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HABITAT REQUIREMENTS OF MIGRATORY BIRDS IN THE MATANG MANGROVE FOREST RESERVE, PERAK

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This study aimed to identify the habitat requirements of two migratory bird families, namely, Scolopacidae and Charadriidae in the Matang Mangrove Forest Reserve, Perak using habitat modelling. In order to determine the population distribution of these migratory birds, the habitat modelling requires information on the surrounding environment. Data on distribution of migratory bird population were utilised to assist the construction of the model. The approach in modelling the habitat was based on geographic information system (GIS) and remote sensing applications using the softwares ArcGIS10.3 and ERDAS Imagine 8.5 respectively. The latter was used to model the relationship between the study parameters (climate, environment and elevation) and the population density of migratory birds. This study showed that GIS and remote sensing were able to utilise data obtained via satellite images and fieldwork for habitat modelling, and that Pulau Kalumpang had the highest density of migratory birds compared with the other stations. Meanwhile, Pulau Sangga Besar and Kertang had potential to be the alternative locations in the next 20 years.

Keywords: Scolopacidae, Charadriidae, GIS, remote sensing, habitat modelling

INTRODUCTION

The population of migratory birds worldwide has been estimated to have declined at a rate of 1% per decade due to disruption of forest ecosystems and human activities. These scenarios have led to the disturbance of the natural habitat of the migratory birds (Robinson & Robinson 1999). According to the Wetlands International, Malaysia, the number of migratory bird species in South-East Asia has decreased tremendously from 2004 to 2006, declining by 22.4% (4480 birds) (Li et al. 2009).

In general, birds migrate to shallow water and muddy areas such as mangrove forests for food, resting areas and protection (Newton 2006). However, extensive agriculture, recreation and housing projects have affected the arrival of migratory birds to the mangrove forests (Studds & Marra 2005). Migratory birds are able to sense changes in the environment as far as 250 to 500 m from their habitat areas as they are highly sensitive compared with other bird species (John 2002). Increase in bird species is directly proportional to the increase in diversity of vegetation species in the mangrove forests (Ambuel & Temple 1983). Therefore, conserving and preserving the mangrove forests through construction of habitat modelling is important as these forests are the hotspot areas for migratory birds during their migratory season.

In this study, the habitat modelling was constructed based on field data collection of migratory bird density. By using this modelling technique, hotspot areas, bird distribution, habitat requirements, areas that are sensitive to development as well as the potential habitat for migratory birds in the future can be precisely identified. Information on the hotspot areas can be used to recognise habitat requirements of the birds for conservation programmes at the Matang Mangrove Forest Reserve (MMRF) (Figure 1).

MATERIALS AND METHODS

Study area

Habitat modelling for migratory birds in this study involved an area of 40,466 ha around MMFR. Several areas were selected, namely, Kerian border, Larut Matang and Manjung. These areas are almost fully covered by soft mud,

the most suitable medium for various mangrove plant species such as *Avicennia* spp., *Rhizophora* spp. and *Sonneratia* spp. The vegetation acts as the natural habitat for a wide variety of wildlife such as insects, small fishes, reptiles, amphibians and, particularly, migratory birds that forage food before continuing their flight.

This study focused on two families of birds, namely, Scolopacidae and Charadriidae. Both families were previously reported to be highly abundant in MMFR (Poole et al. 2011). Data from the previous 10 years of monitoring and netting at 10 selected stations by the Department of Wildlife and National Parks Peninsular Malaysia (PERHILITAN) were used in this study (Table 1).

Data collection

Data in this study were mostly obtained from the agencies responsible for protecting the migratory birds and the mangrove forest in Matang. The agencies were Department of Forestry of Peninsular Malaysia, local authorities, Department of Survey and Mapping Malaysia, Malaysian Meteorological Department, PERHILITAN and Wetlands International. The data were divided into two main formats, namely, spatial and attribute data. A fieldwork was carried out under the surveillance of PERHILITAN of Larut Matang. The purpose was to improve data collection and accuracy, especially in obtaining coordinates of each sampling station, which

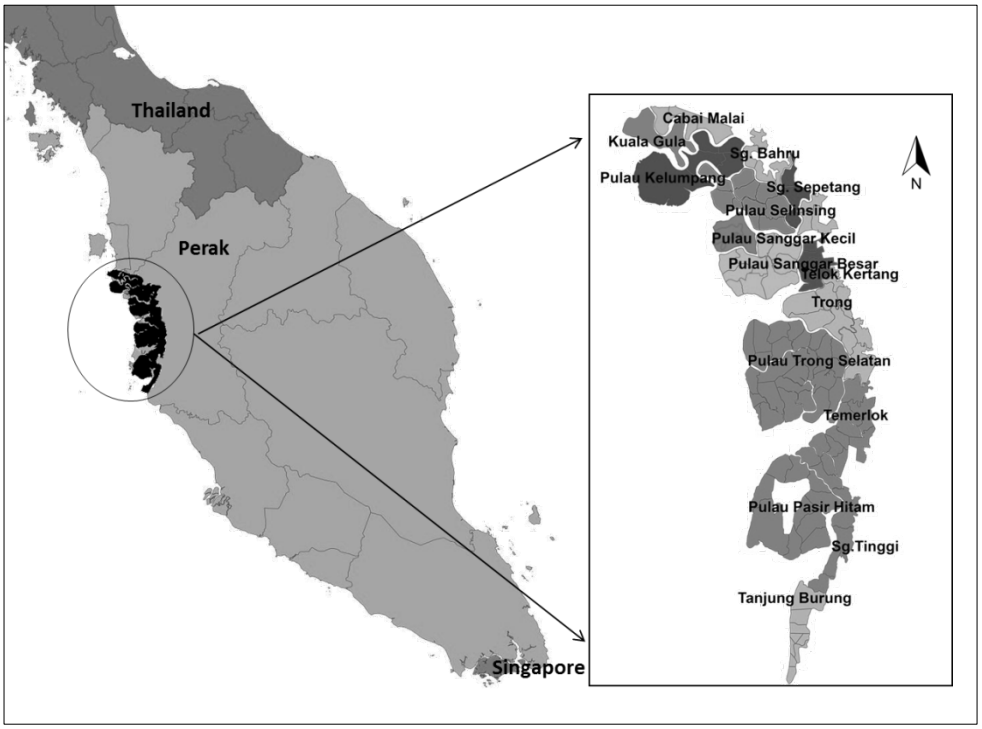

Figure 1 The Matang Mangrove Forest Reserve, Perak, Malaysia

Table 1 Netting stations for migratory birds

Hotspot area	No of birds
Kuala Gula	200,556
Kuala Selinsing	77,723
Kelumpang	108.013
Tasik Kelumpang	71,164
Tasik Trong	46,644
Parit Besar	16,696
Sungai Burung	29,532
Pantai Remis	65,470
Sungai Tiang	32,532
Sangga Besar	49,227

were fundamental in constructing the habitat modelling. Data on physical features of the study areas such as climate, elevation, landuse, land coverage and data related to migratory birds around MMFR from 2000 to 2009 were used in this study (Table 2).

One of the major obstacles in data collection was to get close to the migratory birds. Therefore, study areas were divided into grids which represented the sampling stations. In each sampling station, netting was used for data collection. Mist nets with an average size of 40.5 mm were used to capture birds. Netting activity was conducted in three sessions during the migratory season from September till April the following year using mark and recapture method (Table 3).

Modelling of study parameters

Six parameters (elevation, food availability, temperature, rainfall, landuse and land cover around the study area) were determined to develop the habitat modelling. Geographic information system (GIS) and remote sensing were integrated to construct the habitat model. Both applications involved several phases, namely, preparing data parameter, constructing the parameter relationship model, implementing the model and verifying the produced parameter model. Data from the six parameters were simplified into three categories, namely, climate, environment and topography to identify factors affecting the distribution of migratory birds at 10 previously selected stations (Table 4).

Data were pixelated using GIS with a size of 50 m × 50 m. This size was considered appropriate as the size of each bird netting station set by PERHILITAN was 500 m × 500 m. The ratio of satellite and large-scale data was set at 1:25,000. The remote sensing software (ERDAS Imagine 8.5) and GIS software (ArcGIS 10.3) were used to identify the most important parameter in the habitat requirement of migratory birds using mapping presentations. The prerequisite of each parameter was listed into classes based on the recorded bird density. The class density was determined using the correlation between bird density and each parameter in this study (Table 5).

Table 2 Source and format of data collected for 2000–2009

Data	Source of data	Format data
Study area	Kerian District Council	Spatial
Migratory bird	Department of Wildlife and National Parks, Kuala Gula	Spatial
Fauna	Department of Wildlife and National Parks, Kuala Gula	Spatial
Netting area	Department of Wildlife and National Parks, Kuala Gula	Spatial
Economic activity	Department of Town and Country Planning, Kerian	Spatial
Temperature	Malaysian Metrological Department	Spatial
Rainfall	Malaysian Metrological Department	Spatial
River	Forestry Department of Malaysia	Non-spatial
Boarder	Forestry Department of Malaysia	Atribute
Elevation	Forestry Department of Malaysia	Atribute
Forest compartment	Forestry Department of Larut Matang	Atribute
Forest type	Forestry Department of Larut Matang	Atribute
Forest border	Forestry Department of Larut Matang	Atribute

Table 3 Sampling session for migratory birds

Session	Month
First	August 2009–October 2009
Second	November 2009–February 2010
Third	March 2010–May 2010

Table 4 Distribution by category

Category	Parameter	Type of data
Environment	Food availabilty Forest type Economic activitiy	Observation at field and sampling outcome (bird netting)
Climate	Distribution of rainfall Temperature	Tropical Rainfall Measuring Mission Moderate Resolution Imaging Spectrometer
Topography	Elevation	Shuttle Radar Topographic Mission

Table 5 Density distribution

Distribution rate	Determination value (birds 50 m^{-2})
Very low	25
Low	130
Medium	274
Hign	422
Very high	1445

Simulation of habitat model

Habitat model simulation was used to estimate the future distribution of migratory birds. This study focused on the climate-related parameters since the slightest change of climate contributed to huge impact on the environment which might also affect the habitat of the migratory birds. Therefore, a climatic modelling was employed using preconditions such as changes in temperature and rainfall as the main inputs, the latter constantly changing in the short (5 years) and in the long (20 years) terms.

Changes in temperature and rainfall over the 5 and 20 years were analysed according to a general circulation model, constructed with the support of the Intergovernmental Panel on Climate Change. According to the general circulation model, temperature changed between 1.5 and 4.5% per decade while changes in rainfall during the same period were between 2.5 and 6.5%. This model involved a manipulation on climate parameters according to the preconditions set for temperature and rainfall (Table 6).

Images showing the changes in surface temperature were obtained from Moderate Resolution Imaging Spectroradiometer satellite data. The rate of rainfall was obtained from Tropical Rainfall Measuring Mission. Pixel-based map was used and represented by colour to display the temperature value and rainfall distribution in the study area (Table 7). Climatic characteristics were crucial in the analysis of every netting station and the relationship between temperature changes and rainfall pattern and the migratory birds in the study area was determined. Areas that experienced changes in population size of migratory birds due to the climate change were also identified. This information will be useful in the planning of development around MMFR by identifying the vulnerable areas as well as the potential alternative areas for the habitat of migratory birds facing effects of climatic changes in the future.

RESULTS AND DISCUSSION

Mapping of parameter relationship

The mapping of each and combined parameters (topography, environment and climate) revealed the differences in the density of migratory birds in MMFR. With mapping using GIS application, the relationship between study parameters (climate environment and topography) and the density of bird population could be presented clearly (Figure 2).

The mapping also showed that areas close to the sea had high abundance of food sources such as shrimps, insects, worms, molluscs and seeds, making the areas favoured by migratory birds as habitats. The hotspot areas for migratory birds,

Table 6 Preconditions of climate parameter

Class	Climatic factor			
	Temperature (°C) (5 years)	Temperature (°C) (20 years)	Rainfall (mm) (5 years)	Rainfall (mm) (20 years)
Very low	16.01–18.01	16.03–18.03	1251.03–1261.03	1251.05–1261.05
Low	19.01–20.01	19.03–20.03	1226.03–1237.03	1226.05–1237.05
Medium	21.01–23.01	21.03–23.03	1238.03–1246.03	1238.05–1246.05
High	24.01–26.01	24.03–26.03	1217.03–1232.03	1217.05–1232.05
Very high	27.01–29.01	27.03–29.03	1262.03–1277.03	1262.05–1277.05

Table 7 Pixel representations

Temperature (C°)	Colour representation	Rainfall (mm)	Colour representation
17–20		1110–1134	
20–24		1135–1159	
24–26		1159–1195	
26–28		1195–1222	
> 29		1222–1223	
		1224–1256	
		> 1256	

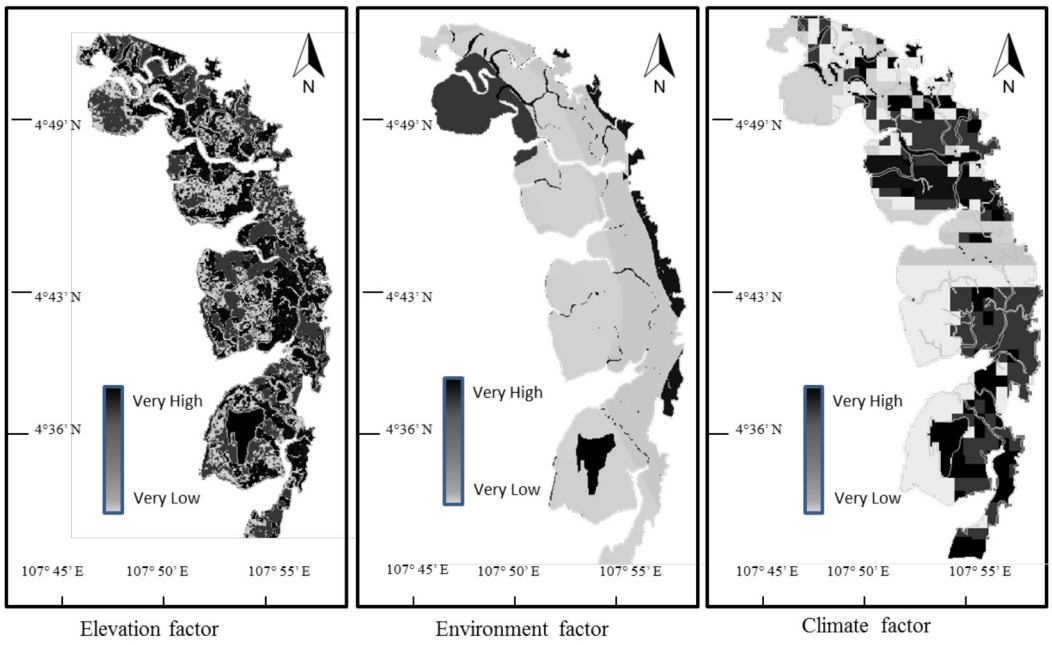

Figure 2 Map of studied parameters

namely Kuala Gula, Pulau Kalumpang, Pulau Selinsing and a small part of Pulau Sangga Kecil, constituting 14% of the total area of the Matang Forest Reserve, recorded 1445 birds 50 m^{-2}. Areas closer to the mainland, e.g. Sungai Baru, Sungai Sepetang, Trong, Temerlok and Sungai Tinggi had moderate levels of food source, i.e. approximately 60 to 80% compared with the hotspots. The density of migratory birds at these areas was very low with 25 birds 50 m^{-2}.

Climate change has been identified as one of the most important element in migratory bird studies due to its impact on food supply and environment (Walther et al. 2002). Climate change affects food availability, migratory bird distribution and their habitat selection for migration and breeding. The distribution of migratory birds showed that the population of migratory birds were high near the mainland of MMFR. During the last 10 years, Pulau Gula, Pulau Selinsing, Pulau Trong Selatan, Pulau Pasir Hitam, Temerlok and Sg. Tinggi recorded average annual temperatures ranging between of 26 and 30 °C and the average annual rainfall between 1040 and 1070 mm. Pulau Sangga Besar and Pulau Sangga Kecil received a minimum arrival of migratory bird compared with the rest of the areas. Temperatures at these two islands ranged between 20 °C to 29 °C and average annual rainfall, between 1030 and 1060 mm.

The different levels of elevation at the MMFR have also affected the distribution of migratory birds. The birds preferred to select low areas for resting areas because of food availability. The MMFR has very gradual cliff (0 to 25 m above the sea level). The contour interval in the area is very low, i.e. about 20 to 40% of the total elevation, resulting in a small difference in the rate of rising water between high tide and low tide. Areas with low contour interval received high arrival of migratory birds due to the soft and muddy cliff which facilitated the birds in foraging food compared with areas near the mainland. However, the birds moved to the mainland to rest since their foraging areas were temporarily flooded with water during high tide.

Significant parameters for habitat selection

The best habitat requirement for the birds was determined based on interrelated parameters. Combination of all parameters contributed towards the highest density of population for migratory birds, mainly at areas around Pulau Gula, Pulau Kelumpang, Pulau Trong Selatan and Pulau Pasir Hitam. Meanwhile, the middle part of the Matang Forest Reserve, i.e. areas around Pulau Sangga Kecil, Pulau Sangga Besar, Telok Kertang, and Trong were the least populated (Figure 3).

The parameters crucial for habitat selection were determined by studying four netting stations in Pulau Kalumpang, Pulau Sangga Besar, Pantai Remis, and Sungai Tian. These netting stations were randomly selected to avoid any bias in the accuracy of the model obtained. The average density was used to identify the important parameters considered by the migratory birds in selecting their habitat around MMFR (Table 8). The individual parameter values for topography, environment and climate were 1.06, 1.09 and 0.92 respectively. However these values exceeded the population density range (0–1). Meanwhile, combination of all parameters gave a value of 0.94 which was approaching 1. This showed that each of the parameter was interrelated and the combination of all parameters contributed towards the most preferred habitat by the migratory birds in the study areas.

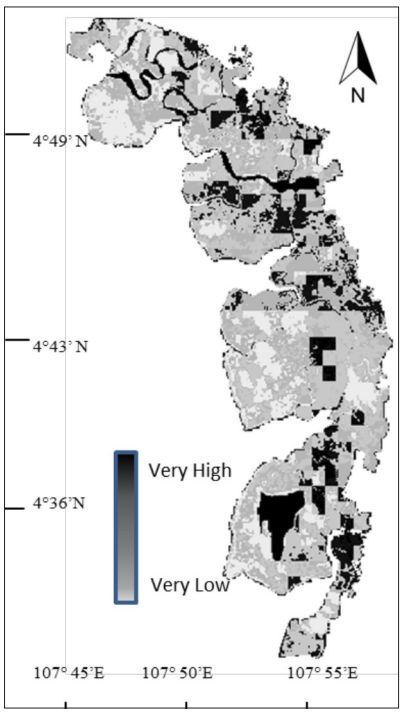

Figure 3 Distribution patterns of population of migratory birds based on combination of all parameters

Expected effects of parameter changes on migratory birds

The simulation model constructed in this study clearly showed significant change in the distribution density of migratory birds during the period of 5 years (2010 to 2014) and in the period of 20 years (predicted until 2029). In 2004, the density of migratory birds at Pulau Kalumpang was 422 birds 50 m^{-2}. The number declined to 274 birds 50 m^{-2} in the same year. Similarly, density

of migratory birds in Pulau Trong drastically declined from 422 to 25 birds 50 m^{-2} in the same year. Pulau Trong is, however, predicted to be a hotspot area during the migratory season for migratory birds in the next 20 years with an average density of 274 birds 50 m^{-2} (Table 9).

Some areas did not experience any changes or were less influenced by climate change in both periods (5 and 20 years). Pulau Pasir Hitam was expected to have a drastic change in the density of migratory birds due to climate change in the next 5 years. Changes in this area require a long time to occur, probably more than 10 years. Meanwhile, no changes were observed in Cabai Malai, Sungai Bahru, Sungai Sepetang and Pulau Kalumpang in the 5- to 20-year-period.

CONCLUSIONS

Migratory birds require a combination of several parameters such as climate, environment and elevation for habitat selection. In this study, Pulau Kalumpang had the highest density of migratory birds. Pulau Sangga Besar and Kertang have potential to be alternative locations in the next 20 years. Habitat requirements need to be maintained and preserved to ensure continuous arrivals of migratory bird species for years to come.

The habitat model provided great information, particularly for agencies that are responsible for monitoring and recording the annual arrival of migratory bird species. This habitat modelling could provide assistance to PERHILITAN to conduct survey and monitoring activities more systematically during migration season. In addition, they could focus on areas that could be major hotspots for migratory birds, thus, initiating the conservation and preservation programmes mainly at these areas.

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Table 8 Average rate ratio of migratory birds

Study parameter	Pulau Kelumpang	Sangga Besar	Pantai Remis	Sungai Tiang	Average rate
Topography parameter	0.93	1.22	0.97	1.12	1.06
Environment parameter	0.55	2.18	1.22	0.42	1.09
Climate parameter	1.10	0.93	0.75	0.90	0.92
Combined parameters	0.99	0.97	0.87	0.91	0.94

Table 9 Changes in population density of migratory bird

Netting station	2009	5 years	20 years
Cabai Malai	238	140	142
Kertang	122	152	175
Kuala Gula	275	154	168
Pasir Hitam	246	244	165
Pulau Kelumpang	318	224	224
Sangga Besar	170	198	191
Sangga Kecil	185	206	164
Selinsing	213	154	139
Sepetang	185	161	142
Sg. Baru	154	160	147
Sg. Tinggi	160	151	110
Temerlok	219	164	153
Trong	159	183	153
Trong Selatan	240	134	194

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