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EFFECTS OF TIDAL STATES AND TIME OF DAY ON THE ABUNDANCE AND BEHAVIOR OF SHOREBIRDS UTILIZING TROPICAL INTERTIDAL ENVIRONMENT

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ABSTRACT

A study was conducted in the mudflats area of Jeram and Remis Beaches, Selangor, Peninsular Malaysia from August 2013 until July 2014 to determine the effect of tidal states and time of the day on shorebird's abundance and behavior. Direct observation techniques (with the aid of binoculars and a video recording) were used in this study. Twenty three species of shorebirds (Density = 413.3 indiv/ha) were recorded in both study areas. Mann-Whitney test showed a significant difference in shorebird abundance between high tide and low tide ($W = 78.0$, $p < 0.005$) and also between behavior of shorebirds with respect to the tidal state; feeding behavior ($W = 222.0$, $p < 0.0001$), preening behavior ($W = 204.5$, $p = 0.0017$) and mobility behavior ($W = 222.0$, $p < 0.0001$). Friedman's Two-Way ANOVA by Ranks proofs the significant difference occurred in shorebird's distribution between ebbing, low tide peak, and rising tides ($S = 17.17$, $p < 0.0001$). χ^2 tests were tested for all behaviors engaged by shorebirds during low tide period and the results showed a significant difference between the behaviors ($\chi^2 = 1831.9$, $p < 0.0001$). ANOVA analysis showed no significance difference in abundance of shorebirds between interval period ($S = 487.0$; $p = 0.554$). However, Friedman's Two-Way ANOVA by rank test shows the significant difference in abundance of shorebirds in high tide ($S = 8.788$, $p = 0.03$) between interval period. On the contrary, the analysis of Friedman's Two-Way ANOVA by ranks highlighted no significance difference in abundance of shorebirds in low tide ($S = 4.526$; $p = 0.21$) between interval time. Therefore, this study showed that the tide does influence the shorebird's abundance and behavior whereas time of the day does not have significant effect on both shorebird's abundance and behavior.

Key words: Avian, coastal area, tide, interval period, feeding, ecology.

INTRODUCTION

Shorebirds, also known as waders, undergo the most spectacular feats of migration seen in the animal kingdom, with some species travelling more than 20,000 km/year during their 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 shorebirds rely on stopover areas along their migratory route to replenish energy and nutrient reserve. Across all avian taxa, populations of migratory shorebirds are among the most uniformly and dramatically in decline (International Wader Study Group, 2003). There is increasing evidence that shorebird populations are declining worldwide (Zöckler *et al.,* 2003; Wetlands-International, 2006).

Shorebird distribution is strongly affected by the environmental condition. Not only the birds but all organisms belonging to plant and animal communities are affected by 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). Analyses of coastal shorebird assemblages indicate that date, tide and weather explain most the variation in species richness and abundance (Burger, 1984; Colwell, 1993). Tide is a major factor influencing the distribution, abundance and behavior of shorebirds (Evans, 1979). Most authors note that shorebirds feed on exposed intertidal areas at low tide, and roost in fields, marshes and bays at high tide (Pitelka, 1979). Shorebirds 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 and can include rock walls, sandpits, oyster leases, saltmarsh and ocean beaches (Lane, 1987).

The ecology of shorebirds 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 access of birds 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 behavior and activity patterns of many coastal species (Connors *et al.,* 1981) by altering the amount of foraging space (Puttick, 1980).

Time of the day also affect the abundance and behavior of shorebirds. Lehmicke *et al.,* (2013), suggested that morning survey resulted in a greater relative abundance of Clapper Rail (*Rallus crepitans*) detections compared to evening surveys. 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 be varied by species and location. For instance, Spear *et al.,* (1999) found no difference between morning and evening detection in California Black Rails *(Laterallus jamaicensis coturniculus*). In contrast, Nadeau *et al.,* (2008) reported that the mean number of all secretive marsh birds detected was greater in the morning and in the evening.

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 into 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). Although migrating birds spend only few months at their breeding grounds and rest of the year migrating or at their wintering quarters, ecological investigations on shorebirds in tropical environment are rare and widely scattered (Kober, 2004) compared to temperate area. Therefore, the aim of this study is to provide information on the effects of tidal cycle and time of the day on distribution and behavior of shorebirds species utilizing the tropical environment, especially in Malaysia.

METHODS

Study Area: Jeram and Remis Beaches are located in West Coast of Peninsular Malaysia (3°13'27"N, 101°18'13"E) (Figure 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 shorebird counts reported by Wetland Internationals in 1999-2004 (Li and Ounsted, 2007) which shows that these sites were 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 with plot size of about 900 m in length and 100 m in width (Figure 2 (a)). In total, the overall size of all plots in Jeram Beach was 27 ha. Unlike Jeram Beach, only two plots were constructed in Remis Beach due to disturbance by human activities (Figure 2 (b)). Plot size in this site was about 700 m long and 200 m wide. A total of 28 ha were used in Remis Beach study.

Shorebird Count: Shorebirds density and abundance were counted in both Jeram and Remis Beaches during all tidal cycles. Bird count and behavior survey were done by using direct observation technique (with the aid of binoculars, 12 X 42 magnification, and 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 shorebirds count was divided into four time intervals; i.e. from 0800 - 1000 hours, 1000 - 1200 hours, 1400 - 1600 hours, and 1600 - 1800 hours. In each interval period, shorebird was counted only in the first 30 minutes in all sampling plots while the rest of the time was used to observe the shorebird behavior when encountering tide. The sampling was conducted in both 'low' and 'high' tides condition to further understand shorebird's stopover ecology. In addition to conducting general bird's counts during low and high tides, the low tide counts were further divided into 'ebbing', 'low tide peak' and 'rising' period intervals. Comparison between these periods will reduce the bias of counting birds during low and high tides periods alone. This will make the results more relevant since during high tide the intertidal areas were fully submerged, The interval period was considered as 'ebbing' if the tide did not completely stop for more than one hour and as 'rising' as soon as the tide started rising. The interval period was considered as 'low tide peak' when the tide is completely stopped until the tide started to rise again. All shorebirds present in each plot were easily identified and counted because the intertidal mudflat area of Jeram and Remis Beaches was relatively open and unvegetated. Flying forward birds were excluded from counting and only those feeding and flying within the sampling area were recorded (Pandiyan *et al.*, 2010). Extreme care were practiced to locate all birds present within the sampling plots and to minimize multiple counting. During sampling, shorebirds are counted from at least 100 m away to ensure the researcher's presence did not affect bird numbers (De Boer and Longamane, 1996). Counting of shorebirds under extreme weather conditions (windy and/or rainy days) was not conducted due to possible adverse effects on bird activity (Conner and Dickson, 1980). Since the birds were not marked, an assumption was made to minimize the effect of multiple counting which is the same birds will forage on the same habitats for at least 2 days. Therefore, sampling were done alternately between two beaches to ensure that the birds counted on the Jeram Beach in the previous day was not the same birds counted on Remis Beach on the next days.

Statistical Analysis: STATISTICA program version 8.0 was used in this study to analyse 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, $\alpha = 0.05$ were used. Mann-Whitney test was used to determine the difference in low tide and high tide counts of shorebirds. Friedman's Two-Way ANOVA by ranks was used to differentiate shorebirds distribution during different stages of low tide i.e. 'ebbing', 'low tide peak' and 'rising. Analysis of behavior of shorebird utilising the area of sampling (i.e. feeding, preening, roosting or resting, and mobile) were compared between low tide and high tide period by using Mann-Whitney test. Chi-Square (χ^2) test was then conducted for all behavior engaged as a function of tidal state (Burger *et al.*, 1996). Friedman's Two-Way ANOVA by ranks was used to test the difference between interval periods (low and high tides) because the data were in interval-scale and not normally distributed (Gardner, 2008).

RESULTS AND DISCUSSION

Twenty three species of shorebirds (density = 413.3 indiv/ha) were recorded in both study areas. Results of this study revealed that the abundance of shorebirds was influenced by the tidal cycle. Mann-Whitney 2 sample *t*-test showed that significant difference occurred between shorebird abundance during low tide and high tide ($W = 78.0$; $p < 0.005$). The abundance of shorebirds was significantly higher during low tide than high tide periods (Figure 3). Low tide peak recorded highest number of shorebirds followed by rising tide. Shorebirds counts was the lowest during ebbing tide. Friedman's Two-Way ANOVA by Ranks proofs the significant difference occurred in shorebird's distribution between ebbing, low tide peak, and rising tide ($S = 17.17$, $p < 0.0001$). Further analysis by using Pairwise Comparisons showed 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 by using Mann-Whitney test for analysis of behavior during both tidal cycles (i.e. high and low tides); feeding behavior ($W = 222.0$, $p < 0.0001$), preening behavior ($W = 204.5$, $p = 0.0017$) and mobility behavior ($W = 222.0$, $p < 0.0001$). Feeding, preening and mobility behavior were frequently observed during low tide compared to high tide. Unlike other behaviors, roosting or resting behaviors showed no significant difference in both tidal levels ($W = 154.0$, $p = 0.8399$). χ^2 test was tested for all behaviors engaged by shorebirds during low tide period and the results show significant difference occurred between the behaviors ($\chi^2 = 1831.9$, $p < 0.0001$). Feeding (50.9%) was the most frequent behavior encountered during low tide period (Figure 4). However, χ^2 test for analysis of behaviors 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 behavior during high tide (Figure 4).

Time of the day did not influence the abundance of shorebirds in this study. The analysis of Friedman's Two-Way ANOVA by ranks highlighted no significance difference in abundance of shorebirds in low tide ($S = 4.526$; $p = 0.21$) between interval time. Similar results of ANOVA analysis showed no significance difference in abundance of shorebirds between interval period ($S = 487.0$; $p = 0.554$). In contrast, Friedman's Two-Way ANOVA by rank test showed a significance difference in abundance of shorebirds 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 significant difference in abundance of shorebirds 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 ($W = 194$; $p = 0.01$).

This study revealed that the use of intertidal mudflat area by shorebirds was influenced by tide cycle. Shorebird's abundance was the highest during low tide compared to high tide. In terms of comparison of different stages of low tide period, 'low tide peak' recorded the maximum number of shorebirds used the mudflats area compared to 'rising tide' and 'ebbing tide'. Different shorebird species tended to use different tide cycle to forage. For example, larger bird such as Lesser adjutant (*Leptoptilos javanicus*) was observed to forage throughout the low tide stage whereas smaller shorebird such as Common redshank (*Tringa totanus*) only forage during 'low tide peak'. This occurred due to differences in morphological characteristic of shorebird species. Larger species have long legs which enable them to use the mudflat area although the area was still covered by water or deeper mud which have higher water content. Baker (1979) reported that leg length was positively correlated with the depth of water in which shorebirds foraged. The longer the leg, the deeper the mud or water content in which they can stand while foraged.

Low tide peak period provide favorable condition for shorebird to feed as the water level which restricted the shorebird movement especially those with shorter leg were completely gone. Generally shorebird species are uncomfortable in water deeper than their upper thigh and will move to higher grounds (Ntiamoa-Baidu *et al.*, 1998). This explains why the number of shorebirds species utilizing the mudflats area were the highest during this period compared to other periods. Followed by low tide peak, rising tide recorded higher number of shorebird. Similar results have been reported by Burger *et al.*, (1977) who found that four of the five species on the mudflat reached peak abundance between 1.5 and 2.5 hours after low tide. The high densities of birds after low tide suggest that the availability of food is the greatest during this period (Burger *et al.*, 1977).

The use of intertidal area can, therefore, 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. Consequently, in virtually all studies conducted in coastal habitats, individuals move to roost where they are comparatively inactive at high tide but feed to varying degrees throughout the subsequent low tide interval.

Birds feeding in the intertidal zones are strongly dependent upon tidal movements, constantly changing the area available for foraging and influencing feeding behavior (Granadeiro *et al.,* 2006). 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). Furthermore, availability of prey is often determined by the maximum depth at which a shorebird can insert its bill into the substrate and maximum leg length (Dann, 1987).

Activity patterns of shorebirds vary diurnally, but mostly in association with the tides (Evan, 1979; Colwell, 1993). In this study, time of the day showed no impacts toward shorebird abundance in low tide period. Similar results were obtained by Burger (1984) through her study on tidal flats which shows that time of the day did not significantly affect variability in shorebird abundance. However, different results were obtained in shorebird abundance in the high tide period between interval times. From the analysis, the abundance of shorebird at high tide differed between early morning (0800-1000 hours) and late morning (1000-1200 hours) and between early morning (0800-1000 hours) and afternoon (1400-1600 hours). Different temperature might also cause the variation of shorebird's abundance between time intervals. The abundance of shorebirds roosting was higher in the morning since the morning's temperature was lower than afternoon's temperature. When exposed to direct solar radiation, shorebirds 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).

Figure 1: Location of Jeram and Remis Beaches on the West Coast of Selangor, Peninsular Malaysia

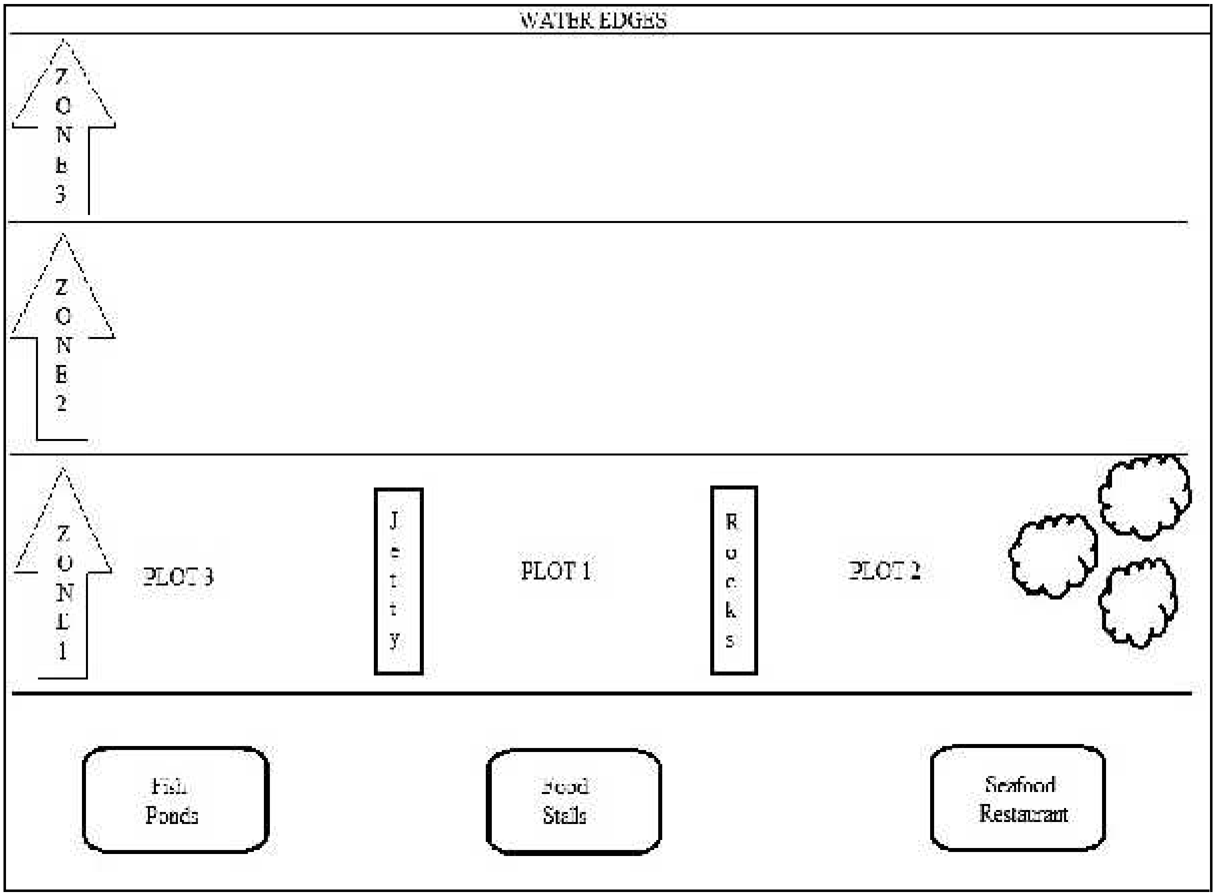

Figure 2(a): The design of sampling plots in Jeram Beach

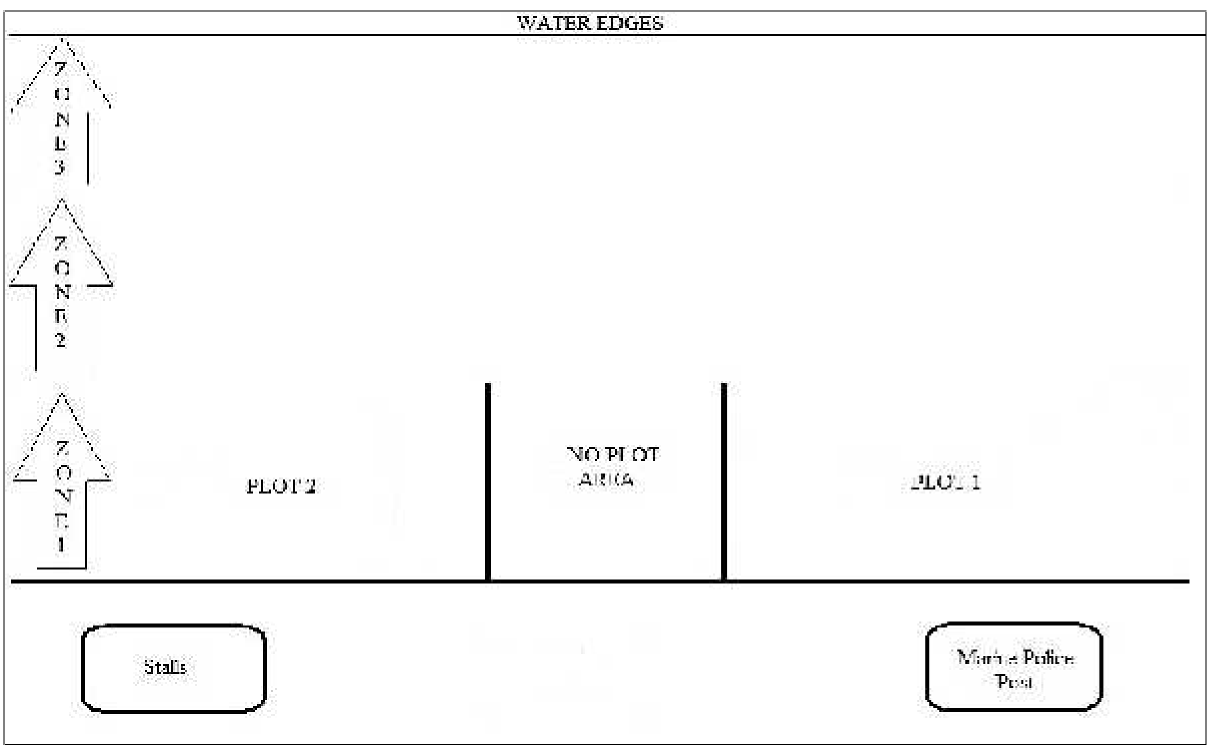

Figure 2(b): The design of sampling plots in Remis Beach

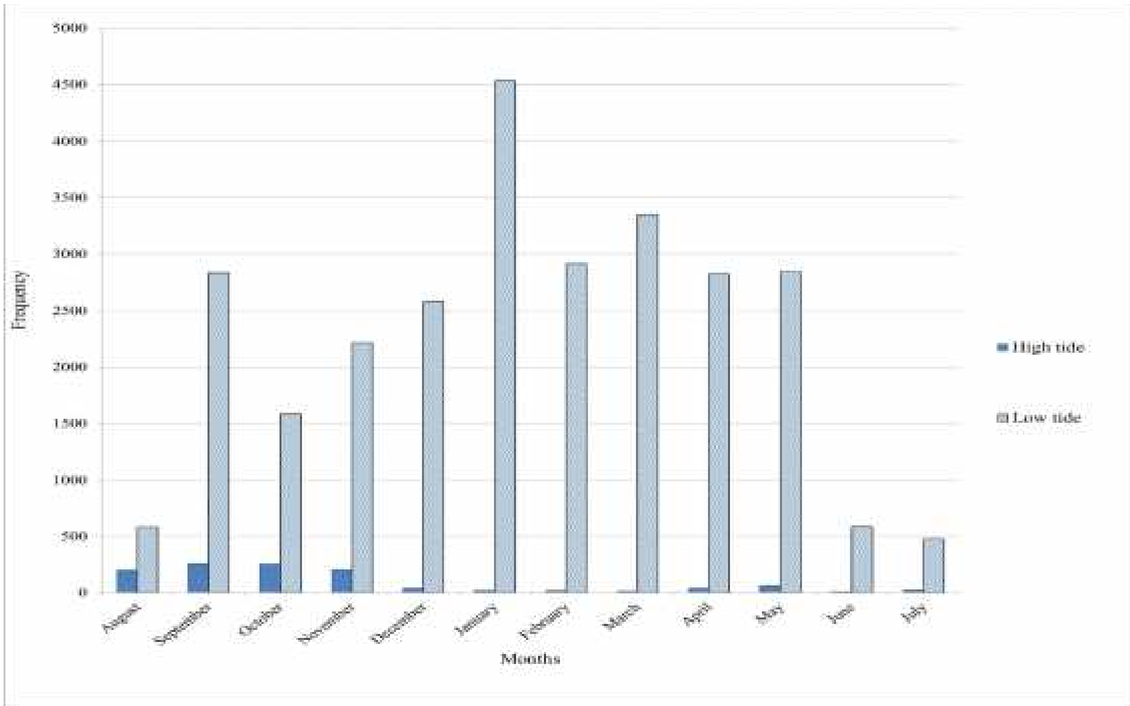

Figure 3: Shorebird's abundance during high and low tides

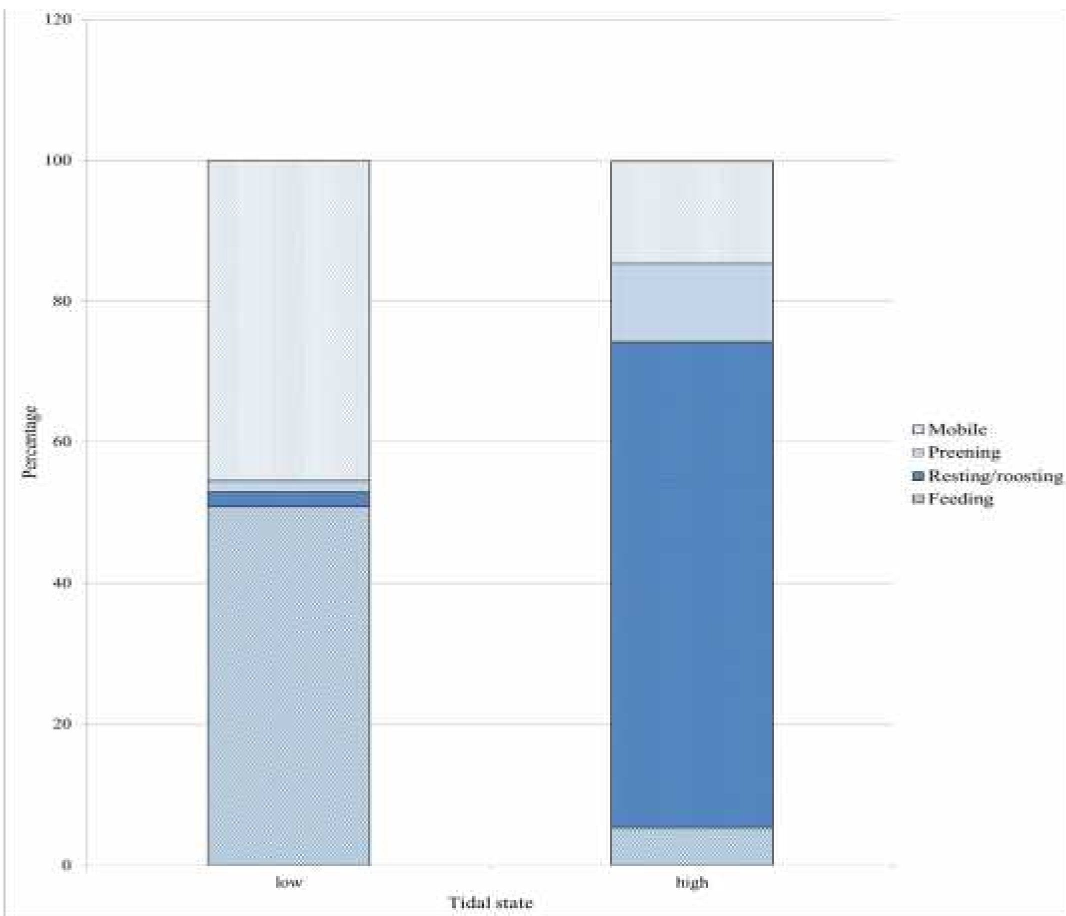

Figure 4: The percentage of behaviors engaged by shorebirds during high and low tides

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