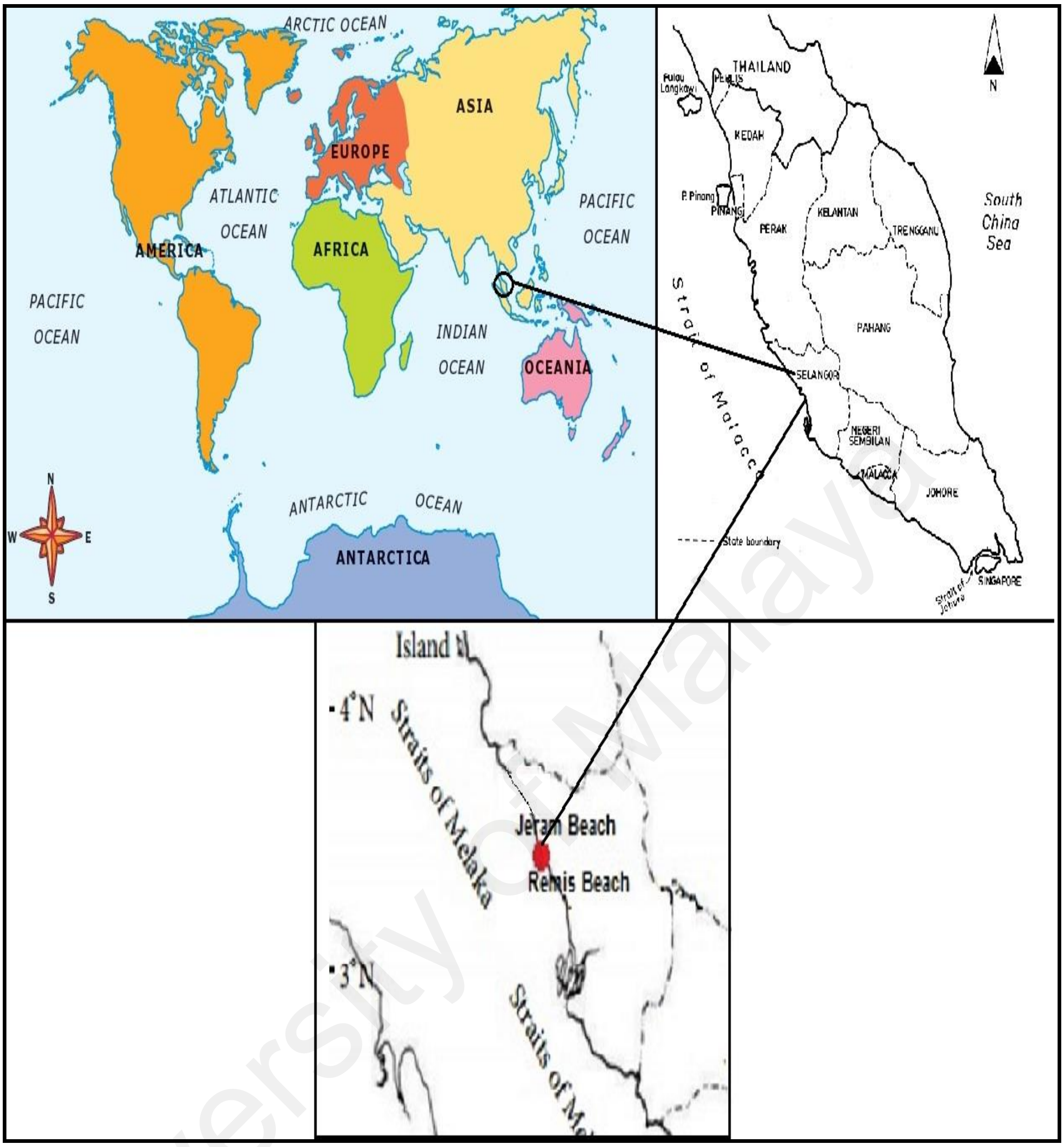


Figure 3.1: Location of Jeram and Remis Beaches on the Selangor Coast on the west coast of Peninsular Malaysia.

Figure 3.2(a): The study site in Jeram Beach.

Figure 3.2 (b): The study site in Remis Beach.

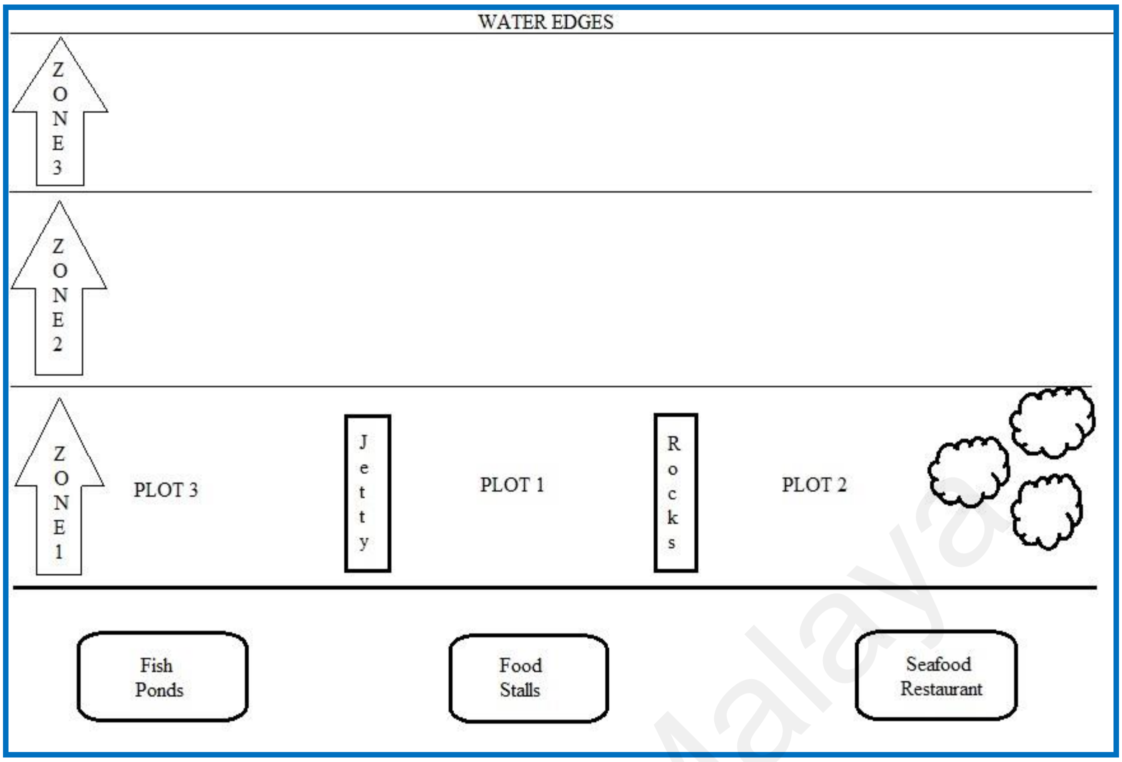


Figure 3.3 (a): The design of sampling plots in Jeram Beach.

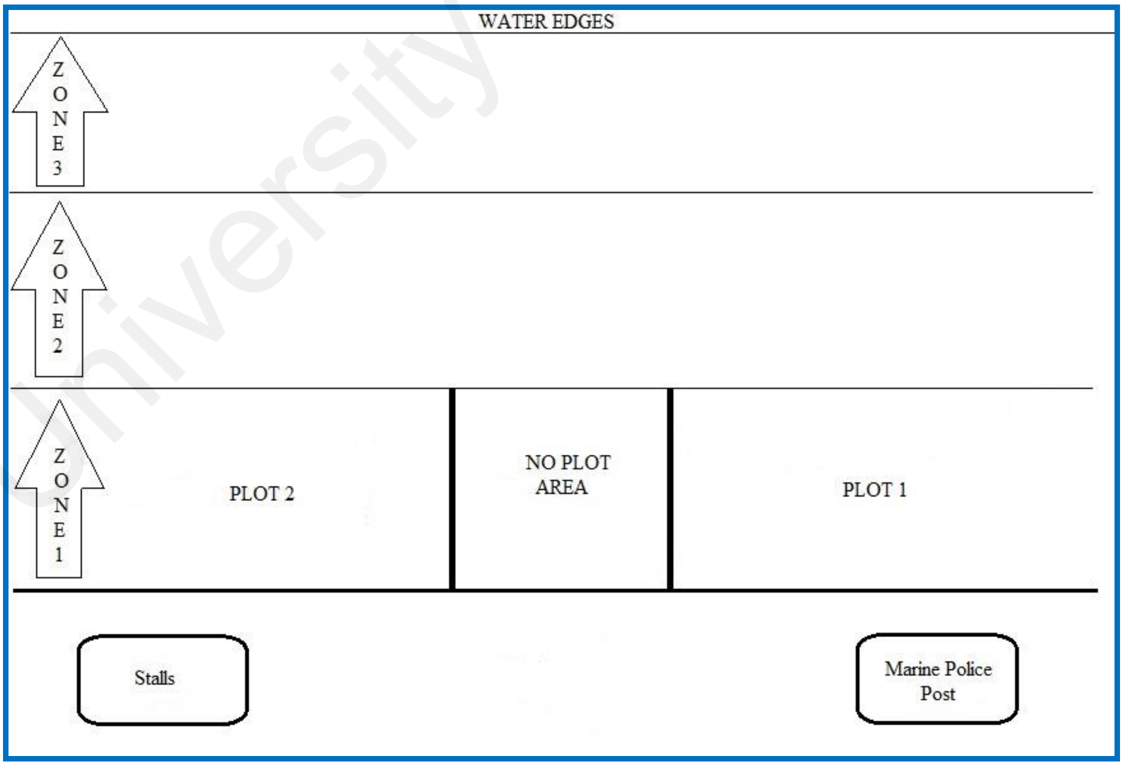


Figure 3.3(b): The design of sampling plots in Remis Beach.

3.3.2 Species Composition and Status

The waders species observed and recorded during the sampling periods were identified based on Robson (2008). The status and distribution of each wader species recorded in Malaysia were then classified based on IUCN Red List of Threatened Species (International Union for Conservation of Nature and Natural Resources 2014) and Checklist of Birds in Malaysia (Malaysian Nature Society Bird Conservation Council 2005; Bird Conservation Council Records Committee of the Malaysian Nature Society, 2010).

3.3.3 Diversity and Abundance

Wader survey was done using direct observation technique with the aid of the binoculars (Nikon 12 X 42) and a video camera (Sony Handycam HDR-SR8 AVCHD Camcorder). The field survey was conducted for one year; from August 2013 until July 2014. A monthly observation was conducted in both study areas in all tidal states for ten consecutive days. 'Direct count technique' was used to count individual waders (Nagarajan and Thiyagesan 1996). Counted waders were identified up to species level based on Robson (2008). The wader count was divided into four time intervals; i.e. from 0800 - 1000 hours, 1000 - 1200 hours, 1400 - 1600 hours, and 1600 - 1800 hours. The time interval of 1200 – 1400 hours was excluded from the study due to the lack of wader's activities. Preliminary sampling was done to support this statement. During each interval periods, wader was counted only for the first 30 minutes in all sampling plots while the rest of the time was used for another aspect of the study. Because the intertidal mudflat area of Jeram and Remis Beaches was relatively open and unvegetated, all wader species present within each plot were counted. Waders flying forward were excluded, and only those feeding in and flying within the sampling area were recorded (Pandiyan et al. 2010). Cares were taken to locate all wader present within the sampling plots and to avoid multiple counting. Plots are considered in low tide condition as soon as marking poles were standing at 30 cm high and large waders can start feeding in the area. For each plot, the diversity and abundance of the waders were calculated. Waders were counted using binoculars from at least 100 m away to ensure the presence of researcher did not affect wader activity (de Boer and Longamane 1996). Counting of waders under extreme weather conditions (such as windy and/or rainy days) was not conducted due to possible adverse effects on wader activity (Conner and Dickson 1980). Since the waders were not marked, an assumption was made to minimize repeated counting. The assumption was all waders counted in one day will be total up and divided by 4 (which represents 4 time intervals) to obtain the average total number of individual counted per interval session. The survey was conducted alternatively in both locations.

3.3.4 Data Analysis

3.3.4.1. Diversity and richness of waders

Indices such as Shannon-Weiner Diversity Index (Shannon Weiner 1949), Simpson’s Index of Diversity and Shannon Equitability or Evenness were used to estimate diversity and richness of waders in the study area. Diversity and relative abundance of a species serve as a basic representation of animal’s community. It can be used to measure relationship between population structure and habitat patterns, or between biotic and abiotic factors. It also useful in the management and monitoring of biodiversity (de Thoisy et al. 2008). Details of the indices as follows:

(a) Shannon-Weiner Diversity Index

$$H = -\sum_{i=1}^{S} p_i \ln p_i$$

where, H = Shannon-Weiner Diversity Index

S = Total number of species in the community

P_i = Proportion of S made up of the *i*th species

Shannon-Weiner Diversity Index is commonly used in biological studies. This index is independent of sample size. The small sample size is sufficient to obtain the significant index value for comparisons. Shannon-Weiner Diversity Index values varies from 0 (indicates community consists only a single species) to a maximum value which can be calculated by using the formula of H' = log S (Lindenmayer and Burgman 2005). S represents the number of species present in the community. The higher the number of species in the community, the higher the value of H'. Shannon's equitability, E_H can also be calculated by dividing the H with H', i.e. E_H = H / H'. Equitability assumes a value between 0 and 1 with 1 being complete evenness. Shannon-Weiner Diversity Index values usually ranged from 1.5 to 3.5 and rarely exceed the value of 4.0 (May 1975).

(b) Simpson's Index of Diversity

$$D = \frac{\sum n(n-1)}{N(N-1)}$$

where, D = Simpson's Index of Diversity

n = the total number of organisms of each individual species

N = the total number of organisms of all species

Simpson’s Index (D), is a measure of diversity, which takes into account both species richness and evenness of the species present. The value of D ranges from 0 to 1. The value of 0 represents infinite diversity whereas the value of 1 represents no diversity. That means, the bigger the value, the lower the diversity. As this does not seem logical, the formula as 1-D is used to calculate the Simpson’s Diversity Index so that the value seems more logical (the greater the value, the higher the diversity).

3.3.4.2. Abundance of waders

There are two components that were taken into consideration in determining species abundance of waders. These are relative abundance and the density of the waders. Formulae involved are as follows:

i) Relative abundance (Percentage)

$$\frac{\text{The number of individual per species}}{\text{Total number of individual recorded}} \quad \text{X} \quad 100\%$$

ii) Species density (Individual per hectare)

$$\frac{\text{Total number of individual per species}}{\text{Total effective area}}$$

Species density is calculated as individual per hectare. The density value for each species is calculated and then the total density for the whole area is calculated by sum up all the density values for each species. The effective areas for Jeram Beach is 27 hectare whereas for Remis Beach is 28 hectare.

3.3.4.3 Analysis of Data

In preparation for statistical testing, all data sets were test with Shapiro Wilke's W test and Anderson's Darling test for normality. Non-parametric test was chosen for further investigation because most of the data were not normally distributed. In all cases, $\alpha = 0.05$ was used. All analysis of data was conducted by using software STATISTICA version 8.0.

3.4 Results

3.4.1 Taxanomic Composition

A total of 32 species or 19,034 individuals of waders which belong to nine families were observed in the study areas (Table 3.1). According to International Union for Conservation of Nature (IUCN) Red List of Threatened Species, three species (9.4%) were classified as Vulnerable. These are Lesser adjutant (*Leptoptilos javanicus*), Chinese Egret (*Egretta eulophotes*) and Far eastern curlew (*Numenius madagascariensis*). One species (3.1%) is classified as Near Threatened. This is a Malaysian plover (*Charadrius peronii*). The remaining 28 species (87.5%) are classified as Least Concern (Table 3.1). This study excluded nine species from further analysis since they were present in small quantities throughout study period (less than 10 individuals were recorded). These species are White-bellied sea-eagle (*Haliaeetus leucogaster*), Chinese egret (*Egretta eulophotes*), Rudy turnstone (*Arenaria interpres*), Black-bellied/grey plover (*Pluvialis squatarola*), Pacific golden plover (*Pluvialis fulva*), Sooty tern (*Onychoprion fuscatusi)*, Long-billed plover (*Charadrius placidus*), Malaysia plover (*Charadrius peronii*), and Little stint (*Calidris minuta*).

Table 3.1: List of bird species found in the study areas with its distribution status and IUCN status.

Family	English Name	Scientific Name	Malay name	Distribution Status	IUCN Status
Accipiridae	White-bellied sea-eagle	*Haliaeetus leucogaster*	*Helang siput*	R	LC
Alcedininae	Collared kingfisher	*Todiramphus chloris*	*Pekaka bakau*	R, M	LC
Ardeidae	Little/striated heron	*Butorides striata*	*Pucung keladi*	R, M	LC
Ardeidae	Little egret	*Egretta garzetta*	*Bangau kecil*	R, M	LC
Ardeidae	Chinese Egret	*Egretta eulophotes*	*Bangau cina*	M	VU
Ardeidae	Grey heron	*Ardea cinerea*	*Pucung Seriap*	R	LC
Ardeidae	Great egret	*Ardea alba*	*Bangau besar*	R, M	LC
Ardeidae	Purple heron	*Ardea purpurea*	*Pucung serandau*	R, M	LC
Charadriidae	Lesser sand plover	*Charadrius mongolus*	*Rapang mongolia*	M	LC
Charadriidae	Greater sand plover	*Charadrius leschenaultii*	*Rapang besar*	M	LC
Charadriidae	Grey plover	*Pluvialis squatarola*	*Rapang kelabu*	M	LC
Charadriidae	Pacific golden plover	*Pluvialis fulva*	*Rapang kerinyut*	M	LC
Charadriidae	Common ringed plover	*Charadrius hiaticula*	*Rapang gelang besar*	V	LC
Charadriidae	Long-billed plover	*Charadrius placidus*	*Rapang paruh panjang*	V	LC
Charadriidae	Malaysian plover	*Charadrius peronii*	*Rapang pasir*	R	NT
Ciconiidae	Lesser adjutant	*Leptoptilos javanicus*	*Burung botak*	R	VU
Laridae	Laughing gull	*Larus atricilla*	-	V	LC
Laridae	Black-legged kittiwake	*Rissa tridactyla*	-	V	LC
Laridae	Little tern	*Sternula albifrons*	*Camar kecil*	R, M	LC
Pandioninae	Osprey	*Pandion haliaetus*	*Helang tiram*	M	LC
Scolopacidae	Far eastern curlew	*Numenius madagascariensis*	*Kendi timur*	M	VU
Scolopacidae	Red necked stint	*Calidris ruficollis*	*Kedidi luris leher*	M	LC
Scolopacidae	Whimbrel	*Numenius phaeopus*	*Kedidi pisau raut*	M	LC
Scolopacidae	Common redshank	*Tringa totanus*	*Kedidi kaki merah*	M	LC
Scolopacidae	Terek sandpiper	*Xenus cinereus*	*Kedidi sereng*	M	LC
Scolopacidae	Rudy turnstone	*Arenaria interpres*	*Kedidi batu*	M	LC
Scolopacidae	Common sandpiper	*Actitis hypoleucos*	*Kedidi pasir*	M	LC
Scolopacidae	Bar-tailed godwit	*Limosa lapponica*	*Kedidi ekor berjalur*	M	LC
Scolopacidae	Little curlew	*Numenius minutus*	*Kendi kerdil*	V	LC
Scolopacidae	Marsh sandpiper	*Tringa stagnatilis*	*Kedidi paya*	M	LC
Scolopacidae	Little stint	*Calidris minuta*	*Kedidi kerdil*	V	LC
Sternidae	Sooty tern	*Onychoprion fuscatus*	*Camar angin*	R, M	LC

Key: R = Resident, M = Migrant, V = Vagrant, LC = Least Concern, VU = Vulnerable and NT = Near Threatened.

Numenius phaeopus *Todiramphus chloris* *Tringa totanus*

Ardea alba *Ardea cinerea* *Leptoptilos javanicus*

Egretta garzetta *Butorides striata* *Calidris ruficollis*

Charadrius mongolus *Charadrius leschenaultia* *Tringa stagnatilis*

Xenus cinereus *Arenaria interpres* *Ardea purpurea*

Figure 3.4: Some species of birds recorded presence in study areas

3.4.2 Wader's Diversity, Abundance and Density

A total of 19,014 individuals recorded during sampling period in which 34.4% belong to family Scolopacidae, 21.9% are Charadridae, 18.8% are Ardeidae, 9.4% are Laridae,and 3.1% are Alcedininae, Pandioninae, Accipiridae, Sternidae and Ciconiidae respectively (Figure 3.5). In terms of species counts, Common redshank (*Tringa totanus*) contributed the highest percentage which is 27.2% from total number of individuals recorded followed by Lesser sand plover (*Charadrius mongolus*) (17.2%), Terek sandpiper (*Xenus cinereus*) (9.4%), Red-necked stint (*Calidris ruficollis*) (6.4%), Little egret (*Egretta garzetta*) (6.4%), Little heron (*Butorides striata*) (4.3%), Bar-tailed godwit (*Limosa lapponica*) (4.1%), Grey heron (*Ardea cinerea*) (3.8%), Great egret (*Ardea alba*) (3.7%), Greater sand plover (*Charadrius leschenaultia*) (3.5%), Lesser adjutant (*Leptoptilos javanicus*) (3%), Far eastern curlew (*Numenius madagascariensis*) (2.7%), Whimbrel (*Numenius phaeopus*) (1.9%), Laughing gull (*Larus atricilla*) (1.6%) and Common sandpiper (*Actitis hypoleucos*) (1.5%). The rest of the species have percentage less than 1% respectively (Figure 3.6).

The compositions of the waders differ significantly in all months ($\chi^2 = 84.35$, $p < 0.001$) (Figure 3.7). The pairwise comparisons were tested and results shows the compositions of the waders differed significantly by the months (Table 3.2; Figure 3.8). Overall, the Shannon-Weiner Diversity Index, H' is 2.303, Shannon's equitability, E_H is 0.2337, and Simpson's Diversity Index is 0.8972. The relative abundance and density of the species were summarised in the Table 3.3 below.

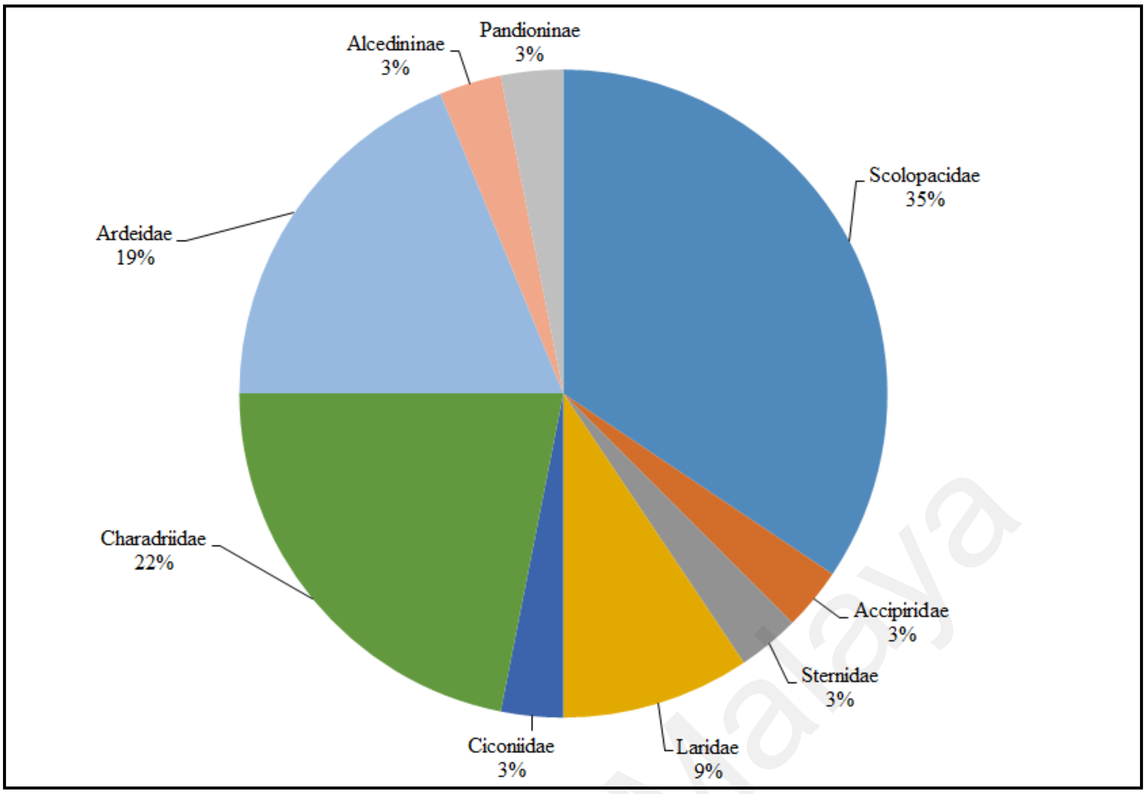


Figure 3.5: Percentage of bird's families recorded during sampling

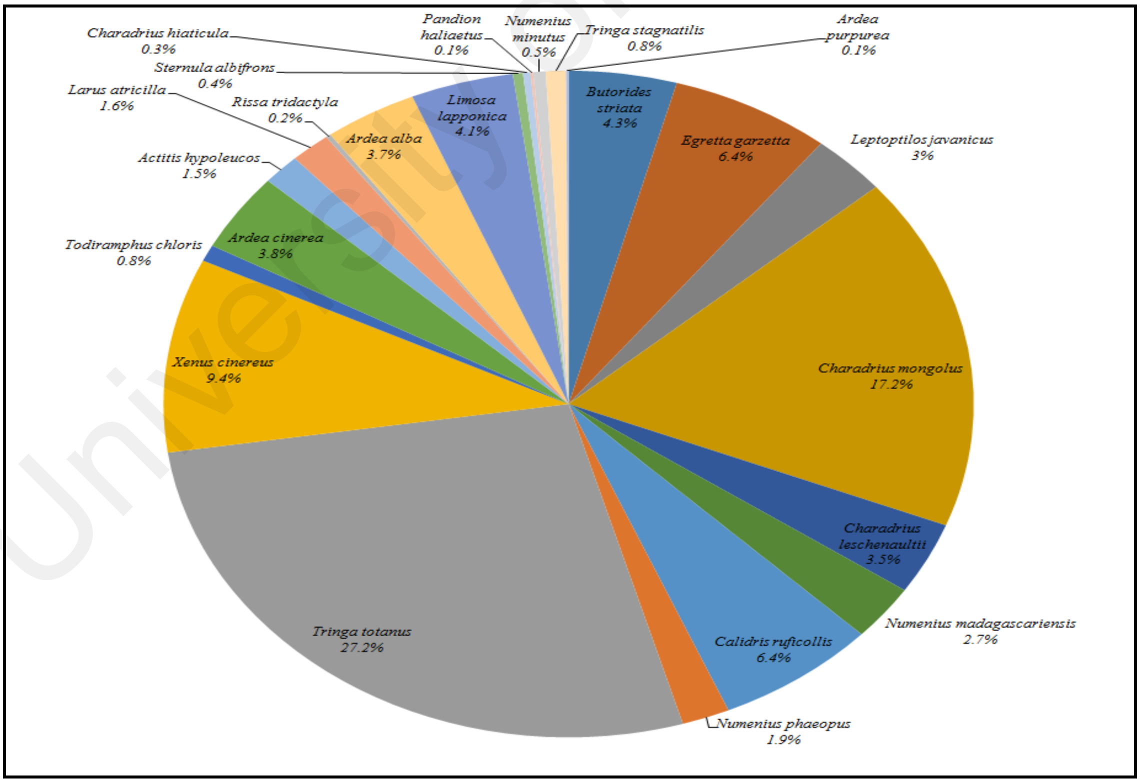


Figure 3.6: Percentage of bird species in study areas

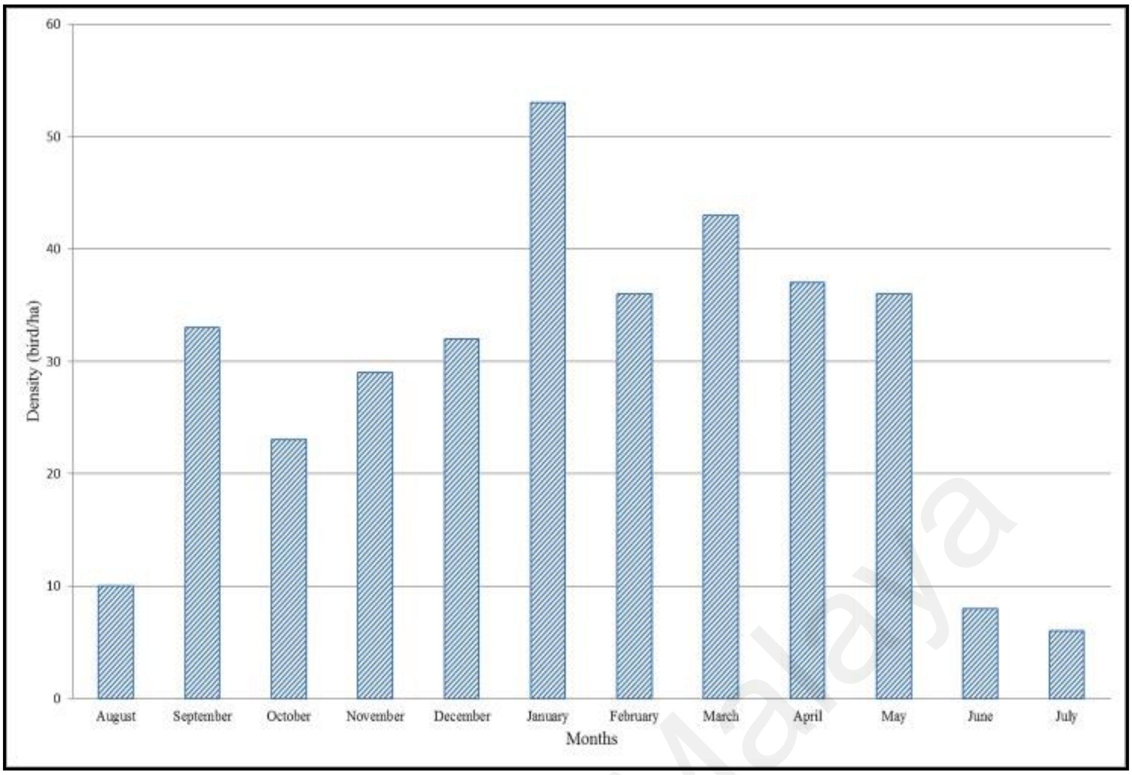


Figure 3.7: Total birds densities in all months in Jeram and Remis Beaches

Table 3.2: The values of pairwise comparison of bird composition between months.

Months	Test value, z	P-value
August – May	-4.326	0.003
August – February	-4.674	0.001
August – April	-5.152	0.001
August – January	-5.196	0.001
August – March	-5.348	0.001
July – May	4.304	0.003
July – February	4.65	0.01
July – April	5.130	0.001
July – January	5.174	0.001
July – March	5.326	0.001
June – February	3.630,	0.042
June – April	4.109	0.007
June – January	4.152	0.006
June – March	4.304	0.003

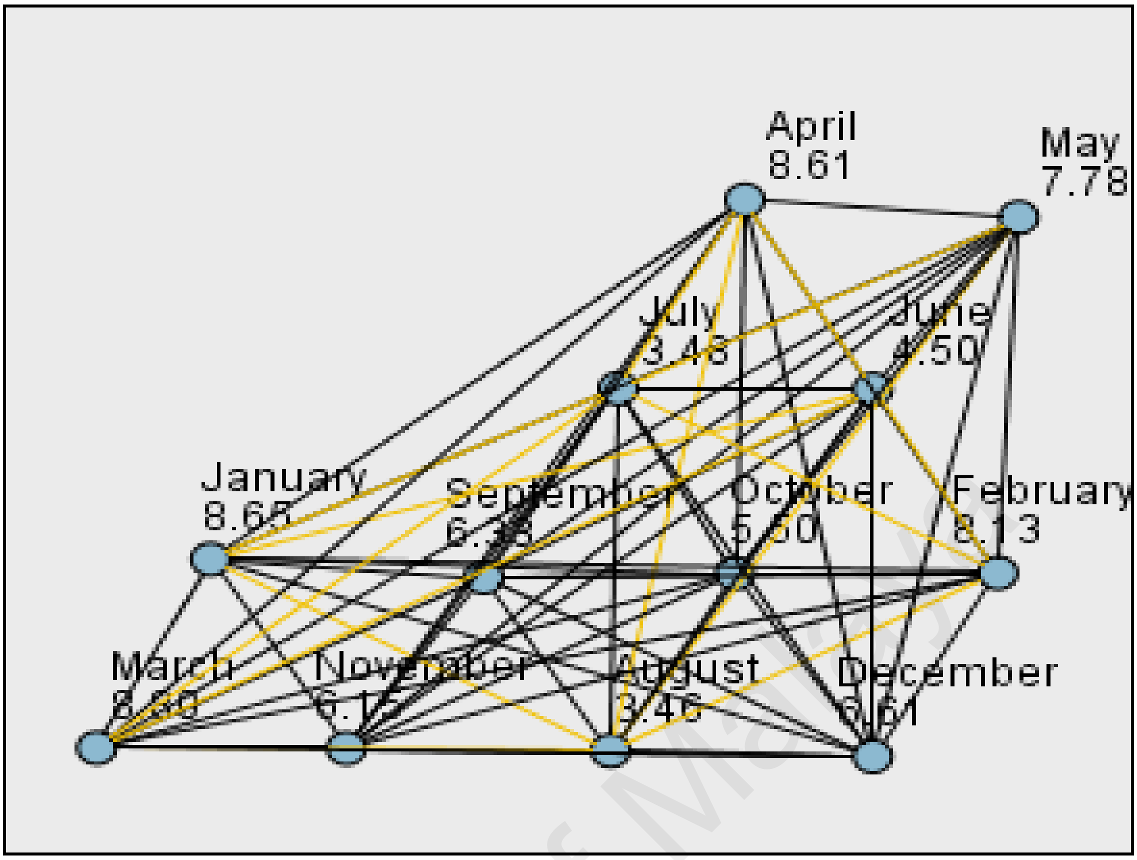


Figure 3.8: The pairwise difference between months

Table 3.3: The summary of relative abundances and densities of bird species during sampling period

Species	Total no. of individual	Relative abundance (%)	Density (Ind/ha)
Butorides striata	822	4.3	14.9
Egretta garzetta	1208	6.4	22.0
Leptoptilos javanicus	566	3	10.3
Charadrius mongolus	3276	17.2	59.6
Charadrius leschenaultii	657	3.5	11.9
Numenius madagascariensis	522	2.7	9.5
Calidris ruficollis	1225	6.4	22.3
Numenius phaeopus	362	1.9	6.6
Tringa totanus	5173	27.2	94.1
Xenus cinereus	1788	9.4	32.5
Todiramphus chloris	148	0.8	2.7
Ardea cinerea	715	3.8	13.0
Actitis hypoleucos	289	1.5	5.3
Larus atricilla	310	1.6	5.6
Rissa tridactyla	29	0.2	0.5
Ardea alba	698	3.7	12.7
Limosa lapponica	787	4.1	14.3
Sternula albifrons	84	0.4	1.5
Charadrius hiaticula	61	0.3	1.1
Pandion haliaetus	18	0.1	0.3
Numenius minutus	102	0.5	1.9
Tringa stagnatilis	161	0.8	2.9
Ardea purpurea	13	0.1	0.2

3.4.2.1 Jeram Beach VS Remis Beach

In terms of comparisons between sampling sites, significant difference were found between waders in Jeram and Remis Beaches ($t = 4.57$, $p = 0.001$) (Figure 3.9). The diversity index was higher in Jeram Beach, H’ = 2.338 compared to Remis Beach, H’ = 2.3154 (Table 3.4). A significant difference were detected between the sampling plots in Jeram Beach ($S = 16.67$, $p < 0.001$) (Figure 3.10). The pairwise comparisons results in significant difference between plot 2 and plot 3 ($z = 1.667$, $p < 0.001$). Likewise, Wilcoxon Signed Rank Test shows a significant difference between the sampling plots in Remis Beach ($W = 78$, $p = 0.003$) (Figure 3.10).

Table 3.4: Comparison between indices value recorded by birds utilising Jeram Beach and Remis Beach

Values	Jeram Beach	Remis Beach
Shannon-Weiner Index, H’	2.338	2.3154
Shannon Equitability/ Evenness, E_H	0.5693	0.6101
Simpson’s Diversity Index, D	0.8942	0.8917
Density (ind/ha)	473	223
Total Species no.	16	20
Total families no.	7	7
Total individual observed	12775	6239
Total areas (ha)	27	28

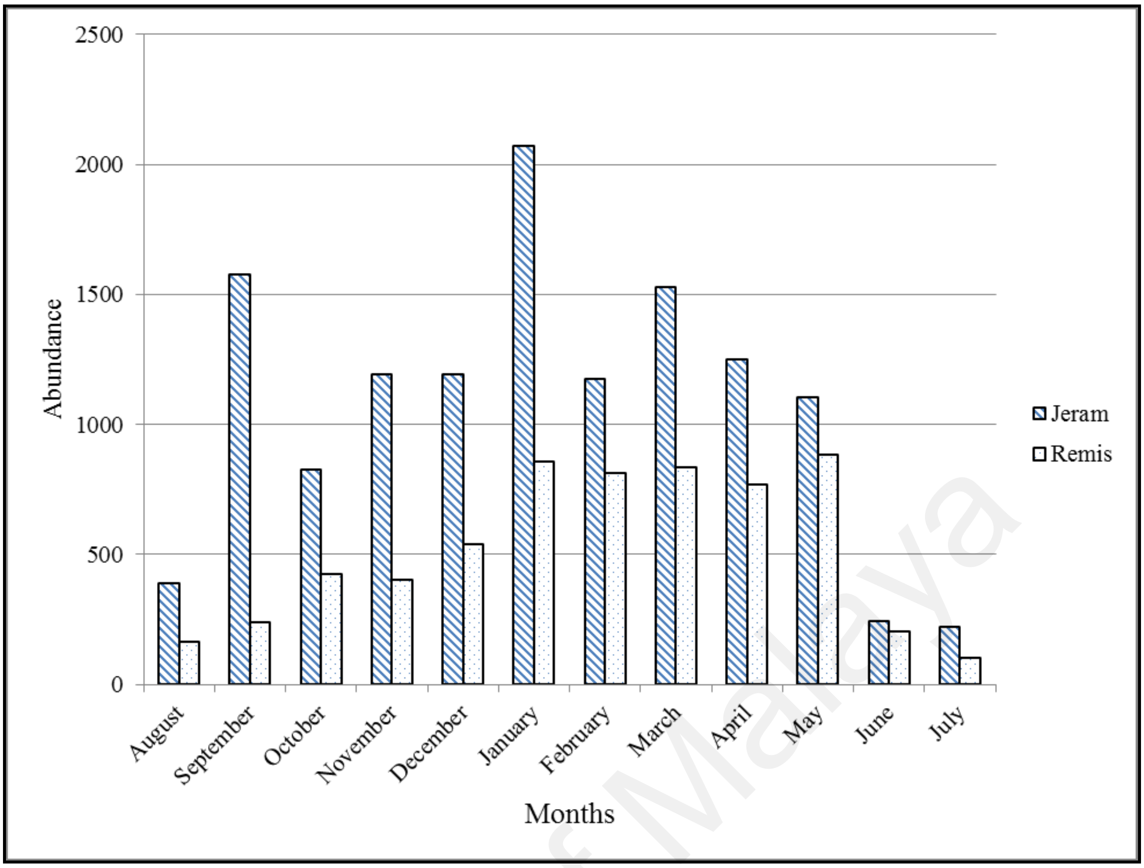
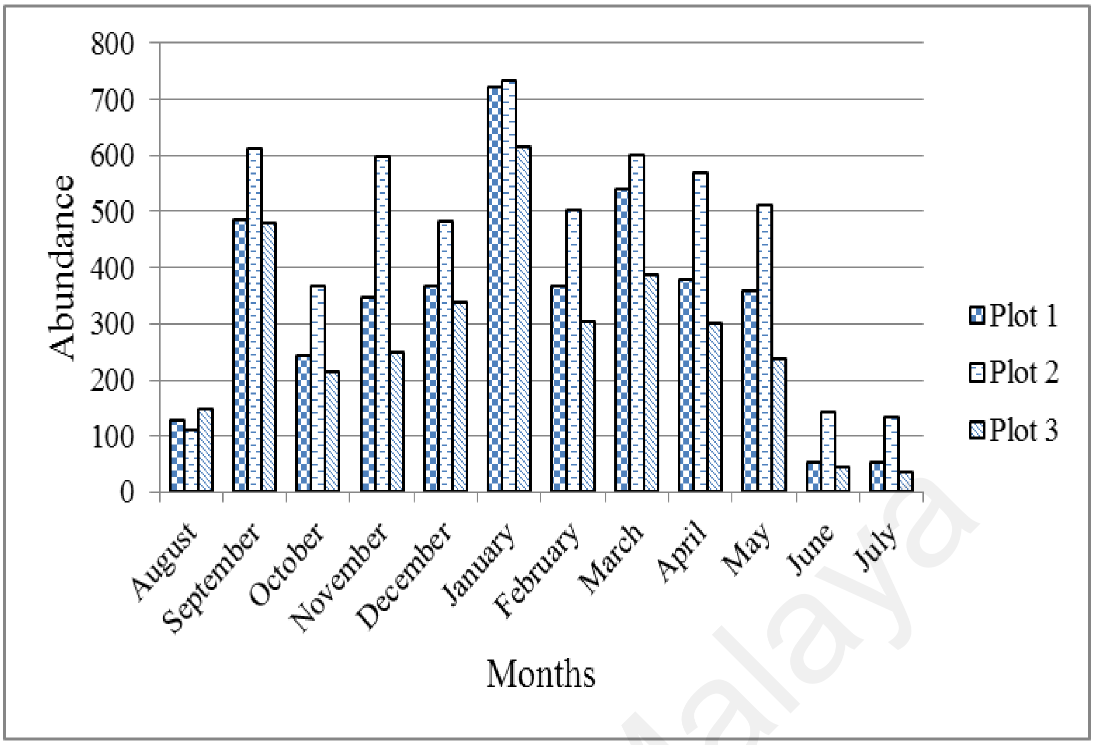
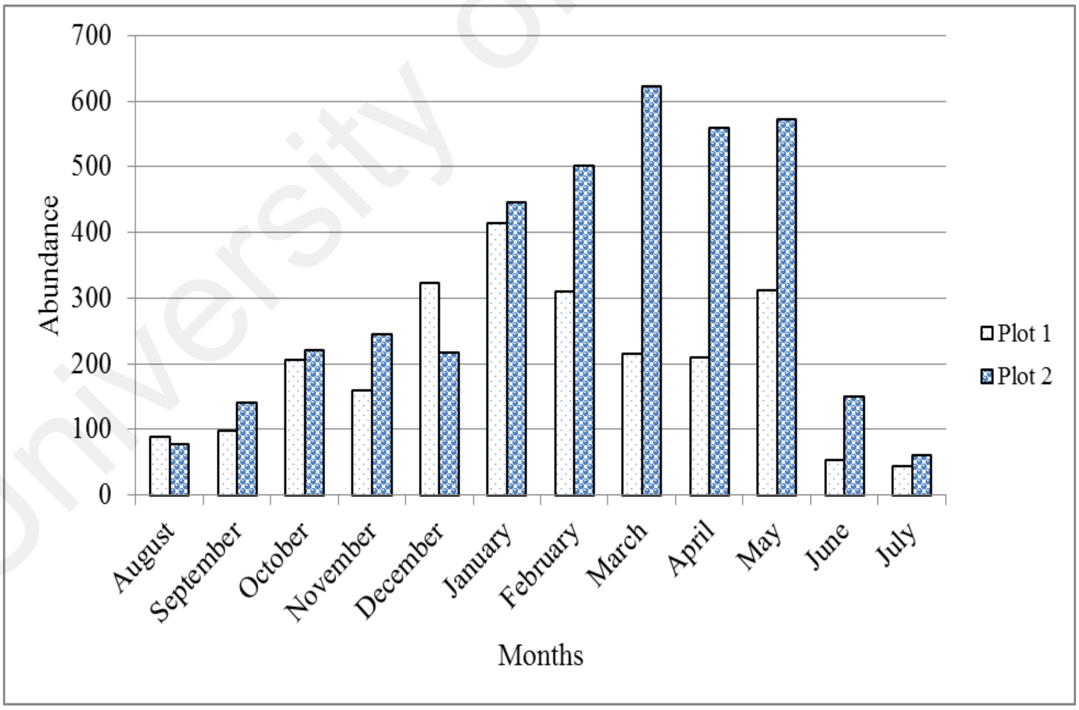


Figure 3.9: The abundance of birds in the sampling areas throughout sampling period



a)

Figure 3.10 (a): The abundance of birds in all sampling plots in Jeram Beach



b)

Figure 3.10 (b): The abundance of birds in all sampling plots in Remis Beach

3.4.2.2 Migratory VS non-migratory seasons

A total of 13,683 individuals of waders species were recorded during migratory seasons (September to May) whereas 5,331 individuals were recorded during non-migratory seasons (June to August). Figure 3.11 indicates the percentage of the wader distribution status. The diversity of wader species were higher during migratory seasons (H' = 5.6768) than non-migratory seasons (H' = 4.0698). Meanwhile, Simpson's Diversity Index is 0.8476 in migratory seasons and 0.6963 in non-migratory seasons. Besides that, Shannon Equitability or Shannon Evenness calculated the value of 0.7388 and 0.5818 during migratory and non-migratory periods respectively. Furthermore, the results also indicated that the higher mean of the wader density at the study area during migratory season, i.e.240 ind/ha compare to 97 ind/ha in non-migratory season (Figure 3.12). The analysis of 2 samples *t*-test shows that a significant difference in wader abundance between migratory and non-migratory seasons (t = 2.39, p = 0.036). The decrease in number of individuals was found in migratory species and also for species which have both migrant and resident populations. On contrary, population of resident species was increased during non-migratory seasons (Figure 3.13).

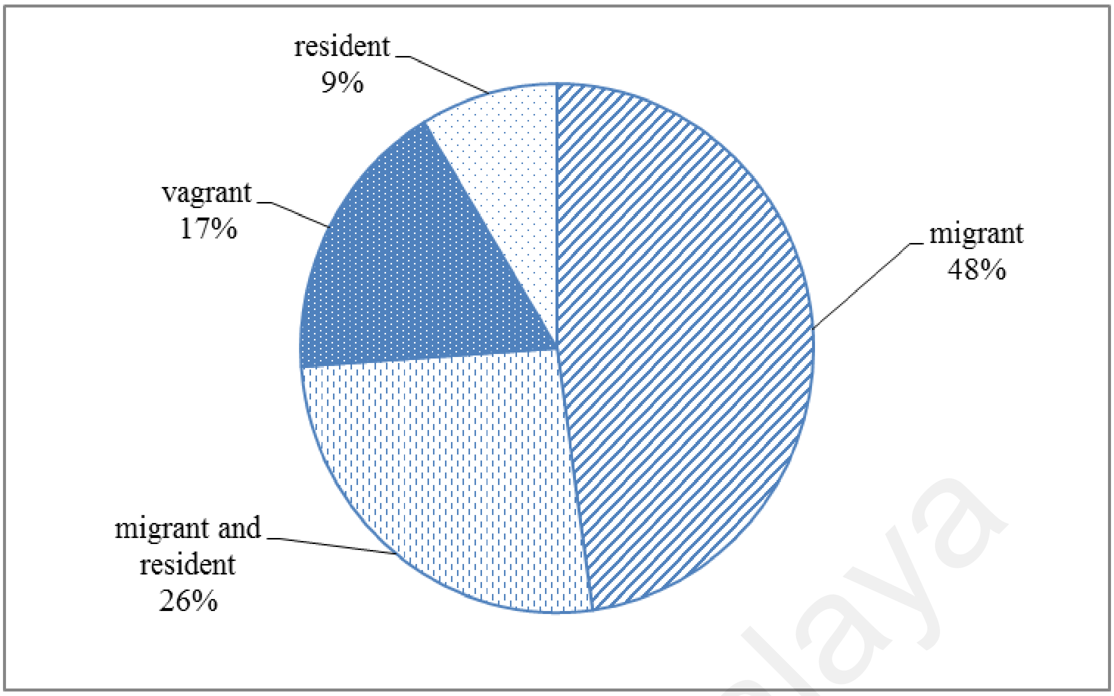
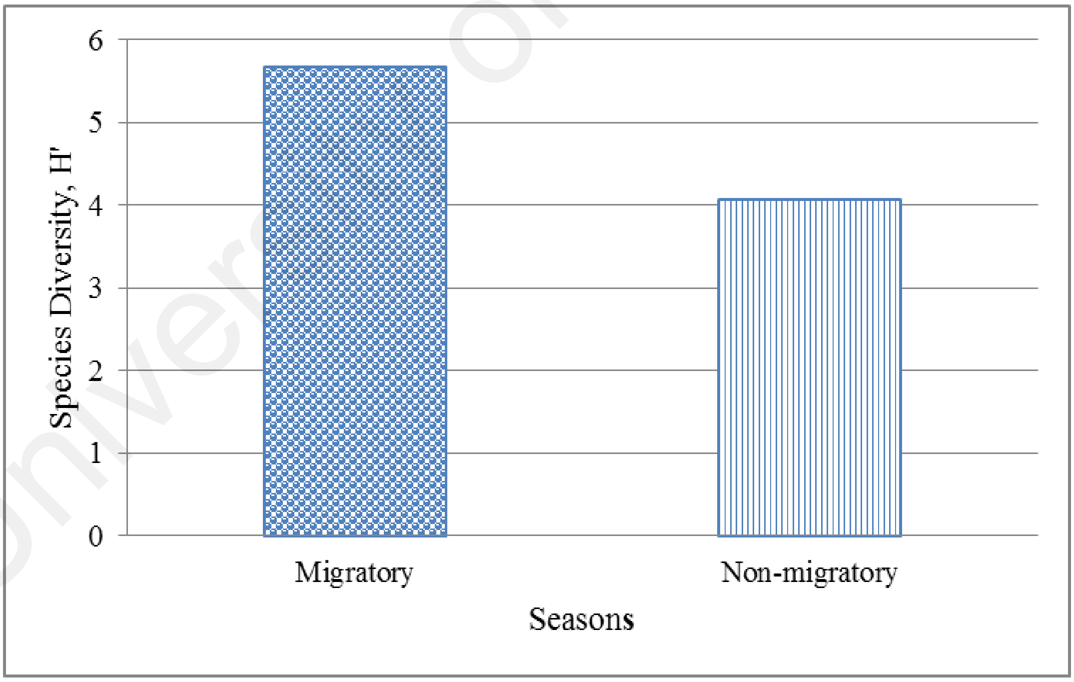


Figure 3.11: Percentage of bird distribution status



(a)

Figure 3.12(a): Diversity of waders in Jeram and Remis Beaches during migratory and non-migratory seasons.

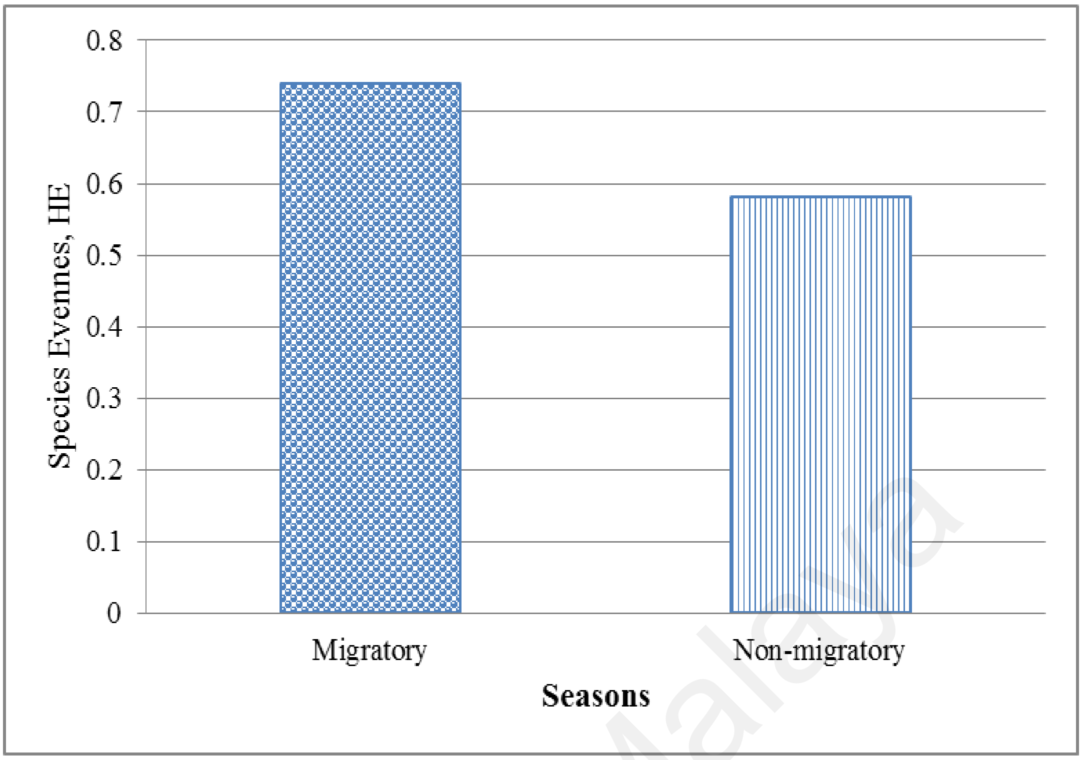
(b)


Figure 3.12(b): Species richness of waders in Jeram and Remis Beaches during migratory and non-migratory seasons.

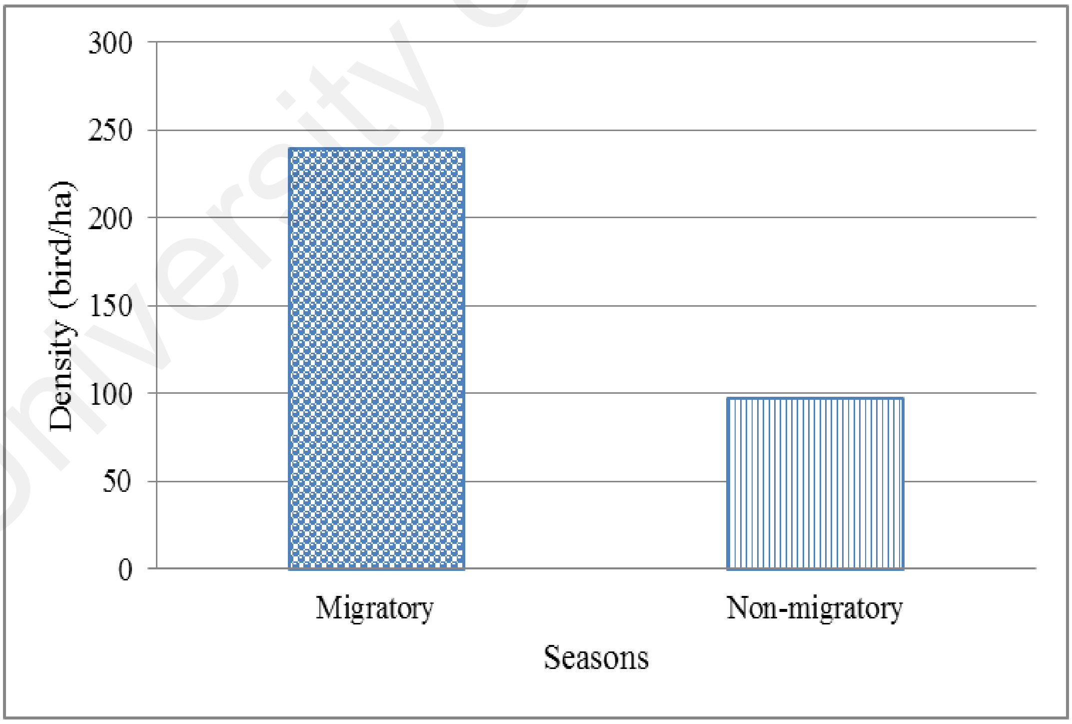
(c)


Figure 3.12(c): Density of waders in Jeram and Remis Beaches during migratory and non-migratory seasons.

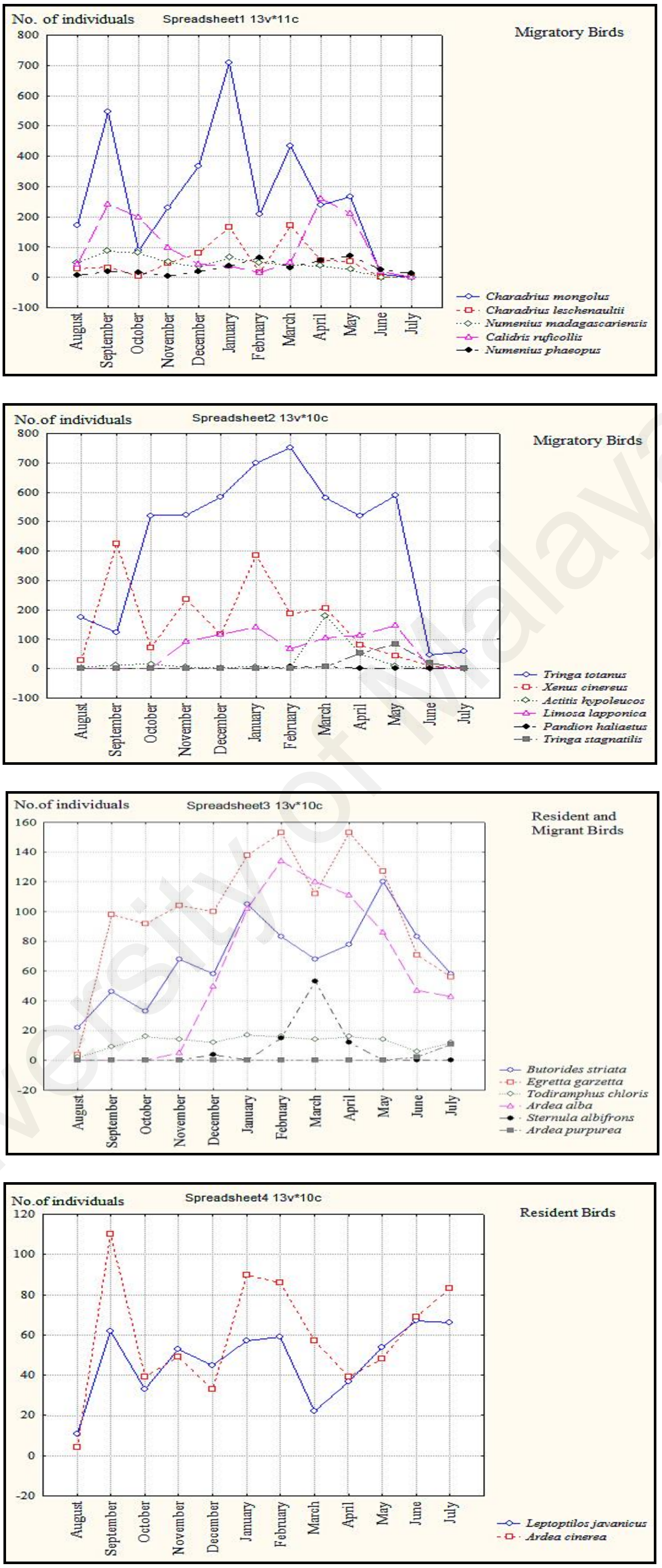


Figure 3.13: Trend of wader abundance during study period in both beaches.

The wader abundance was differed significantly in Jeram and Remis Beaches during migratory period (t = 4.39, p = 0.001) but not during non-migratory period (t = 0.78, p = 0.456). The wader abundance also shows no difference in all plots in Jeram Beach during migratory period (F = 3.23, p =0.063) and non-migratory period (F = 0.86, p = 0.448). Similar results was found in all plots in Remis Beach during migratory period (t = -1.2, p = 0.253) and non-migratory period (t = -1.12, p = 0.295).

3.4.2.3 Comparisons of avian abundance with previous study in Selangor

A total of 26 species of waders were recorded in previous study conducted by Riak et al. (2003) in the mudflat area of Kapar, Selangor. As comparison, this study recorded high number of species which is 32 species. The Shannon-Weiner Diversity Index, H' recorded by Riak et al. (2003) is 4.336 while this study shows the value of 4.653. Twelve species of waders that were recorded by Riak et al. (2003) were not recorded in this study. These are Asian dowitcher (*Limnodromus semipalmatus*), Black-tailed godwit (*Limosa limosa),* Common greenshank (*Tringa nebularia*), Curlew sandpiper (*Calidris ferruginea*), Eurasian curlew (*Numenius arquata*), Great knot (*Calidris tenuirostris*), Nordmann's greenshank (*Tringa guttifer*), Oriental pranticole (*Glareola maldivarum*), Red knot (*Calidris canutus*), Sanderling (*Calidris alba*), Sharp-tailed sandpiper (*Calidris acuminate*) and Wood sandpiper (*Tringa glareola*). In contrast, this study recorded some species which were not recorded by previous study. These are Black-legged kittiwake (*Rissa tridactyla*), Far eastern curlew (*Numenius madagascariensis*), Great egret (*Ardea alba*), Purple heron (*Ardea purpurea*), Little egret (*Egretta garzetta*), Little tern (*Sternula albifrons*), Little/striated heron (*Butorides striata*), Osprey (*Pandion haliaetus*), Greater sand plover (*Charadrius leschenaultia*), Grey heron (*Ardea cinerea*), Laughing gull (*Larus atricilla*) and Lesser adjutant (*Leptoptilos javanicus*) (Table 3.5).

Table 3.5: Comparison between wader species recorded in this study with previous study in Selangor

Common name	Scientific name	MA 1	MA 2
Asian dowitcher	*Limnodromus semipalmatus*	√(2)	-
Bar-tailed godwit	*Limosa lapponica*	√(898)	√(787)
Black-bellied plover/ Grey plover	*Pluvialis squatarola*	√1054	√(1)
Black-legged kittiwake	*Rissa tridactyla*	-	√(29)
Black-tailed godwit	*Limosa limosa*	√(1233)	-
Collared kingfisher	*Todiramphus chloris*	-	√(148)
Common greenshank	*Tringa nebularia*	√(470)	-
Common redshank	*Tringa totanus*	√(2705)	√(5173)
Common ringed plover	*Charadrius hiaticula*	√(384)	√(61)
Common sandpiper	*Actitis hypoleucos*	√(310)	√(289)
Curlew sandpiper	*Calidris ferruginea*	√(429)	-
Eurasian curlew	*Numenius arquata*	√(1238)	-
Far eastern curlew	*Numenius madagascariensis*	-	√(522)
Great egret	*Ardea alba*	-	√(698)
Great knot	*Calidris tenuirostris*	√(220)	-
Greater sand plover	*Charadrius leschenaultii*	-	√(657)
Grey heron	*Ardea cinerea*	-	√(715)
Laughing gull	*Larus atricilla*	-	√(310)
Lesser adjutant	*Leptoptilos javanicus*	-	√(566)
Lesser sand plover	*Charadrius mongolus*	√(3567)	√(3276)
Little curlew	*Numenius minutus*	√(3)	√(102)
Little egret	*Egretta garzetta*	-	√(1208)
Little tern	*Sternula albifrons*	-	√(84)
Little stint	*Calidris minutus*	√(3)	√(2)
Little/striated heron	*Butorides striata*	-	√(822)
Malaysian plover	*Charadrius peronii*	√(204)	√(1)
Marsh sandpiper	*Tringa stagnatilis*	√(431)	√(161)
Nordmann's greenshank	*Tringa guttifer*	√(6)	-
Oriental pratimcole	*Glareola maldivarum*	√(18)	-
Osprey	*Pandion haliaetus*	-	√(18)
Pacific golden plover	*Pluvialis fulva*	√(233)	√(1)
Purple heron	*Ardea purpurea*	-	√(13)
Red knot	*Calidris canutus*	√(134)	-
Red necked stint	*Calidris ruficollis*	√(61)	√(1225)
Ruddy turnstone	*Arenaria interpres*	√(155)	√(7)
Sanderling	*Calidris alba*	√(39)	-
Sharp-tailed sandpiper	*Calidris acuminata*	√(1)	-
Terek sandpiper	*Xenus cinereus*	√(295)	√(1788)
Whimbrel	*Numenius phaeopus*	√(1056)	√(370)
Wood sandpiper	*Tringa glareola*	√(2)	-
Total		15151	19034

Key: ‘MA 1’ = Riak et al. (2003), ‘MA 2’ = This study, ‘MA’ = Mudflat Area, ‘√’ = Species presence, ‘-‘ = Species absence, ‘( )’ = abundance.

3.5 Discussion

3.5.1 Species Composition and Status

The wader community in Jeram and Remis beaches composed of shorebirds and water birds. The presence of three vulnerable species (i.e. Lesser adjutant, Chinese Egret, and Far eastern curlew) and one near-threatened species (i.e. Malaysian plover) indicated that Jeram Beach and Remis Beach are important area for wader conservation. Lesser adjutant and Far eastern curlew were recorded every month throughout the study period and it is believed that these sampling areas are important roosting and feeding areas for the species. In contrast, Chinese egret and Malaysian plover were believed to be accidently occurred in the sampling areas because both species were sighted only once during the study period.

Although this study recorded the presence of near-threatened species (i.e. Malaysian plover) only once, it is believed that this species had becoming locally extinct as their abundance was previously sighted higher (Riak et al. 2003) in the nearest area of Kapar Mudflat, Selangor. This can be true only if the resources availability of both locations were similar. Waders are increasingly threatened by anthropogenic habitat change (Yasue and Dearden 2006). Moreover, tropical species (in particular species in South-East Asia) may be even more vulnerable to development because of weaker conservation regulations in many of these countries (Kontogeorgopoulos 1999).

3.5.2 Wader's Diversities, Abundances and Densities

Seasonal variation of wader's abundance was observed during the study period due to the presence of large numbers of migrant and resident waders which assembled in the sampling sites during migratory period. In January, wader abundance was at peak due to the presence of migrant wader during migratory periods while in July, most migrant species were already departed from sampling sites to their breeding grounds. Similar results were recorded in Pulicat Lake, India (Kannan and Pandiyan 2012).

The abundance of wader species was believed to link with the variation in prey abundance (Evans and Dugan 1984). Numerous studies have demonstrated a positive correlation between wader abundance and prey densities (e.g Zharikov and Skilleter 2004; Lomoljo 2011) especially during nonbreeding season when invertebrate prey abundance often increases and energetic costs associated with maintenance and migration increase (Kersten and Piersma 1987). Optimal foraging theory stated that animals should forage in a manner that maximises their energy gain (Pyke et al. 1977). Therefore, in relation to wader distribution on non-breeding grounds, one would expect more waders at intertidal flats which provide greater densities of available prey (Finn 2010). Previous studies suggested that waders choose to feed in habitats where the greatest foraging success can be gained (Barbosa 1996; Rippe and Dierschke 1997; Van Gils et al. 2006). Furthermore, abiotic factors such as salinity and substrate which vary with spatial scales, strongly influence wader distribution through their impact on the distribution of prey organisms (Wolff 1969).

Wilhm and Dorris (1966) have proposed a relationship between species diversity and pollution status of the sampling sites. Staub et al. (1970), have also proposed the state of pollution based on the scale of the species diversity. He proposed another scale of pollution status in terms of species diversity as: Shannon-Weiner Index value of 3.0-

4.5 as slight pollution, 2.0-3.0 is light pollution, 1.0-2.0 is moderate pollution and 0.0-1.0 is heavy pollution. According to this scale, the sampling sites in this study were categorized as lightly polluted as the Shannon-Wiener Diversity Index was ranged between the values of 2.0-3.0. Birds serve as excellent indicators of environmental health and change. They occupy a wide range of niches, use many types of food and physical resources, and are sensitive to environmental changes (Mackinnon et al. 2012). The presence of abundant waders in the study areas indicated that the population occurred in both mudflats areas was still tolerable. Furthermore, Bhandarkar and Bhandarkar (2013) suggested that the values above 3.0 indicate the structure of habitat is stable and balanced while the values under 1.0 indicate pollutions and degradation of habitat structure.

The higher the value of Evenness Index indicates a low concentration of dominance of species diversity at a specific site. Anitha et al. (2004) suggested that when all species in the sample are equally abundant, an evenness index would decrease toward zero as the relative abundance of the species diverges away from the evenness. The evenness was closely associated with the diversity values, the lowest diversity producing the lowest evenness value.

3.5.2.1 Jeram Beach VS Remis Beach

The higher index value reflects the higher species richness and diversity exists within a particular habitat compared to habitat with lower index value. Meanwhile, the number of species documented in a community may reflect the characteristics of the habitat and the interactions among species that live in that community (Schluter and Ricklefs 1993(a)). The higher number of species within a particular habitat shows the better habitat qualities and therefore more interaction occurred between the species lives within the community.

In Jeram Beach, plots 2 recorded the highest abundance of waders counted throughout the study periods followed by plot 1 and plot 3. Based on observations, compared to plot 1 and plot 3, less disturbances was found in this plot. Plot 1 was located near the food stalls and usually people tend to wander around this plot compared to the other plots. While in plot 3, the presence of dogs which were observed causing disturbance were occurred in this area. Plot 2 was considered to be the most isolated from disturbances and the small mangroves forest also situated in this plot. Mangroves generally situated within the tidal limits on alluvial flats in the delta (Benfield 2002), on sheltered muddy coastal areas (Hogarth 1999; FAO 2004), in estuaries and on marine shorelines (Benfield 2002), where other plants cannot grow (Maguire et al. 2000).

Contradictory findings on wader numbers in mangrove forests have been reported by several authors. Nisbet (1968) reported 135 wader species in the mangrove habitats of Peninsular Malaysia whereas Murphy and Sigurdsson (1990) identified sandpipers, plovers, herons and egrets in Singapore mangrove habitats. Study by Ghasemi et al. (2012) shows that more than 80% of waders at both mangrove habitats in their study sites were recorded on intertidal mudflats, which is considered the most important habitat for waders.

Habituation can be defined as a decline in responding to a repeatedly presented stimulus. In this context, waders species were no longer responses towards human which they usually encountered and show no harms towards them. Wader individuals might insist to forage in the area although human disturbance might occur in that area to optimize their energy use. Flying to another foraging area will increase energy expenditure. According to Charnov (1976), when some patches are richer than others, optimally foraging individuals that maximizes energy gain should allocate their foraging effort to those patches that are more profitable than the average patch in the environment.

3.5.2.2 Migratory VS non-migratory seasons

The abundance of waders was significantly differed between migratory and non-migratory seasons. The diversities and evenness index were higher in migratory seasons. This occurred because the majority of the waders utilizing the mudflats area of both beaches were comprised of migratory wader species. Similar trends were found in Kuala Gula, Perak (Lomoljo 2011). He found that the species diversity and richness of wader were the highest in northward migration (January to May) compared to southward migration (August to December). The high diversity of waders found during northward migration might be related to high diversity and abundance of their preferred macrobenthic prey encountered in the mudflat habitat. In contrast, previous study at Kapar, Selangor found that the wader abundance was significantly higher during the southward migration compared to the northward migration (Riak et al. 2013). The high abundance may be due to the longer duration of stay and overwintering at Kapar. An increased in wader population was observed in this study compared to the previous study conducted in the coastal mudflat area of Jeram in 2001 and Remis in 2004 (Li and Ounsted 2007).

The assemblage of big flocks of migrant waders in the sampling sites was observed to have a significant effect on resident waders. The presence of migrant species was observed to displace members of resident wader species. Although resident waders were presence throughout study periods, the decreased in populations size was observed during migratory season. These happened may be due to competition between resident and migrant species. Coexistence with competitors usually results in fitness costs that can be due to direct interactions such as resource competition (Wedin and Tilman 1993; Forsman et al. 2007).

Kalejta (2002) found that 70% of interspecific aggression initiated by migrant waders was directed at resident wader during summer. Similarly, 79% of all aggressive encounters initiated by resident wader were directed at migrant wader. Morphologically similar individuals are likely to utilize similar food resources or foraging microhabitats, thus more likely to be involved in aggressive encounters over these resources (Recher and Recher 1969). Fights are quite common between conspecifics but did not occur between interspecific. This is because waders are more aggressive in defending their personal space to conspecifics than others (Goss-Custrad 1970).

3.5.2.3 Comparisons of waders abundance with previous study in Selangor

Compared to the study conducted by Riak et al. (2003), this study recorded the highest number of species and individual of waders. The increases in population size of wader in these areas is maybe due to variation in characteristics between both study areas. Inadequate intertidal resources (Smart and Gill 2003), predation risk and constant human disturbance during foraging and roosting (Yasue 2006; Weston and Elgar 2007) would be the causes of population declines in a particular habitat.

Wader distributions and densities usually match the distribution of their preferred prey species (Zharikov and Skilleter 2004). Non-breeding waders generally seek habitat where resource availability is adequate, stable and predictable (Evans and Dugan 1984). Arshad and Riak (2004), indicated that a total biomass of the benthic macrofauna was higher in the mudflat area of Remis Beach compared to mudflat area of Kapar. Furthermore, the highest contribution to total biomass was derived from bivalves which were abundantly found in Remis Beach during that time. Sources of prey would be the main reasons which explained the higher abundance of wader in this study compared to the previous study.

Selecting an area to live is crucial to all animals, as individuals that occupy sites with greater foraging success and lower predation risk potentially have higher reproductive success and survival, and realize higher fitness (Fretwell and Lucas 1970; Stephens and Krebs 1986; Cresswell 1994; Leyler et al. 2012). Perceived predation risk is thought to underpin the selection of both feeding and roosting sites by waders (Lawler 1996). Waders will select roosts closest to their low tide intertidal feeding habitat and sites which usually have an open aspect allowing easy detection of birds of prey in day-time high tides (Rogers 2003). Most wader species prefer open roost sites which allow easy detection of potential predators. Therefore, most wader will avoid areas with tall vegetation (Rogers et al. 2006) such as mangrove, as this vegetation can provide cover for ambushing birds of prey (Dekker and Ydenberg 2004). Ash ponds at the Kapar Power Station and its surrounding mudflats have been a significant stopover site for migratory wader in Malaysia (Bakewell 2009). The coast of Kapar is characterized by a semi-diurnal tidal area which predominantly surrounded with mangroves forests growing along the shoreline. The eastern and southern parts are heavily occupied by oil palm plantations, manufacturing industries, residential areas and shipping ports (Sabuti and Mohamed 2012). Mangrove forest and intertidal mudflats habitats are particularly important for resident waders as they provide places to feed, roost and breed (Bakewell 2009). Lack of mangrove forest, except for plot 2 in Jeram Beach was thought to increase the population size of wader in this study. For small waders, feeding closer to cover entails a higher risk both of being attacked by predator (Whitfield 2003). On contrary, larger waders (i.e. Lesser adjutant, Great Egret, Grey heron, etc.) were observed to use the area near to the mangrove forest more frequently. Mangroves forests offer a considerable variety of food resources for many wader species (Skiletter and Warren 2000). Mangroves forest support variety of coastal fisheries (Walters et al. 2008) which in turn provided the food resources for wader species.

Stopover sites that combine high abundance of food with a relatively less a disturbance-free environment allow waders to maximize foraging time and quickly replenish their energy reserve (Helmers 1992). Meanwhile, the sites with extensive anthropogenic and/or natural disturbance may force waders to spend less time foraging (Thomas et al. 2003), expending more energy in avoiding disturbance, or abandon the sites (Burger 1986; Harrington 1999). Lower quality stopover sites may result in poor body condition and affect wader's ability to reach breeding or wintering grounds and reduce survivorship (Pfister et al. 1998). Compared to Kapar Ash Ponds, disturbance was likely to be occurred in these study sites because it were more exposed to human activities such as mussels collections and recreations. Although, this study recorded higher population size, the comparative study between this study and the previous study might be invalid due to the significant difference in time exist between studies. Time difference of 10 years might cause anything to be happen and perhaps if details study was conducted in the mudflat of Kapar, it may results in higher population sizes.

3.6 Conclusion

It can be concluded that wader densities and abundance is varied with time. Migratory season recorded higher number of wader species and individuals recorded compared to non-migratory season. The quality of resources offer by adjacent habitats will draw more individuals utilizing the area. The habitat with good quality has more abundances of food resources, have low predation risk and low disturbances which consequently results in higher chances of foraging success. The knowledge on abundance of waders community utilizing the mudflats area of stopover sites in Malaysia should be enhanced in order to fully understand their ecology and therefore will facilitate the efforts to conserve endangered wader species presence within these stopover sites.

CHAPTER 4: THE EFFECTS OF TIDAL STATES AND TIME OF DAY ON ABUNDANCE AND BEHAVIOUR OF WADERS UTILISING A TROPICAL INTERTIDAL ENVIRONMENT

4.1 Introduction

Surveys of wader numbers and distribution patterns have been used for a variety of purposes. These include determining the geographical distributions of species, obtaining population numbers which further lead to Ramsar listings, monitoring populations in order to detect the changes over time and understanding the environmental factors that underlie the density differences and habitat preferences between species (Finn 2010). Many factors influenced the distribution and behaviour of waders within their nonbreeding grounds.

Waders use the intertidal areas predominantly as a foraging habitat. Beside the dispersal of food, diverse environmental conditions might affect the foraging and the distribution of waders (Burger 1984; Evans and Dugan 1984; Goss-Custard 1984; Kober 2004). Foraging of animals living in intertidal areas are further restricted by the tides. The cyclic tidal inundation of mudflats and beaches causes changes both in the available feeding space and in the diversity and availability of prey items (Puttick 1980; Barbosa 1997). Besides tidal restriction, time of the day also affects the behaviour and distribution of waders in a particular feeding ground. Understanding these factors and how they affect the distribution and behaviour of waders is crucial because most of conservation efforts can be effectively implemented if the ecology of wader species in their nonbreeding grounds were fully studied.

The study on the waders utilizing the tropical areas is still lacking compared to the study conducted in temperate areas. Therefore, the objectives of this study are; (1) to relate the effect of the tidal cycle on the abundance and behavior of tropical waders, and, (2) to determine the effect of different interval periods of the day on the abundance of tropical waders utilizing the coastal mudflats area of Jeram and Remis Beaches, located in Selangor, Peninsular Malaysia.

4.2 Literature Review

Wader distribution is strongly affected by environmental conditions. Not only birds, but all organisms including plant and animal communities, are affected by the physical characteristics of the environment (Gillis et al. 2008). Some species are very specialized, and only use sites with specific resources (Piersma 2006), or sites where they can build up enough weight for long distance journeys (Warnock 2010). Analyses of coastal waders assemblages indicate that date, tide and weather explain most variation in species richness and abundance (Burger 1984; Colwell 1993). Tide is the major factor influencing the distribution, abundance and behaviour of waders (Evans 1979). Most authors note that waders forage on exposed intertidal areas at low tide, and roost in fields, marshes and bays at high tide (Pitelka 1979). Waders use roost sites at high tide to rest, preen and bath while their low tide feeding habitat is inundated (Spencer 2010). Roost sites are usually above the mean high water mark which includes rock walls, sandpits, oyster leases and saltmarshes (Lane 1987).

The ecology of waders in coastal habitats is strongly influenced by food. Environmental factors, principally tides and weather, constrain food availability on a relatively predictable daily and seasonal basis by limiting waders' access to invertebrate prey (Puttick 1980; Burger 1984). Although the impact of abiotic factors varies among habitats, tides influence communities at both freshwater and estuarine sites (Burger 1984). Furthermore, tides influence the behaviour and activity patterns of many coastal species (Connors et al. 1981) by altering the amount of foraging space available (Puttick 1980).

Time of the day also affects the abundance and behaviour of waders. Previous study showed that there was a greater relative abundance of Clapper Rail (*Rallus longirostris*) detections in the morning than afternoon surveys (Lehmicke et al. 2013). Variation in time of the day affects factors such as temperature and man-made noise levels, i.e. morning have less human or boat activity than afternoon. However, timing sensitivities may vary by species and location. For instance, Spear et al. (1999) found no difference between morning and evening detection in California Black Rails *(Laterallus jameicensis coturniculus*).

Tropical intertidal environments differ in several aspects to habitats in temperate zones. Tropical habitats show a large variability in temperature and rainfall, which leads to episodically high rates of evaporation and precipitation, which results in sharp gradients of salinity, temperature and dissolved nutrients in tropical waters (Alongi 1990). Fluctuation in salinity may constitute a major factor controlling the distribution of estuarine animals (Rajean and Julian 1993). Since migrating birds spend only a few months at their breeding grounds (and the rest of the year migrating or at their wintering quarters), ecological investigations on waders in tropical environments are scarce and widely dispersed (Kober, 2004) compared to studies in temperate areas.

4.3 Methodology

4.3.1 Study Areas

Jeram and Remis Beaches are located in West Coast of Peninsular Malaysia ($3^{o}13'27''$N, $101^{o}18'13''$E) (Figure 4.1) where semidiurnal tides prevail. The distance between Jeram Beach and Remis Beach is approximately 2 km. The selected study areas comprise approximately 55 ha of the intertidal mudflats area. The selection of these sites was based on past history of shorebird counts reported by Wetland Internationals in 1999-2004 (Li and Ounsted, 2007) which shows that these sites was previously known to be important stopover sites for shorebirds. The study areas were further divided into small plots. In Jeram Beach, three plots were constructed and size of each plot is approximately 900 m in length and 100 m in width (Figure 3.2(a)). In total, the overall plot’s size in Jeram Beach is 27 ha. Unlike Jeram Beach, only two plots were constructed in Remis Beach due to human activities constraints (Figure 3.2(b)). Size of each plot is approximately 700 m in length and 200 m in width. A total of 28 ha of area were used in Remis Beach study.

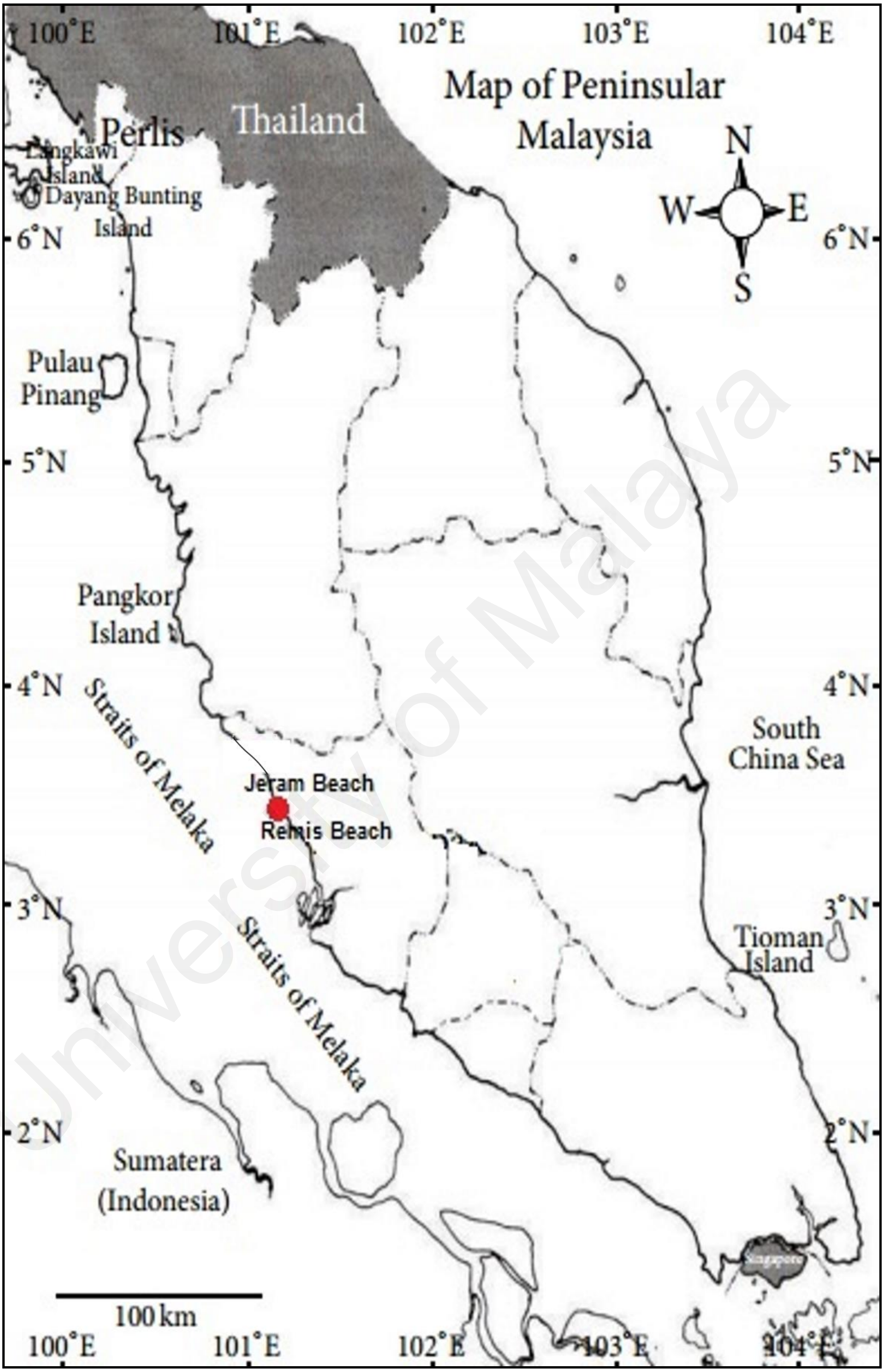


Figure 4.1: Location of Jeram and Remis Beaches in Selangor, Malaysia.

4.3.2 Wader Counts

Wader density and abundance were estimated on both Jeram and Remis Beaches during all tidal cycles. Wader count and behaviour surveys were conducted using direct observation technique with the aid of binoculars (12 X 42 magnification) and a video recorder (Nagarajan and Thiyagesan 1996) from August 2013 until July 2014. A monthly observation was conducted in both study areas for ten consecutive days. The wader count was divided into four time intervals: 0800–1000 hours, 1000–1200 hours, 1400–1600 hours and 1600–1800 hours. In each interval period, waders were counted only in the first 30 minutes in all sampling plots, while the rest of the time was used to observe wader's behaviour when encountering the tide. The sampling was conducted at both 'low' and 'high' tides to further understand wader stopover ecology. Since the intertidal areas were fully submerged during high tide, the low tide counts were further divided into 'ebbing', 'low tide peak' and 'rising' intervals so that the comparisons between these periods could reduce the bias of counting low tide and high tide periods alone. The interval periods were considered 'ebbing', if the tide was still not at its lowest point after more than one hour, whereas the interval period of 'rising' began as soon as the tide began rising. Meanwhile, the interval periods were considered 'low tide peak' when the tide was at its lowest point until the tide started to rise again. All wader present in each plot could be easily identified and counted because the intertidal mudflat areas of Jeram and Remis Beaches were relatively open and unvegetated. Flying forward waders were excluded from counting and only those feeding and flying within the sampling area were recorded (Pandiyan et al. 2010). Extreme care was used to locate all waders present within the sampling plots and to minimize multiple counting. During sampling, waders were counted from at least 100 m away to ensure the researcher's presence did not affect wader numbers (de Boer and Longamane 1996). Counting of waders under extreme weather conditions (windy and/or rainy days) was not conducted due to possible adverse effects on wader activity (Conner and Dickson 1980).

4.3.3 Data Analysis

Statistical software, STATISTICA (StatSoft Inc. 2007) was used in this study to analyze all data. In preparation for statistical testing, all data sets were tested with Shapiro Wilke's W test and Anderson's Darling test for normality. In all cases, $\alpha = 0.05$ was used. A Mann-Whitney U test was used to determine the difference between low and high tide counts of waders. A Friedman's Two-Way ANOVA by ranks was used to differentiate the waders' distribution during different stages of the low tide, i.e. 'ebbing', 'low tide peak' and 'rising. Analyses of wader behaviour utilizing the area of sampling (i.e., feeding, preening, roosting or resting, and mobile) were compared between low tide and high tide periods using a Mann-Whitney U test. Chi-Square, χ^2 tests were then conducted for all behaviour engaged in as a function of tidal state (Burger et al. 1996). A Friedman's Two-Way ANOVA by ranks was also used to test the differences between interval periods (low tides and high tides). A Friedman's Two-Way ANOVA by ranks was used because the data were in interval-scales and not normally distributed (Gardner 2008).

4.4 Results

4.4.1 Tidal Effect on Wader's Abundances and Behaviours

Based on the results, this study discovered that the abundance of waders was influenced by the tidal cycle. Mann-Whitney 2 sample *t*-test shows that significant difference occurred between wader abundance during low tide and high tide ($W = 78.0$; $p < 0.005$). The abundance of waders was significantly higher during low tide periods than the high tide period (Figure 4.2). The low tide peak recorded the highest number of waders followed by the rising tide. The wader count was lowest during the ebbing tide. The Friedman's Two-Way ANOVA by ranks supported that a significant difference occurred in wader distribution between ebbing, low tide peak and rising tide ($S = 17.17$, $p < 0.0001$). Further analysis using pairwise comparisons shows that differences occurred between ebbing and low tide peak ($Z = -1.667$, $p < 0.0001$) and between rising and low tide peak ($z = 1.083$, $p = 0.024$). The same results were obtained using a Mann-Whitney U test for the analysis of behaviour during both tidal cycles (i.e., high and low tides); feeding behaviour ($W = 222.0$, $p < 0.0001$), preening behaviour ($W =204.5$, $p = 0.0017$) and mobility behaviour ($W = 222.0$, $p < 0.0001$). Feeding, preening and mobility behaviour were frequently observed during low tide compared to high tide. Unlike other behaviour, roosting or resting behaviour shows no significant difference in both tidal levels ($W =154.0$, $p = 0.8399$). χ^2 test was tested for all behaviour engaged by waders during low tide period and the results show significant difference occurred between the behaviour ($\chi^2 = 1831.9$, $p < 0.0001$). Feeding (50.9%) was the most frequent behaviour encountered during low tide period, followed by mobility (45.4%), roosting or resting (2.1%) and preening (1.6%) (Figure 4.3). However, χ^2 test for analysis of behaviours during the high tide period could not be conducted due to small sample size. Roosting or resting (68.9%) counts the highest percentage of frequently occur behaviour during high tide (Figure 4.3).

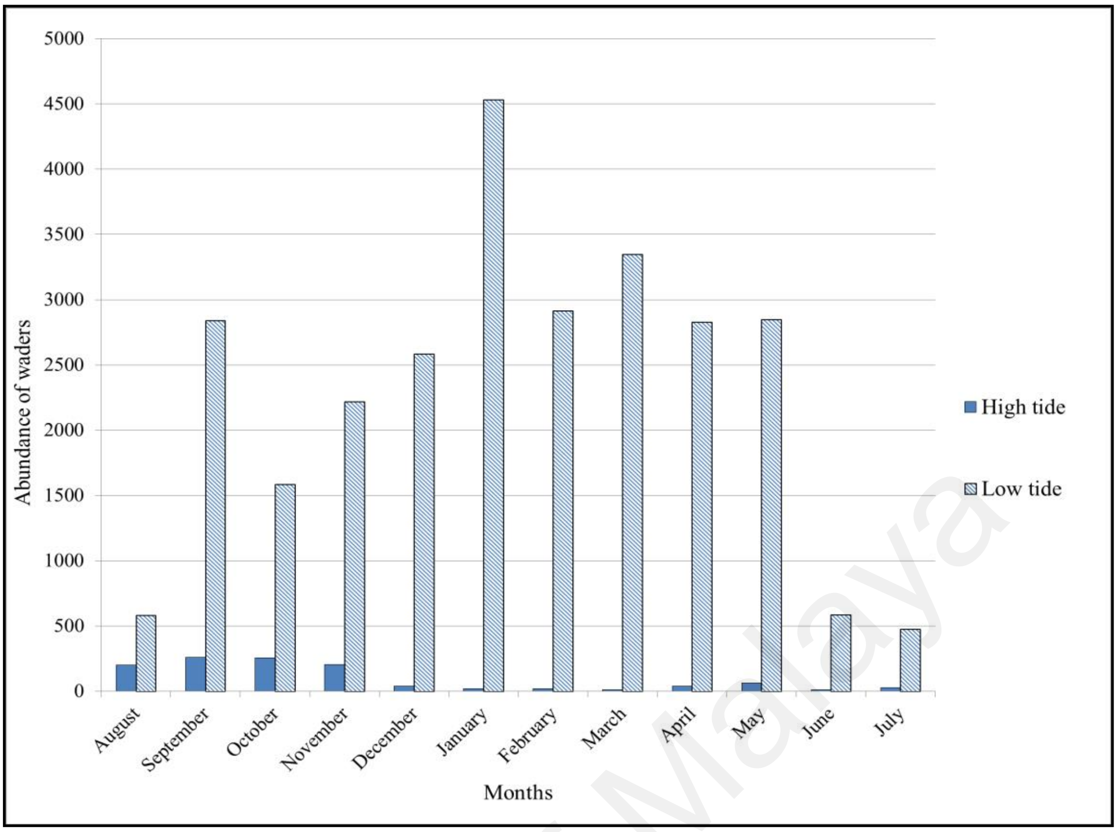


Figure 4.2: The abundance of waders during high and low tides in both beaches.

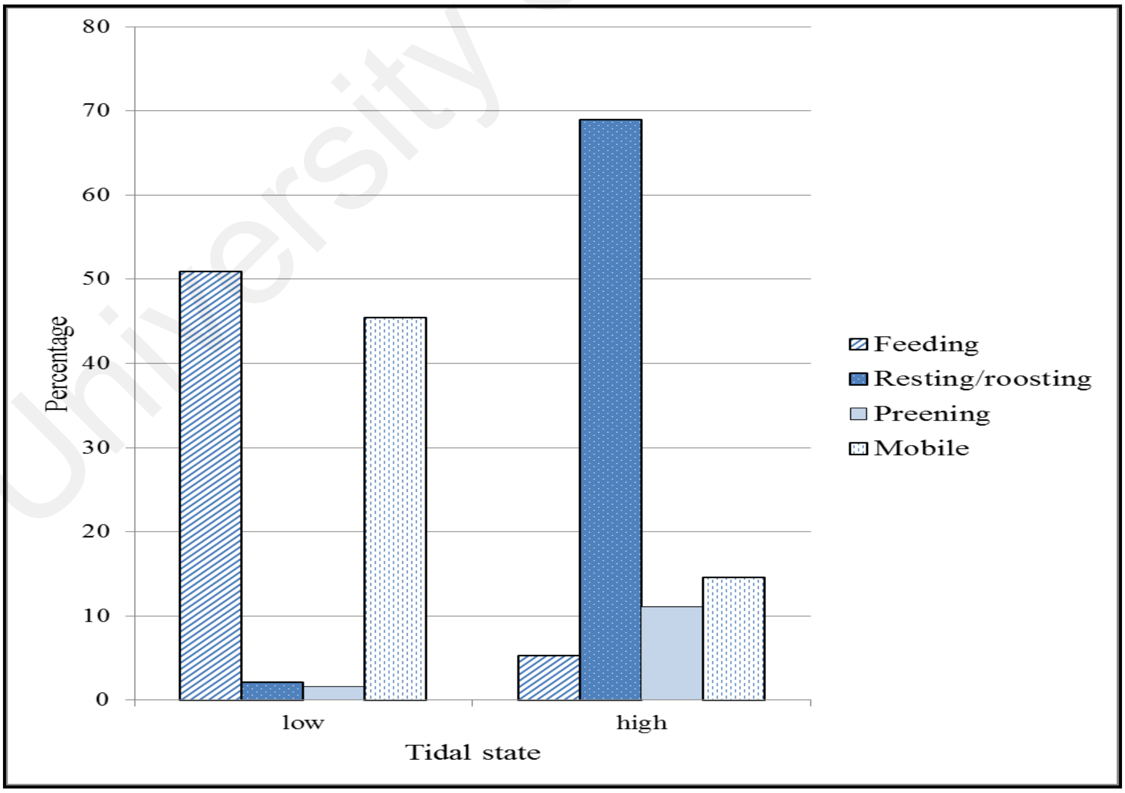


Figure 4.3: Percentage of waders engaged in a variety of behaviours at both study sites.

4.4.2 The Effect of Time of the Day on the Wader's Abundance

Time of the day does not influence the abundance of waders in this study. The analysis of Friedman's Two-Way ANOVA by ranks highlighted no significance difference in abundance of waders in low tide (S = 4.526; p = 0.21) between interval time. Similar results of ANOVA analysis show no significance difference in abundance of waders between interval period (S = 487.0; p = 0.554). In contrast, the Friedman's Two-Way ANOVA by rank test shows a significance difference in abundance of waders in high tide (S = 8.788; p = 0.03) between interval period. Further analysis by using Mann-Whitney 2 samples *t*-test results in a significance difference in abundance of waders in high tide between interval periods of 0800-1000 hours with 1000-1200 hours (W = 185.5; p = 0.043) and 0800-1000 hours with 1400-1600 hours (W = 194; p = 0.01) (Figure 4.4).

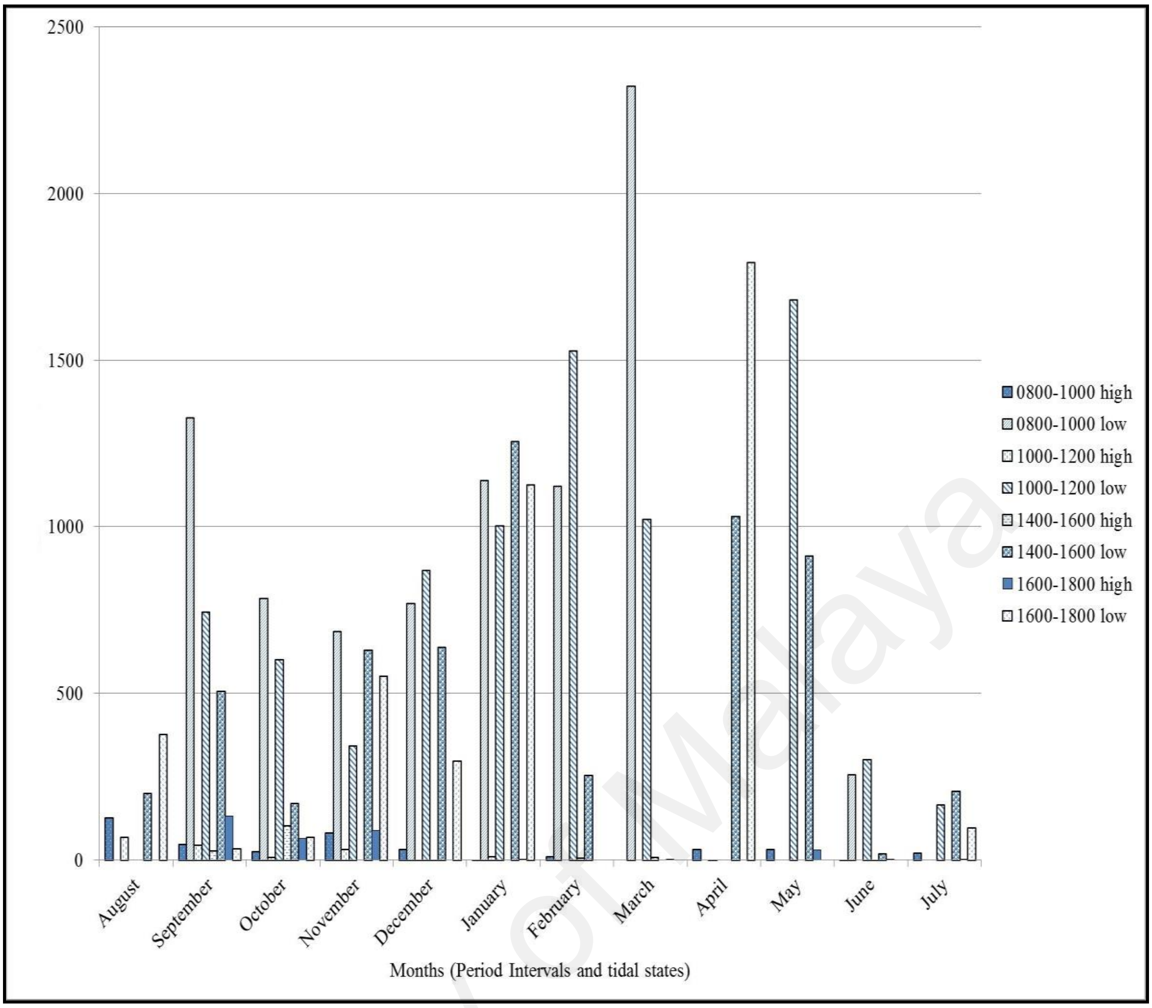


Figure 4.4: The differences in wader's abundances between tidal states within intervals periods.

4.5 Discussion

This study revealed that the use of the intertidal mudflat area by waders was constrained by the tide cycle. The abundance of waders was highest during low tide compared to high tide. In terms of comparison between different stages of low tide, ‘low tide peak’ recorded the maximum number of waders using the mudflats compared to ‘rising tide’ and ‘ebbing tide’. Different wader species tend to use different tide cycles to forage. Larger waders such as Whimbrel (*Numenius phaeopus*) for example was observed to forage during all low tide stages, whereas smaller waders such as Common redshank (*Tringa totanus*) only foraged during ‘low tide peak’. This occurred due to differences in the morphological characteristic of wader species; larger species have longer legs, which enable them to use the mudflat area although it was still covered by water or deeper mud, which has a higher water content. Leg length was positively correlated with the depth of the water in which waders foraged (Baker 1979). The longer the leg, the deeper the mud or water content in which they stood while foraging.

The low tide peak period provide a favourable condition in which waders could feed, as the water level that restricted the wader’s movement, especially those with shorter legs, was completely gone. Generally, waders were uncomfortable in water deeper than their upper thigh and moved to higher ground (Ntiamoa-Baidu et al. 1998). This explained why the number of wader species utilizing the mudflats was highest during low tide. Followed by the low tide peak, the rising tide recorded a higher number of waders. Similar results were shown by Burger et al. (1977), who majority of species on the mudflat reached its peak abundance between 1.5 and 2.5 hours after low tide. The high densities of waders after low tide suggest that the availability of food is the greatest during this period (Burger et al. 1977).

The use of the intertidal area can be best understood as a ‘dynamic exploitation model’ (Van de Kam et al. 1999), in which its use was constantly changed in response to the moving water line. In almost all studies conducted in coastal habitats, waders move to roosting site where they are comparatively inactive at high tide, but feed to varying degrees throughout the subsequent low tide interval. Waders feeding in the intertidal zones are strongly dependent upon tidal movements, constantly changing the area available for foraging and influencing feeding behaviour (Granadeiro et al. 2006). Most species segregate themselves in the intertidal habitat according to preferences for sediment penetrability and water depth, as waders prefer to feed in shallow water or wet substrates (Lane 1987). Furthermore, availability of prey is often determined by the maximum depth at which awader can insert its bill into the substrate and maximum leg length (Dann 1987).

Activity patterns of waders vary diurnally, but mostly in association with the tides (Evans 1979; Colwell 1993). In this study, time of day had no impact on wader abundance during low tide. Similar results were obtained by Burger (1984) which showed that time of day did not significantly affect variability in wader abundance. However, different results were obtained in wader abundance during the high tide period between time intervals. From the analysis, the abundance of waders at high tide differed between morning (0800–1000) and late morning (1000–1200) and between morning (0800–1000) and afternoon (1400–1600). Different temperatures might cause the variation in wader abundance between time intervals. The abundance of roosting waders was higher in the morning since the morning’s temperature was lower than the afternoon’s temperature. When exposed to direct solar radiation, waders were at risk of heat stress, and only used roost sites with wet substrates or shallow water, where counter-current exchange mechanisms could be used to lower body temperature (Battley et al. 2003).

4.6 Conclusion

This study concluded that tide do influenced abundance and behaviour of waders, whereas time of day did not have a significant effect on waders’ abundance or behaviour. Study on wader’s ecology and use of habitat at their important stop-over wintering sites is crucial so that better conservation efforts can be implemented to overcome the current problems of declining wader’s population.

CHAPTER 5: RELATIONSHIPS BETWEEN MORPHOLOGICAL CHARACTERISTICS AND FORAGING BEHAVIOUR OF FOUR SELECTED SPECIES OF WADERS UTILISING TROPICAL MUDFLATS

5.1 Introduction

Migratory wader generally utilised very different habitats, great distances apart, during breeding and non-breeding seasons (Hale 1980; Lane 1987; Piersma 1997; Finn 2010). It is widely suggested that waders should choose to feed in places where they can get the most food in the shortest time (Colwell and Landrum 1993; Barbosa 1996; Finn 2010).

Migratory waders provide an opportunity to study behavioural interactions among species for both prey and foraging space because they often forage in dense flocks, concentrating along relative narrow tide lines (de Boer and Longamane 1996). Feeding behaviour and habitat selection in waders is heavily influences by their morphology, particularly leg length and bill length and shape (Baker 1979). In fact, habitat requirements for different species and guilds of the waders vary in time and space, and this can be detected only by behavioural studies (De Leon and Smith 1999).

This study is aiming to determine the significance relationships between morphological characteristics and foraging behaviour adapted by waders species utilizing the mudflats area of Jeram Beach and Remis Beach, Selangor, Peninsular Malaysia. Four species of waders were chosen in this study. These are Common redshank (*Tringa totanus*), Lesser adjutant (*Leptoptilos javanicus*), Whimbrel (*Numenius phaeopus*) and Little heron *(Butorides striata*). These species were chosen due to differences in term of size and foraging techniques, and also because they can be easily distinguished from one to another.

5.2 Literature Review

Waders are a highly mobile group of animals and have sophisticated site-sampling processes that operate at larger spatial scales than most of the other animals (Quaintenne et al. 2011). Waders refer to the bird species that entirely depend on wetlands for a variety of activities such as foraging, nesting, loafing and moulting (Rajpar and Zakaria 2009) and generally forage during low tide and can be observed on beaches, intertidal mudflats, freshwater and brackish wetlands, farmland and salt marshes (Lane 1987). Waders are important components of estuarine mudflats. The foraging behaviour is broadly defined as the allocation, acquisition and assimilation of food by organism (Aboushiba et al. 2013).

Estuarine mudflats are very important for many wader populations during winter and migration, many species of which feed almost exclusively on intertidal benthic invertebrates at low tide (Erftemeijer and Lewis 1999). Mudflats in estuaries are also vital feeding habitats for resident bird populations (Goss-Custard and Verboven 1993). In tropical regions, the biodiversity of benthic macrofauna on intertidal mudflats is much higher; macrofauna are produced ten times faster here than in temperate intertidal habitats (Ansell et al. 1978; Alongi 1990). During migratory seasons, foraging is the most important activity for waders utilizing the mudflats area, as it allows them to survive and ensures their safe arrival at the breeding ground. The foraging ecology is often characterized by food selection, habitat preference and prey capturing tactics or behaviour employed by wader species in a particular habitat (Danchin et al. 2008; Aboushiba et al. 2013).

The morphology of a wader is considered as an important factor in restricting the range of foraging maneuvers it can perform (Martin and Karr 1990; Soh 2001). Bill length and shape have important implications on foraging behaviour (Pierre 1994;

Zweers and Gerritsen, 1997; Barbosa and Moreno 1999; Nebel et al. 2005), microhabitat selection (Gerritsen and van Heezik, 1985) and choice of diet (Lauro and Nol 1995; Mascitti and Kravetz 2002; Durant et al. 2003; Nebel et al. 2005). Longer bills are associated with probing depth, plunging or sweeping bill movement in the water, while shorter bills were associated with routing and pecking at the substrate surface (Barbosa and Moreno 1999). Baker (1979) shows that foraging depth is correlated with culmen and tarsus lengths. Nebel et al. (2005) found that bill shape (either straight or curve bill) affects foraging technique used by Western sandpipers (*Calidris mauri*). Pecking or feeding on epifaunal invertebrates is associated with a straight bill while probing or feeding on infaunal prey is facilitated by curve bill. In term of foraging strategies, the functional requirement of tactile foraging strategy was high penetration capacity which is influenced by bill morphological characters (Zweers and Gerritsen 1997). The general morphological requirements necessitate that the bill be long and narrow but not very slender, and the penetrating portion should be flattened either vertically or horizontally. Time spent feeding also varies with respect to the size of the wader (Ntimao-Baidu et al. 1998). Larger waders spent less time foraging than smaller waders by eating larger and more profitable prey.

The majority of the studies on the foraging behaviour of waders were conducted in temperate climate areas. The feeding ecology of wader species in tropical countries, especially Malaysia, is poorly understood. Previous studies by Lomoljo (2011) focused on the correlation between wader density and prey density whereas Riak (2004) focused on waders' habitat utilization. To date, no detailed information has been obtained on the correlation between wader's morphological characteristics and their feeding ecology in Malaysia.

5.3 Methodology

5.3.1 Study Area

The Jeram and Remis Beaches are located on the Selangor Coast on the West Coast of Peninsular Malaysia (3^{o}13'27"N, 101^{o}18'13"E) (Figure 4.1) where semidiurnal tides prevail. In Jeram Beach, the mudflat was fringed by a mangrove stand of stunted *Avicennia alba* Blume and few scattered *Sonneratia* sp. (Polgar 2012). The distance between Jeram Beach and Remis Beach is approximately 2 km. The selected study areas comprise approximately 55 ha of intertidal mudflats, i.e. 27 ha in Jeram Beach and 28 ha in Remis Beach. The selection of these sites was based on past wader counts reported by Wetland Internationals from 1999–2004 (Li and Ounsted, 2007), which shows that these areas were previously known to be important stopover sites for waders. Three plots were constructed in Jeram Beach while two plots were setup in Remis Beach. The plots were further divided into three zones (Figure 3.2(a) and Figure 3.2 (b)).

5.3.2 Foraging Behaviour

The foraging behaviour of four selected wader species was studied from August 2013 to July 2014 using direct observation technique. Selected focal waders were observed using binoculars (12 X 42 magnifications), stopwatches and video recorders. The selected focal wader must be actively foraging (each individual was observed until they were done foraging, i.e. starting from the wader began actively searching for prey until the prey was completely swallowed); if the wader left within 30 seconds, it was discarded from the analysis (Burger et al. 2007). Data recorded from different sites and months were pooled to increase replications (Green et al. 2014). The observations were conducted during low tide period only (i.e. during ebbing tide, low tide peak and rising tide). This was done to reduce the bias of only larger waders can forage during high tide since they have longer legs. The observations were conducted within four interval periods (i.e. 0800-1000 hours, 1000-1200 hours, 1400-1600 hours and 1600-1800 hours). Since the sites were situated close to each other (i.e., 2 km apart), the habitat characteristics is not too different. To start the observation, a focal wader was selected from a flock. Once a wader was chosen, the next wader selected for observation must be located at least 10 meters away from the previously observed wader. This was done to avoid multiple observations of the same individual. Four species of waders were chosen for this study. These are Lesser adjutant (*Leptoptilos javanicus*), Common redshank (*Tringa totanus*), Little heron (*Butorides striata*) and Whimbrel (*Numenius phaeopus*). These species were chosen due to differences in term of size and foraging techniques, and also because they can be easily distinguished from one to another. The following data were collected:

a) Pecks or probes/min – were used to calculate feeding rate and percentage of successful attempts by bird species. Feeding rate is the total number of feeding attempts (pecks or probes) made by bird per minute (Kober 2004). Meanwhile, the percentage of successful attempts was calculated by dividing the number of feeding attempts that resulted in prey consumptions per minute by the total number of feeding attempts made per minute and then multiplying by 100 (Kober 2004). The summarized formula as follows:

$$\text{Percentage of successful attempts (\%)} = \frac{\text{Number of successful strike (pecks or probes)}}{\text{Total number of pecks or probes}} \times 100\%$$

b) Prey items/min – was used to determine the success rate. Success rate is the number of prey items consumed per bird per minute.

c) Prey type – was classified into Fish, Bivalve, Worm, Crab and Unknown (can be aquatic insects or invertebrate fauna). Prey will be classified as unknown when it cannot be clearly seen.

d) Prey size – the size of the prey were estimated based on percentage of the prey size with respect to the bill length of the wader species (the information was obtained from the literature). The formula is as follow:

$$\text{Prey size (mm)} = \frac{\text{Percentage of estimated prey in bill}}{100\%} \quad \text{X} \quad \text{bill size}$$

e) Searching time – starting from the wader was actively scan for the prey until the prey was first captured, estimated in seconds (Kober 2004).

f) Handling time – time from the picking up of the prey item until it was swallowed entirely, estimated in seconds (Kober 2004).

g) Time spent for foraging – were calculated by sum of the total searching and handling time (Kober 2004).

h) Microhabitat – the sampling plots were divided into three zones based on the water content in each zone, i.e. zone 1 (0 m until 250 m; usually dry sand or moist or shallow mud); zone 2 (251 m – 500 m; wet or deep mud); (3) zone 3 (501 m until water edges; shallow or deep water).

i) Probing depth – the probing depth was estimated based on the maximum percentage of bill length inserted into the mud or water. The formula is as follow:

$$\text{Probing depth (mm)} = \frac{\text{Percentage of estimated bill inserted into the mud or water}}{100\%} \quad \text{X} \quad \text{bill size}$$

j) Water or mud depth – Water or mud depth was estimated based on maximum percentage (%) of the leg disappeared in the water or mud. The length of the leg of selected waders was estimated by doubling the length of tarsus (the information was retrieved from the literature). The formula is as follow:

$$\text{Water/ mud depth (mm)} = \frac{\text{Percentage of estimated leg immersed in the water or mud}}{100\%} \times \text{leg length}$$

k) Flocking behaviour – wader was classified as solitary when foraging alone or quite far from other birds; but was classified as flocking bird when foraging in a group or flock either in intraspecific flock or interspecific flock. Their behavior such as aggression, competition, territorial and cooperation were then recorded by using a video recorder.

l) Foraging techniques – Foraging techniques engaged by wader was divided into three techniques i.e. (1) Tactile hunting technique : forage as they walk, probing continuously with the bill into the substrate (Baker and Baker 1973; Gerritsen and Sevenster 1985); (2) Visual-feeding technique: forage in a continuous fashion; pecking at items seen on the substrate surface (Anderson 1981) and; (3) Pause-travel technique: forage by scanning the area in front of them and pecking at the substrate surface when prey is detected in a stop-run-stop fashion (Metcalfe 1985; Pienkowski 1983).

Table 5.1: Measurements of bill size and tarsus length based on previous studies.

Species	Source	Bill length (mm)	Average bill length (mm)	Tarsus length (mm)	Average tarsus length (mm)
Lesser adjutant	Murray (1890)	266.7	266.7	228.6	228.6
Common redshank	Hale et al. (2005)	43.7	42.8	51.6	49.6
	Thompson et al. (1990)	41.8		47.6	
Little heron	Wells (1999)	75.0	75.0	49.0	49.0
Whimbrel	Poole and Gill (2000)	87.2	84.6	55.9	59.9
	Morozov (2000)	82.0		63.8	

5.3.3 Data Analysis

Statistical software, STATISTICA (StatSoft Inc., 2007) was used to analyze all data. In preparation for statistical testing, all data-sets were tested with Shapiro Wilke's W test and Anderson's Darling test for normality. In all cases, $\alpha = 0.05$ was used. A total of 205 focal observations were recorded for Common redshank, 75 observations for Lesser adjutant, 53 observations for Little heron, and 38 observations for Whimbrel (Table 5.2). Due to differences in number of focal observations recorded, all recorded data were divided into 12 months (i.e. from August 2013 until July 2014) to obtain the average or mean of each data. A Spearman Rank Correlation Analysis was used to determine the correlation between the bill size of the wader and the time spent for foraging (Kober 2004); the bill size of the wader and the estimated prey size; the bill size of the wader and probing depth; and the leg length of the wader and water or mud depth. The non-parametric Kruskal-Wallis Test was used to study the relationships between wader species and probing depth (mm). In addition, a one-way ANOVA was used to determine the differences in time spent for foraging and different foraging techniques. All requisites of data reliability were followed (Battisti et al. 2014). The statistical test used was based on McCrum-Gardner (2008).

Table 5.2: Summary of frequency of wader species observed (n) from August 2013 until July 2014

Months	Species (n)			
	Lesser adjutant	Common redshank	Little heron	Whimbrel
August	6	4	8	4
September	10	20	2	3
October	11	42	2	2
November	3	23	4	2
December	7	33	7	4
January	9	19	5	4
February	5	17	3	4
March	5	17	5	3
April	5	11	5	3
May	6	10	5	3
June	4	5	4	3
July	4	4	3	3
Total	75	205	53	38

5.4 Results

a) Feeding rate and percentage of successful attempts

The feeding rates are different between species. Kruskal-Wallis Analysis test shows that there is significant difference in feeding rates values obtained between species (H = 139.58, p < 0.001) (Figure 5.1). Furthermore, pairwise comparisons analysis supported the previous statement by proving that the differences occurred between species i.e., Little heron and Lesser adjutant (z = 107.39, p < 0.001); Little heron and Whimbrel (z = -159.31, p < 0.001); Little heron and Common redshank (z = 187.7, p < 0.001); and Lesser adjutant and Common redshank (z = 80.3, p < 0.001). Table 5.3 summarized the obtained values.

Table 5.3: Summarized of obtained values for feeding rate and percent of successful attempts between species.

Species	Feeding rate			Percent attempts successful (%)
	n	mean	SE	
Little heron	53	1.396	0.197	73
Common redshank	210	14.881	0.768	7.3
Lesser adjutant	76	7.99	1.06	13
Whimbrel	34	11.21	1.36	8.9

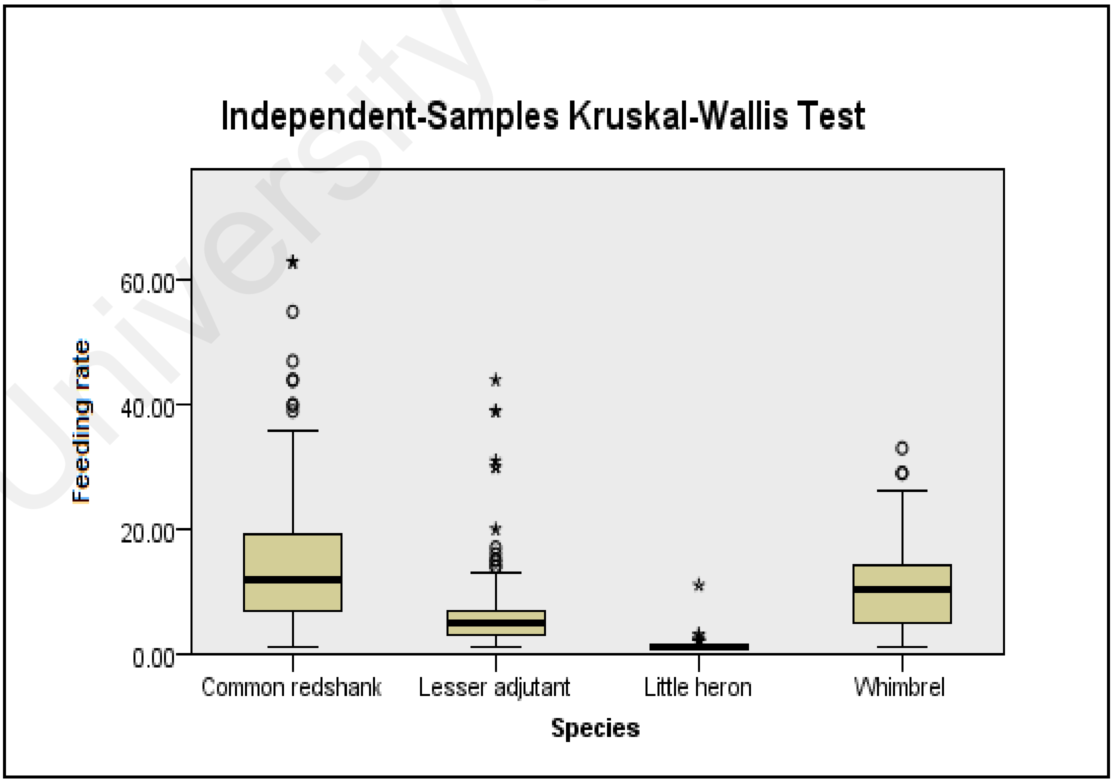


Figure 5.1: Feeding rate of four selected wader species.

b) Success rate

The success rates were different between species (Table 5.4). Non-parametric Kruskal-Wallis Analysis test support that there is significant differences in success rates between the species (H = 11.18, p = 0.011). The test differences were further analyzed by using Mann-Whitney test which shows that the differences lied between Little heron and Common redshank (W = 5743, p = 0.0114) and also between Lesser adjutant and Common redshank (W = 9353, p = 0.012). Spearman correlation analysis was then conducted to test the relationship between feeding rates and success rates. A significant correlation were found between both feeding and success rates (R = -0.293, p < 0.001).

Table 5.4: The summarized value of number of prey taken, average minutes and success foraging rates between species

Species	No. of prey taken	Average minutes	Success rate
Little heron	54	36.95	1.46
Common redshank	227	111.95	2.03
Lesser adjutant	79	51.16	1.54
Whimbrel	34	17.46	1.95

c) Prey type

In terms of diet choice, five prey items were observed as a main diet choice for waders which are Fish, Bivalve, Worm, Crab and Unknown (Table 5.5). Based on observation, Bivalve is the most preferred diet choice among wader species which counts a total of 34% followed by Fish (29%), Unknown (18%), Crab (12%) and Worm (7%

Table 5.5: Diet choice and their abundance choose by wader species.

Species	Prey type	No. of prey counted
Little heron	Fish	35
	Bivalve	0
	Worm	0
	Crab	0
	Unknown	17
Lesser adjutant	Fish	51
	Bivalve	7
	Worm	2
	Crab	2
	Unknown	15
Whimbrel	Fish	8
	Bivalve	17
	Worm	1
	Crab	7
	Unknown	0
Common redshank	Fish	13
	Bivalve	102
	Worm	25
	Crab	34
	Unknown	35

d) Prey size

Prey size was strongly influenced by the bill size or bill length of a particular species. Analysis of Spearman Rank Correlation shows a significant relationship between bill size and the estimated prey size obtained while foraging (R = 0.891, $p < 0.05$). Bill size influenced the choice of prey size by which the longer the bill, the larger the prey items choose by the wader. During field surveys, Lesser adjutant which have the longest bill tend to choose fish as their main diet whereas Common redshank which have the shortest bill was observed to consumed bivalve.

e) Searching time

Friedman's Two-Way Analysis of Variance by Ranks Test indicated that no significant difference for searching time of preys between species (F = 4.92, $p = 0.178$).

f) Handling time

The handling time were significantly different between wader species (F = 19.49, $p < 0.05$). Further analysis by using Pairwise Comparisons Test highlighted that the differences between Lesser adjutant and Whimbrel (z = -1.7, p = 0.019) and also between Common redshank and Little heron (z = 1.6, p = 0.034).

g) Time spent for foraging

The differences in handling time were found to influence the total time spent for foraging between waders species (F = 13.3, p = 0.004). Pairwise Comparisons Test suggested that the significant difference occurred between Little heron and Lesser adjutant (z = -1.667, $p = 0.009$) and between Lesser adjutant and Common redshank (z = 1.583, $p = 0.016$). A Spearman Rank Correlation shows a significant relationship between bill size and time spent for foraging (R = 0.443, p < 0.05) (Figure 5.2; Table 5.5). Based on observation, wader with longer bill spent more time foraging compared to wader with shorter bill. Wader with longer bill tends to choose prey with greater size compared to wader with shorter bill. Thus, more time is needed to fully handle and swallowed the larger prey items.

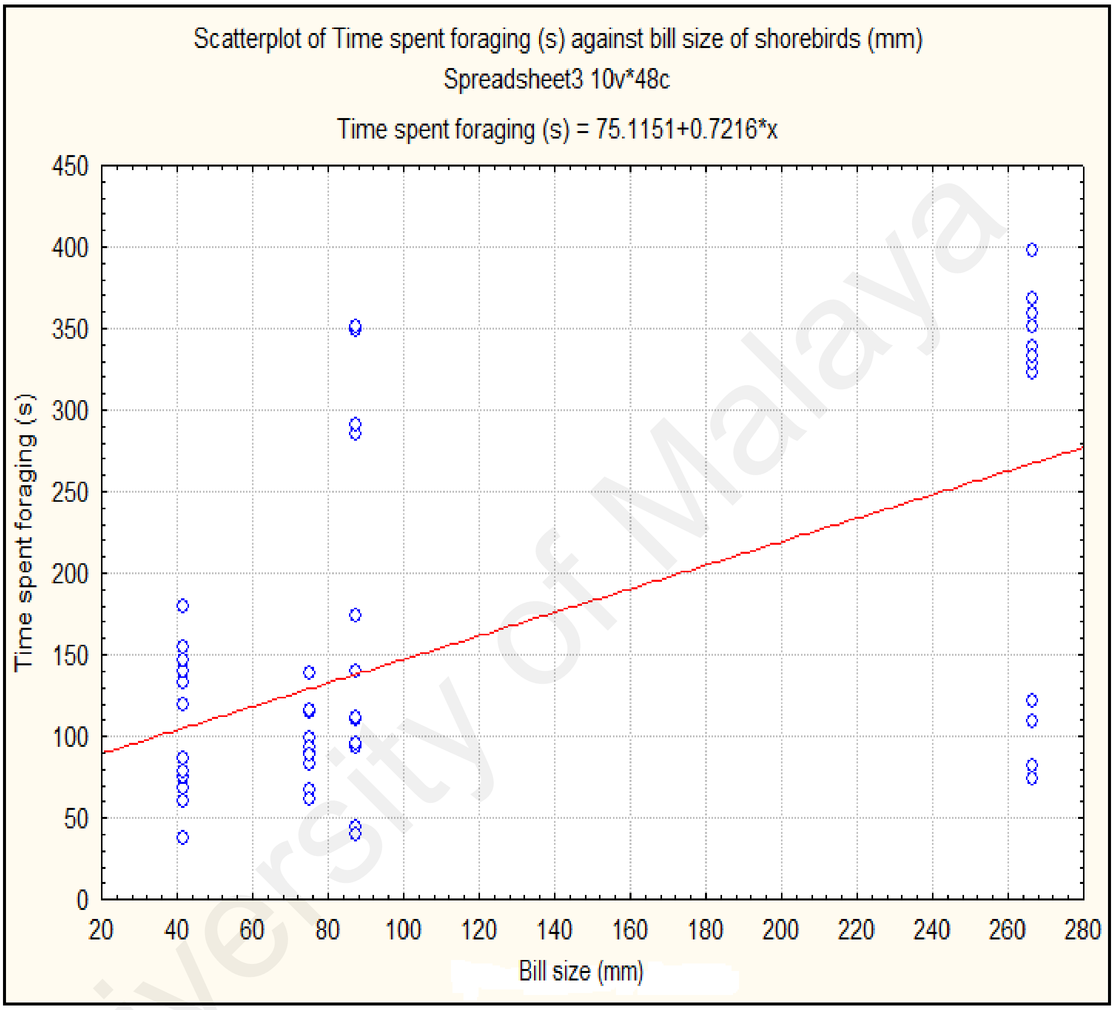


Figure 5.2: Positive correlation between bill size and time spent for foraging by waders.

h) Microhabitat

All wader species were observed using all zones for foraging during study periods. However, the preference of particular zones was varied among species. Common redshank shows higher percentage of using zone 1 (72.2%) while Little heron also choose zone 1 the most (14.4%). In contrast, Whimbrel used zone 2 the most while foraging (21.3%) and Lesser adjutant used zone 3 as their most frequently used foraging sites (40%) (Figure 5.3).

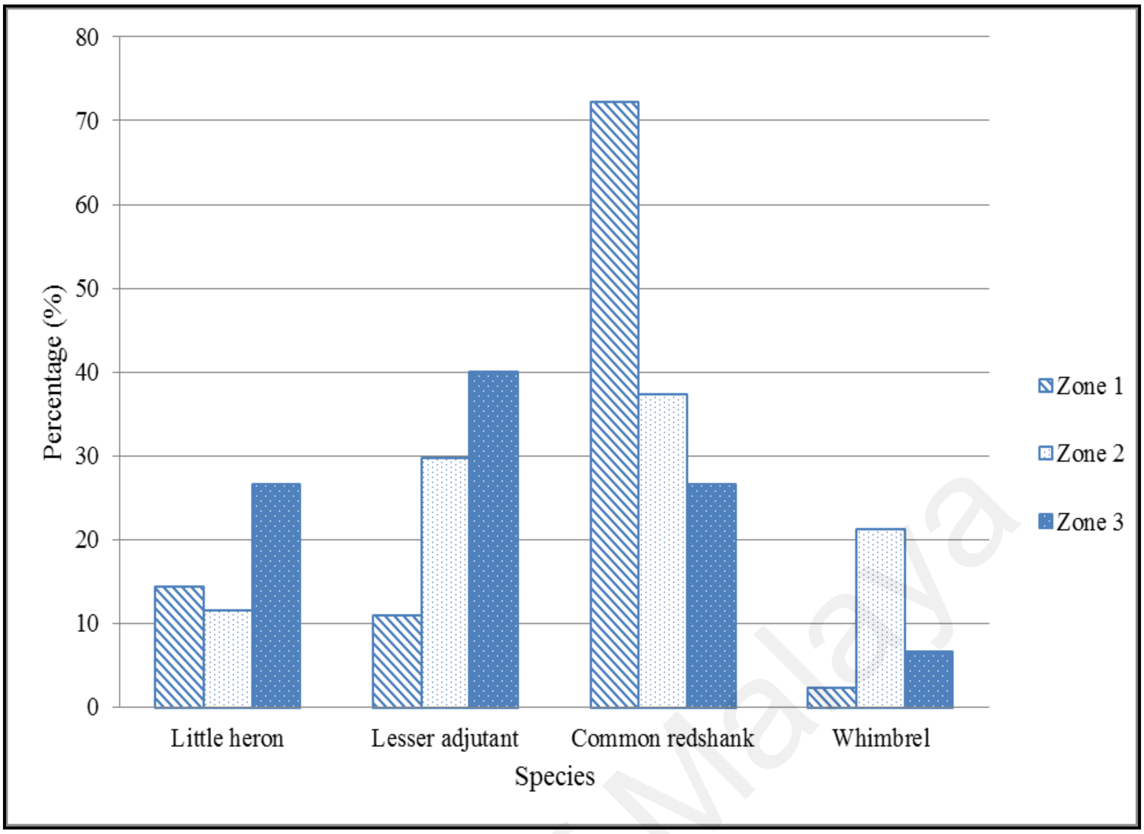


Figure 5.3: Percentage of habitat use by wader species

i) Probing depth

Probing depth was also varied depending on various bill sizes of wader species. This can be proved by the analysis conducted by using a Spearman Rank Correlation, which shows a significant relationship between bill sizes and probing depth while foraging ($R = 0.42$, $p = 0.003$). It is also found that probing depth was varied between species. Kruskal-Wallis Analysis test shows a significant difference between average estimates of real probing depth of the waders (mm) and species ($H = 15.96$, $p = 0.0012$). Bonferroni's post-hoc test with correction $\alpha = 0.05$ is further calculated and the results shows that the significant difference exist only between Little heron and Lesser adjutant ($z = 3.97$, $p = 0.001$). Besides, it is also found that wader with shorter bill tend to probe deeper than wader with longer bills. Usually, Common redshank inserted most of its bill into the mud while foraging whereas Lesser adjutant, Little heron and Whimbrel only inserted part of their bills while foraging (Table 5.5).

j) Water or mud depth

The water or the mud depth where the wader stood while foraging was also influenced by the length of waderlegs. A Spearman Rank Correlation shows a significant relationship between the length of waders legs and water or mud depth ($R = 0.706$, $p < 0.005$; Table 5.6). Preference of deeper water or mud depth while foraging increases with respect to leg length of the wader species. This study revealed that Lesser adjutant tend to forage in deeper mud area and near to the water edges.

k) Flocking behaviour

The flocking behaviour was common in smaller size wader such as Common redshank. During observation periods, common redshank were never been observed foraged individually. This species were usually formed a group while foraging either in intraspecies flocks or interspecies flock. Interspecific flocks were often formed with Common redshanks, Lesser sand plover and Greater sand plover. Whimbrel was sometimes observed foraged near these flocks. Whimbrel also found to forage alone sometimes. On contrary, Little heron was observed foraged almost exclusively alone. Meanwhile, Lesser adjutant practiced both strategies; either foraged alone or in the group. Interactions such as aggression, competition, cooperation and territorialism were formed by waders foraged in the flocks. During the study period, smaller size waders were observed forming groups or flocks while foraging whereas larger size wader did otherwise. Common redshank was the most dominant interspecies flock observed. Although mixed flocks were formed, the aggressive behaviour tends to occur among similar species rather than mixed species. For example, during surveys, Common redshank was observed being aggressive to each other while fighting for the same food resources.

l) Foraging technique

Table 5.7 shows foraging techniques practiced by waders species. Little heron only practiced pause-travel techniques, while Lesser adjutant and Common redshank used all techniques while foraging**.** However, the most preferred feeding technique used by Lesser adjutant and Common redshank was the tactile-hunting feeding technique**.** In contrast, the Whimbrel engaged in both tactile-hunting and visual-feeding techniques, but not pause-travel technique. No significant differences were found between time spent foraging and different feeding techniques (F = 0.26, *p* = 0.778).

Table 5.6: Summary of bill size, average estimated probing depth, length of leg, average estimated water/mud depth per year and average time spent foraging by waders

Species	Bill size (mm)	Estimated probing/ foraging depth (mm)	Length of the leg (mm)	Estimated water/mud depth (mm)	Time spent foraging (s)
Little heron	75	24	98	27	1,130
Lesser adjutant	266.7	82	457.2	134	3,186
Whimbrel	84.6	41	119.8	22	2,085
Common redshank	42.8	33	99.2	38	1,280

Table 5.7: Sample size (n), mean and standard error of time spent foraging and foraging techniques used by species

Species	Foraging techniques	Time spent foraging (s)		
		n	mean	Standard error
Little heron	Pause-travel	53	68.62	5.69
	Tactile-hunting	0	0.00	0.00
	Visual feeding	0	0.00	0.00
Lesser adjutant	Pause-travel	17	134.65	18.50
	Tactile-hunting	56	77.34	8.13
	Visual feeding	2	24.00	4.00
Whimbrel	Pause-travel	0	0.00	0.00
	Tactile-hunting	33	36.70	2.03
	Visual feeding	5	120.00	0.00
Common redshank	Pause-travel	2	50.00	0.00
	Tactile-hunting	171	46.09	2.58
	Visual feeding	32	39.53	2.54

5.5 Discussions

Food is importance for survival of migratory waders where energy expenditure is extremely high (Kersten and Piersma 1987). The foraging success is of crucial importance for them in terms of maintaining the healthy body condition and in fuelling-up before long-distance migration and breeding (Evans and Dugan 1984; Battley et al. 2003; Battley et al. 2004; Finn 2010). The success rate combines the feeding rate and the percent of feeding attempts that are successful (Finn 2010). In this study, the feeding rate and success rate were differed between the species. The feeding rate of Little heron was the lowest compared to the other species because the total number of feeding attempts (which are pecks or probes) was lower in this species. This happened because Little heron was observed to practise Pause-travel technique that required more time of searching or scanning for the prey items before captured it. Therefore, less feeding attempts were made by this species which in turns lead to the lower feeding rate. Moreover, the success rate was also differed between species. Common redshank recorded the highest success rate compared to the other species because of the number of prey taken per minute was the highest in this species. Common redshank consumed smaller prey items compared to Lesser adjutant and Little heron. Smaller prey items required less time to be consumed and also less profitable compared to larger prey items. Therefore, more prey need to be consumed in less time in order to fulfil the energy required by the wader species. In addition, a significant weak negative correlation was found between feeding and success rates. Finn (2010) recorded similar result. He found that the high feeding rate offer a low success rate and vice versa. Success rate alone can be a poor indicator for intake rate, especially when comparing different habitats and prey types (Goss-Custard 1970, Kalejta and Hockey 1994, Durell et al. 1996; Barbosa 1997; Finn 2010). This is because waders may capture and consume items at a higher rate when preys are small than when they are large (due to greater handling time of larger prey) and larger prey had a greater biomass value. Intake rates have the potential to be much higher when waders consume large prey, even though the feeding rate may be lower (Goss-Custard 1970).

Moermond (1990), suggested that any subtle differences in wader's morphological traits, such as length of the wing, tarsus and toes could result in different foraging maneuvers. This study shows that differences in bill size and leg length in wader species influenced time spent for foraging, size of captured prey, probing depth, and habitat preferences while foraging. The longer the bill, the more time was spent during foraging, the larger the prey and the deeper the area they preferred to forage. Based on observation, Lesser adjutant and Little heron have longer bills and their diets mainly comprised of larger prey items such as fish. Larger prey required longer swallowing and digesting times, allowing waders to spend more time foraging. Increasing the time spent for handling the prey resulted in an increase in the time spent foraging. On the contrary, waders with shorter bills (the Common redshank) were observed to feed on bivalves more frequently. Smaller prey reduced handling time and, thus, reduced time spent foraging. Similar results have been reported by Durell (2000), which show that waders with longer bills generally feeds on larger prey than waders with shorter bills. Probing depth was hypothesized to increase as the length of the wader's bill increased. Waders with longer bills (Lesser adjutants) were observed to probe in deeper mud and higher water as compared to other species. A study of the differences in bill sizes of male and female Western Sandpipers (*Calidris mauri*) which shows that females, who have longer bills, foraged in sites with a higher water content than males did, where the probing technique may be more effective (Gerritsen and Van Heezik 1985; Fernandez and Lank 2008). Although waders with longer bills probed deeper than shorter billed waders, the percentage of which the bill inserted into the mud or water while foraging was differed. Shorter billed waders tended to insert the majority or all of their bills into the mud or water while foraging. Usually, the Common redshank inserted the majority of its bill into the mud while foraging, whereas Lesser adjutant, Whimbrel and Little heron only inserted part of their bills while foraging. Deeper probing resulted in a more profitable prey item. The size of the prey increased with respect to burrowing depth. A previous study found that larger worm species (*Nereis diversicolor*), which is longer than 10 cm, was usually found at a depth of 10 to 14 cm (Esselink and Zwarts 1989).

The conservation of declining waders depends on developing an adequate understanding of what types of intertidal environment are utilized by the waders on their feeding grounds (Watkins 1993). Species differ in response to periodical changes in mudflat's availability. Some concentrate their feeding effort near the tidal line, whereas others tend to arrive to their foraging grounds well after the tidal passage (Burger et al. 1977). Relationships between morphology and foraging ecology are well known in waders (Carrascal et al. 1990). Baker (1979) showed that leg length was positively correlated with the depth of water in which waders foraged. The longer the leg, the deeper the mud or water depth in which the waders stood while foraging. This study revealed that the Lesser adjutant tended to forage in deeper mud and areas close to the water's edge. Meanwhile, the Common redshank was commonly found utilizing the area closest to the beach, which was shallower and drier. Previous study by Isola et al., (2000), shows that waders with shorter legs and tarsi such as Least Sandpiper *(Calidris minutilla*), (Western Sandpiper (*Calidris mauri*), Dowitcher (*Limnodromus* spp.) and Dunlin (*Calidris alpina*) were constrained to use mudflats or shallow water zones along the wetland's edge. Heterogeneity in the physical characteristics of foraging areas can also influence foraging behaviour. Increased water content makes substrates easier to penetrate and increases invertebrate activity, rendering prey more susceptible to water predation (Mouritsen and Jensen 1992; Colwell and Landrum 1993). Conversely, standing water can decrease available foraging area if it is too deep in relation to tarsus length for waders to use (Boettcher et al. 1995; Fernández and Lank 2008). The data provided by Weber and Haig (1996), also revealed that an increase in the range of depths used by larger wader species, which wade in deeper habitats. Foraging close to the water edge might be advantageous because of increase penetrability and increase of prey activity (Colwell and Landrum 1993). Therefore, drier substrates and more structurally complex microhabitats may be favored by waders with shorter bills (Whitfield 1990; Zharikov and Skilleter 2002).

It is well established that waders benefit from feeding in flocks. Foraging birds often forms groups to reduce predation risk while foraging by decreasing the costs of vigilance (Hamilton 1971; Bednekoff and Lima 1998; Burger et al. 2007). As group size increases, scanning rates or vigilance decreases (Roberts 1996). However, some species form groups because of resource location in which they forage together because the food is clumped or prey densities are higher in some places than others (Burger et al. 2007). When a large group of waders forages in the same place, competition can result, either for the prey itself or for access to the prey (Stillman et al. 2000). Competition occurs when feeding rate is negatively related to competitor density and when the presence of an individual impedes the access of another individual to a resource (Cresswell et al. 2001). Aggression should occur only when individuals can increase their share of resources that are concentrated by being aggressive (Beauchamp 1998). Increasing spatial clumping of resources, such as prey, can lead to increase competition (Schmidt et al. 1998).

This study shows a significant difference between average estimates of probing depth and species. The differences in probing depth exist only between Little herons and Lesser adjutants. This may be due to differences in their bill sizes. Lesser adjutants have longer bills than Little herons. Waders with longer bills will benefit by probing deeper into the mud. The differences in habitat use exist in sandpipers due to variations in bill length (Harrington 1982), i.e. longer billed individuals foraged in muddier habitats than shorter billed individuals.

In addition, certain aspect of bill morphology and micro-anatomy are known to be adapted to specific modes of foraging. The foraging technique engaged in while foraging also differed between species. Tactile hunting was the most dominant technique used by the Lesser adjutant, Whimbrel and Common redshank, whereas the pause-travel technique was the only technique used by the Little heron. The different types of feeding techniques are likely to influence the vigilance patterns of wader species. Pause-travel species can be more vigilant with their heads up, scanning the environment; when they locate a prey item, they run to catch it (Barbosa 1997). It is assume that tactile-hunting technique increase the chances of successful foraging, since much of the wader’s time is concentrated on searching for food, compared to pause-travel technique, in which the wader spends much of its time being more vigilant than foraging. Moreover, shorter billed waders were restricted to a certain mud depth or water level compared to the longer billed wader. Therefore, tactile-hunting technique was observed to be the most profitable, since the wader using this technique will probe as deep as possible to obtain more profitable prey, which burrow deep into the mud. This study suggests that time spent foraging did not differ between foraging technique. However, different results have been shown by Pienkowski (1983), where Plovers, which exhibit visual foraging technique, spend less time feeding than Sandpipers, which exhibit tactile or continuous hunting technique. Furthermore, the pause-travel species was frequently observed foraging alone, whereas tactile and visual feeding species usually foraged in a flock. Foraging in groups is beneficial because it reduces the risk of predation and, thus, reduces the cost of vigilance (Burger et al. 2007).

5.6 Conclusion

For conclusion, the morphologies of waders play an important role in determining foraging behaviours. Species with different foraging strategies will acquire better food resources from different habitats and may be able to avoid interspecies competition. Thus, sufficient energy and nutrients can be replenished to enhance the survival of wader species in the area.

CHAPTER 6: EFFECTS OF DISTURBANCE ON THE ABUNDANCE AND FORAGING BEHAVIOUR OF WADERS IN THE TROPICAL MUDFLAT AREAS

6.1 Introduction

Waders occupy habitats that are highly valued by humans for commercial, recreational, and agricultural purposes. Consequently, human activity has the potential to negatively influence the behaviour, local distribution and abundance, productivity, and survival as well as population dynamics of waders in variety of habitats (Colwell 2010).

Disturbance can be defined as 'any situation in which a bird behaves differently from its preferred behaviour' (Boere 1975) or 'any situation in which human activities cause a bird to behave differently from the behaviour it would exhibit without the presence of that activity' (Oranjewoud 1982).

Most studies on the effects of disturbance on waders were conducted in temperate areas while ecological investigations on waders in tropical environments are scarce (Kober 2004). To date, no detailed study was conducted to determine the factors affecting the distribution of the wader species in Malaysia.

Therefore, this study aim to investigate how disturbances caused by humans, vehicles and dogs are affecting the abundance and feeding behaviour of waders species utilizing the coastal mudflats area of Jeram and Remis Beaches in Selangor, Peninsular Malaysia.

6.2 Literature Review

Increasing levels of human disturbances in estuaries are exerting pressures on wader populations (Hill et al. 1997). On their roosting and foraging grounds, waders are experiencing high disturbance rates from fisherman, watercrafts, walkers, dogs (Burger & Gochfeld 1991; Fitzpatrick & Bouchez 1998; Paton et al. 2000; Blumstein et al. 2003) and coastal development activities (Burton et al. 2002; Durell et al. 2005). Waders often respond to the presence of recreational activities in their environment by deviations from their predominant behavior (Platteeuw & Henkens 1997). Human-induced disturbance at high tide roost sites (Burton et al. 1996) and low tide feeding sites (Burger 1981; Thomas et al. 2003) can also results in higher energy expenditure and a reduction in food intake for birds at their non-breeding or staging sites (Stillman & Goss-Custard 2002; Coleman et al. 2003), which can impinge on their ability to build fat reserves to fulfil their annual cycle of moult, migration and breeding (Spencer 2010). In coastal wetlands, the loss and degradation of roosting habitat can directly impact wader populations, as roosting takes up to 50% of their daily activity (Burton et al. 1996). Waders that remain in areas with high disturbance may spend less time roosting and more time being vigilant or active (Barbee 1994; Morton 1996). Previous study recorded that the scanning rate of wader increases with respect to disturbance, implying a greater proportion of time spent in vigilance (Fitzpatrick & Bouchez 1998). Burger et al. (2004) found that wader foraging is disrupted by the presence of people and dogs. Furthermore, Burger and Gochfeld (1998) found that many species of waders decreased their foraging time and increased their vigilance when people were nearby.

Most studies on the effects of disturbance on waders were conducted in temperate areas while ecological investigations on waders in tropical environments are scarce (Kober 2004). To date, no detailed study was conducted to determine the factors affecting the distribution of the wader species in Malaysia.

6.3 Methodology

6.3.1 Study Areas

Jeram and Remis Beaches are located in West Coast of Peninsular Malaysia (3^{o} 13’ 27” N, 101^{o}18’13”E) (Figure 4.1). The distance between Jeram Beach and Remis Beach is approximately 2 km. The selected study areas comprise approximately 55 ha of the intertidal mudflats area. The selection of these sites was based on past history of waders counts reported by Wetland Internationals in 1999-2004 (Li & Ounsted 2007) which shows that these sites were known as important stopover site for waders. In Jeram Beach, the mudflat was fringed by a mangrove stand of stunted *Avicennia alba* Blume and few scattered *Sonneratia* sp. (Polgar 2012). The study areas were further divided into small plots. In Jeram Beach, three plots were setup in which the size of each plot is approximately 900 m length and 100 m width. The total sampling area in Jeram Beach is 27 hectares. However, only two plots were established in Remis Beach due to high intensity of human activities. The size of each plot is approximately 700 m length and 200 m width. A total sampling area in Remis Beach is 28 hectares.

6.3.2 Wader Counts

This study was conducted from November 2013 until July 2014. Monthly observations were conducted to count wader individuals in both study areas for ten consecutive days by direct observation technique using a binocular (12 x 42 magnifications) and a video recorder (Nagarajan & Thiyagesan 1996). The count was divided into four daily sessions, i.e. from 0800 – 1000 hours, 1000 – 1200 hours, 1400 – 1600 hours, and 1600 – 1800 hours. During each session, waders in all plots were counted for the first 30 minutes while the remaining time was used to study wader's reaction towards disturbance. The number of wader species, type of disturbance (from humans, dogs or vehicles), disturbance's frequency and disturbance's activity (fisherman, walkers, passed by dogs, dogs whose intentionally chased the waders, seen and heard vehicles, unseen but heard vehicles) were recorded. In addition, the response of waders towards disturbance and their distance from disturbance were also recorded. The approximate distances from approaching disturbance were recorded as soon as the wader started showing responses towards the disturbance.

6.3.3 Data Analysis

STATISTICA (StatSoft. Inc. 2007) was used in this study to analyze all data. All data sets were tested with Shapiro Wilke's W test and Anderson's Darling test for normality. In all cases, $\alpha = 0.05$ was used. Mann-Whitney test was used to determine the difference in the abundance of bird species in Jeram and Remis beaches. One-way ANOVA were then carried out to test the differences in wader's abundance in all plots in Jeram Beach while Wilcoxon Signed Rank Test was conducted to analyse wader's abundance in Remis Beach. The Spearman's rank correlation was then used to identify the relationships between wader abundance with types of disturbances. The frequencies of each type of responses (feeding behavior) toward disturbance were compared between the seven species which commonly exposed to disturbances by using Chi-Square, χ^2 tests (Fizpatrick & Bouchez 1998).

6.4 Results

The abundance of waders between Jeram and Remis Beaches shows no significant differences (t = 2.96, p = 0.05). However, more waders species were recorded in Jeram Beach (H' = 2.338) than Remis Beach (H' = 2.3154). On contrary, the abundance of wader was different in all sampling plots. A significant different on wader's abundance was recorded between the sampling plots in Jeram Beach ($S = 16.67$, $p < 0.001$). The pairwise comparisons analysis proved differences between plot 2 and plot 3 are significant ($z = 1.667$, $p < 0.001$). Likewise, Wilcoxon Signed Rank Test shows a significant difference on wader's abundance between the sampling plots in Remis Beach ($W = 78$, $p = 0.003$). In Jeram Beach, plot 2 recorded highest number of wader counted throughout study period followed by plot 1 and plot 3.

Seven species of waders were identified for further analysis. These species were used to study their response towards frequency of disturbance (these species were often found near the human community compared to other species). These species are Great egret (*Ardea alba*), Little heron (*Butorides striata*), Lesser sand plover (*Charadrius mongolus*), Little egret *(Egretta garzetta*), Lesser adjutant (*Leptoptilos javanicus*), Whimbrel (*Numenius phaeopus*) and Common redshank (*Tringa totanus*). Significant correlation was found between the abundance of bird with the frequency of disturbances (humans, dogs and vehicles) ($p < 0.05$) (Table 6.1). However, the interpretation of the p-value alone without the consideration of r value was not accurate. According to results, human have strong positive correlation with waders abundance in both beaches. Meanwhile dogs do not have significant effects on waders in Jeram Beach (since the value of r obtained is very weak ($r = 0.0836$) and weak positive correlation with waders in Remis Beach. Moderate positive correlation were found between vehicle and waders in Jeram Beach. However, vehicles do not have significant effect on waders in Remis Beach since ($r = -0.0255$) Human was a major contributor of disturbance towards waders (47.5%), followed by dogs (32.1%) and vehicles (20.4%). Among these, the most disruptive activity was mussel collection by human (29.4%) (Table 6.2).

Table 6.1: Results of Spearman's rank correlation analysis on the relationship between waders with disturbance from human, dogs and vehicles on Jeram Beach and Remis Beach.

Sites	Human		Dogs		Vehicles	
	R	p	R	p	R	P
Jeram	0.7236	<0.05	0.0836	<0.05	0.4531	<0.05
Remis	0.6862	<0.05	0.2576	<0.05	-0.0255	<0.05

Table 6.2: Types of disturbances source, activities, frequency and percentage of disturbance of waders.

Types of disturbance source	Type of activities	Frequency	Percentage (%)
Human	Fishermen	12	2.7
	Walkers	69	15.5
	Collecting mussels	131	29.4
Dogs	chasing the birds	54	12.1
	passing by	89	20
Vehicles	Sound but not seen	25	5.6
	Sound and can be seen	66	14.8

The responses towards disturbance are varied between species (Figure 6.1). χ^2 analysis indicated that all species responded to disturbance in all of four ways categorized, but there were significant differences between the species in the frequencies of these responses ($\chi^2 = 98.77$, $p < 0.05$). Figure 6.2 shows the percentage of wader's responses towards disturbance. The most preferred distance by wader species in tolerating approaching disturbance was between 1 to 5 meters (Figure 6.3).

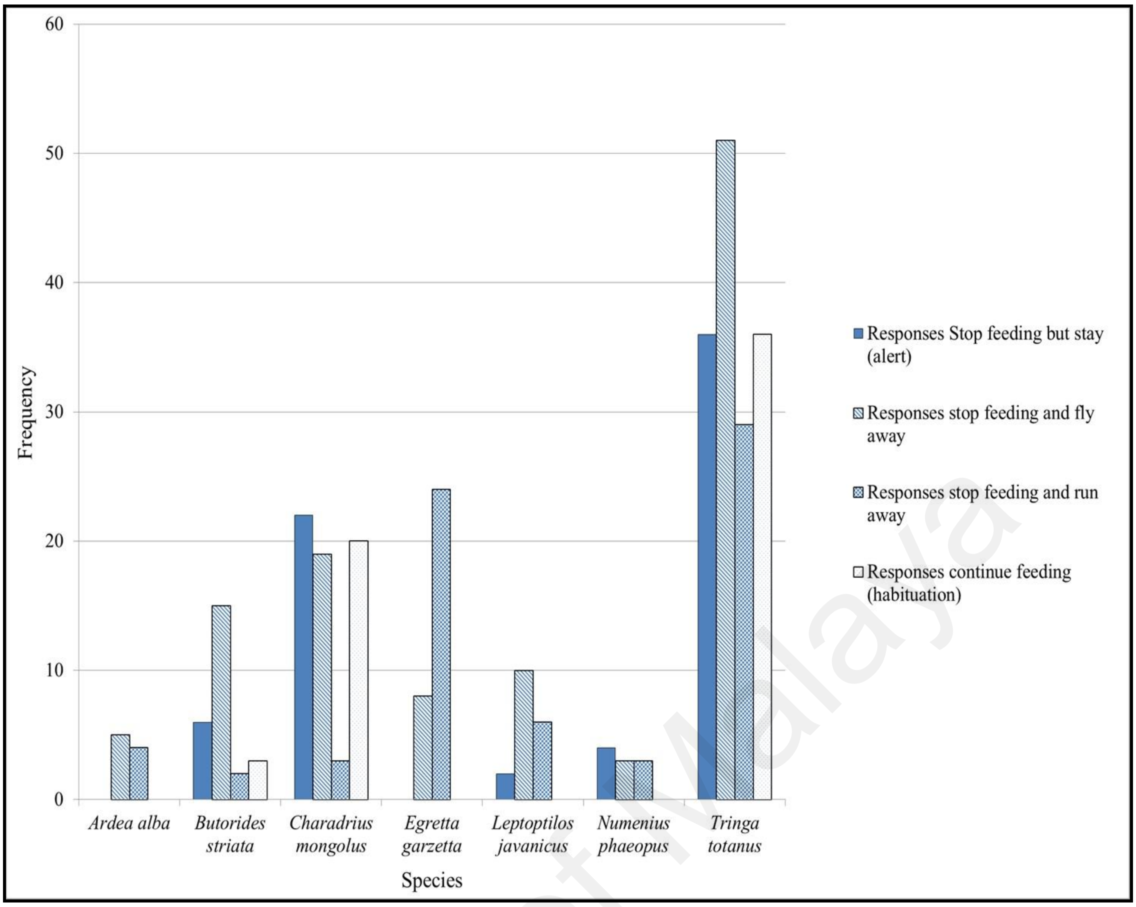


Figure 6.1: Frequency of responses shown by different species of waders towards disturbances

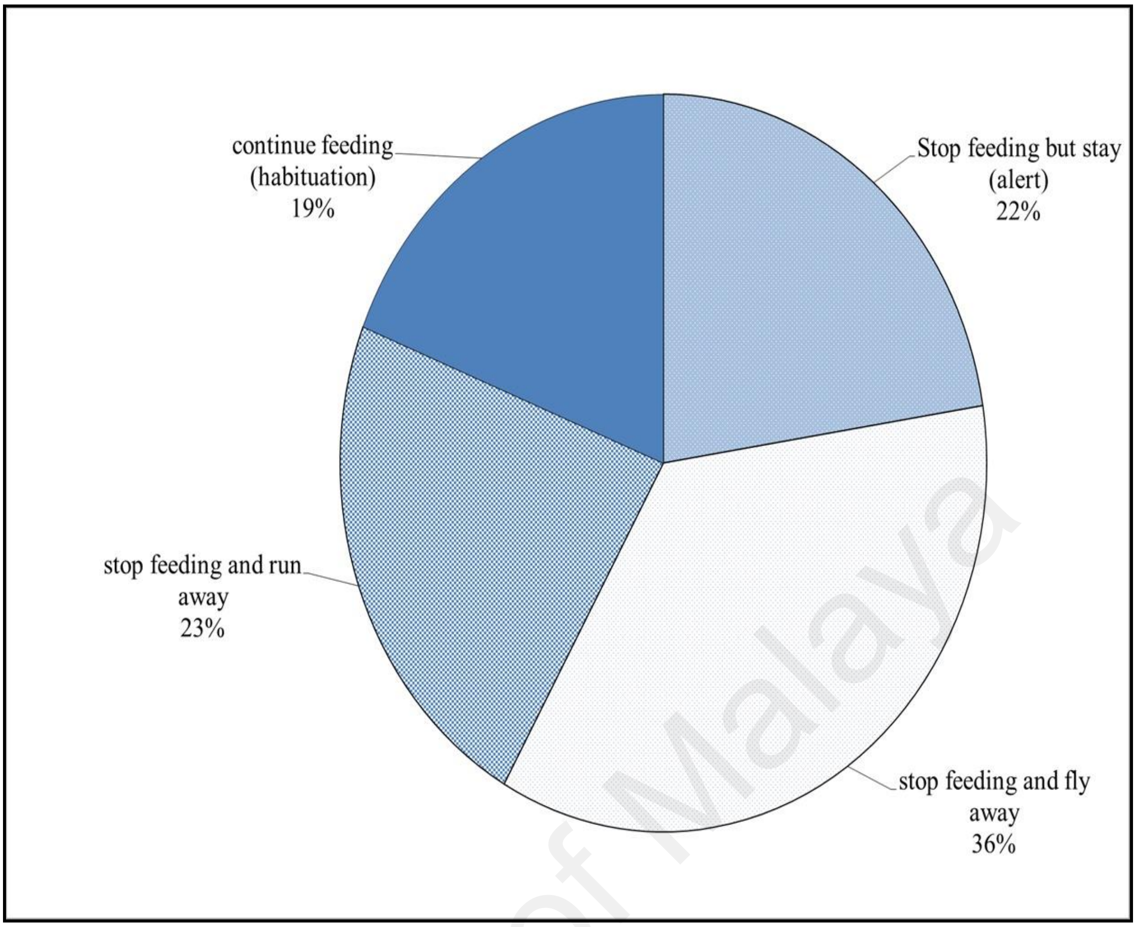


Figure 6.2: Percentage of response of waders upon disturbance

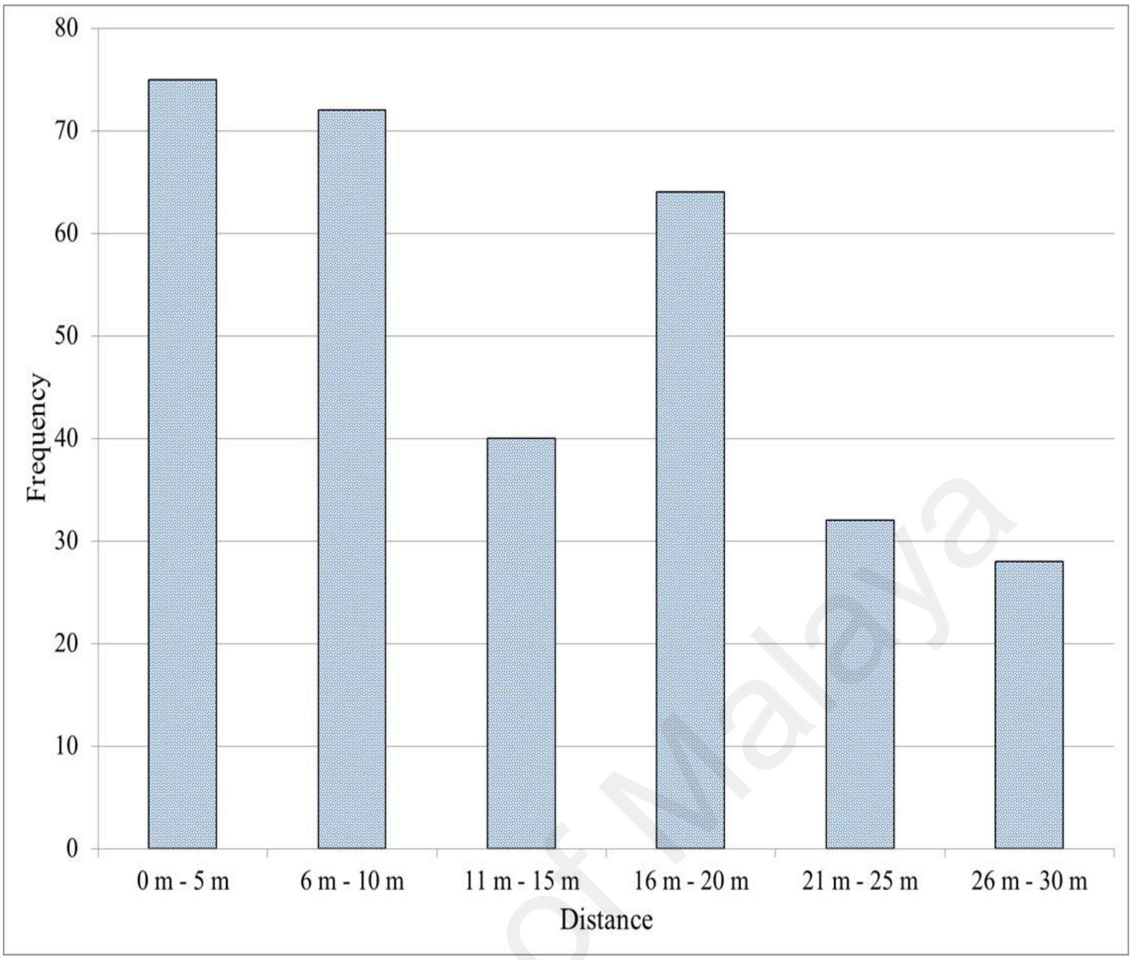


Figure 6.3: Preferred distance by waders towards sources of disturbances

6.5 Discussions

Any deviation from normal behaviour in response to unexpected occurrences in the vicinity of a wader can be defined as a disturbance (Platteeuw & Henkens 1997). Result shows that the abundance of waders between Jeram and Remis Beaches was not significantly different. However, the diversity index obtained was higher in Jeram Beach compared to Remis Beach. Higher index value reflects higher species richness and diversity in a particular habitat compared to habitat with lower index value. The number of species documented in a community may reflect the characteristics of the habitat and the interactions among species that live in that community (Schluter & Ricklefs 1993 (b)). The higher number of species within a particular habitat indicates that the habitat is of better quality and therefore more interaction occurred between species living in the community.

Although the abundance of waders was not significantly different between sampling areas, the abundance of waders was different in all sampling plots. In Jeram Beach, plot 2 recorded highest number of bird counted throughout the study period followed by plot 1 and plot 3. Observations suggested that less disturbance were recorded in this plot. Plot 1 was located near to the food stalls and people have tendency to wander around this plots compared to the other plots. Presence of dogs in plot 3 was clearly influenced wader's abundance recorded in that plot. Plot 2 was considered to be the most isolated from disturbances and small mangroves area is also situated in this area. Presence of mangrove forest had served as protection area for waders during disturbance. Most wader species flew towards the mangrove forest upon disturbance. Presence of the dogs was seen as threats by wader species in plot 3. Similar result was found in Southern California beach which recorded 39% of disturbance was caused by dogs (Lafferty 2001). The effect of disturbance on waders by dogs is disproportionate due to some dogs have tendency to chase waders. Therefore some waders, such as snowy plovers (*Charadrius nivosus*), were more sensitive to the disturbance caused by dogs than human (Lafferty 2001).

On contrary, the analysis shows that plot 2 in Remis Beach recorded the highest number of waders utilizing the mudflats area although the intensity of disturbance was higher than plot 1. It is believe that this occurred because wader in this area was habituated. Waders can become habituated to disturbance (Fitzpatrick & Bouchez 1998) because habituation require predictable patterns of human activity which birds can learn and identify which one do not pose any threat (Burger 1989; Burger & Gochfeld 1991). In this context, wader species were no longer responses towards human which they usually encountered and show no harms to them. Wader are said to be habituated if no responses are shown although the disturbance agent was too close to the wader. Compared to plot 1, mussel's collection activities were the highest in plot 2. This indicated that plot 2 have more food resources for waders. Waders are keen to forage in the area where the food is plentiful although disturbance by humans occurred. This is to optimize energy use because flying to another foraging area will increase energy expenditure. When some patches are richer than others, optimally foraging individuals that maximizes energy gain should allocate their foraging effort to those patches that are more profitable than the average patch in environment (Charnov 1976).

Because of the tidal restrictions on their foraging area, disturbance by human activities during their feeding periods might have potentially serious effects on the ability of waders to acquire sufficient food (Fitzpatrick & Bouchez 1998). It is found that human have the greatest impact on waders in the study areas. Results from studies of disturbance effects on foraging behaviour have been inconsistent with some studies which found a negative association between human activity and time spent for foraging

(Burger & Gochfeld 1991; Thomas et al. 2003), whereas others found no effect (Barbee 1994; Morton 1996; Trulio & Sokale 2008). Previous study had demonstrated that human activity on beaches affects wader feeding activities. Burger (1993) found that waders devote nearly 70% of their time for foraging and 30% of their time watching for people or predators. When the population of people increases, waders forage less than 40% of their time while the rest of their time is spent avoiding people. The human-related disturbance that seems to cause the greatest negative impact on coastal waders is the presence of dogs, whether on a leash or frees to roam. In Jeram Beach, we found that dogs, give no significant effect on waders abundance meanwhile in Remis Beach, dogs has very weak effect on waders abundance. Similar results found by McCrary and Pierson (2000) which found that the relationship between waders and dogs was not significant. This results was suprising because based on observations, dogs are sighted to chase waders on many occasions. The reason of getting no or weak correlation might be due to small sampling size in which the data recorded involving the dogs was few compared to humans. However, on contrary, multiple studies have found that waders and other types of birds responded to dogs as more of a threat than people walking without a dog and the birds tended to flush sooner when a dog was present (Lord et al. 2001; Miller et al. 2001; Gray 2006).

The responses towards disturbance were varied between species in this study. Larger and solitary waders such as Lesser adjutant, Great egret and Little egret often responses by run or flew away when encountered disturbance at a distance of at least 10 meters away from the source of disturbance. In contrast, smaller and flocking waders such as Common redshank and Lesser sand plover have a tendency to fly or run away from the approaching disturbance of at least 1 meter away from them. Some of the flocks are habituated with the presence of human and did not fly away but continue feeding. However, either larger or smaller wader shows no tolerance towards the presence of dogs. All of them flew away as soon as the dogs were approaching them. Common redshank was observed to ignore sound produced by unseen vehicles and continue feeding but was flying away from the feeding ground when vehicles approaching them. Earlier studies noted that different species responded differentially to disturbances (Burger 1981; Fitzpatrick & Bouchez 1998). Fitzpatrick & Bouchez (1998) suggests that this relates to differences among species in cryptic plumage. Although it is not clear that plumage explains most of the variation, such a pattern is consistent with the observation that snowy plovers rely on cryptic coloration and remaining motionless to avoid predators and was much more hesitant to fly (25%) from a disturbance relative to other species (75%) (Lafferty 2001). Individuals that do not flush until the disturbance source is very close are trading the risk of starvation against the risk of predation (Stillman & Goss-Custard 2002; Beale & Monaghan 2005). Individuals that flush sooner due to disturbance may be in a better condition and have the capability to respond to the disturbance, while waders in poorer condition may need to continue forage until the last possible moment because the need to consume as much resources as possible (Stillman & Goss-Custard 2002; Beale & Monaghan 2005). Larger species tended to flush when the disturbing agent was further away, likely due to their need for more space to take off compared to a smaller wader (Rodgers & Schwikert 2002; Rodgers & Schwikert 2003).

The types of disturbance also affect response time by individual waders. Borgmann (2011) showed that types of disturbances that cause waders to flush sooner included motorized boats at high speeds (Bellefleur et al. 2009), all-terrain vehicle (McGowan & Simons 2006), and activities with rapid movement such as running and unleashed dogs (Burger 1981; Lafferty 2001). Waders react to the presence of nearby humans in various ways. Depending on the proximity and type of human activities (such as walking, running, fishing, and dog exercising), waders may respond either by spending more time watching the potential human threat (Burger 1991; Fitzpatrick & Bouchez 1998), or by walking away from approaching human (Fitzpatrick & Bouchez 1998), or by taking flight and moving to nearby undisturbed section of the beach (Smit & Visser 1993). High levels disturbance caused by human activity can affect the survival and fitness of waders (Durell et al. 2005; Goss-Custard et al. 2006). However, their tolerance towards disturbances varies among species (Furness 1973; Durell et al. 2005). The frequency of disturbance and distance at which waders take flight are often the quantified measure of disturbance (Burger 1981). Although these types of reactions have some effects on waders, particularly a reduction in foraging time, a potentially more serious consequence of human and dog activities would be the abandonment of a valuable foraging area by some or all waders. However, these large behavioural responses do not necessarily mean that more waders will die, as they may have spare time to compensate for the disturbance or may simply move to another feeding area after being disturbed (Gill et al. 2001). Moreover, since flying is energetically expensive, waders that flush in response to disturbance will need to acquire additional resources to compensate both for increased energy expenditure due to flight and lost foraging time. Thus, frequencies of disturbance could have large energetic consequences for waders and potentially affect population size.

6.6 Conclusion

This study concluded that disturbance caused a major impact on wader abundance and influenced their foraging behaviour. Response of wader species toward disturbances were varied according to the types of disturbance and level of intensity of disturbances. By understanding how wader species response toward disturbance, the conservation efforts can be implemented more effectively in the future.

CHAPTER 7: GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATION

7.1 General Discussion

Significant gaps in knowledge remain for many wader species either resident or migrant species that spend their non-breeding season in Malaysia, as there has been limited number of studies investigating the factor which affecting the distribution, abundance and foraging behaviour of waders in Malaysia. This study aims to improve the data regarding the abundance of wader species utilizing the mudflats area of Jeram and Remis Beach which were previously known as important stopover sites for migratory waders (Li and Ounsted 2007) and provide new detail information on factors which influence the abundance and foraging behaviour of waders in Malaysia.

A total of 32 species and 19,034 individuals of waders were recorded throughout the study period. Besides, this study recorded few species which were listed as Vulnerable according to IUCN Red List of Threatened Species. Such species are Lesser Adjutant (*Leptoptilos javanicus*) and Far Eastern Curlew (*Numenius madagascariensis*) which recorded most of the time throughout the study period. The range and status of Lesser adjutant are rare resident of Peninsular Malaysia meanwhile Far Easten Curlew are rare coastal passage migrant in Peninsular Malaysia. Since Lesser adjutant were recorded throughout the study period starting from August 2013 until July 2014, it can be suggested that this species were common resident in the sampling areas. Meanwhile, Far Easten Curlew were recoded from August 2013 until May 2014, it can be suggested that this species are common passage migrant in the study areas. The migratory season in Malaysia was commonly falls between September until March. However, the results of this study find a significant finding which was different. The migratory season in this study falls between September until May. This happened maybe due to longer stay of migrant species in both study areas. Longer stay can be related to increasing in temperature or global warming in the breeding ground. Senner (2013) found that, conflicting warming regimes in in mid-continental North America caused the Godwit (*Limosa* spp.) population to arrive later to their breeding grounds and this consequently limit their ability to properly time their breeding efforts. Based on this finding, it can be concluded that mudflats area of Jeram and Remis Beaches are important feeding and stopover habitat for resident and migrant population. Urgent need on conservation efforts need to be done in these areas so that vulnerable species were not becoming endangered in future.

The abundance of wader was affected by temporal variation, tidal cycle and disturbance. The abundance of the waders differ significantly in all months. Highest waders abundance were found in January while the lowest were in the July. January is the peak season for migrant species to stay in the sampling areas. Meanwhile in July, the migrant species had decreased due to their departion to their breeding grounds. The abundance of wader was also significant between high and low tide. Comparisons of wader's abundance between different states of low tide resulted in significant difference of low tide peak with the ebbing and rising tide. Low tide peak recorded highest number of waders compared to other states. The low tide peak period provide a favourable condition in which waders could feed, as the water level that restricted the wader's movement, especially those with shorter legs, was completely gone. Generally, waders were uncomfortable in water deeper than their upper thigh and moved to higher ground (Ntiamoa-Baidu et al. 1998). This explained why the number of wader species utilizing the mudflats was highest during low tide. Followed by the low tide peak, the rising tide recorded a higher number of waders. Similar results were shown by Burger et al. (1977), who majority of species on the mudflat reached its peak abundance between 1.5

and 2.5 hours after low tide. The high densities of waders after low tide suggest that the availability of food is the greatest during this period (Burger et al. 1977). Besides tides, disturbance also influenced the abundance of waders utilizing the foraging mudflats area.

The significant difference of waders abundance was found with the abundance of humans, dogs and vehicles. Strong positive correlation was found between abundance of waders and human. The result was suprising because the assumptions were not meet. Supposedly, the abundance of waders were reduced with the increase of human's abundance. However, this result recorded contrary. Humans are positively correlated to waders due to the distance of waders with human. During low tide, intertidal area exposed was quite large. Most of waders segregate to forage in the middle of the mudflats or near the water edges. Mudflats restricted the movement of human. Therefore, most of the time, humans were found nearer the shoreline and not in the middle of mudflats. Only small species of waders which is less sensitive towards disturbance forage nearer the shore. Thus, the effect of humans toward waders was difficult to be seen. Lafferty (2001) said that when disturbed birds moved, they did not often move out of the sector where they were disturbed, making the effect of disturbance on displacement difficult to detect on the scale of sector.

Tide constraints the movement of wader in the foraging ground. Because of this constraints, adopting an opportunistic foraging strategies allowing migrant and resident waders with a flexible strategy that allows them to increase their probability of being able to replenish energy and nutrient reserves. Waders with different strategies select different habitat and forage on different prey items, which may effectively avoid interspecific competition.

7.2 Conclusion and Recommendation

This study was setup to determine the distribution and abundance of wader species utilizing the mudflats areas of Jeram and Remis Beach, Selangor. In addition, the study also examines the factors that affecting the distribution and behaviour of wader species and to investigate the effects of morphological characteristics of wader on the foraging behaviour adapted by the wader species. The study on waders utilizing tropical mudflat area is still lacking compared to the study conducted in temperate areas. Tropical intertidal environments are different in some aspects than the temperate environments. Tropical habitat shows a large variability in temperature and rainfall which in turns may influence the distribution and behaviour of waders utilizing this area. Understanding the ecology of wader species in tropical areas is crucial because the knowledge gain through the ecological study can be used for effective conservation efforts.

The main empirical findings are chapter specific and were summarized within the respective empirical chapters. In chapter 3, the distribution of wader species utilizing the coastal mudflats area of Jeram and Remis Beaches, Selangor were discussed. In this chapter, few objectives were addressed; (1) to gather the information about the diversity and abundance of wader species in Jeram Beach and Remis Beach and thus makes the comparison between these sampling sites; (2) to determine the wader diversity during migratory and non-migratory seasons and examine the effects of migratory waders on resident population and lastly; (3) to compare the results of this study with the previous study. This chapter highlighted few significant findings. Firstly, the diversity and abundance of wader species were higher in Jeram Beach compared to Remis Beach. The good quality offers by adjacent habitats will draw more individuals utilizing that area. The habitat with good quality has more abundances of food resources, have low predation risk and low disturbances which consequently results in higher chances of foraging success. Secondly, the wader diversity was recorded to be higher in migratory season compared to non-migratory season. Seasonal variation of wader’s abundance was observed during the study period due to the presence of large numbers of migrant and resident waders which assembled in the sampling sites during migratory period. On contrary, the waders diversity was lower during the non-migratory season was due to departure of migrant species towards their breeding grounds. The assemblages of abundance of resident and migrant species in these areas indicated that these areas are important stopover sites. Thirdly, the comparison study of the results obtained in this study with the previous study found that increasing in the number of species recorded. The increases in population size of waders in these areas were believed due to variation in characteristics between both study areas. However, some of the wader species recorded in the past study was not recorded in this study. The possible reasons might due to inadequate resources, constant disturbance and habitat loss. The knowledge on abundance of waders community utilizing the mudflats area of stopover sites in Malaysia should be enhanced in order to fully understand their ecology and therefore will facilitate the efforts to conserve certain endangered waders species presence within these stopover sites.

In conjunction to waders diversity and abundance study in the previous chapter, Chapter 4 was aimed to study the factors caused the variation in distribution and behaviour of waders species in both mudflats areas. The objective of this chapter was sub-divided into 2 more objectives which are; (1) to relate the effect of the tidal cycle on the abundance and behaviour of tropical waders, and (2) to determine the effect of different interval periods of the day on the abundance of tropical wader utilizing the coastal mudflats area of Jeram and Remis Beaches, located in Selangor, Peninsular

Malaysia. The result of the study shows that the abundance of wader species was significantly higher during low tide compared to high tide. During low tide period, “low tide peak” recorded the highest number of individuals utilizing the mudflats area followed by “rising tide” and “ebbing tide”. Besides, waders were recorded to be actively foraging during low tide compared to high tide. Meanwhile, during high tide, roosting or resting was the major activities showed by waders. Tidal cycles play an important role in determining the availability of exposed foraging areas and thus influence the abundance and behaviour of tropical waders. Moreover, results of the study also found that time of the day gives no impact in tropical wader abundance. However, few interval periods give significant difference in wader abundance due to temperature differences in tropical climate. Tidal state and habitat structure (i.e. dry sand, muddy flats and watery flats areas) influenced the wader’s decision to forage.

Chapter 5 relates how the morphological characteristics of wader species lead to different foraging strategies they engaged. The differences in morphologies such as differences in length of the leg of waders will caused the variation in habitat used when the tidal cycle is altered. The feeding rate, success rate, prey type and size, searching and handling time, time spent foraging, microhabitat, probing depth, water or mud depth, flocking behaviour and foraging techniques were varied between the species due to their morphological differences. Species with different foraging strategies will acquire food resources from different habitats and may end up in avoiding interspecific competition. Thus, sufficient energy and nutrient can be replenished to enhance survival of wader species in the area. Morphometric considerations can provide valuable insights to elucidating not only wader foraging decisions but also broader scale inter- and intra-species comparisons regarding distribution patterns and niche partitioning (Nebel et al. 2005).

Chapter 6 aims to investigate how disturbance caused by human and dogs affecting the abundance and behaviour of tropical waders. In addition, disturbance can be a major threat to wader species as it may influence both the foraging behaviour and abundance of waders. In this study, Remis Beach was observed as important ecotourism sites. Frequent visits by humans caused a high intensity of disturbance towards wader species utilizing that area. To reduce the impacts of ecotourism on foraging waders, managers of project should consider on concentrating ecotourism only on certain areas to allow waders to become habituated to disturbance there and also to help isolate source of disturbance. The refuges waders areas should also need to be considered closed to ecotourism areas. The area should be managed to provide adequate food resources for the target species. Finally, visitors should be educated about the effects of their behaviour towards waders, how to reduce their negative impacts and how their activities influence management of species of conservation concern.

Other than that, the most sensitive species (i.e. the species with the greatest flushing distance, for example in this study, Little Egret) can be used to set the barrier or buffer zones for mixed-groups of waders at foraging and loafing sites. Furthermore, instead of buffer zones, mitigation or physical barrier (such as retaining wall) can be used to prevent direct visual contact between waders and disturbances with low noise levels. This can be implied particularly in the area where the foraging and loafing activities of waders were the highest. Study of species composition and abundance is important because the managers of conservation projects should monitor the changes in species composition to adjust buffer distances to reflect the presence of new, more sensitive species with larger flushing distances.

Other than human, this study also recorded that dogs was the major disturbance towards wader species. Majority of the waders observed showed no tolerance towards the presence of the dogs near the foraging areas. More stringent law enforcement was thought to be the most effective ways to prevent the disruption of dogs towards waders. This can be done by severely fine the dog's owner. Consequently, this acts might deterred others from allowing their dogs to wander around the beaches. Such law was previously implemented by Australian government under the 'Marine Parks Act 2004': 'Marine Parks (Moreton Bay) Zoning Plan 2008'. Under this act, dogs must be controlled when near the waders or else the penalties will be applied.

This study highlighted a limitation which in turns might affect the quality of the results obtained. The method use in this study was only the direct observation technique. This technique has a disadvantage due to the tendency of repeated sampling of the same waders since the wader was not marked. However, it almost impossible to mark all wader individual's presence throughout the study period due to the mudflat characteristics. The mudflat condition limits the researcher movement and because of that the direct observation technique was the most practical technique chosen in this type of study.

Hence, it can be concluded that the waders distribution, abundance and behaviour were strongly affected by various factors such as tidal state, time of the day, intensity of disturbance and physical morphology of wader species.

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