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Factors Affecting Nest-site Selection of the White-Bellied Sea Eagle *Haliaeetus leucogaster* (Gmelin, 1788) in Coastal Rainforests, Peninsular Malaysia

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Abstract: The White-bellied Sea Eagle (*Haliaeetus leucogaster*) is resident from India to Australia but little is known about its nesting habitat. Our aim was to compare the characteristics of selected nest trees versus randomly selected trees and to identify factors affecting nest-site selection of this species. We evaluated 13 variables of 73 nest trees and 73 randomly selected trees in Penang National Park, Penang Island, Malaysia. On average, the selected nesting areas were 210 m from the nearest seashore, and were at an elevation of 106 m above sea level (a.s.l.). Nests were placed at the centre of nest trees (57.5%) and the selected nest trees were placed in the middle of the nesting area (43.8%) and faced westwards and north westwards (53.5%). There were significant differences in slope of the nesting area, nearest distance to tourist areas, distance between nest trees, comparative height of nest trees, height class of nest trees, type of crown, and crown density between selected nest and random trees. Logistic regression analysis showed that the position on the middle of the slope and the distance between nest trees were the only important variables related to nesting. The results suggest that management of the nesting habitat of this species should focus on tall trees with layered canopies in the middle of a slope in the nesting area and as far away as possible from tourist areas.

Key words: Breeding, *Haliaeetus leucogaster*, nest tree, nest-site selection, nesting area, rainforest, White-bellied Sea Eagle

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Introduction

Habitat selection is part of avian life history evolution (Martin 1995), with nest site selection being one important factor in the survival of birds (Jones 2001). Nest site selection can be viewed as habitat occupancy with the choice of a nest site representing a feature in a breeding habitat patch (Misenhelter & Rotenberry 2000; Møller 1988). Determining and monitoring nesting habitats can provide valuable information on the characteristics of nesting habitats and nest trees, which in turn can be useful for conserving raptor species populations.

The White-bellied Sea Eagle (*Haliaeetus leucogaster*) (Gmelin 1788) is a resident species

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from India through Southeast Asia to Australia (Bird Life International 2012) that inhabits rocky coasts, islets, and areas near larger bodies of water. In fact, all varieties of seashores and large estuaries, including lower-relief coasts backed by mangrove and peat-swamp forests have been recorded as breeding habitats of the species (Wells 1999). Nests are 120–170 cm in width (Katdare & Mone 2013) and are used for multiple years (Favaloro 1944). The breeding season of the White-bellied Sea Eagle in Southeast Asia is from September to June (Robson 2002).

Despite the large range of the White-bellied Sea Eagle, most studies conducted on the species have been in Australia (Bilney & Emison 1983; Debus 2008; Emison & Bilney 1982; Shephard 2004; Shephard *et al.* 2005; Thurstans 2009a, 2009b; Wiersma & Richardson 2009). However, the majority of the species range is in Southeast Asia, where little information on its nesting ecology is known (Azman *et al.* 2013; Masdouqi 2011; Sarker 1985). What has been evaluated has been the eagle's breeding biology in Hong Kong (So & Lee 2010) and several studies related to conservation issues in Indonesia (Gunawan 2005; Gunawan *et al.* 2010; Kristiawan *et al.* 2005).

The species distribution has been evaluated along with a determination of nest site selection based upon mean nest tree height, nest height, and nest tree diameter at breast height (dbh) in Australia (Emison & Bilney 1982; Shephard 2004). Further nest site selection studies have also taken into account elevation, slope, aspect, ruggedness, distance to nearest road, building, and waterbody (Masdouqi 2011). However, the only comprehensive work on nest site selection has been that of Thurstans (2009a), who considered many characteristics of nest sites and modeled nesting habitat of the White-bellied Sea Eagles in Tasmania for mapping purposes with a focus towards use as a conservation planning tool. However, neither the characteristics of the nesting areas and nest trees nor the selection versus availability of them have previously been published.

Because Southeast Asia is losing its rainforests faster than any other equatorial region, and has the least remaining primary rainforest (Benders-Hyde 2002) it is especially important that studies be carried out on species such as the White-bellied Sea Eagle, which is a scarce inhabitant of the tropical rainforests which has hitherto been poorly studied in the region. Despite the many studies that have been conducted on the White-bellied Sea Eagle, details of its habitat selection are poorly known and knowledge of its nest-site characteristics is limited (Emison & Bilney 1982; Masdouqi 2011; Shephard 2004; Thurstans 2009a), making any conservation or management objectives a challenge (Gandiwa *et al.* 2014; Upadhaya *et al.* 2015). Therefore our overarching aim was to determine whether or not characteristics of nest trees are different from those of randomly selected trees. Based upon this aim, our objective was to determine if the characteristics of the nesting areas and nest trees differed in comparison to random trees in the eagles' breeding areas in the rainforest on offshore islands of western Peninsular Malaysia.

Materials and methods

Study areas

Penang Island is in Penang State in the northwest of Peninsular Malaysia. The island covers an area of 293 square km (Anonymous 2012a) and is situated at 5°12'–5°30'N and 100°09'–100°26'E (Masdouqi 2011). The highest point on the island is 795 m above sea level (a.s.l.). The climate of Penang Island is dictated by the surrounding sea and wind with an average annual rainfall of 2,670 mm, the majority of which occurs during the southwest monsoon from late September to early January (Anonymous 2012a). Much of the island is covered with hilly and inland forests, with mangrove forest on the coast. Major forms of land use include plantations, scrub, grassland, mining areas, and urban areas (Masdouqi 2011). Only 17% of the forest has been gazetted and most of this is confined to the uplands (Ho *et al.* 1999).

Penang National Park is located in the northwest of Penang Island. On 4 April 2003, Pantai Acheh Forest Reserve was declared Penang National Park (hereafter PNP) and was the first protected area in Penang State. The park lies at 5°28'N, 100°10'E and covers an approximately 2,562.9 ha, comprising 1,181.9 ha of land, primarily coastal hill dipterocarp forest, coastal mangrove forests, sandy beaches and rocky shores, and 1,381.0 ha of sea areas (Department of Wildlife and National Park 2012). The highest mountain peak in PNP is 464 m a.s.l. The park contains a diversity of habitats with hills, sandy and rocky beaches, streams and coastal forests, representing most of the natural habitats of Penang Island. Throughout the higher elevations

of the park, the vegetation cover consists primarily of emergent dipterocarp tree species including *Shorea* sp., *Hopea* sp. and *Dipterocarpus* sp. believed to be preferred by the sea eagles, in addition to medium sized trees, such as *Gluta* sp. and *Eugenia* sp. (Masdouqi 2011). Over 1,000 species of plants, 163 species of birds, 44 species of reptiles and 36 species of mammals have been recorded in the park (Department of Wildlife and National Park 2012).

Field observations

Field studies were conducted from February to May 2012 and September 2012 to September 2013. These periods cover most of the breeding season of the species in Southeast Asia (Robson 2002). Primary field observations were carried out to determine the nesting areas of White bellied Sea Eagles and the types of tree preferred for nesting. However, as only a few nests were found outside PNP, the study focused on the park where there was known to be a large breeding population (Khaleghizadeh & Anuar 2014). After one-day of hiking inside the park's rainforest it was concluded that it was too difficult to survey from inside the forest because of the dense canopy and poor visibility through the foliage of the middle story plants and trees (see also Masduqi 2011) which makes it difficult to see the top of the trees. We therefore used boats to find eagle nests by approaching them from the sea (Dennis *et al.* 2011b) whenever possible. Because of the steepness of the terrain in coastal areas, we were able to cover significant parts of the park by boat (Fig. 1). During our field surveys, we were helped by local people and park rangers who were very good at finding eagle nests. A total of 30 boat surveys were conducted which enabled us to detect nests from the sea coast up to the mountain peaks that the areas of PNP covered by the surveys are shown in (Fig. 1). A pair of Opticron 10 × 42 binoculars was used to identify raptor species and to locate nests. Nests were identified by their large size (c. 100 cm in width), the presence of adult or juvenile White-bellied Sea Eagles around the nest, and the lack of any other large raptor species in the vicinity. The coordinates of the nests were recorded from the nearest accessible point to the nest tree using a handset Garmin GPS. The location of each nest was then mapped and the nests were numbered.

During our field studies, we attempted to find as many nest trees as possible. When every nest was found, the coordinates and characteristics of the nest tree were recorded by the corresponding author. For each eagle nest tree, the following variables of nest-site selection were recorded: distance of nest tree from the seashore (m), average height of adjacent trees (m), nest tree condition (live or dead), type of nest tree crown, density of crown, nest tree height, nest height above the ground, nest orientation, and comparative height of nest tree in a 50 m radius (see Table 1). The distance and direction of the nest trees from the seashore were measured using GPS and a compass, and the distance of various land features from the nest trees were determined using SPOT 5 imagery taken in 2010. The characteristics of the nest trees were recorded from a boat.

During our bimonthly field surveys, a maximum total of 40 adult White-bellied Sea Eagles were observed within the PNP. Because of the close distance between eagle nests, discrimination between active and inactive nests was often very difficult, although it was possible in some circumstances. Alternative nests will be used by a pair of birds in different breeding seasons (Emison & Bilney 1982). Only eight nests showed some evidence of recent activity during the study period (adults were observed at the nest at least three times during our bimonthly field surveys). As the aim of this study was to assess nest site selection, both active and inactive nests were included in nest site analyses.

To evaluate patterns of nest site selection we used a comparison of selected suitable sites versus random available habitats (Brooks & Temple 1990). Specifically, we measured 73 randomly selected trees throughout the study area in PNP. The number of randomly selected trees was the same as the number of nest trees, and they were scattered throughout the study areas at intervals of about 200 m, similar to the distance between nest trees. We tried to cover the range of most of the studied variables such as elevation, aspect, tree height and type of crown when locating randomly selected trees. Variables of nesting areas and nest trees were recorded for the randomly selected trees (except for the impossible variables of nest height and nest to top height).

Data analysis

Using a geographical information systems (GIS; ArcGIS 9.3 software), coordinates of nest trees were converted into a geo-referenced map

Table 1. Description of factors and variables.

Factor	Description
Nest-site (also spelled nestsite and nest site in the literature)	"Nest-site selection" is a subset of "habitat use" (Jones 2001). The place for building nests within a nesting territory that is separated from other nest-sites. In our present study we used the term *nest-site selection* for both nesting areas and nest trees
Nest tree	A tree with a White-bellied Sea Eagle nest
Clumped nests	A group of nests which are clustered as alternative nests being used in different breeding seasons (Emison & Bilney 1982, Thurstans 2009*b*). In this study, we consider clumped nests if they were located within a radius of 100 m of each other.
Double nests	A nest tree with two nests
A. Nesting area	
Nesting area (more accurate than breeding ground and nest-site)	The area having a nest tree with similar slope, aspect, and other physiographic factors (in our study within a 100-metre radius of the centre point of nest trees)
Distance to the nearest seashore (m)	The straight line distance between a nest and the nearest point on the seashore
Aspect of nesting area	Geographic aspect of the nesting area calculated for every 45° of the compass: north, northeast, east, southeast, south, southwest, west, northwest
Slope of nesting area (%)	The percentage of the difference of the lowest and the highest elevation of a nesting area divided by straight line distance between the two points (it should be noted that the slope has two different units and a 100% slope equals an angle of 45°).
Position of nest on the slope	The position of the nest on the slope of the nesting area in three categories: low, middle and high
Adjacent tree height (m)	Average height of all trees within a 50 m radius
Height classes of adjacent trees in the nesting area (according to adjacent tree height)	Height classes were categorized as: short = up to 12 m, medium-height = 12 – 16 m, tall = above 16 m
Distance to the nearest tourist areas (m)	The nearest straight line distance to tourist areas where some tourists can be seen on daily basis
B. Nest trees	
Random tree	A randomly selected tree in the study area
Nest tree condition	Recognised as live, partially dead, or dead
Height class of nest trees	Short = 0 – 10, medium = > 10 – 15, tall = > 15 – 20, very tall = > 20)
Comparative height of nest tree in 50 m radius	Was the nest tree the tallest tree within a 50 m radius, or was it similar in height or lower than other trees
Type of crown cover	Divided into five groups: long trunk with semi-spherical crown, Acacia-like crown, layered with bigger crown, coconut tree, and full crown (Fig. 2)
Crown density	Divided into three classes according to the ability of eagles to fly into the crown: dense, semi-dense, open
Nest orientation	Orientation of nests divided into five groups: centre, north, east, south, and west. Nests built at the joint of the main trunk were considered as centre; the geographic position of nests built on other branches in relation to the main trunk was considered as the nest orientation
Distance between nest trees (m)	The straight line distance between a selected nest tree and the nearest nest tree

and a distribution map of nest trees was produced (Fig. 1) using SPOT 5 imagery in 2010 with landscape features. Other data were then extracted from geographic maps for both selected nest and random trees, including distance of the nest trees from the nearest seashore (m), elevation of the nest trees (m a.s.l.), aspect of nesting areas, slope (%) of nesting areas, position of nest trees on

nesting areas, and distance to the nearest tourist areas. These data were obtained by overlaying various maps and establishing different layers in the GIS. Data were analysed in SPSS 17.0. The independent samples *t*-test (Mann-Whitney *U*) was used to compare quantitative variables and multinominal regression was used to compare quantitative data between selected nest and random trees. A binary logistic regression was conducted to find effective variables through multivariate analysis (by computing qualitative and quantitative variables together) for both nesting areas and selected nest trees (as compared with random trees). Results are presented as means ± standard deviation, unless otherwise noted, with a $P \leq 0.05$ considered significant.

Results

Nesting areas

During the present study, 75 nests and 73 nest trees were found in PNP on Penang Island (Fig. 1). Regarding geographic variables, the aspect of most of the nesting areas was towards the west (38.4%, Fig. 1, Table 2). Over half of the nest trees (51.6%) were located among medium-height trees (Table 2). Almost half (43.8%) of the nests were located in the middle of a slope (Table 2), and on average, the nesting areas were on a slope of 39% (± 7 SD) (Table 3). The average distance between the nest trees and the nearest seashore was 210 (± 156 SD) m and the average elevation of the nest tree was 108 (± 51 SD) m a.s.l. (Table 3). Selected nest trees and random trees differed in terms of slope (Z = –2.423, *df* = 72, *P* = 0.014) and the distance to the nearest tourist area (Z= –2.641, *df* = 72, *P* = 0.01) (Table 3), while there was no difference in elevation, the distance to the nearest seashore, and the height of adjacent trees between selected nest and random trees ($P > 0.05$, Table 3). Logistic regression showed that only the position of the nest trees in the middle of a slope in the nesting ground showed significant difference compared with randomly selected trees (Wald = 4.857, *P* = 0.028, Table 4).

Nest trees

There were 72 live trees and one dead tree among the 73 trees. Nest trees with layered crowns were most frequently selected, followed by those with long trunks (55.6% and 29.2%, respectively, Table 2). Some 57.4% of the nest trees were the tallest

Table 2. Characteristics of qualitative variables of nesting areas and nest trees for selected nest and random trees of White-bellied Sea Eagle in Penang National Park. Values in parentheses are % share of sub-groups within each variable.

Variables	Selected nest trees	Random trees	*P*- value of Multinominal Regression
Position of nest tree on slope	Low (17.8), middle (43.8), high (38.4)	Low (37.0), middle (34.2), high (28.8)	0.054
Aspect of nesting area	Flat (0), north (15.1), northeast (1.4), east (2.7), southeast (2.7), south (15.1), southwest (9.6), west (38.4), northwest (15.1)	Flat (6.8), north (9.6), northeast (2.7), east (5.5), southeast (1.4), south (12.3), southwest (4.1), west (37.0), and northwest (20.5)	0.171
Height class of adjacent trees	Short (14.1), medium-height (51.6), tall (34.4)	Short (25.4), medium-height (28.4), tall (46.3)	0.063
Height class of nest trees	Short (0.0), medium (1.5), tall (30.9), very tall (67.6)	Short (6.0), medium (25.4), tall (47.8), very tall (20.9)	0.001
Nest tree condition	Dead (1.4), partially dead (1.4), live (97.2)	Dead (1.5), partially dead (0), live (98.5)	0.498
Type of crown	Full crown (0), coconut (0), layered (55.6), Acacia-like (15.3), long trunk (29.2)	Full crown (48.5), coconut (3.0), layered (34.8), Acacia-like (3.0), long trunk (10.6)	0.001
Crown density	Dense (2.9), semi-dense (17.4), open (79.7)	Dense (48.5), semi-dense (12.1), open (39.4)	0.001
Comparative height	Tallest (57.4)	Tallest (26.9)	0.001
Nest orientation	North (9.6), east (15.1), south (9.6), west (8.2), centre (57.5)	-	

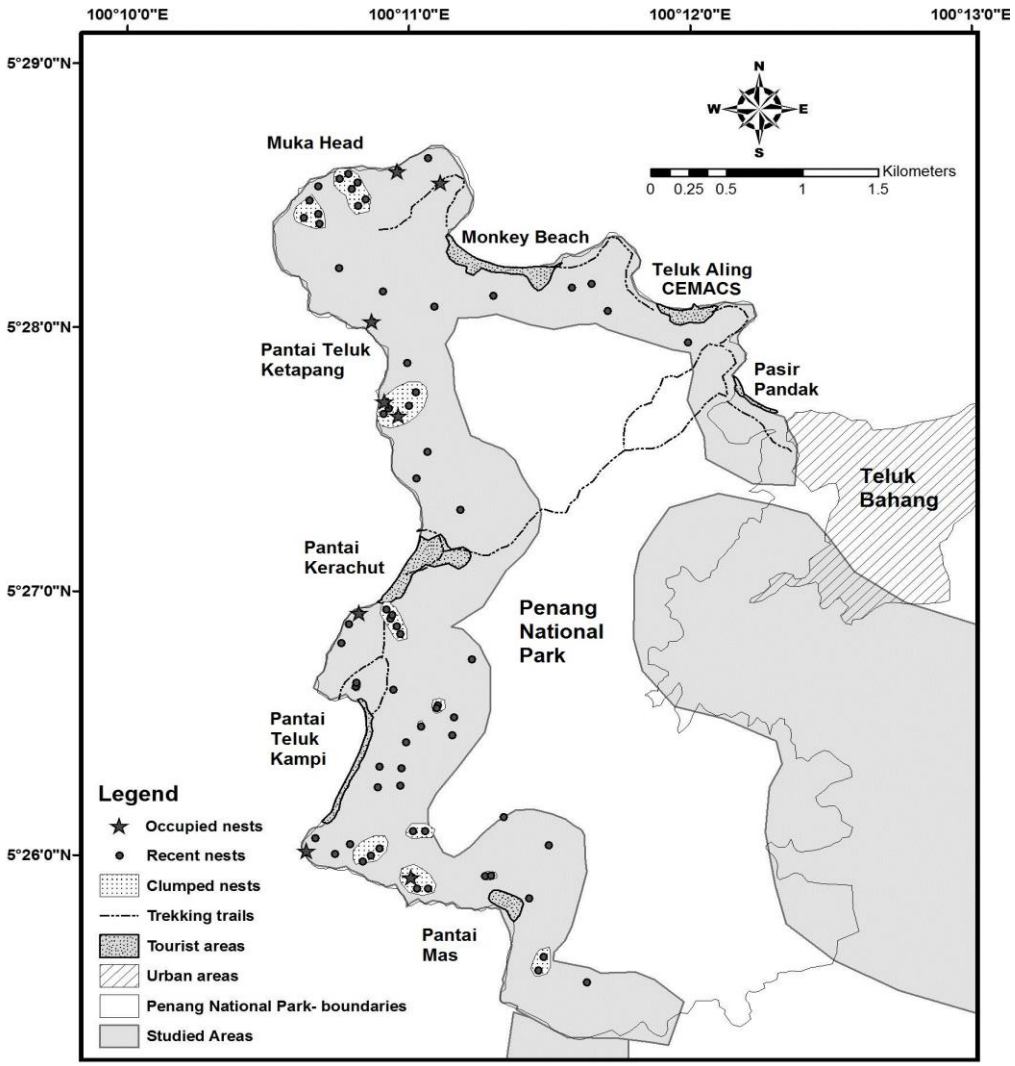

Fig. 1. Map of Penang National Park showing location of White-bellied Sea Eagle nests.

tree within a 50 m radius and 57.5% of the nests were built at the centre of the main stem of nest tree, followed by 15.1% in the eastern part of the nest tree (Table 2). Differences were found in the distance between the nest trees, height classes of nest trees, comparative height of nest trees, type of crown, and crown density between selected nest and random trees ($P < 0.01$, Tables 2–3). Furthermore, the distance between nest trees (Wald = 7.945, $P = 0.005$) had significant effects on the selection of nest trees compared with random trees (Table 5).

Discussion

Characteristics of the nest trees selected by White-bellied Sea Eagles were different from those of a random selection of trees in adjacent areas. Eagles' selected tall trees, often on a slope, that were closer together with one another than random trees. Furthermore, 53.5% of the nests were on slopes that had a westerly or northwesterly aspect. In comparison, Masdouqi (2011) found that 64.7% of nests were on slopes that faced west or south ($n = 34$, Masdouqi 2011). In Tasmania, most nests were on southeast facing slopes, providing shelter from prevailing westerly winds (Thurstans 2009a). The wind direction in Penang National Park, based on readings from Butterworth Weather Station, is from the west-northwest, with an average wind speed of five knots (Anonymous 2012b). However, the aspect of the slope itself was not very important, on the selection of nest trees in the park.

Table 3. Statistics of quantitative variables of nesting areas and nest trees for selected nest and random trees of White-bellied Sea Eagle in Penang National Park.

Variables	Selected nest trees				Random trees				Mann-Whitney *U* Sig.
	N	Mean	+St. Dev.	Min.–Max.	N	Mean	+St. Dev.	Min.–Max.	
Nearest distance to seashore (m)	73	210	153	31–795	73	225	167	43–774	0.738
Elevation (m a.s.l.)	73	106	51	31–249	73	98	56	12–241	0.236
Slope of nesting area (%)	73	39	7	20–59	73	35	12	060.2	0.014
Nearest distance to tourist areas (m)	73	449	268	34–1004	73	339	259	0–1075	0.010
Distance between nest trees (m)	73	143	113	22–482	73	214	75	81–496	0.001

Table 4. Statistics of Logistic Regression of variables of nesting areas of White-bellied Sea-Eagle in Penang National Park.

Variables entered in step 1	B	S.E.	Wald	Df	Sig.	Exp(B)
Distance to Shore	0.000	0.003	0.008	1	0.927	1.000
Elevation	–0.006	0.009	0.512	1	0.474	0.994
Slope	0.036	0.032	1.253	1	0.263	1.037
Aspect			2.017	8	0.980	
Aspect (1)	10.488	10299.711	0.000	1	0.999	35889.863
Aspect (2)	–18.673	18591.028	0.000	1	0.999	0.000
Aspect (3)	8.041	8874.647	0.000	1	0.999	3106.610
Aspect (4)	2.528	17331.827	0.000	1	1.000	12.526
Aspect (5)	4.301	3687.888	0.000	1	0.999	73.792
Aspect (6)	–11.844	18154.143	0.000	1	0.999	0.000
Aspect (7)	0.967	680.922	0.000	1	0.999	2.629
Aspect (8)	14.114	24801.022	0.000	1	1.000	1347653.329
Slope Position			4.865	2	0.088	
Slope Position (1)	1.020	0.463	4.857	1	0.028	2.773
Slope Position (2)	–0.194	0.351	0.306	1	0.580	0.824
Adj. Height Class			4.742	2	0.093	
Adj. Height Class (1)	–0.297	0.452	0.431	1	0.512	0.743
Adj. Height Class(2)	–0.732	0.375	3.809	1	0.051	0.481
Distance to Tourists	0.001	0.001	1.363	1	0.243	1.001
Constant	–1.083	4985.521	0.000	1	1.000	0.339

The choice of nesting area seems to be based on the availability of forested knolls or hills overlooking the shore, a nearby lagoon, or a large reservoir (Wells 1999). In Tasmania, the nest sites were located to avoid high wind events (Thurstans 2009a), while in PNP, most of the nest trees were along western coasts which are exposed to the prevailing winds. The preponderance of nests along the west coast of PNP is not surprising, as most of the coastal areas of PNP are in western areas, with only a small proportion of the coast being in the north (Fig. 1). This problem of exposure to the wind is probably reduced by choosing a nest tree in the middle of a slope. In fact, the position of the nest trees on the slopes was an important variable among nest-site variables, and the percentage of selected nest trees in the middle and upper parts of the slopes were higher than that of the available nest trees (Table 2).

However, the high density of nests in the southern parts of Pantai [Beach] Kerachut and

Table 5. Statistics of logistic regression of variables of nest trees of White-bellied Sea-Eagle in Penang National Park.

Variables entered in step 1	B	S.E.	Wald	Df	Sig.	Exp(B)
Tree Height Class			5.992	3	0.112	
Tree Height Class(1)	1.186	14841.157	0.000	1	1.000	3.275
Tree Height Class(2)	0.866	11061.946	0.000	1	1.000	2.378
Tree Height Class(3)	0.236	4947.053	0.000	1	1.000	0.790
Crown Type			3.510	4	0.476	
Crown Type(1)	20.056	11078.343	0.000	1	0.999	512901356.988
Crown Type(2)	–5.607	8647.718	0.000	1	0.999	0.004
Crown Type(3)	–7.194	19266.666	0.000	1	1.000	0.001
Crown Type(4)	6.391	14579.462	0.000	1	1.000	596.498
Crown Density			0.016	2	0.992	
Crown Density(1)	0.030	0.831	0.001	1	0.971	1.031
Crown Density(2)	0.049	0.694	0.005	1	0.943	1.051
Tallest Tree(1)	0.745	0.577	1.666	1	0.197	2.106
Nest Distance	–0.007	0.002	7.945	1	0.005	0.993
Live Condition(1)	21.693	40192.970	0.000	1	1.000	2638142394.89
Constant	–7.190	6467.396	0.000	1	0.999	0.001

Pantai [Beach] Teluk [Bay] Kampi (Fig. 1) suggests that sheltered aspects are favoured by

However, the high density of nests in the southern parts of Pantai [Beach] Kerachut and Pantai [Beach] Teluk [Bay] Kampi (Fig. 1) suggests that sheltered aspects are favoured by the eagles, as found by Dennis & Lashmar (1996) and Williams (1997) in Australia. This suggests that there is some advantage to positioning nests in more sheltered positions, regardless of climate. The tall trees may also face the prevailing winds given their height above the canopy (Foster & Wallis 2010). The placement of 57.5% of the nests at the centre of nest trees in PNP may be a protective measure when building nests.

The distance between the nest site and the seashore chosen by the White-bellied Sea Eagle may be related to the foraging trips that range from 0.05 to 6.2 km (n = 28, mean 2.15 km) for the species (Wiersma & Richardson 2009). Selection of nest sites close to the seashore has also been reported in another sea eagle species, the Bald Eagle (*Haliaeetus leucocephalus*) in Maine, USA (Livingston *et al.* 1990). The choice of low elevation (108 m a.s.l.) may simply indicate that the nest trees were close to the seashore. As Thurstans (2009a) stated, it can be due to "minimizing energy expenditure for climbing to the nests at high elevation and foraging at sea level." Alternatively, it could also shorten the eagles' daily trips to their nest (Zub *et al.* 2010) as their diet is mainly fishes (Debus 2008; Robson 2002; Smith 1985) and all 24 successful attacks on prey in PNP and adjacent areas were on fish (A. Khaleghizadeh, unpubl. data).

The White-bellied Sea Eagle nests 10–50 m above the ground (Robson 2002). In Tasmania, 68% of nest trees were taller than the height class of adjacent trees (Thurstans 2009a), compared with 57.4% in our study. In PNP, the selected nest

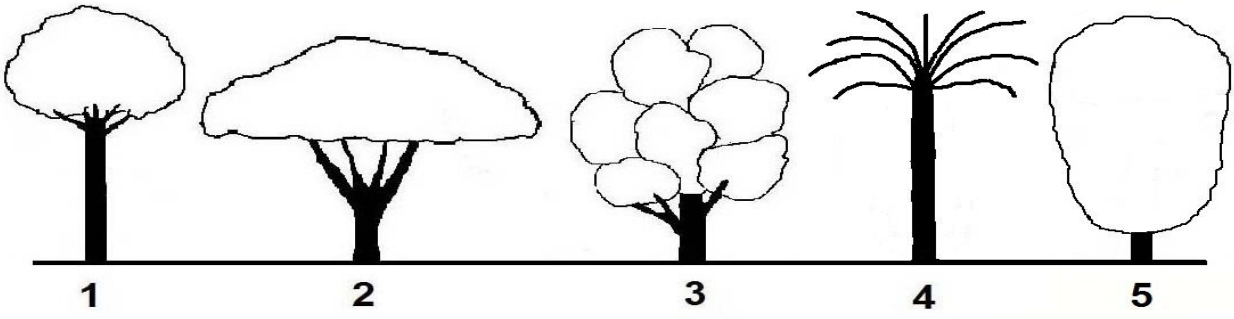

Fig. 2. Types of crown: 1 = Long trunk with semi-spherical crown, 2 = Acacia-like crown, 3 = Layered with bigger crown, 4 = Coconut tree, 5 = Full crown.

trees were often the tallest trees within a 50 m radius, while only 26.9% of the random trees were the tallest within a 50 m radius (Table 2). Furthermore, the type of crown between nest trees and random trees differed (Table 2). Specifically, 29.2% of selected nest trees and only 10.6% of random trees had long trunks, while 55.6% of selected nest trees and only 34.8% of random trees were layered. The eagles avoided trees with full crowns (0.0% of selected nest trees versus 48.5% of random trees, Table 2). Other sea eagles build nests in tall emergent trees, as shown in White-tailed Sea Eagles (*Haliaeetus albicilla*) in Hokkaido, Japan (Shiraki 1994). Selection of open crowns (79.7%) versus random trees (39.4%) suggests that birds are selecting trees which provide an "unobstructed flight path to the nest" (Edwards & Collopy 1988) and "enhanced visibility of intruders or family members returning to the nest" (Livingston *et al.* 1990).

Most of the tall trees in PNP were at a height of > 20 m, and none exceeded the maximum of 50 m mentioned above. Nest trees differed from random tree in terms of height, with 67.6% very tall for nest trees versus 20.9% very tall for random trees (Table 2). These taller trees with "rigid trunk and sturdy limbs probably provide forks suitable for supporting nests" (Edwards & Collopy 1988), as 57.5% of nests were built in the centre of nest trees (Table 2).

The White-bellied Sea Eagle is classified as Least Concern by IUCN (BirdLife International 2012), but its population seems to be declining and is considered a threatened species in Victoria, Australia (Clunie 2003). In Australia, the main threats to the White-bellied Sea Eagle have been identified as forest clearance in addition to the loss and degradation of breeding habitat (Bilney & Emison 1983; Clunie 2003; Emison & Bilney 1982). Human disturbance could also affect the vulnerability of nest sites to threats where nests in territories with high levels of disturbance have lower productivity, as on Kangaroo Island (Dennis *et al.* 2011a). However, in the case of PNP, human disturbance caused by tourism seems to pose the greatest threat. The trees selected for nesting were significantly further away from tourist areas than random trees (449 m, compared with 339 m; Table 3). In PNP, there were many potential nest sites in the northern part of the park, but only a few of them were used (Fig. 1). Thus, it is likely that the higher levels of disturbance in the northern part of PNP, is responsible for the relatively low density of nesting eagles in this area. Large buildings are found at various localities in the northern part of the park, and the movement of people associated with these building could also disturb the shy sea eagles and deter them from nesting in this area. Inside the national park, there are two main hiking trails, one from the main entrance to Muka Head, and another to Pantai [Beach] Kerachut and Teluk [Bay] Kampi (Fig. 1), and are another source of human disturbance. Fishing, forestry operations, and agriculture are other activities inside or around the national park (Masdouqi 2011). Fortunately, there have been no reports of hunting of the birds in PNP. Whether or not the presence of monkeys in the northern parts of park acts as a deterrent to nesting eagles is unknown.

Our findings suggest several recommendations for management. First, in order to reduce the effects of human disturbance on White-bellied Sea Eagles, we recommend that the current coastal hiking trails be more concealed so that the presence of visitors to the park will have fewer negative effects on the eagles. The park managers are discouraged from developing tourist areas in the western part of the park. Second, future development of urban areas and roads must be banned around the park. Third, we suggest the use of smaller boats by the boat service bringing tourists to and around the park. Fourth, fishermen should be discouraged from closely approaching the coastline of the park to reduce the effects of human disturbance near the White-bellied Sea Eagle nests. Finally, since the park is a protected area, it should be carefully managed to sustain a stable population of White-bellied Sea Eagle in Penang National Park and adjacent areas.

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