The University of Papua New Guinea

School of Natural and Physical Sciences

Department of Biology

Bachelor of Science Honours

HONOURS DISSERTATION

Nest- site selection and Behavioural Biology of the New Guinea Harpy Eagle, *Harpyopsis novaeguineae*

By

Leo. A. Toweyasali Legra

Submitted as partial fulfilment to the degree of Bachelor of Science Honours as required under the By- Laws and Statures of the University of Papua New Guinea for Higher Degree level education

June 2005

Table of Contents **Page**

ABSTRACT

Not much is known about the New Guinea Harpy Eagle (NGHE). So far only three studies have been done on the species. Two are short communications, one on temporal variation of the frequency of vocalizations and the other on attempts of the NGHE to capture a monitor lizard. The third study was conducted over a two-year period and was more in-depth covering hunting behaviour, calls, dispersion, and habitat use and conservation status of the NGHE. Though these studies have revealed some information much remains to be discovered. I visited six NGHE nest trees from October to December 2003 and February, April to June and September 2004 in order to observe juvenile NGHE behaviour and study their habitat selection. I found and tagged fifty- nine NGHE roost trees and measured the height, DBH, branch type, tree type, location, accessibility and local disturbance at both roost and nest trees. Roost trees averaged 28 m high (range 15-45m) and 67 cm DBH (range 23- 144 cm). NGHE nest trees were of greater DBH ($t=4.21$, $P<0.05$) and height ($t=5.44$, $P<0.001$) than random trees. NGHEs were selecting nest trees with relation to the type of tree ($G=10.17$, $P<0.05$), the bark characteristics ($G=7.14$, $P<0.05$), accessibility to the nest ($G=7.82$, $P<0.05$) and the level of disturbance at the nest site ($G=22.13$, $P<0.05$). At the macro scale, habitats of nest sites were largely forested, further away from the nearest human walking track and located further from the nearest source of water. I collected a total of 30 prey items from around nest and roost trees. NGHEs consumed mammals (70%), birds (23%) and reptiles (7 %). Calling activity of the NGHE was evenly distributed throughout the day. Nest site selection studies are important for the conservation of species and their habitats. Information from these studies could be used to help designate areas that are adequate and of importance to focal species.

INTRODUCTION

The New Guinea Harpy Eagle (NGHE), *Harpyopsis novaeguineae,* is one of the most rare and endemic raptors found on the island of New Guinea (Watson and Asoyama 2001). The NGHE ranges from sea level to 3 200 m above sea level and is found only on the mainland of the island of New Guinea (Beehler et al. 1986). Though it is large in size and widely distributed it is rarely encountered in undisturbed forests where it habits (Diamond 1972; Coates 1985; Watson and Asoyama 2001). It is estimated to have a large home range, of about 9.1- 16.9 km^2 (Watson and Asoyama 2001).

The NGHE is largely unknown because not much work has been done on the species. So far only three studies have been done on the species. Two of these studies are short communications, one on temporal variations of the frequency of vocalisations (Schulz 1987) and the other on attempts of the NGHE to capture a monitor lizard (Beehler et al. 1992). The third study was more in- depth and conducted over a two-year period. It looked at dispersion, habitat use, hunting behaviour, vocalisations and conservation status of the NGHE (Watson and Asoyama 2001).

Culturally the NGHE was a highly valued animal; its feathers were used in traditional body decorations and it was also consumed as meat (Gould 1970; Majnep and Bulmer 1977; Coates 1985; Gregory 1995; Helden 1998; Watson and Asoyama 2001). The feathers of the NGHE were also used as payments in bride price ceremonies (Brown 1972; Watson and Asoyama 2001). In the past, useage of the NGHE was mainly for cultural purposes, however this is not the case today. Feathers and live birds are being sold for cash and this may possibly lead to a decline in the population of the birds (Helden 1998; Watson and Asoyama 2001). Much of this problem is confounded further with the type of weapons that are used in hunting, where increased useage of guns with their high accuracy has led to a large number of the birds being killed (Helden 1998).

With the increase in human population and the increased demands for gardening land and logging activities, more and more of the habitat of the NGHE is being destroyed. For a species that needs vast tracts of virgin rainforest to survive, its hope of surviving is threatened by infringement of developments into its natural habitats (Watson and Asoyama 2001). It remains with us to save this species from extinction. In order to do this, more research needs to be done in those areas, which matter most to the NGHE, that is, habitat selection (nest- site selection) and its behavioural (feeding and hunting) biology.

Nest site selection studies of raptors and other birds for that matter have been given much consideration and studied the world over. These studies have revealed that raptors do not randomly select nest sites and habitats but use certain environmental cues when selecting nesting or hunting habitats. For example studies on Brown Goshawks, *Accipiter fasciatus*, reveal that Brown Goshawks were nesting in very tall trees and that these trees were on the edge of large (>10 ha) groves or on the edge or within small (2-10 ha) groves (Aumann 1989; Aumann 2001a). Kruger (2002) found used nests of buzzards to have more forested area, fewer buildings in the area and a higher number of branches supporting the nest. Northern Goshawk (*Accipiter gentilis*) occupied nests were also found to be in more forested areas (Kruger 2002). Martinez et al. (2003) used prediction models to explain habitat preferences of Eurasian Eagle Owls (*Bubo bubo*) at different scales. They found that at a 7 km^2 habitat preference scale the model predicted relief as the most important variable in choosing habitat; scrubland cover at a 25 km^2 habitat preference scale and scrubland cover and minimum altitude above sea level at 100 km^2 habitat preference scale. Findings from these studies are important for species conservation and their natural habitats because they provide measurable parameters that help conservationists define optimal habitats for conservation.

Earlier studies on raptors centred more on the breeding biology of raptors and some aspects of their habitat. For example studies such as the breeding ecology of raptors in the Eastern Great Basin of Utah (Smith and Murphy 1973); taxonomy of some Australasian raptors (Amadon 1978); and reproductive success of Peregrine Falcon, *Falco peregrinus- tundrius* (Calef and Heard 1979) looked specifically at raptors in general and provided insights into their breeding ecology and taxonomy.

Recent studies on breeding biology of raptors, however, tend to emphasise the importance of nest occupation rate and reproductive success (Kruger 2002). This, Kruger (2002) argues, is a good measure of the habitat preference of a species. However, a setback of this is the requirement of long- term data on nest occuppancy (Kruger 2002). Such long-term data on nest occuppancy is not available for the NGHE due to the species being very elusive and difficult to study; the period of time it takes for the fledgling to be independent of its parents and the very fact that not many studies have been done on the species. Thus with these limitations, this study on nest site selection could not take into account occupation rate and reproductive success.

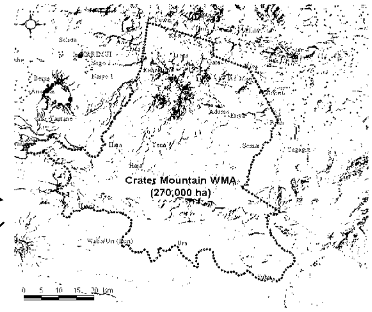
Studies on nest site selection and behavioural biology of raptors are needed due to huge territory occupancy by raptors and that most of these habitats are being destroyed and thus need to be conserved (Diamond 1972; Coates 1985; Beehler et al.

1986; Sharp et al. 2001). Habitat loss today has been identified as the primary factor that is affecting avian populations around the world (Thiollay 1996; Thiollay 1998; Bisson et al. 2002). Studies into nest site selection of raptors can help indicate those areas that are being selected and are of importance to the focal species (Newton and Marquiss 1976; Bisson et al. 2002). Such areas sometimes encompass the habitats of other smaller organisms that live within that territory. Thus conserving these habitats could also lead to other species and their habitats being safeguarded (Ferrer and Negro 2004; Roberge and Angelstam 2004).

Safeguarding populations of one species and its habitats that eventually lead to habitats and populations of other sympatric species being safeguarded are referred to as the umbrella and flagship species concepts. The flagship species concept refers to a species that is normally a large charismatic vertebrate, which can be used to arouse public interest and sympathy (Simberloff 1998). The umbrella species concept on the other hand refers to species that need large tracts of habitat, hence saving them would automatically save other sympatric species (Simberloff 1998). The umbrella and flagship species concepts are sometimes referred to as shortcuts by conservationists (Simberloff 1998). With the difficulty experienced in monitoring and managing biodiversity, solutions that involve less time and effort are often considered and used. The umbrella and flagship species concepts are two conservation solutions that are currently being used by conservationists to help save species and their habitats. However for a species to be used as a flagship or umbrella species much of its habitat requirements and behavioural biology have to be known.

This study focused on nest site selection and behavioural biology of the NGHE. Nest site selection and behavioural biology studies of the NGHE are needed to ensure that management of NGHE populations are in habitats that are selected by the NGHE and that managed areas encompass as much as possible the preferred habitats that are selected by the NGHE. This is crucial, in that how much of an area managed is enough and is able to sustain a small NGHE population and more importantly for how many number of years. Studies into behavioural biology of the NGHE are important to determine why the NGHE selects such habitats and more importantly indicate those areas that are of greater importance to the survival of the NGHE, for instance nesting trees.

With this study I tried to answer various questions on ecological and biological aspects on behaviour of the NGHE. Namely, what type of roost trees were the NGHEs using? What sort of behaviour was the NGHE exhibiting at these types of roost trees? What were the prey items of the NGHE and how was it capturing such prey? With regard to habitat, I tried to answer the following questions: why do NGHEs select such nest trees and when selecting nest trees what features of the tree were the NGHEs selecting for; why do they select type of habitat surrounding nest tree (micro habitat) and the habitat features that were important in the selection process and why do New Guinea Harpy Eagles select general habitat (landscape selection)?



A. Papua New Guinea

B. CMWMA boundaries ©WWF-2005

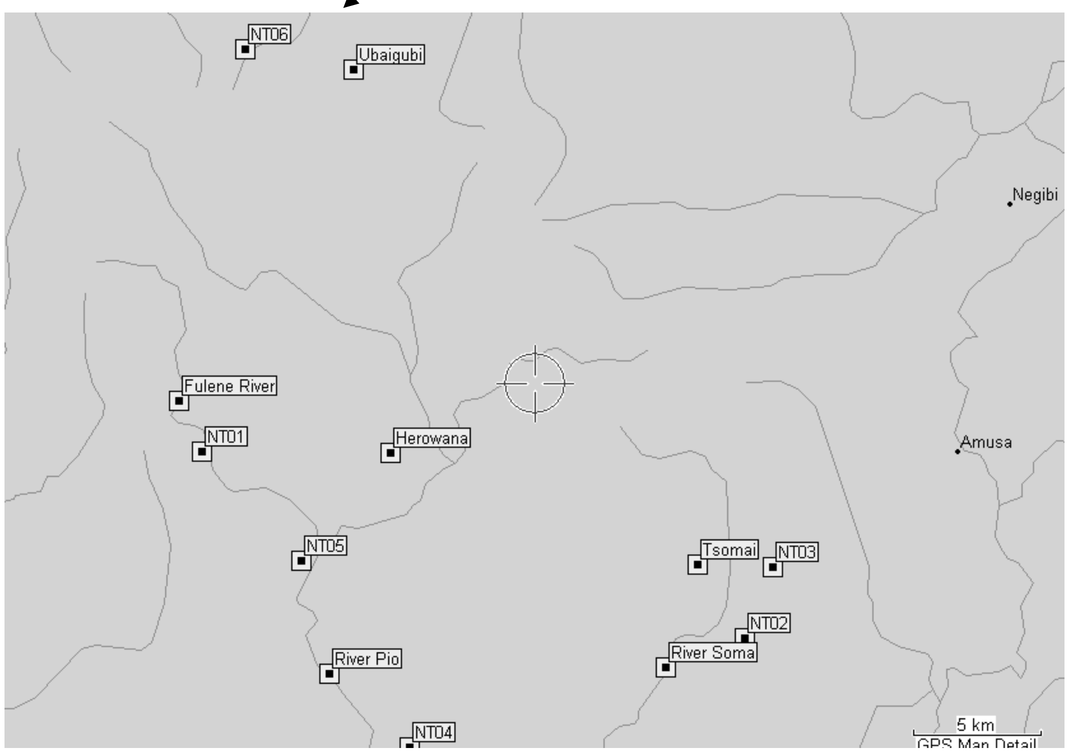


Figure 1: Map A shows Papua New Guinea and the Northern tip of Australia and also show the position of the Crater Mountain Wildlife Management Area (CMWMA) in PNG (*This is indicated by the circle*). Map B shows the boundaries of the CMWMA. Map C shows some parts of the CMWMA but more importantly it also shows the location of the 6 NGHE nest sites (NT01-NT06), the locations of the three major villages where the study was done and some of the major rivers. Maps A and C were created using Map Source software program version 4.09, 1999-2002 Garmin Corporation.

STUDY SITE

This study was conducted in Herowana (6^o39'253'' S, 145^o11'829'' E), Ubaigubi (6^o31'122'' S, 145^o11'051''E) and Tsomai (6^o41'592'' S, 145^o18'362'' E) villages in the Crater Mountain Wildlife Management Area (CMWMA). The CMWMA covers an area of 2700 km^2 (Figure 1) on the southern side of the central cordillera of the island of New Guinea and encompasses the provinces of Chimbu, Eastern Highlands and Gulf where landowners strive to collectively manage natural resources sustainably (Watson and Asoyama 2001). The study area was in the altitudinal range of 1300 to 2800 m above sea level. The vegetation there is mostly lower to mid montane rainforest (Wright et al. 1997). The annual rainfall averages 4- 5m each year (Figure 2).

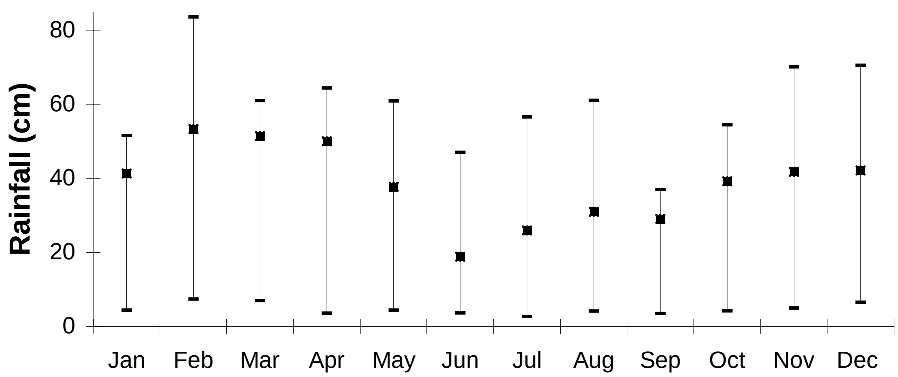


Figure 2: Means and ranges of monthly rainfall at Herowana. Rainfall was measured at Herowana airstrip over a 4 and a half-year period. The study was done at six different locations, all within 16 km of the Herowana airstrip.

METHODS

Nest

Nest trees were located through monthly monitoring checks and through behavioural observations of the NGHE. All sightings reported by local informants of possible nests trees were visited and NGHE behaviour observed if present. Nest trees were identified by climbing nearby trees and also through observations on the behaviour of the NGHEs. Once a nest tree was identified, it was tagged and then later returned to for measurements to be carried out. Nest trees were climbed and features of the nest structure, presence of leaves in nest, alignment of the nest on the tree (whether it was in a branch crotch or against nest tree bole) and the placement of the nest whether it was on a horizontal or vertical branch were measured.

Nest tree

I selected and measured 14 variables at the nest tree during 2003 and 2004 (see Appendix 1). Nest tree variables measured include the diameter at breast height (DBH), which was measured using a DBH tape; tree height, this was measured by extrapolating from a 2m rod placed at the base of the tree; the nest height and the lowest branch height were measured following the same procedure that was used to measure nest tree height. Nest trees were identified into emergent, canopy and sub-canopy type trees. Bole type of the nest trees were categorised as straight, inclined and branching. Crown of the nest trees were measured as oval, irregular, cone or table. Bark characteristics were measured by giving a score of 0-5, where 0 is very smooth and 5 is very rough. The presence of lianas were measured in the same manner but this time instead of rough and smooth, 0 represented none, while 5 was very dense. The presence of epiphytes on the tree was measured the same way as lianas, but measurements were done separately for the crown and bole. Canopy cover under nest tree was measured 1 meter uphill from base of tree using a sperical densiometer. Accessibility to the nest was measured as easy (no vegetation within a radius of 10 meters around the nest tree was higher than the level of the nest), moderate (some of the vegetation surrounding the nest tree was higher than the nest) and difficult (vegetation around the nest tree was both higher than the nest and abundant). The amount of disturbance was also measured by accounting for trails, cut trees, landslips and tree fall gaps within 10 metres of the nest tree. All cuts on individual trees or shrubs were counted as one irrespective of the number of cuts on the one tree or shrub.

Nest site (Microhabitat)

Habitat selection measurements were done at different spatial scales, as described by Kruger (2002) (also see Figure 3). The microhabitat in this case is referred to as the nest site. This was the habitat that was encountered within a 20 m radius around the nest tree. Within this radius I chose and measured 13 variables that describe the microhabitat (Appendix 2). I measured distance from the nest tree to the nearest river/ stream and ridges. I also scored for the amount of canopy cover above the nearest river or stream whether canopy cover was closed or open above the river or stream. I also measured the width of the rivers and the location of the tree whether it was on a slope or on a flat. I measured slope (^{o}) and aspect (^{o}) of the area around the nest site. I also scored for the position of the microhabitat on the slope, whereby base of slope was given a score of 1, middle of slope a score of 2 and top of slope a score of 3. I also measured the distance to the next canopy tree. Trees greater than 10 cm DBH and over story trees in the microhabitat were counted. The amount of shrub layer and under story within the microhabitat was also measured and given a score of 0-5, where 0 was none and 5 was very dense.

Random tree variables

I measured the same variables (as those at nest trees) at randomly selected trees in order to determine whether NGHEs were randomly selecting trees to build their nests. To select random trees, I pulled a 100m transect line from the nest tree along 4 principle compass points. Then from the base of the nest tree I chose 2 random bearings from each of the four principle compass points ($0\text{-}90^0$, $91\text{-}180^0$, $181\text{-}270^0$, $271\text{-}360^0$). I then paced random distances < 50m at random bearings. At the end of the paced distance, the nearest canopy tree was chosen and measured (variables measured at random trees are listed in Appendix 1). I also measured the habitat around random trees to determine if NGHE were also randomly selecting nest sites (variables measured are listed in Appendix 2).

Macro habitat (general landscape)

At a 2 km radius (13 km^2, estimated home range of the NGHE; Watson and Asoyama, 2001; see Figure 3) around the nest tree I measured the amount of forested area (ha), the area covered by clearings (ha) and water areas (ha). The amount of forested areas, clearings and water areas are also given as percentages of the total radius measured. The number of disturbances within each 2 km radius was also counted. The distances (km) to the nearest track and the distances (km) to the nearest source of water were also measured. Distances to the nearest permanent human settlement areas were also measured.

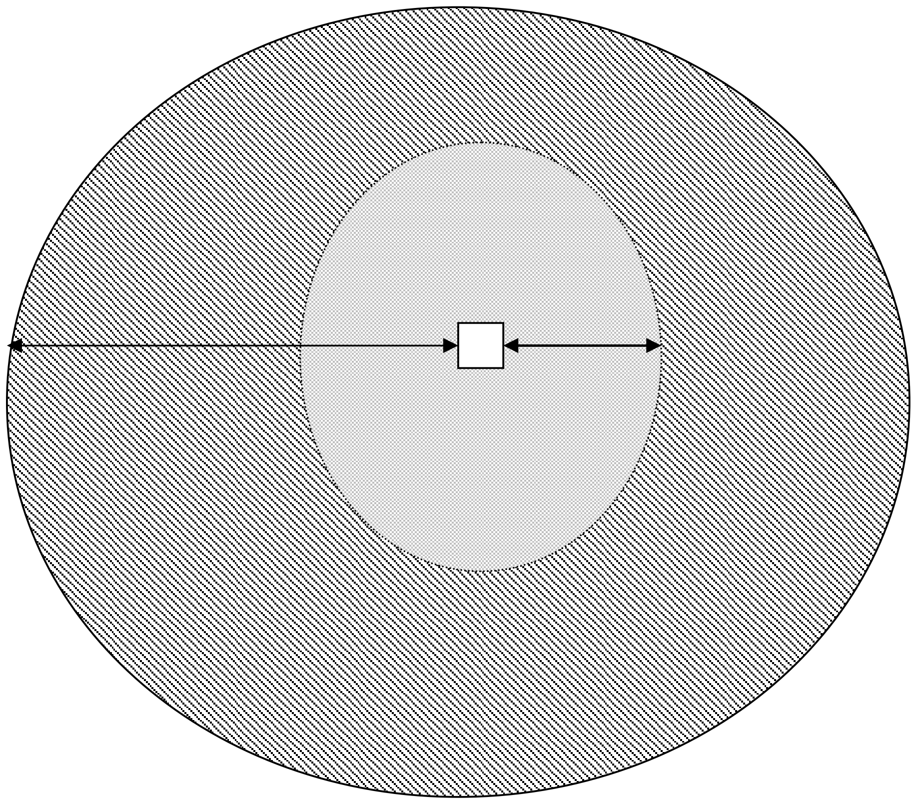


Figure 3: Microhabitat and landscape selection scales**.** *Box =nest tree; Small circle=microhabitat selection (20 m radius); Large circle= Landscape selection scale (2km radius).*

Roost trees/ Behaviour

During the months of October to December 2003, February, April to June and September 2004, I observed 6 NGHE fledglings to obtain data on their behaviour. One of the fledglings had to be habituated for two weeks, due to it being very elusive and was difficult to observe. Observations of the young during this time involved locating the NGHE young and recording calls for 10 minutes on an hourly basis and recording all the types of behaviour undertaken during the period of observation. With behaviour of the NGHE I also pooled together data collected by trained local assistants from 3 years of monitoring work on the NGHE.

I located roost trees by following harpy eagles as they moved about and tagging the trees that they sat on and exhibited some kind of behaviour, whether this was calling or just being stationary. I later returned and made measurements on these trees (See Appendix 3).

STATISTICAL METHODS

I used t- tests (for continuos variables) and Chi-squared and G-tests (for discrete variables) to investigate the differences between nest vs. random trees and nest- sites vs. random microhabitats and roost trees (Sokal and Rohlf 1969). All variables were tested using Statistix Software package (Statistix 8 2003).

RESULTS

Nest

Nests of NGHE are built on existing clusters of epiphytes and moss (Figure 4a and 4b). The NGHE nest does not show the typical nest structures of other eagles where nests are huge and composed of small twigs and branches with the interior of fur, feathers and grass and sprigs. However it places twigs and branches on existing clusters of epiphytes and moss. The NGHE may line its nest with leaves (local informants, pers. com.), however this was not seen in some of the nests climbed (M. Gilbert, pers. com, pers. obs.). Due to the nests been inactive for some time leaves may have been blown away by wind. Five of six of the nests of the NGHE were on horizontal branches at an average of 3.1 m (N=6) away from the main tree trunk and 1 nest was between branch crotches against the tree bole. Four nests of the NGHE were between branch crotches while the other two nests were just placed on horizontal branches.

Figure 4a. Photograph showing NGHE nest.

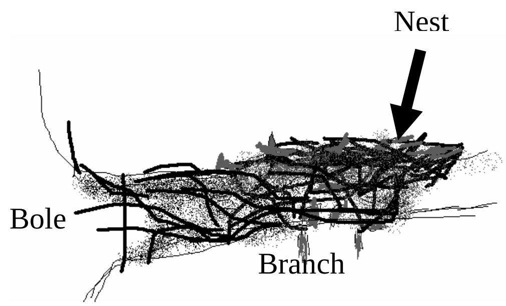


Figure 4b. Illustration of a typical NGHE nest.

Nest and random trees

Six nest trees were located and measured during the period of the study (Table 1). *Syzygium* species was mostly selected and used as nest trees (N=3, see Table 1). All nest trees were emergents and straight boles (Table 2). NGHEs appear to be placing nests in trees with greater DBH (t=4.21, P=0.0056, see Table 2) and height (t=5.44, P=0.0004, see Table 2) compared to random trees. NGHEs were also selecting nest trees based on the height of first branch (t=2.62, P=0.0390, see Table 2). Nest height was also significantly different when tested against suitable nesting branch heights of random trees (t=8.65, P<0.001, see Table 2). Proportion of nest height against tree height was significant (t=7.81, P<0.001, see Table 2). Canopy cover 1m uphill from tree base was not significant.

Table 1: The families and species names of nest trees (N=6). The nest tree numbers are also shown. Certain nest trees have only genus names shown.

Nest tree number	Family name	Genus name
NT01	Theaceae	*Eury* c.f. *roemeria*/ *E.acuminata*
NT02	Xanthophylloceae	*Xanthphyllum*/ *Drapetes* c.f. *lasiogynoides*
NT03	Myrtaceae	*Syzygium* spp
NT04	Myrtaceae	*Syzygium* spp
NT05	Meliaceae	*Aglaia argeatea* Blane
NT06	Myrtaceae	*Syzygium* spp

Table 2: The mean, standard deviation and range of nest and random trees.

RNTH refers to relative nest height against tree height and CC refers to the amount of Canopy Cover. Asterisks mark parameters that were significantly different. Parameters not marked were not significant.

Variables	Nest tree (6)			Random trees (48)		
	Mean	SD	Range	Mean	SD	Range
DBH*	83.13	20.40	66.7- 111.4	46.97	14.38	19.8-73.4
Tree height**	35.5	3.39	30-40	26.77	5.60	15-35
Lowest branch height*	22.66	5.35	115-30	16.65	4.84	8-26
Nest height**	29.66	3.72	30-35	10.90	10.72	-
RNTH	85.03	4.57	80-92.11	39.12	38.65	-
CC						
- under nest	88.5	4.83	80.5-93.24	-	-	-
- 1m uphill from tree base	88.3	2.58	84.66-91.68	89.92	3.84	72.44-94.54
Bark characteristics*	2.5	0.55	-	1.54	0.62	-
Lianas	1.17	0.82	-	1.46	0.85	-
Epiphytes						
- Crown	3	0.63	-	1.56	1.32	-
- Bole	1	0.63	-	1.08	0.85	-
Accessibility*						
- Easy	0.67	0.52	-	0.13	0.33	-
- Moderate	0.33	0.52	-	0.56	0.50	-
- Difficult	0	0	-	0.31	0.47	-
Disturbance*						
- Manmade	6	9.19	2-24	1.31	2.54	1-11
- Natural	6.67	6.62	1-18	5.29	3.43	1-14

*P<0.05
**P<0.001

Table 3: Variables measured at NGHE nest trees and random trees shown as percentages. TT refers to the tree type (i.e. emergent, canopy and sub canopy), BT refers to the bole type (i.e. straight or inclined bole) and CS is the tree crown shape. Asterisk marks parameters that are significantly different. Parameters not marked were not significant.

Variables	Nest trees (N=6)	Random trees (N=48)
	Percentages	Percentages
TT**		
- Emergent	100	29
- Canopy	-	56
- Sub canopy	-	15
BT		
- Straight	100	69
- Inclined	-	31
CS		
- Oval	17	48
- Irregular	50	27
- Cone	-	8
- Table	33	17

**P<0.0001

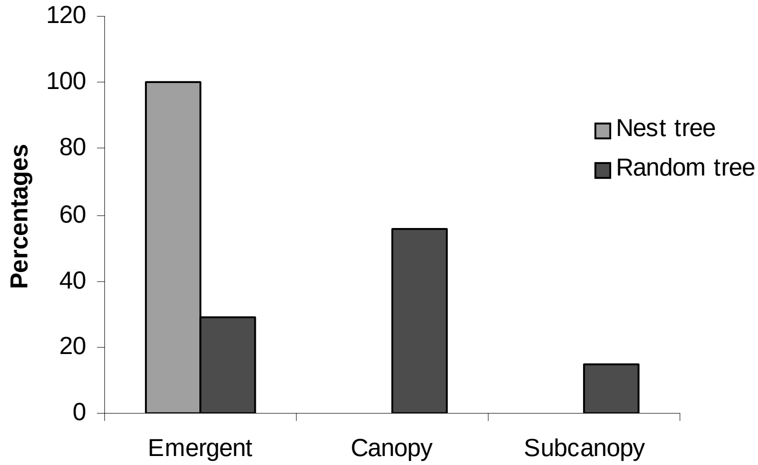


Figure 5: Tree types of nest (N=6) and random trees (N=48). All nest trees were emergents whereas with random trees, tree types were either emergent, canopy and sub canopy trees.

All nest trees were emergents (100%, N=6, see Figure 5), yet only 29% of random trees were emergents (N=48, see Table 3). A significant result was obtained when nest trees were compared with random trees (G=10.17, P=0.0006, see Table 3). Bark characteristics and accessibility to the nest tree were also significant (G=7.14, P=0.0068; G=7.82, P=0.020, see Table 2) but a larger sample size of nest trees is needed to make this test to be robust. Disturbance at the nest site was also significant (G=22.13, P<0.05, see Table 2). All other variables were not significant (see Table 3 and Table 2).

Table 4. The mean, range and standard deviation of micro- habitat variables.

Continuos variables are denoted with a C and discrete variables with a D.

Variables	Nest trees (N=6)			Random microhabitats (N=24)			Variable type
	Mean	SD	Range	Mean	SD	Range	C/D
Distance to rivers (m)	102.83	66.96	12-200	70.3	97.58	3.4-400	C
Distance to ridges (m)	186.67	188.22	10-500	88.45	100.90	7-300	C
Canopy cover above river							
- Closed (%)	0.83	0.41	-	0.75	0.444	-	D
- Open (%)	0.17	0.41	-	0.5	0.889	-	D
Width of rivers (m)	4.93	5.86	1-16	6.8	5.57	1-20	C
Location of tree							
-on slope (%)	100	-	-	100	-	-	D
Slope (^{o})	25.33	12.04	8-42	31	15.42	2-58	C
Slope position							
- Base (%)	0	-	-	0.35	0.49	-	D
- Middle (%)	0.83	0.41	-	0.6	0.50	-	D
- Top (%)	0.16	0.41	-	0.05	0.22	-	D
Distance to next canopy tree (m)	6.94	5.34	0.3-14.35	7.03	4.48	2-15	C
Number of trees >10 cm DBH	76.17	31.02	48-136	61.6	26.66	16-105	D
Number of over story trees	11.83	2.93	8-15	13.45	4.87	5-23	D
Aspect (^{o})	152	87.41	32-268	175.2	95.86	30-312	C
Amount of shrub layer	2.5	0.84	2-4	2.85	0.93	1-4	D
Amount of under story	2.5	0.84	2-4	2.5	0.89	1-4	D

Nest- site (Microhabitat Selection)

All nest trees were on slopes with a southerly or easterly aspect and were on average 103 m to the nearest source of water (stream/ river). Canopy cover above water was mostly closed, 83 % canopy closure (Table 4). There were significantly more trees greater than 10 cm DBH within 20 m radius of the nest tree than at random microhabitats around random trees ($G=92.881$ $P<0.001$). Nest trees were significantly located on sloping habitats than were random trees ($G=4.009$, $P=0.045$). All other variables were not significant (see Table 4).

Macro- habitat (general landscape)

The average amount of forested area within 2 km of the nest tree was 1536.8 ha. The percentage of area covered by forests within 2 km radius of the nest tree is 96 percent. Clearings in this area averaged 13.9 ha (an average of 1 percent of the 2 km radius) and water areas were 47.4 ha in average (a mean percentage of 3). The mean distance from the nest tree to the nearest forest track was 0.256 km. The mean number of permanent disturbances within 2 km of the nest tree was 9.4. The mean distance to the nearest source of water was 64.9 m. The mean distance of the nest tree to the nearest settlement was 6.17 km.

Roost trees

Fifty-nine roost trees were identified, tagged and measured during the period of the study (Table 5).

Table 5: Variables measured at roost trees (N=59). The mean, standard deviation (SD), range, percentages are shown. See Appendix 2 for definitions of variables.

Variables	Mean	SD	Range	Percentage
DBH	67.07	22.35	22.6-144	-
Height	27.71	6.25	15-45	-
Branch height				
- Horizontal	-	-	-	69
- Vertical	-	-	-	31
Tree type				
- Emergent	-	-	-	51
- Canopy	-	-	-	47
- Sub canopy	-	-	-	2

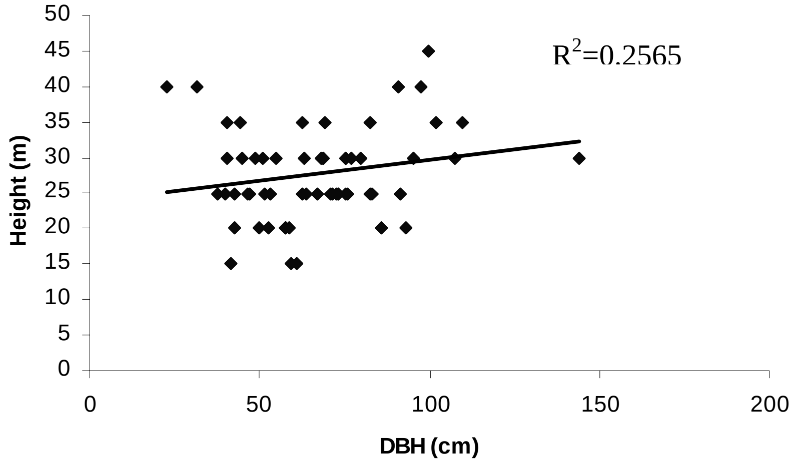


Figure 6: The heights and DBH of NGHE roost trees (N=59) showed a positive correlation.

There was a positive correlation (R=0.5065, N=59, P<0.001) between the height and DBH of roost trees (see Figure 6). The DBH of roost trees were categorised into different classes and statistically tested with trees from a 1 ha plot in Crater Mountain Wildlife Management Area, Papua New Guinea (Wright et al. 1997)(see Figure 7). NGHEs more frequently roosted in trees between 40-60 cm DBHs than in trees above or below this DBH class (see Figure 7). NGHEs preferred this DBH class of trees rather than randomly selected roost trees (G=202.26, df=2, P<0.001). NGHEs roosted more often on horizontal branches than on vertical branches (χ^2=10.75, df=1, P<0.05) (Figure 8). NGHEs were also roosting more often on emergent and canopy trees than on sub canopy trees (χ^2=26.67, df=2, P<0.05) (Figure 9).

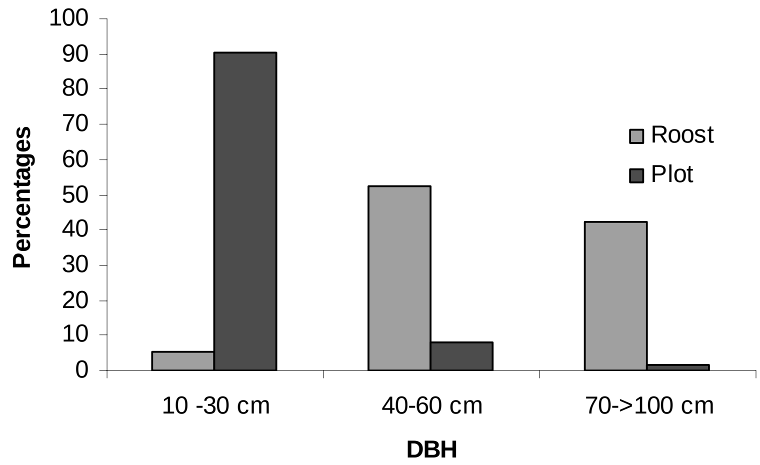


Figure 7: DBH classes of roost trees (N=59) in comparison to size- class density of trees >10 cm (N=693) in a 1 ha plot in Crater Mountain Wildlife Management Area (Wright et al. 1997). Roosts trees are denoted as roost in the legend while trees in the 1 ha plot are denoted as plot.

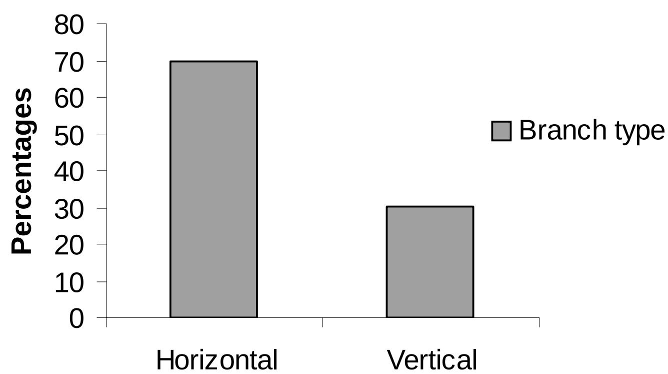


Figure 8: The branch types used by NGHEs on roost trees shown as percentages**,** N=59. Branch types used by NGHEs as roosting branches are shown as horizontal and vertical branches.

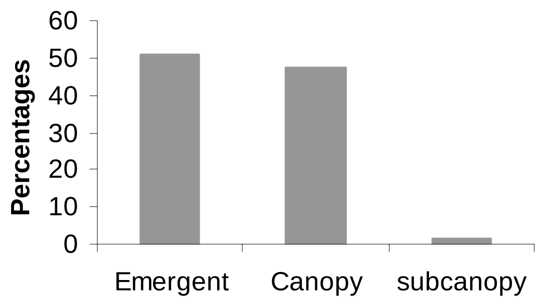


Figure 9: The tree types given as percentages that are selected by the NGHEs as roost trees, N=59. Tree types used as roosting trees by NGHEs were either emergents, canopy or sub canopy trees.

Behaviour

During the period of the study 6 NGHEs juveniles were observed exhibiting various behavioural types. Behavioural data were also pooled together from 3 years of monitoring data (1999-2003) and are presented in different categories below.

Breeding

No breeding behaviour was observed in the adults due to the difficulty of prolonged observation of these elusive birds. At all active nest sites visited I encountered only paired adults with one juvenile. Clutch size of the NGHE at this stage is unknown due to lack of sufficient data, but in these six cases it appeared only one young typically fledges per nest.

Calls

Calls of the NGHE were of two types, confirming the observations of Watson and Asoyama (2001). The first type is the plucked bowstring type call, "uumh" often associated with the adult birds. The other call is the "uhk uhk" type (sounds more like a hiccup) that is frequently given by the juvenile. The adults sometimes exhibit the two call types as a duet. Duet calls sounded more like "uumh uhk uhk". Calls of the NGHE were evenly distributed throughout the day (Figure 10).

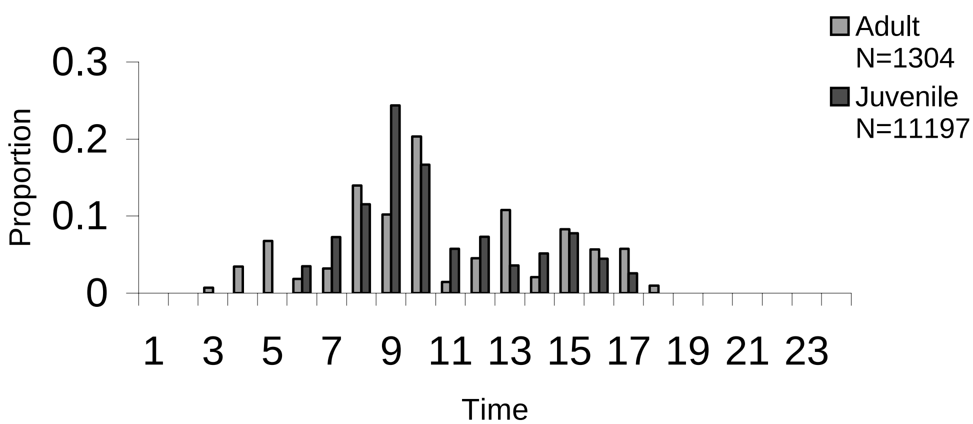


Figure 10: Proportion of adult and juvenile NGHE calls by time of day. All calls of NGHEs recorded during the study were separated into both juvenile and adult calls and graphed by time of day.

Plucked bowstring calls were given at a very low frequency. Low frequency calls from adults were observed on three occasions to result in the juvenile flying to the adults and feeding on prey left there by the adults. Such calls sometimes begin at dusk the previous day then stopping and starting again the following morning.

When the NGHE juvenile is calling it sometimes stops and searches the ground below then continues calling again. During such calls the juvenile at times faces one direction to make one note, and then turns its head to the other direction to make the other note in a series of long calls. To call the NGHE juvenile tilts its neck upright aligning its head with the tail and opens its mouth in a gulping motion resulting in sound being emitted.

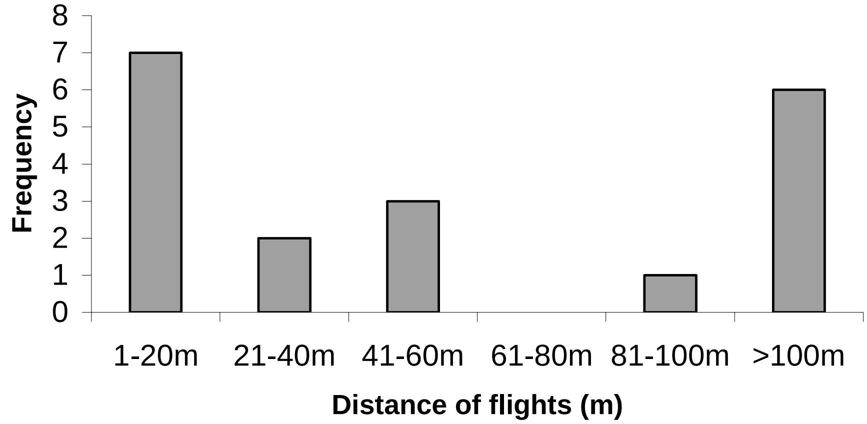
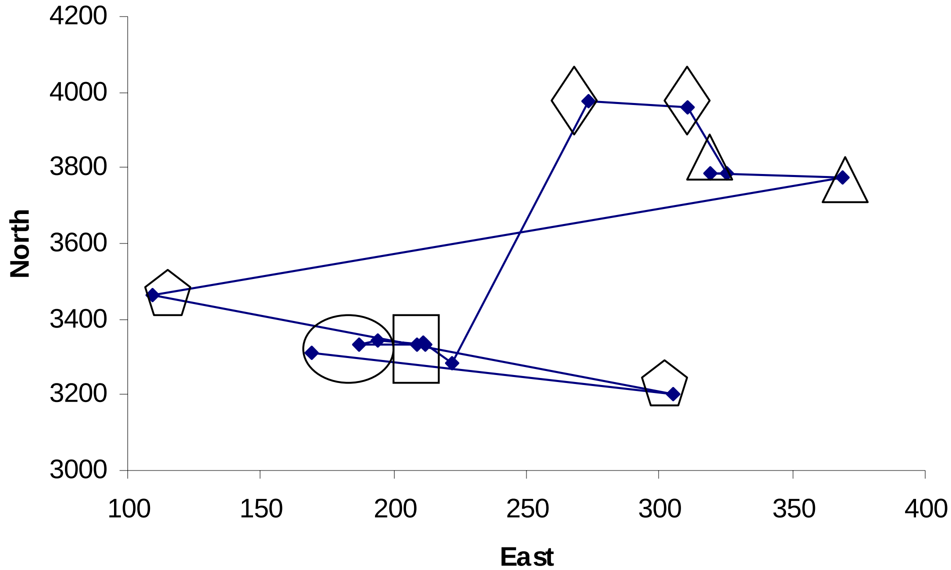


Figure 11: Flight distances of NGHE between roost trees in distance classes. Nineteen sequential flights were recorded during the study.

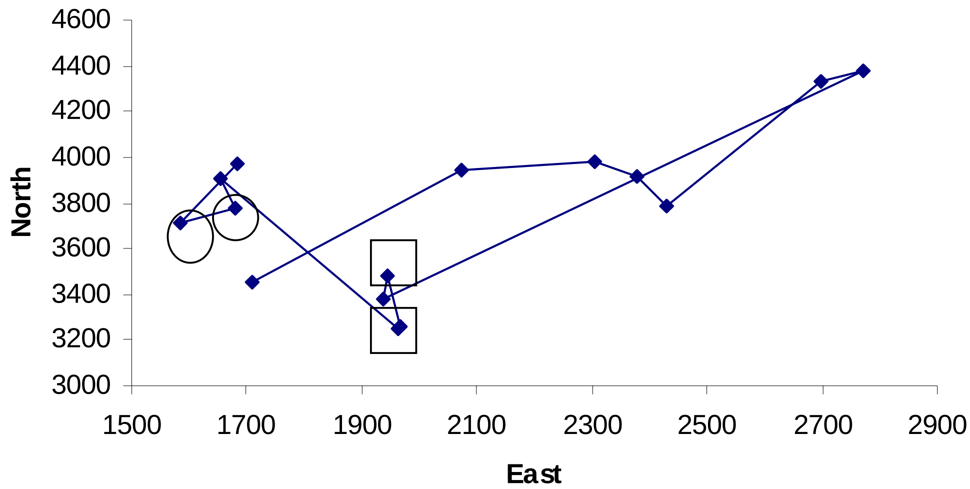
Flight patterns

Most of the flights observed during the period of the study were of the juvenile NGHE. Nineteen sequential flights of the juvenile NGHE were observed and distances measured between these roost trees (Figure 11). Six of these flights were greater than 100 m (out of this 6, 2 were more than 200m). The smaller number of sequential flights (See Figures 12A, B, C, D and E) between roost trees is due to weather conditions affecting observations of NGHE juveniles over consecutive days. In all of the observed flights of both the juvenile and adult NGHE, no soaring was observed. Flights of the adults were observed but due to thick foliage, it could not be determined whether such flights led to hunting or they were just search flights or in between flights to perches.

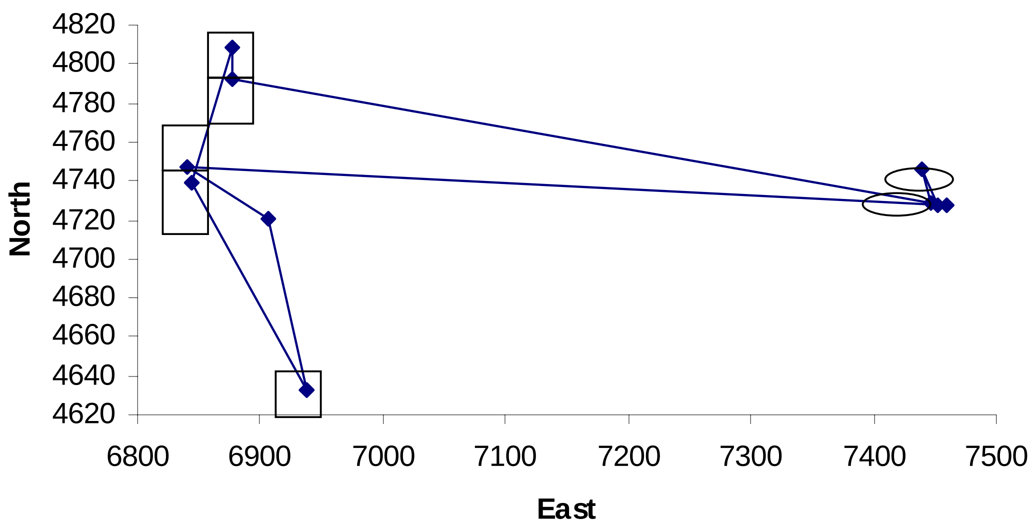
A. Fulene nest site



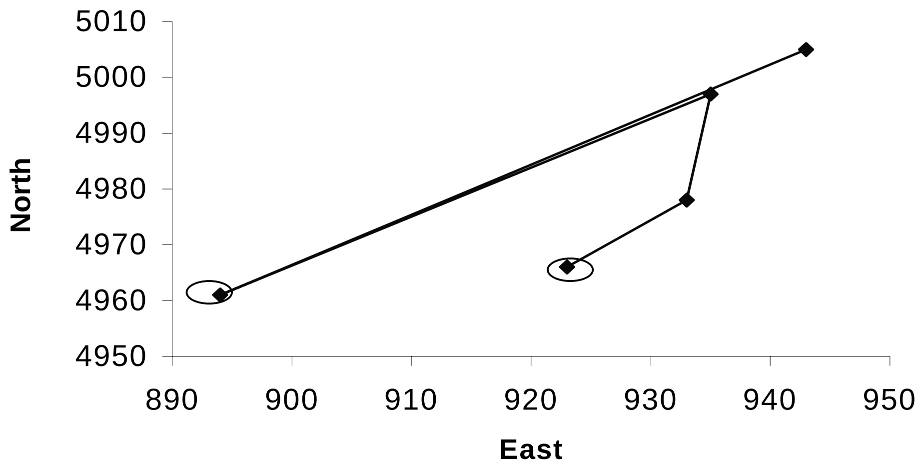
B. Hekwaijoalapi nest site



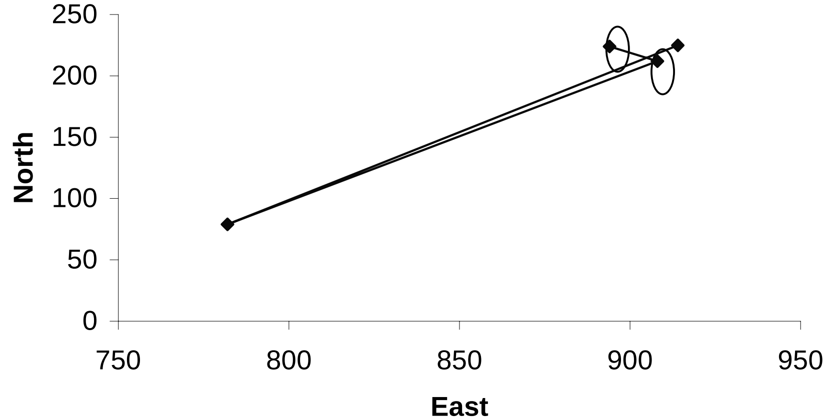
C. Imanabenetai nest site



D. Ubaigubi nest site



E. Uluae Jorapi nest site



F. Hegoaguvelai nest site

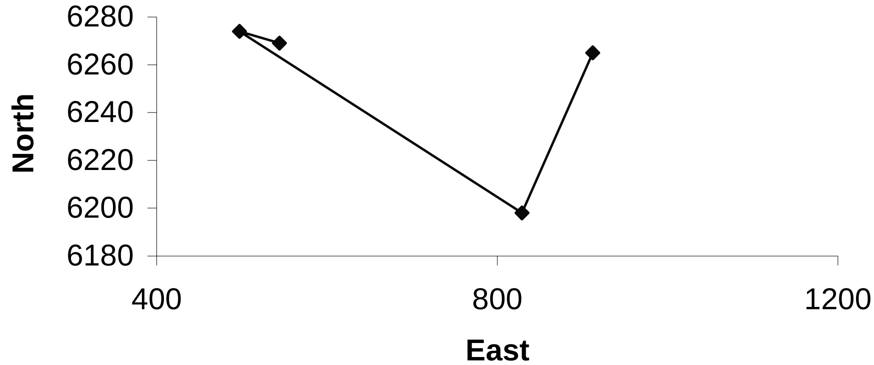


Figure 12A, B, C, D, E and F: Fledgling movements around five nest sites. All points indicate GPS fixes of roost trees. *The different shapes indicate sequential movements (a shape appearing more than once at a nest site indicates movement between such points).* All movement was over a day except for nest site E that was over two days. **Daily home ranges** (Home Ranger Software, Hovey 1999)**: A=** 85.189 ha, **B=** 485.615 ha**, C=** 65.138 ha**, D=** 1.528 **ha, E=** 32.467 **ha, F=** unable to obtain home range due to small number of points (No sequential movement of NGHE juveniles were observed at this site).

Hunting and feeding behaviour

No hunting behaviour of the NGHE was observed during the period of the study. On one occasion a juvenile NGHE was observed poking its head into the cavity of a tree, which it rapidly flew to from a roost tree from which it was observed calling early on. Once on the tree the juvenile was seen poking its head into a cluster of epiphytes that were growing between two adjoining branches. The juvenile NGHE also pushed its claws into holes in the clustered mass. The juvenile then moved to another side of the tree and carried out its searching using its feet and head. After some time the juvenile just gave up and flew off without making any kill. I did not see what the juvenile was chasing, but from the excited behaviour of the juvenile it looked like there was a hidden animal among the clusters of epiphytes. An adult NGHE was also observed searching among epiphytes in the canopy, running along branches and hopping from branch to branch (A. Mack, pers. com.).

During the period of the study it was observed that once a prey is killed the feathers, fur and gut of the animal are removed before the prey is carried to a tree to be consumed. I did not observe any consumption of prey on the ground. On three separate occasions the gut remains and fur of mammals were observed near tree bases that were hollow and covered in epiphytes. Snapped twigs and scattered debris indicated signs of struggle, which may likely be that the NGHE hunted its prey by extracting it from the base of the tree and killed it there.

Feeding of the juvenile was infrequent and at times there was no feeding for up to two days. However at a particular nest site where the juvenile was observed when it was about a year old, feeding occurred nearly every day. A month (February 2002) later the juvenile was observed feeding daily and the adults were constantly nearby keeping watch. The following month (March 2002) the juvenile was observed being fed after every second day.

Prey items included mammals, birds and reptiles. A total of 30 prey items were collected from around nest and roost trees. Mammalian prey made up 70 percent of NGHE diet, while avian prey made up 23 percent and reptiles the remaining 7 percent. *Phalanger* species were the main prey item (50 %) consumed by NGHE (Figure 13).

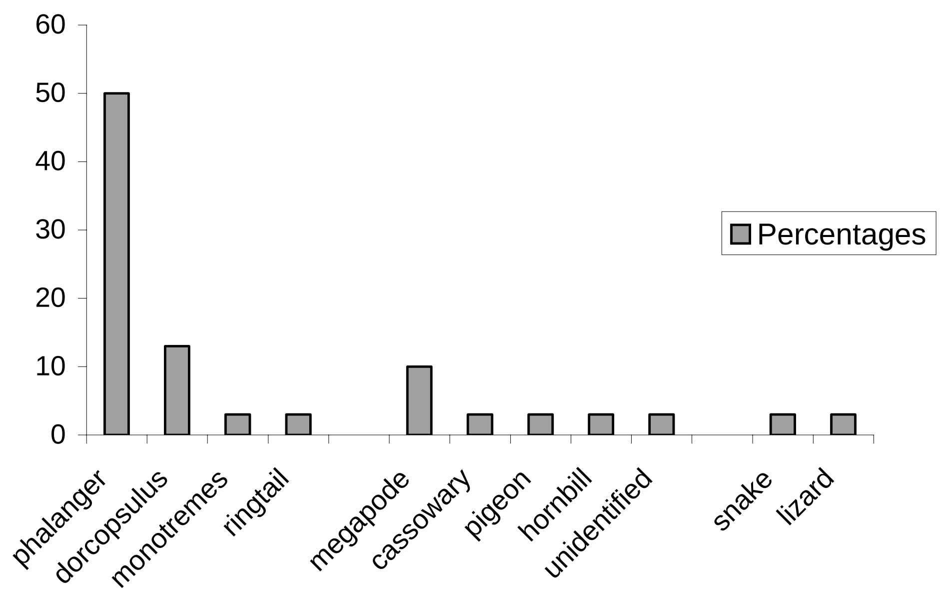


Figure 13: Prey items (N=30) of the NGHE collected during the period of the study. Prey items are classed as species and shown as percentages of the total number of prey items collected.

Table 6: The percentage (%) and standard deviation of 10 behavioural types exhibited during 190 different observational days. **PREEN**= *cleaning of feathers with beak,* **Search=** ***sit on branch and looks around,*** **Tuck=** *lifts leg and tucks under breast,* **Scratch=** *ruffle crown feathers with claws,* **Feeding, Stretch=** *stretches wings and legs,* **Motion=***any movement on branch of tree,* **Stationary=** *just sitting there looking around without moving legs or wings except head,* **Calls, Defecation.**

Behavioural types	Percentages	Standard deviation
Preen	7.4	0.405
Search	8.5	0.853
Tuck	2.3	0.732
Scratch	4.0	1.257
Feeding	6.5	1.922
Stretch	6.8	2.358
Motion	17.6	3.508
Stationary	17.8	4.010
Calls	26.2	4.023
Defecation	2.8	2.704

Daily behaviour at roost trees

Data of behavioural observations collected during the study and pooled together from 3 years of monitoring work was used. All behavioural types were separated into ten categories (Table 6).

Calls were the most frequent behaviour exhibited by NGHEs at perches, followed by just being stationary and also movement along tree branches (see Table 6). NGHEs also searched and preened feathers while at perches and also exhibited other behaviour at perches (see Table 6).

DISCUSSION

Nests

New Guinea Harpy Eagle (*Harpyopsis novaeguineae*) nests are somewhat different to that of other Accipitridae species, in this case eggs are laid on nests that have been built on existing clusters of epiphytes and moss and not on nests entirely made out of twigs and branches (M. Gilbert, pers. com, pers obs.) (Figure 4a and 4b). The Harpy Eagle (*Harpia harpyja*) of the Neotropics, presumed to be a close relative of the NGHE builds nests from twigs and sticks (R. Piana, unpublished data), sticks sometimes as large as 5.1cm in diameter and 1.2m in length (Rettig 1978). Sprigs (both dry and green) are then added to this existing material (Rettig 1978). Aumann (2001a) found the raptors in his study area to use stick nests. The minimal useage of twigs and branches by the NGHE in nest construction may likely be a tactic to avoid predators whereby the NGHE makes use of existing structures like the clusters of epiphytes and moss that blend in well with the environment thus aiding in camouflaging the nests. The long- eared owl *Asio otus* uses a somewhat similar strategy but instead of building nests it resorts to using old corvid nests that have been built in coniferous trees, due to coniferous trees having more foliage (helps in camouflaging the nest) than deciduous trees that are just starting to leaf in spring and do not have much foliage (Tome 2003).

Nests of NGHEs were also being placed at greater heights (see Table 2). Brown Goshawks were also found to place nests towards the top with a proportional (nest height above ground/ nest tree height) mean of 73 percent (Aumann 1989). Higher placement could be associated with avoidance of climbing predators (Newton and Marquiss 1976; Sharp et al. 2001).

Nest tree

Nest trees of NGHE chosen were mostly those of the hardwood species (see Table 1). Selections of nest tree vary in terms of species and at this stage it cannot be ascertained whether NGHEs select certain species, until further studies are done.

Nests of NGHEs are in trees that are emergents, with greater DBH and height compared to random trees (see Table 2). Nest trees were all straight boled, however when tested against random trees there was no significant difference. This could be due to the smaller sample size of nest trees. The Harpy Eagle of the Neotropics is also known to select emergent trees to build its nests above the rainforest canopy (Alvarez-Cordero 1997). Aumann (2001a) found similar results for ten raptor species that he studied during a three-year period. The raptor species chose trees that were taller, of a greater girth and more foliated than other trees that were generally available in those habitats (Aumann 2001a). Penteriani et al. (2001) in a study on goshawk nest- site selection also found that goshawks selected nest trees based on high DBH and high crown cover.

Canopy cover of nest tree 1m uphill from base of tree was not significantly different when compared with canopy cover of random trees. This is true for the area where much of the forest floor remains dark most of the time with less light reaching the forest floor. The higher number of over story trees greater than 10 cm DBH (see results under Microhabitat selection) confirms this result.

NGHE nests were also placed on horizontal branches and were much higher than suitable nesting branches found in random trees. The Harpy Eagle of the Neotropics uses horizontal branches also when building nests (Alvarez-Cordero 1997). Horizontal branches provide the developing chick (Harpy Eagle, *Harpia harpyja*) with comfortable paths for movements during the last three months of development (R. Piana, unpublished data). Aumann (1989) found Brown Goshawks to sometimes build nests in forks of horizontal or sloping branches.

The high useage of horizontal branches in nest trees are important to NGHEs for the protection and safety of the juvenile. Horizontal branches may be used for caching prey by the NGHE adults and also to ensure that the juvenile has enough space to move around and not fall off the nest tree. The NGHE has been observed to return later to prey that it fed on previously but did not complete eating. Caching of prey has been observed in raptors like the Brown Falcon, where the remains of larger prey are cached to provision the offspring throughout much of the day (McDonald 2004).

The high man- made disturbance around nest trees (see Table 2) may have likely resulted from early visits to the nest site by people and local research assistants, thus the results may not be significant though analysis show a significant result.

Easy accessibility to the nest may be associated with easy movement of prey to the nest and also for easy transport of large sticks to the nest (Shultz 2002). It could also ensure easy visibility of the nest tree by the parents for safeguarding of the juvenile. Easy accessibility to nest trees was found to be a significant variable of the Crowned Hawk- Eagle (*Stephanoaetus coronatus*) when selecting nest trees (Shultz 2002).

The medium bark characteristics found on nest trees indicate that nest site selection by the NGHE does not favour climbing predators by selecting for trees that do not have a very rough bark, it also is not selecting trees with very smooth bark which would be safer from climbing predators. Thus this selection could be based on another factor and not predation, however a larger sample size of nest trees is needed to confirm this result

Microhabitat

All nest trees of NGHEs were located on slopes with a southerly or easterly aspect that could be associated with maximising updrafts when flying away from the nest (Table 4). This behaviour has been observed in the Harris's Hawk where it selected physiographic features that favoured the presence of updrafts (Jimenez and Jaksic 1993). Other explanations for such positioning include better shading, lower evaporation rates and better protection from solar radiation (Aumann 1989). Though nest placement might be to take advantage of prevailing winds, better protection from solar radiation and also for better shading, this cannot be associated with the NGHE until further studies are done.

The greater number of trees with greater than 10 cm DBH may be associated with concealing the nest tree (Table 4). This could be a tactic to confuse predators from identifying which is the nest tree. Giese and Cuthbert (2003) found similar results in woodpecker nest tree selection, where nest trees are surrounded by a high number of potential nest trees that might reduce predator efficiency. They also suggest that a high number of trees surrounding the nest tree may also be important habitats for prey. However this cannot be associated with NGHEs due to NGHEs hunting over a large area and probably not so much as around the nest.

Macro habitats

Macro habitats typically had large amounts of forest cover, small area of clearings and had fewer disturbances in the area. These results are similar to those found in the goshawks studied in Germany where occupied nests had more forested areas (Kruger 2002). Martinez et al. (2003) also found that the Eurasian Eagle Owl (*Bubo bubo*) selected nesting cliffs that had high percentages of scrubland cover surrounding them.

Longer distances of the nest tree to the nearest forest track ($\bar{x}$ =0.256 km) was also typical of the macro habitat selected by the NGHE and may be associated with secretiveness. Kruger (2002) found similar results in the goshawks. Goshawks preferred deep and very remote forest patches that were far from human disturbances (Kruger 2002).

Proximity of the nest tree to streams ($\bar{x}$ =0.0649 km) on the macro habitat scale could be associated with early warning of intruders or a local concentration of prey (Aumann 1989). However this result could differ at the microhabitat scale (see reasons stated under micro habitat selection above). The NGHE may also be avoiding people by building nests away from rivers where people are likely to travel.

Greater distances between the nest trees and permanent human settlements may be associated with NGHEs avoiding humans. Local informants indicate that in the past hunting of NGHEs was a common practise. This however has changed after the area was gazetted as a wildlife management area. Thus the greater distances of nest trees to permanent human settlements could be associated with other factors rather than avoidance of humans, however a greater sample size is needed to confirm these results. The Harpy Eagle of the Neotropics has been observed to nest 90 m away from a national road and in 1998 the road was rebuilt but this disturbance did not affect the normal development of the juvenile (R. Piana, unpublished data). This may just be a one off case because human infringement and developments into the habitats of Harpy Eagles (*Harpia harpyja*) are the major cause of decline in Harpy Eagle populations (Alvarez-Cordero 1994; Alvarez-Cordero 1997).

Roost trees

Roost trees with greater girth (DBH) and height could be associated with NGHEs selecting roosts that provided perches that were wide enough to ensure prey are safely placed during feeding. Relatively adult NGHEs by placing prey in roosting trees with greater girth and height ensure the juvenile is able to find such prey and feed on this prey without having to carry the prey to another tree that had similar advantages because the juvenile at this stage may not be able to carry such heavy prey to another tree or there is the risk that it may injure itself by carrying it to a suitable tree to feed without being disturbed by predators.

Selection of horizontal branches over vertical branches as perches could be associated with horizontal branches having a wider area for safe keeping of prey while feeding and also for caching prey (Aumann 1990; McDonald 2004) (see Figure 8). Roost trees were more often canopy trees than emergents or sub canopy (Figure 9). Such selection could likely be based on the notion that a higher perch offers good visibility down to the forest floor that could serve as a lookout for prey and also to watch out for predators. In addition higher perches could likely be good vantage points for calling and listening, however this may likely be for other purposes other then calling and listening stations. Aumann (2001a) indicates that more foliated trees aid in concealment and also shading. More studies are needed to confirm whether NGHEs are using emergent and canopy trees as roosts for shading and concealment purposes.

Calls

NGHEs called throughout much of the day, indicating that NGHEs are at least vocally active throughout the day. This finding supports other previous studies where most calls were recorded during the day (Schulz 1987; Watson and Asoyama 2001). However the results from this study differ from the study done on Mt Missim, Morobe Province, in that calls do not produce a bi modal distribution but are evenly distributed through out the day (Schulz 1987). This might be due to a larger sample size in this study.

Watson and Asoyama (2001) describe a "chuck chuck" call and a call similar to the noise produced from a plucked bowstring. Diamond (1972) describes the plucked bowstring call as a "bung" type call, while Beehler et al (1986) describes a low staccato "uumpph" or "okh" note. I identified "uumh" calls that could be the plucked bowstring call described by Diamond (1972) and Beehler et al (1986). The "ohk" and "chuck chuck" calls described in Beehler et al (1986) and Watson and Asoyama (2001) can be identified with "uhk" call that I describe in this study. More often the adults gave the "uumh" type call at a low frequency. The juveniles observed during the study mostly gave the "uhk uhk" type call. This type of call was often at a higher frequency and could be easily heard. Watson and Asoyama (2001) indicate the call to have a high frequency of 1400- 1600hz compared to the plucked bowstring call that was at a low frequency (<500hz). High frequency calls by juveniles could be associated with calling to adults. This could also be the only sound the juvenile is able to make with the immature vocal cords that it has and may possibly be an immature version of the plucked bowstring call, in this case, the "uumh" call. Watson and Asoyama (2001) indicated that low frequency calls by the adults could be territorial calls, however throughout this study, territorial behaviour was not observed in the birds due their elusive nature. Lower frequency calls would travel further than higher frequencies, thus they might be better for long distance communication between adults while the higher frequency calls are for short distance between juveniles and parents. Until further studies are done NGHEs cannot be said to be territorial birds and the roles of these vocalizations remains unclear.

Duetting was also observed in the NGHEs. The adults gave the "uumh" and "uhk" calls in a combination. This behaviour was also observed in the Brown Goshawk (*A. fasciatus*) (Aumann 1988a). Aumann (1988a) also observed that duetting sometimes occurred after copulation in the Brown Goshawk. The adult Harpy Eagles of the Neotropics have also been observed duetting, with the female calls being pitched differently to that of the male (Rettig 1978). Whether such calls are territorial in nature or are advertisorial calls by the parents (NGHEs) of their whereabouts or calls emanating after coitus, more research is needed to confirm this.

Flight

NGHEs exhibited mostly short flights that were between perches. Watson and Asoyama (2001) observed very similar flights. Kenward (1982) also found Northern Goshawks (*Accipiter gentilis*) to exhibit similar flight patterns. Only 6 flights were greater than 100m. Watson and Asoyama (2001) also found that most flights of the NGHEs were less than 100m (only 4 were greater than 100m). This could possibly be an indication that the NGHE more often exhibits short flight patterns and undertakes longer flights only when necessary, for instance crossing a ravine. Such behaviour could be associated with hunting or avoiding predators. A shorter flight between perches results in that area being thoroughly searched for prey and at the same time tree cover provides better concealment from predators. Aumann (2001b) found similar behaviour in the Spotted Harriers.

In addition to short stay perch flights, the NGHE was not observed soaring. Watson and Asoyama (2001) indicated that this behaviour is associated with the wing loading of the NGHE, which in this case was 1.3 times greater than values obtained for other soaring eagles. Gamauf et al. (1998) also found that lower wing loading was associated with raptors that exhibited active flight hunting mode, for instance soaring hawks. The inability of NGHEs to soar may be due to the habitat in which they are found. The thick forested area in which NGHEs are found restrict movement, hence movement through the area is possible by undertaking shorter flights. Thick canopy cover when foraging by soaring could hinder visibility thus this may be the reason behind NGHEs not using soaring flights to forage but instead resorting to shorter and perch hunting flights (Watson and Asoyama 2001).

Daily home ranges of NGHEs on average were estimated at 134 ha (Figure 12). This is much smaller compared to the estimated home range given by Watson and Asoyama (2001). The daily home range in this study was obtained from roost trees of the NGHE and sequential movements of the juvenile, which resulted in a smaller mean value. Home ranges of the Harpy Eagle of the Neotropics are said to be at least several thousand hectares. Thiollay (1998) found hawk eagles and serpent eagles on islands smaller than 1 km^2. Some pairs were also found to range over two or three small islands (Thiollay 1998). True home ranges of NGHEs at this stage cannot be realistically determined until radio telemetry studies are done on the NGHEs.

Breeding, feeding and hunting behaviour

Clutch size of the NGHE is not known and throughout this study no observations on breeding were made. However the number of offspring observed during the study with adult pairs was one. Little Eagles successfully raised one young per successful nest (Aumann 2001a). Aumann (2001a) observed that smaller species (like the Collared Sparrowhawk, the Australian Hobby and the Nankeen Kestrel) had 2- 3 young per successful nest while on the other hand the larger species (like the Little Eagle, the Black- breasted Buzzard and the Whistling Kite) had fewer young per successful nest, in this case one. This may be associated with longer period of time for young to fledge, hence offsetting or delaying breeding in the larger species (Aumann 1988a). Smaller offspring numbers in the NGHE could mean that the adults cannot afford to raise and feed more than one young including themselves, thus opting for one and delaying breeding till the juvenile is independent.

The NGHE hunts by either extraction of prey from tree cavities or on the ground floor. They also hunt by searching along mossy branches and in clusters of epiphytes and moss. Peres (1990) observed a Harpy Eagle (*Harpia harpyja*) successfully capture an adult male Red Howler Monkey (*Alouatta seniculus*) by soaring low over the canopy and hitting the monkey. Eason (1989) observed Harpy Eagles of the Neotropics to use forest edges and patches of open forests to undergo hunting. The Harpy Eagle of the Neotropics was also observed diving into the crown of a fruiting tree that was being foraged by several bird species from a tree perch (R. Piana, unpublished data.). Diving and attacking prey that is on the ground is also a tactic used by the Harpy Eagle of the Neotropics to hunt for prey (R. Piana, unpublished data). Ground hunting was also observed in the Brown Goshawk (*Accipiter fasciatus*) but this was only for first year birds (Aumann 1988b).

Avian and mammalian prey that are killed on the ground floor appear to be cleaned of their guts and fur/ feathers then carried to tree branches to be consumed. Aumann (1988b) observed Northern Goshawks to clean prey early in the breeding seasons when juveniles were not fully developed. However this ceased after the third week (Aumann 1988b). During the study juveniles (about > 1 year old) were observed to still continue to feed on prey that had been cleaned of fur and feathers. This removal of the fur/ feathers and gut could likely be associated with lightening the weight of the prey so that it could be carried to a tree branch to be consumed. The Harpy Eagle of the Neotropics have been observed to remove fur with a sideways pulling action of the beak (Fowler and Cope 1964). This however took place on a tree branch high up in the forest while the juvenile was feeding on the thigh of a monkey (Fowler and Cope 1964). Thus removal of fur could just be associated with cleaning prey before consumption and not lightening weight of the prey for easy carriage. More studies are needed to explain this behaviour in the NGHEs.

Consumption of prey during the study period was mostly observed to occur on tree branches. Observations of a NGHE killing a 6 kg tree kangaroo (*Dendrolagus matschiei*) in the Huon Peninsula (Papua New Guinea) show that the skin surrounding the skull had been removed and flesh/ meat around the skull consumed (G. Porolak, pers. com.). Thus the adult NGHE could possibly be consuming small parts of killed prey while on the ground. Debus (1984) and Calaby (1951) observed this behaviour in the Little Eagle, whereby the head and forequarters of lagomorphs were already eaten, before delivery at the nest. This could possibly be associated with lightening weight of prey for easy carriage.

NGHEs consume mostly mammalian prey (70 %), followed by avian (23 %) and reptilian prey (7%) (Figure 13). The Harpy Eagle of the Neotropics feeds primarily on arboreal mammals (cebid monkeys, sloths and procyonids) but occasionally takes terrestrial mammals like agoutis (*Dasyprocta agouti*) and fawns of brocket deer (*Mazama americana*) (Fowler and Cope 1964; Rettig 1978; Peres 1990). Aumann (1988a) observed that female Goshawks attacked mammalian prey more often than avian prey, which could be associated with females being larger (females, $\bar{x}$ =561g and males, $\bar{x}$ = 349g) in size than males thus they are unable to chase down more agile prey, hence fall back to hunting more slower prey, like mammals. However, such reasoning cannot be associated with this study due to the lack of data on body mass of NGHEs.

Mammals are more or less slower than birds and can be easily captured without exerting so much energy than trying to chase down and hunt avian prey. However, reptiles are even slower than mammals so why aren't the NGHE feeding more on reptiles? This could be related to the size of reptiles, in that reptiles are much smaller than mammals hence NGHEs would have to hunt more reptiles to obtain the necessary nutrients required or it could be associated with reptile availability.

Hunting and feeding on mammals is a better option, due to most mammalian prey killed by the NGHEs are slow and large in size thus frequent hunting is minimised. Barton and Houston (1993) indicated that large meals were digested more thoroughly than several small meals. However he also stated that large meals increased body weight thus affecting flight (Barton and Houston 1993). This may not be an issue with NGHEs due to shorter travelled distances.

Daily behaviour at roost

NGHEs searched more often when on roost tree than any other behavioural type (see Table 6). Searching at most times was accompanied with calls. This could indicate that NGHEs more often exhibit foraging and hunting behaviour than breeding. This could be associated with large size of the bird hence it needing more food. In addition such behaviour could mean that NGHEs with their large size cannot afford to breed on a yearly basis due to foraging being an expensive exercise and thus more time has to be spent searching for food to feed growing young. Since most of the behavioural data was from NGHE juvenile this could likely be behaviour that is associated with growth and thus this could possibly mean that NGHE juveniles need to be fed often.

The NGHE has been observed on one occasion to undergo allopreening (G. Druliner, pers. com.). Allopreening has been observed in one or more species of 19 different orders of birds and raptors are no exception (Tyne and Beger 1976). The Mississippi kite (*Ictinia mississippiensis*) has been observed to undergo allopreening (Botelho and Gennaro 1993). Juvenile kites mostly underwent allopreening and such behaviour was rarely exhibited (Botelho and Gennaro 1993). ”Allopreening can be regarded as a form of agonistic behaviour in which the normal tendencies of attacking or fleeing, when two individuals are in close proximity, are in conflict with sexual and opposing attacking and fleeing tendencies” (Tyne and Beger 1976). Such reasoning cannot be associated with the NGHE until further studies are done.

NGHE juveniles on average exhibit behaviour similar to other Accipitridae species (see Table 6). Ellis (1979) describes similar behaviour also in the Golden Eagle (*Aquila chrysaetos*). The juvenile Harpy Eagle of the Neotropics exhibits somewhat similar behaviour to the juvenile of the NGHE in that at 7 months old Harpy Eagle juveniles called frequently and were mostly found near the nest tree (Rettig 1978). This could possibly indicate ancestral traits that are common across Accipitridae species. At this stage commonly shared traits and adaptive traits of the NGHE cannot be possibly determined and needs more in depth research.

CONSERVATION ISSUES

The population status of the NGHE out in the wild remains unknown. Although this study has brought to light some of the biology and habitat requirements of the NGHE, much about its population status remains unknown. Whether populations are declining or remain stable is still unanswered. Cultural importance of the NGHE and the use of its feathers for traditional adornmentation could lead to substantial declines of the NGHE in the wild, at least in some areas where it is most hunted. With this cultural importance there is also the live animal trade and the sale of wildlife parts that may also contribute to declines in NGHE populations even in areas where it is not used for traditional purposes by landowners.

Logging and habitat destruction may also lead to declines in the NGHE populations out in the wild. The NGHE may be disturbance sensitive, as suggested by my results where there were NGHE nest sites in areas with fewer disturbances and also fewer human tracks and far from villages. However at this stage nothing is certain until further studies are done on disturbance and its effect on the reproductive success of the NGHE. We can be able to say more conclusively that NGHEs are disturbance sensitive if it is shown that reproductive success is lowered by disturbance.

The NGHE will make a good umbrella/ flagship species for conservation due to it selecting large areas and its affinity for undisturbed forests. Selection of such large areas of forests and more importantly undisturbed forests, by a single animal paves a very interesting and better option in conservation. Such areas could encompass many animal habitats thus safeguarding large habitats of the NGHE would result in at least some undisturbed areas being safeguarded and also the habitats and populations of other animals that are found within these areas.

CONCLUSION

The preliminary findings in this study indicate that NGHEs select emergent trees as nest trees and these trees are of the hardwood species that are highly valued as timber. NGHEs also select nesting sites in relation to certain micro and macro habitat variables. In addition NGHEs exhibit various behavioural types commonly found in other Accipitridae species. The lack of sufficient information on the behavioural biology, ecology and life history of the New Guinea Harpy Eagle hinders the proposition of management plans. Thus for a better and realistic management of NGHE populations, more research into the areas of breeding biology, ecology and life history of the NGHE must be undertaken. I hope that this study may inspire further research into the unique life of New Guinea Harpy Eagles and other birds of prey in Papua New Guinea.

ACKNOWLEDGEMENTS

Many thanks to Drs Andrew Mack, Debra Wright and Mr Ross Sinclair for providing logistical support and continuos advice in seeing this project to completion. I thank Professor Lance Hill for being my Honours supervisor at the University of Papua New Guinea, School of Natural and Physical Sciences. I am also indebted to Mr Paul Igag who taught me the techniques of rope climbing. The Peregrine Fund and Wildlife Conservation Society provided funding for this study. I thank the staff of Research and Conservation Foundation, staff of Peregrine Fund Library and students and staff of Wildlife Conservation Society- PNG Program for providing assistance whenever needed. Many thanks go the various Gimi landowners on whose land I worked, especially lapun Falau and Jacob Nemo of Ubaigubi; Nalex Hulisi, Armstrong Enemecio and Malijoba Yanaga (one of those very exciting old woman that I have ever met) of Tsomai; Avit Wako, lapun Hatwara, Iso Asoyama, Isacc Morimimo and David Sima of Herowana village. Finally to my two assistants Smith Asoyama and Amos Hatwara of Herowana village, what can I say but thanks, without you guys much of this project would never have been complete. Lastly to my mum, Orpah Florence A. Toweyasali and dad, Otto Ignatius Legra for their understanding, their great respect for education and for not holding me back from pursuing further studies.

LITERATURE CITED

Alvarez-Cordero, E. (1994). "Harpy Eagles- The World's largest raptors." Wildbird: 30-33.

Alvarez-Cordero, E. (1997). "Raptor Rescue: Mapping Venezuelas' Harpy Eagle Habitat." GPS World **9**.

Amadon, D. (1978). "Remarks on the Taxonomy of Some Australasian Raptors." Emu **78**(3): 115-118.

Aumann, T. (1988a). "Breeding behaviour of the brown goshawk *Accipiter fasciatus*." Australian Birdwatcher **12**: 258-267.

Aumann, T. (1988b). "Foraging behaviour of the brown goshawk (*Accipiter fasciatus*) in south eastern Australia." Journal of Raptor Research **22**(1): 17-21.

Aumann, T. (1989). "Breeding parameters of the brown goshawk *Accipiter fasciatus* in south- eastern Australia." Emu **89**: 112-118.

Aumann, T. (1990). "The breeding behaviour of brown goshawk *Accipiter fasciatus didimus* pair." Australian Birdwatcher **13**(5): 156-163.

Aumann, T. (2001a). "Breeding biology of raptors in the south- west of the Northern Territory, Australia." Emu **101**: 305-315.

Aumann, T. (2001b). "Habitat use, temporal activity patterns and foraging behaviour of raptors in the south- west of the Northern Territory, Australia." Wildlife Research **28**: 365-378.

Barton, N.-W.-H. and D.-C. Houston (1993). "The influence of gut morphology on digestion time in raptors." Comparative Biochemistry and Physiology A Comparative Physiology.

Beehler, B. M., W. Crill, et al. (1992). "New Guinea Harpy- eagle attempts to capture a monitor lizard." Emu **92**: 246-247.

Beehler, B. M., T. K. Pratt, et al. (1986). Birds of New Guinea, Princeton University press.

Bisson, I.-A., M. Ferrer, et al. (2002). "Factors influencing nest-site selection by Spanish Imperial Eagles." Journal of Field Ornithology.

Botelho, E.-S. and A.-L. Gennaro (1993). "Parental care, nestling behaviors and nestling interactions in a Mississippi kite (*Ictinia mississippiensis*) nest." Journal of Raptor Research.

Brown, P. (1972). The Chimbu: a study of change in the New Guinea highlands, Schenkman Publishing Company, Inc.

Calaby, J. H. (1951). "Notes on the Little Eagle, with particular reference to rabbit predation." Emu **51**: 33-56.

Calef, G. W. and D. C. Heard (1979). "Reproductive Success of Peregrine Falcons *Falco-Peregrinus-Tundrius* and Other Raptors at Wager Bay and Melville Peninsula Northwest-Territories Canada." Auk.

Coates (1985). The Birds of Papua New Guinea, Australia, Dove publications pty,ltd.

Debus, S. J. S. (1984). "Biology of the little eagle on the northern tablelands of New South Wales." Emu **84**: 87-92.

Diamond, J. M. (1972). Avifauna of the Eastern Highlands of New Guinea. USA, Nuttal ornithological club.

Eason, P. (1989). "Harpy eagle attempts predation on adult Howler Monkey." Condor **91**: 469-470.

Ellis, D. H. (1979). "Development of behaviuor in the golden eagle." Wildlife Monographs **43**(4).

Ferrer, M. and J.-J. Negro (2004). "The near extinction of two large European predators: Super specialists pay a price." Conservation Biology.

Fowler, J. M. and J. B. Cope (1964). "Notes on the Harpy Eagle in British Guiana." The Auk **81**(3): 257-273.

Gamauf, A., M. Preleuthner, et al. (1998). "Philippine birds of prey: Interrelations among habitat, morphology and behavior." Auk.

Giese, C. L. A. and F. J. Cuthbert (2003). "Influence of surrounding vegetation on woodpecker nest selection in oak forests of the Upper mid west, USA." Forest and Ecology Management **179**: 523-534.

Gould, J. (1970). Birds of New Guinea. London, Great Britain, Methuan and co ltd.

Gregory, P. (1995). The Birds of the Ok Tedi Area, Independent Publishing, Papua New Guinea.

Helden, F. V. (1998). Between Cash and Conviction

The Social Context of the Bismarck- Ramu Integrated Conservation and Development Project, The National Research Institute.

Jimenez, J.-E. and F.-M. Jaksic (1993). "Observations on the comparative behavioral ecology of Harris' hawk in central Chile." Journal of Raptor Research.

Kruger, O. (2002). "Analysis of nest occuppancy and nest reproduction in two sympatric raptors: Common Buzzard, *Buteo buteo* and Goshawk, *Accipiter gentilis*." Ecography **25**(5): 523- 532.

Majnep, I. S. and R. Bulmer (1977). Birds of my Kalam Country, Auckland University Press.

Martinez, J. A., D. Serrano, et al. (2003). "Predictive models of habitat preferences for the Eurasian eagle owl *Bubo bubo*: a multiscale approach." Ecography **26**(1): 21-28.

McDonald, P. G. (2004). "The breeding ecology and behaviour of a colour- marked population of Brown Falcons (*Falco berigora*)." Emu **104**: 1-6.

Newton, I. and M. Marquiss (1976). "Occupancy and success of nesting territories in the European Sparrowhawk." Raptor Research **10**(3): 65-71.

Penteriani, V., B. Faivre, et al. (2001). "An approach to identify factors and levels of nesting habitat selections: a cross- scale analysis of Goshawk preferences." Ornis Fennica **78**(4): 159-167.

Peres, C. (1990). "A Harpy Eagle successfully captures an adult male red howler monkey." Wilson Bulletin **102**(3): 560-561.

Rettig, N., L (1978). "Breeding behaviour of the Harpy Eagle (*Harpia harpyja*)." The Auk **95**: 629-643.

Roberge, J.-M. and P. Angelstam (2004). "Usefulness of the umbrella species concept as a conservation tool." Conservation Biology.

Schulz, M. (1987). "Temporal variation in the frequency of Vocalisations of the New Guinea Harpy Eagle." Emu: 257-258.

Sharp, A., M. Norton, et al. (2001). "Breeding activity, nest site selection and nest spacing of Wedge- tailed Eagles (*Aquila audax*) in western New South Wales." Emu **101**: 323-328.

Shultz, G. M., A.S (2002). "Nest- site selection of the crowned hawk- eagle in the forests of Kwazulu-natal, South Africa and Tai, Ivory Coast." Journal of Raptor Research **36**(4): 300-308.

Simberloff, D. (1998). "Flagships, umbrellas, and keystones: Is single-species management passé in the landscape era?" Biological Conservation **83**.

Smith, D. G. and J. R. Murphy (1973). "Breeding Ecology of Raptors in the Eastern Great Basin of Utah USA." Brigham Young University Science Bulletin Biological Series.

Sokal, R. R. and F. J. Rohlf (1969). Biometry.

Statistix (2003). "Analytical Software." **8**.

Thiollay, J.-M. (1996). "Distributional patterns of raptors along altitudinal gradients in the northern Andes and effects of forest fragmentation." Journal of Tropical Ecology.

Thiollay, J. M. (1998). "Current status and conservation of Falconiformes in Tropical Asia." Journal of Raptor Research **32**(1): 40-55.

Tome, D. (2003). "Nest site selection and predation driven despotic distribution of breeding long- eared owls *Asio otus*." Journal of Avian Biology **34**(2): 150-154.

Tyne, J. v. and A. J. Beger (1976). Fundamentals of Ornithology, John Wiley and Sons, Inc New York.

Watson, M. and S. Asoyama (2001). "Dispersion, habitat use, hunting behaviour, Vocalisations and conservation status of the New Guinea harpy Eagle (*Harpyopsis novaeguineae)*." Raptor research **35 (3)**: 235-239.

Wright, D. D., J. H. Jessen, et al. (1997). "Tree and Liana Enumeration and Diversity on a One- Hectare Plot in Papua New Guinea." Biotropica **29**(3): 250- 260.

APPENDIX 1: Nest and Random tree variables.

Variables	Description	C/D*
DBH (cm)	Measured at breast height, above buttress using DBH tape	C
Tree height (m)	Estimated height by extrapolating from 2m rod placed at base of tree	C
Lowest branch height (m)	Followed same procedure above	C
Nest height (m)	Followed same procedure as in measuring tree height	C
Suitable nesting branch height (m)	This variable describes branches that have the presence of moss, epiphytes and lianas. They are large and have the appearance of a nest branch. Height measured using same procedure used to measure tree height.	C
Proportion of nest and tree height (%)	Calculated using nest and tree heights	C
Tree type	Trees were either emergent (1), canopy (2) or sub canopy (3)	D
Bole type	Bole type was either straight (1), inclined (2) or branching (3)	D
Crown shape	Shape was either oval (1), irregular (2), cone (3), table (4)	D
Bark characteristics	Given a score of 0 (very smooth) to 5 (very rough)	D
Lianas	Given a score of 0 (none) to 5 (very dense)	D
Epiphytes	Given a score of 0 (none) to 5 (very dense)	D
Canopy cover (%)	Calculated from canopy openness that was measured using a sperical densiometer. The mean of 4 readings at the principal compass points (N,S,E,W)	C
Accessibility	Easy (1), Moderate (2) and Difficult (3)	D
Disturbance	Number of trails, cut trees, landslips, tree fall gaps within 10 metres radius of nest tree	D

*C denotes Continuos variables and D, Discrete variables.

APPENDIX 2: Variables measured at the nest- site and random microhabitat sites (microhabitat scale).

Variable descriptions
Distance form the nest tree to the nearest river (m)
Distance from the nest tree to the nearest ridge (m)
The amount of canopy cover above the river that is open or closed (%)
The width of the rivers (m)
The location of the tree either on a slope or on a flat
Slope (^{o})
Slope position (base=1, middle= 2 and top=3)
Distance from the nest tree to the next canopy tree (m)
Number of trees> 0.1m DBH
Number of over story trees
Aspect (^{o})
The amount of the shrub layer (0-5, 0=none, 5= very dense)
The amount of under story (0-5, 0=none, 5= very dense)

APPENDIX 3: Variables measured at and around roost trees.

	Sampling methods
DBH (cm)	Measured diameter of tree at breast height (DBH) using DBH tape
Tree height (m)	Estimated height of tree by extrapolating from a 2m rod placed at the base of the tree
Branch type	Noted whether NGHEs sat on a vertical or horizontal branch
Tree type	Type of roost trees were notes as either emergent, canopy or sub canopy trees