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Breeding Biology of the Crested Serpent Eagle *Spilornis cheela hoya* in Kenting National Park, Taiwan

Ta-Ching Chou, Pei-Fen Lee and Huisheng Chen

ABSTRACT

The Crested Serpent Eagle *Spilornis cheela* is widely distributed in the Oriental region. These snake-eating eagles generally soar above the hill ridges and cry noisily in the low hill country on Taiwan, making them conspicuous, but their nests have rarely been found and described. We located twelve serpent eagle nests between 1995 and 2002 in Kenting National Park, southern Taiwan. All nest trees were standing in the creek valleys. Both evergreen broadleaf and hard-leaf trees were used as nest trees. All nests were built on top of vines, and thus concealed from both researchers and predators alike. Only females were observed to incubate the eggs. Only one egg was laid and one eaglet fledged from each of these nests. The breeding success was 92% for all twelve pairs observed. Two forms of juvenile plumage were observed, dark and light. The plumage of the dark form juveniles was very similar to their parents and is not described in any references.

INTRODUCTION

The snake-eating *Spilornis* serpent eagles are endemic to the Oriental region. Due to their high soaring behaviour and loud vocalization, they are easily located in the wild, but the biology of this genus is poorly studied (Brown & Amadon 1968). Only four individual Crested Serpent Eagle nests were reported in northern Taiwan during the past decade (Lin *et al.* 1998). Knowledge of the breeding biology and habitat requirements of all *Spilornis* serpent eagles in Asia, necessary for future management and conservation measures, is in essence not available.

The Crested Serpent Eagle is the most widely distributed and diverse species of this genus. The Formosan Crested Serpent Eagle *Spilornis cheela hoya* is endemic to the island of Taiwan and the largest subspecies in terms of body size (Brown & Amadon 1968). This eagle often soars above the canopy and cries noisily in the hill country, which makes it conspicuous, but knowledge of its breeding biology and habitat characteristics are lacking. It is listed as "valuable and rare" by the Council of Agriculture of Taiwan, and is under the protection of the "wildlife conservation law".

Many researchers have shown that several raptor species select specific sites for the placement of their nests. Newton (1979) pointed out that a lack of nest sites might limit several breeding populations of raptors. Therefore, identification of nesting requirements is one of the key elements of integrated management (Plunkett 1977). Olendorff and Zeedyk (1977) suggested that management agencies should obtain and use current quantitative information on occupied or suitable habitats to full advantage within their respective planning and decision-making frameworks.

Three categories have been used to describe the breeding habitat used by birds of prey: 1) nest characteristics (e.g. diameter, height, mean supporting branch diameter, height of tree, diameter at breast height (DBH) (Bednarz & Dinsmore 1982); 2) nest site characteristics or microhabitat (e.g. the immediate vicinity of the nest); and 3) nesting habitat (e. g. characteristics within the home range of a nesting pair (Bednarz & Dinsmore 1982; Mosher *et al.* 1987; Kennedy 1988).

Knowledge of breeding biology and nest-site selection is not known for many Asian raptors, but is necessary for their management and conservation. Owing to the urgent need for ecological data, this study was initiated to record the basic breeding biology of the Formosan Crested Serpent Eagle and to understand its habitat characteristics in Kenting National Park, Taiwan. These were recorded at three scales; 1) nest dimensions, 2) the microhabitat within 17.84m radius of the nests (1,000m^2), and 3) the macrohabitat adjacent to the nest trees.

MATERIAL AND METHODS

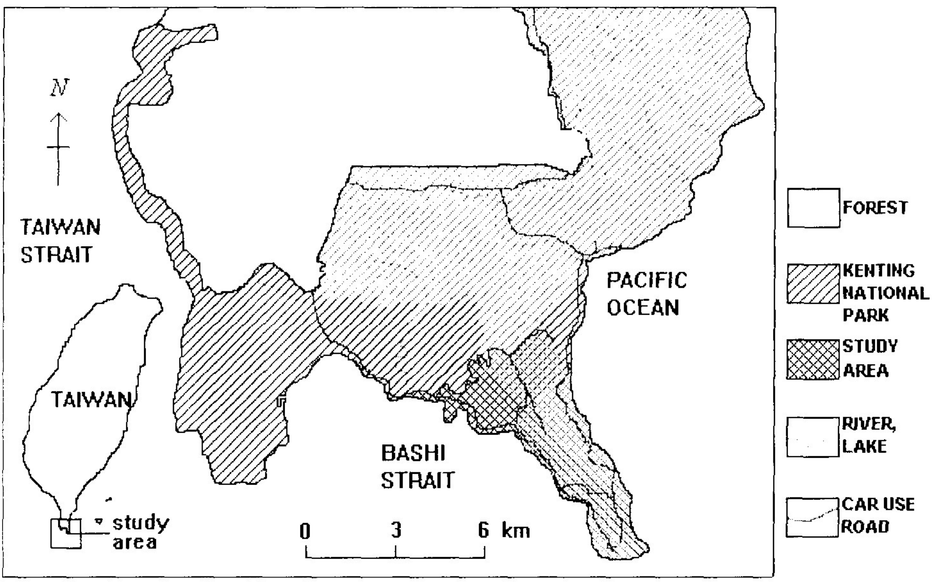
Study Area

Field data were collected from 8 March to 7 July 1995, 31 January to 27 June 1996, and March 1999 to 10 August 2002 in the Kenting-Olanbi Peninsula of Kenting National Park (21°55' N and 120°49' E, Figure 1), near the southern tip of Taiwan. The study area is characterized by uplifted coral reefs located on the south-eastern tip of the park. Historically, the habitats in this area were disturbed by early aborigines' slash-and-burn farming activities. More recently, herding livestock by local villagers and the government animal husbandry institute combined with tourism have become the primary disturbance factors. This area is comprised of pastures, brush land, tourist trails and facilities, and various stages of forest regeneration (Su 1985). The area covers 2037ha.

Kenting National Park supports a typical "tropical monsoon forest". Average annual temperature is 24.4° C (9.5 - 37.1° C), with the highest monthly mean temperature of 27.8° C in July and lowest of 20.4° C in January. Ninety percent of the 2247 mm precipitation is concentrated in summer (May to

September). Several typhoons hit this national park during summer every year. Strong and dry monsoons from the north-east blow into the area from October through March. The highest mean monthly wind speed of 6.05m/sec and highest mean monthly wind gusts of 18.3m/sec occur in November. Because of the strong winds, the less wind-resistant tropical rain forests are distributed only on the south-western slopes of the Olanbi Peninsula and along the valleys or coral reef canyons in the other parts of the national park, while the more wind-resistant evergreen hard-leaf forests, shrub lands and grasslands are distributed on the exposed ridges and north-east facing slopes (Su 1985; Chang *et al.* 1985).

Figure 1. Study area in Kenting National Park, located in the southern tip of Taiwan.



Nest Searches

We did intensive search on foot throughout the entire study area to locate nests. Once a nest was found, the location was marked on a 1:5,000 aerial photomap or a Garmin GPS was used to obtain the co-ordination, and the status of the nest (e.g. incubation or brood-rearing stage) was recorded. We minimized disturbance to the nests by using a mirror fixed on a pole, or climbing to an adjacent tree or coral reef and then checking the nest with Leica 8 x 42 binoculars. We recorded whether the adults were at or near the nest, and the number of eggs or chicks, or other signs of activity. Only fresh nest structures with green twigs and other indications of use were considered as occupied nests or breeding attempts.

Habitat measurements

After the juveniles fledged, the nest and nest-site characteristics were measured. The methods used were modified from Bednarz and Dinsmore (1982). Nest tree characteristics included species, DBH, and height. The nest placement included distance from the nest to the main trunk and number of support branches. The location characteristics included the distances from the nest to a permanent source of water, to a main road, to the nearest open area or edge, to a house, or any man-made building or structures. Measurements were taken by using 10m DBH tape for bole and branch diameters, a Paul E Lemmon Forest 24 grid semi-spherical densimeter for canopy cover percentage, a 50m tape for nest dimensions and other distances, and a clinometer for height. Distances greater than 50m were measured with a ruler from aerial photos and converted into metres.

Microhabitat characteristics included the vegetation structure and topography. The quadrant method, employing a 1000m^2 (radius = 17.84 m from the nest tree) plot was used to quantify nest-site vegetation variables. Vegetation characteristics included the number of woody plants by size classes, understory cover percentage by different life form classes, canopy cover percentage, average canopy height, and classes of forest types. Topographic characteristics included altitude, slope, nest site aspect and topography type.

The vine cover percentage was determined by ocular and densimeter estimate of the proportion of a 17.84m radius plot covered with vines.

In addition, we established four transects following the cardinal directions centred on the nest tree. Four canopy cover percentage readings were taken with a 24 grid semi-spherical densimeter on each transect line with a 5m interval from the nest tree. Thus the canopy cover percentage was the mean of these 16 readings. Estimates of canopy heights were taken with a clinometer on points 20m from the nest tree on each transect. The canopy height was the mean of these four measurements.

Vegetation surrounding nests was classified into secondary or plantation forest, evergreen broad-leaf forest, and Sclerophyllous forest. The dominant vegetation types of secondary or plantation forest were divided into 1) *Calophyllum inophyllum* regeneration type, 2) *Casuarina equisetifolia* plantation type, 3) *Terminalia catapa* plantation type, 4) *Diospyros discolor* plantation type, 5) mixed semideciduous regeneration type, or 6) other. The dominant vegetation types of evergreen broad-leaf forest were divided into coastal forest type and *Ficus-machilus* forest type. The dominant vegetation types of Sclerophyllous forest were divided into *Acacia confusa* forest type and coral rock vegetation type. The nest site aspect was determined with a military compass.

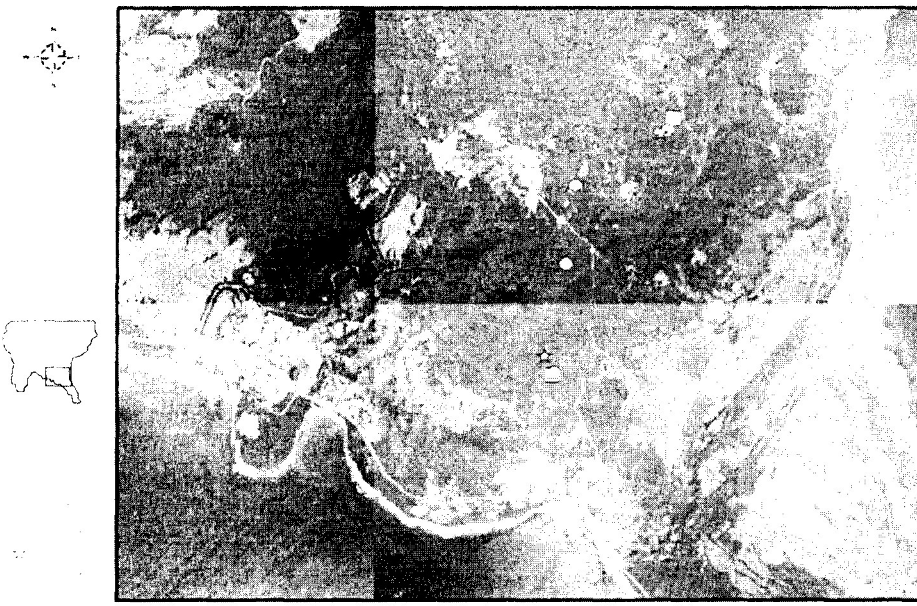
Aspects of slopes supporting nest trees were categorized and. a line based on the direction for each nest tree was marked. Slope percentage estimates were taken with a clinometer from17.84m above and below the nest tree. The altitude was determined from 1:5,000 aerial photomaps with topographic lines. The topography of the nest site was defined as east slope or west slope, and each position was further classified as ridge, cliff, plain, valley toe and slope.

Macrohabitat variables include distances between nests and forest edges, roads, buildings and permanent water sources. These distances were measured from the 1:5,000 aerial photos with a ArcGis Software. All data were analyzed with Microsoft Office Excel statistical software.

RESULTS

During the field seasons, 12 occupied Formosan Crested Serpent Eagle nests were located, one in 1995, two in 1996, three in 2000, four in 2001and two in 2002 respectively (Figure 2). Besides these, 10 -25 Crested Goshawk *Accipiter trivirgatus* nests were also found in every field season. No other resident accipitrine nests were found. In early October and late March (mainly Gray-faced Buzzard-hawk *Butastur indicus*) and late September and April (mainly Chinese Sparrowhawk *Accipiter soloensis*), migratory raptors and late wintering hawks were observed in the Olanbi Peninsula.

Figure 2. Distribution of the Formosan Crested Serpent Eagle nests found in Kenting National Park, Taiwan (1995 – 2002).



Breeding Behaviour

The actual initiation date of nest building was not known, but a completed nest structure was found as early as mid-March 2001. An egg was found in this nest in 10 April 2001. Later, between 10 and 13 May, an eaglet was hatched. Thus the incubation should last around 40 days. During incubation and brood-rearing, only females were found to bring in fresh twigs to two nests.

Crested Serpent Eagles do not always reuse the same tree to place their nests. Only two trees were used over consecutive years, and one nest tree was used repeatedly for three breeding seasons in four years. The mean distance between new nests and nests of the previous year in the same forest patch was 23.2 m (range = 0 – 55.8 m, n = 5).

We observed social aerial displays year round during all field seasons. Both sexes and both mature- and immature-plumaged (30.1%) birds participated in aerial displays. These involved calling *hu-hu-hu-huliu-huliu* while the eagles were soaring in the sky (Figure 3).

Figure 3. Aerial display of an adult Formosan Crested Serpent Eagle

Serpent Eagles often soar in flocks, up to 11 being often observed soaring together in the study area. These birds could be seen displaying and flying over different pairs' nests. Because of this behaviour, it was difficult to define an aerial territory. The eagles could be seen riding on the same thermal but rarely with obvious aggressive interactions.

One copulation was observed in late March.. A female was perched on a branch in the canopy calling a long *huii-huii* sound for about five minutes. A male then glided in silently from around 300m away to perch next to the female. After about 10 seconds, the male jumped on the back of the now silent female and started to copulate with a high-pitched "*gii-gii-gii-gii*" vocalization for about five seconds, then dismounted and flew away.

The colour of two fresh eggs was a uniformly dingy white, covered with irregular orange-brown spots.

Only females were observed to incubate the eggs in five different nests. During the incubation and brood-rearing period, the females emitted "*hui-*" calls urgently on detecting the males approaching or bringing prey to the nest. The males brought food items directly to the nest or to an adjacent branch. The female would then eat them or feed them to the eaglet. Most of the time, the males just dropped the prey and took off. During the later part of the brood-rearing period (after 25-30 days), both parents brought prey to the nest for their young at the same time in three observations of food deliveries to three different nests. Males were not seen to feed the eaglets, so we are not sure whether the males feed their young or not.

One juvenile was observed to stay in the nest for at least 63 days. During this study, the parents did not direct any defensive behaviour toward us when we were in the vicinity. All females and their young sat very tight, crouching low in the nest when other birds of prey flew overhead, monkeys called or we were making observations during the incubation and early brood-rearing period (about 1-12 days after hatching).

Figure 4. A black breast/belly juvenile plumages Formosan Crested Serpent Eagle

During this study, we observed 17 kills brought to an intensively monitored nest, and five additional prey items brought to the other three nests. The Crested Serpent Eagles were observed to consume at least eight species of vertebrates and one invertebrate. Their prey ranged from large centipedes and small lizards to medium- sized rodents and large snakes over 2m in length (Table 1). Snakes were the most frequently observed prey items (>55 %). Centipedes seemed to be taken quite often in this area.

Table 1. Prey species consumed by Formosan Crested Serpent Eagles in Kenting National Park, Taiwan. Based on observations of 17 prey items brought to an intensively monitored nest and records of the remains of five prey at three additional nests.

Species	*Frequency*
REPTILES	
Lizards *Japalura spp.*	1
Toads *Bufo melanostictus*	1
Snakes *Cyclophiops major*	4
Ptyas mucosus	2
Trimeresurus stejnegeri	3
Naja atra	1
Elaphe spp.	1
Unidentified	1
MAMMALS	
Rat *Rattus spp.*	1
Arthropoda	
Centipede	7

Reproductive success and cause of failure

In the study area, Formosan Crested Serpent Eagles produced one egg per nest in all nests (n = 12). Two types of juvenile plumage were observed , two young were the black (Figure 4) and nine were the white breast/belly (Figure 5) types. The black type has never been described in the literature. Only one nest did not produce fledglings. The total breeding success of observed nests from 1995 to 2002 was 91.7%. The cause of one failure was unknown. No sign of humans was observed during the study., so human persecution was probably not responsible. From this eaglet's development, it was evidently suffering from malnutrition. It disappeared from the nest in May, when approximately 30 days old.

Figure 5. A white breast/belly juvenile plumages Formosan Crested Serpent Eagle

The nests, nest trees and macrohabitat

The Crested Serpent Eagle mean nest dimensions were 48.0 cm (n = 1) in diameter, 23.0cm (n = 1) in depth, with a nest cup depth of 6.0cm (n = 7). Nests were placed at a mean of 8.3m (n = 12) above the ground. The mean canopy cover directly over nests was 75.0 % (n = 3). Nests were placed on average 3.7m (n = 12) from the main trunk and were supported by a mean of 2.0 (n = 12) branches. The mean diameter of supporting branches was 9.5cm (n = 7).

Crested Serpent Eagles used four tree species (in three families) on which to place their nests (Table 4). They seemed to have a high tendency to use Euphorbiaceae (58.3 %, n = 12). The average tree height was 13.3m (n = 12).

The mean DBH was 48.2cm. The mean distances from occupied nest trees to the nearest building, permanent water, road, and forest edge were 482.1m, 166.7m, 277.8m, 101.8m respectively (Table 3).

Table 2. Tree species used by Formosan Crested Serpent Eagle to place their nests in Kenting National Park, Taiwan (1995 - 2002).

FAMILY	*SPECIES*	*No. of nests*
Euphorbiaceae	*Bischofia javanica*	5
	Melanolepis multiglandulosa	1
Fabaceae	*Acacia confusa*	4
Moraceae	*Ficus ampelas*	2
	Total	**12**

Table 3. Formosan Crested Serpent Eagle nest tree characteristics and distances between nest trees and various landscape and man-made features in Kenting National Park, Taiwan (1995 - 2002).

Variables	*Mean*	*SD*	*n*
Nest tree			
Height (m)	13.3	3.6	12
DBH (cm)	48.2	17.1	12
Distance (m) from nest trees to			
Building	482.1	185.1	12
Water	166.7	127.9	12
Road	277.8	153.2	12
Edge	101.8	73.6	12

The microhabitat

The mean canopy height at the nest sites was 11.8m and the mean canopy cover percentage was 78.8%. The mean vine cover percentage in the canopy was 3.1 % within a radius of 17.84sq.cm centred on the nest tree.

In the understory shrubs (22.1%) predominated significantly. Bare ground comprised a mean of 15.0 % of the understory plots at all nest sites.

The DBH of over 96.4% stems of woody plants within a radius of 17.84m from the nest trees were less than 30cm. The average number of stems of all woody plants at nest sites was 98.8 and the basal area was 15192.0sq.cm.

33.3 % of the nests were found in *Acacia confusa* type of sclerophyllous forest, 66.7% in *Ficus-Machilus* evergreen broad-leaf forests. No nests were found in secondary or plantation forests.

The mean altitude of nest trees was 116.0m in the study area. The nest sites were located on an average of 30.6 % slopes (Table 4). These slopes were facing in seven major directions except for west.

About 58.3 % (n=7) of the nests were found east of the main ridge, while 41.7 % (n=5) were located west of it.

In terms of topography, all the nest sites were in valley bottoms, and none was found on the plains, coral reef cliffs or other.

Table 4. The mean altitudes and slopes of Crested Serpent Eagle nest sites in Kenting National Park, Taiwan.

Variables	*Mean*	*SD*	*Range*	*n*
Altitude (m)	116	22	87-157	12
Slope (%)	30.6	18.0	16-84	12

DISCUSSION

Breeding Biology

From our observations, the eagles seemed to start breeding about one month earlier than in northern Taiwan (Lin *et al.* 1998), which is similar to the Crested Goshawks in Kenting and northern Taiwan. The warmer climate in the south might play an important role in regulating their breeding chronology (Chen 1997).

The incubation period in Kenting seemed to be longer than in northern Taiwan (>40 days versus 35 days, Lin *et al.* 1997). Because in both studies the actual dates of egg laying and hatching were not available, we can only say that incubation took at least 35 days.

The brood-rearing period of serpent eagles in northern Taiwan was 78 days (Lin *et al.* 1998), which was much longer than the 63 days that we observed in Kenting.

Our observations suggested that serpent eagles might occasionally use old nest structures if these were not destroyed by typhoons in summer and monsoons in winter. But the reasons for an old nest site being abandoned or a new site selected are still unknown.

Cody (1985) suggested that birds selected a specific nest site to maximize their reproductive success. At least three factors influencing nest site selection have been suggested: 1) nest predation, 2) environmental stresses on eggs or nestlings (Cody 1985), and 3) accessibility for the parent birds (Bednarz and Dinsmore 1982). Drent (1975) argued that nests function to enhance incubation effectiveness in several ways – by providing thermal isolation, rendering protection from predator and helping to maintain optimal positioning of the eggs. Most raptors require relatively large nests, which makes them difficult to hide. Therefore they are placed in such a way as to minimize accessibility. Many tree-nesting raptors select relatively taller trees to reduce accessibility to predators. For example, Crested Goshawks in Kenting selected nest trees taller than the surrounding canopies (Chen 1997). Walsberg (1985) pointed out that key environmental factors influencing eggs and nestlings are humidity and temperature. During the course of incubation, eggs typically lose 9 – 18 % ($\bar{x}$ = 16 %, n = 75 species) of their initial mass in water (Drent 1975). Wind might also be an important factor as it relates to environmental humidity, which may increase the dehydration rate of eggs in aerial nests (Walsberg 1985). Although the actions of parent birds primarily regulate the thermal environment of the eggs for most avian species, other factors including sun and wind also play an important role The Crested Serpent Eagles in Kenting National Park built relatively small nests and placed them in vines, which may serve to conceal the nest from predators. In Kenting, arboreal nest predators such as Taiwan Beauty Snake (*Elaphe taeniura friesei*), Formosan Macaques (*Macaca cyclopis*), and Gem-faced Civet (*Paguma larvata taivana*) were major threats to Crested Goshawk nests (Chen 1997). The same predators might pose threats to the serpent eagle nests in the Kenting area.

Probably the most important environmental stress factors influencing Kenting are the winter monsoons. The vegetation distribution in this area is mostly regulated by the winter monsoons, where the less-wind-resistant tropical rain forests are distributed only on the south-western slopes of the Olembi Penisulla and along the valleys or coral reef canyons, while the morewind-resistant evergreen hard-leaf forests, shrub- and grasslands are distributed on the exposed ridges and northeast-facing slopes (Su 1985). Crested Goshawks in theKenting area selected sheltered slopes to reduce wind effects (Chen 1997), although our study produced no evidence that Crested Serpent Eagles did so. We suggest that their different nesting pattern in the same area may be related to the presence of vines entangled with the nest to help stability against the monsoons during the early breeding season. Besides, part of the reason why serpent eagles nested farther inside the forest patch than in northern Taiwan (102m versus 60m, Lin *et al.* 1998) may also be because this placement shelters the nests against the effects of wind since the winter monsoon is much stronger in Kenting and almost the entire forest area would be influenced by edge effects, since little forest habitat there is > 50 m from the edge. Thus, in Kenting, placement of nests in the interior of forest patches and selection of specific topographic types may both be important factors in reducing the effects of wind.

Although Crested Serpent Eagles in Kenting did not all nest close to a permanent source of water, all nests were in sheltered stream valleys. This correlation might be related to higher humidity and sheltered topographic situations, which might mitigate extreme environmental and wind effects. The concentration of nests in these two circumstances may be related to selection, to reduce adverse wind effects and, perhaps, increase humidity. In addition, the ferns observed around nest sites may indicate higher humidity (Polunin 1960).

In terms of management of Formosan Crested Serpent Eagle breeding habitat in Kenting National Park, we recommend that the remaining forest patches should be carefully protected. The eagles need relatively larger forest patches so that they can place their nests away from the edges. Specifically, the forests that support taller trees in the stream valleys should be protected and not fragmented any further. These areas seem to be critical locations that shelter serpent eagle nests from the winter monsoons.

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Ta-Ching Chou, Pei-Fen Lee
Dept. of Zoology, National Taiwan University
Taipei, Taiwan
Tel: 886-2-23623501
Fax: 886-2-23636837
E-mail: jonathan@oikos.zo.ntu.edu.tw

Huisheng Chen
Dept. of Biological Sciences, University of Arkansas
Fayetteville, AR, 72701, USA
Tel: 1-479-5276330
Fax: 1-479-5276330
E-mail: hxc07@uark.edu