# Karst Habitat Fragmentation and the Conservation of the White-Headed Langur (Trachypithecus leucocephalus) in China

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# Karst Habitat Fragmentation and the Conservation of the White-headed Langur (*Trachypithecus leucocephalus*) in China

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**Abstract:** The white-headed langur survives in just four karst forest fragments in China: one in the Longgang National Nature Reserve on the border of the counties of Longzhou and Ningming (NS habitat); a second in Chongzuo Banli Provincial Nature Reserve, Chongzuo County (CZ habitat); and two in Fusui Papen Provincial Nature Reserve, Fushui County (F1 habitat and F2 habitat), all in the southwest of Guangxi Province. The population is fewer than 700. We used GIS of Mapinfo Professional 7.0 and Arcview 3.2 to study karst landscape features (forest fragmentation and patchiness of natural formations and those resulting from or affected by human activities) in the known range of the white-headed langur. Results indicated that the NS fragment was the best conserved regarding the presence of natural karst hill system forest and the connectivity of forest habitat, and having the least agriculture. F1 and F2 ranked the second and the third in these aspects, while the CZ forest was the most fragmented and degraded by human activities. Most of the plains in F1, F2 and CZ were cultivated, given over to sugarcane plantations — the most widespread cash crop in the southwest of Guangxi province. The four karst habitats and their populations of white-headed langurs are facing similar problems, most marked in F1, F2 and CZ. Foremost are cultivation and human interference, then firewood collection and illegal hunting. Fortunately, the government has initiated some measures to mitigate the affects of human activities, including clamping down on illegal hunting.

**Key Words:** Conservation, fragmentation, karst habitat, white-headed langur, *Trachypithecus leucocephalus*

## Introduction

Habitat fragmentation is one of the main factors causing decreases in animal populations in the wild (Caro 1998). The forests of the karst fengcong (peak cluster) depression provide a very special type of habitat (Jiang 1996). They are naturally isolated from other peak clusters, but they are now suffering intense fragmentation, reduction and degradation of the forests within the clusters due to intensive agricultural activities in the flat lowlands (Jiang 1996; Huang 2002; see Fig. 1). The white-headed langur, *Trachypithecus leucocephalus*, occurs only in these forests, but their fragmentation and degradation, along with illegal hunting, is driving them to extinction. It is one of the world's most endangered primates (Konstant *et al.* 2002–2003).

The white-headed langur is one of a few primates endemic to Asian karst forests, one of the so-called limestone langurs (Huang 2002; Groves 2004; Nadler 2006). It is found only in the karst hills of four counties (Longzhou, Ningming, Chongzuo and Fushui) in southern Guangxi province, China, between 107°46' and 108°03'E and 22º25' and 22°31'N (Li *et al*. 2003). These langurs are well adapted to this environment, skillfully climbing up and down the cliffs to reach the caves where they sleep at night (Huang *et al*. 2003a; Huang and Li 2005). The most recent surveys have indicated that many groups have been lost from the smaller karst forests, and that white-headed langurs now remain in just these four forest habitats of the larger region (Huang *et al.* 2002; Huang *et al.* 2003b). The so-called NS habitat is in Longgang National Nature Reserve at the border between the counties of Longzhou and Ningming. The CZ habitat is in Chongzuo Banli Provincial Nature Reserve, in Chongzuo County. The F1 and F2 habitats are in Fusui Papen Provincial Nature Reserve in Fushui County (Fig. 2).

White-headed langurs typically form groups containing an adult male with a number of adult females and their offspring. Group size ranges from 3–16 (Huang *et al.* 2003a; Li and Rogers 2004). Similar to François' langur (*Trachypithecus françoisi*), another primate that occurs in the karst fengcong depressions in Fusui County (Hu *et al.,* 2004), the

white-headed langur suffers from illegal hunting and habitat deterioration. We carried out this study to collect information on vegetation cover, fragmentation, landscapes, and human activities in order to better understand the threatened status of the white-headed langur and evaluate options for conservation measures.

## Study Area

The study was carried out in three nature reserves: Longgang National Nature Reserve on the borders of the counties of Longzhou and Ningming; Chongzuo Banli Provincial Nature Reserve in Chongzuo County; and Fusui Papen Provincial Nature Reserve in Fushui County in the southern Guangxi Province (Fig. 2). This covers the entire known range of the wild population of the white-headed langur. Average annual precipitation in the region is 1,022 mm, with an average daily temperature of 22.1°C (Huang 2002). The four areas consist of karst hills and flat lands in the valleys (Fig. 1) in the triangular region between north Mingjiang River, south Zuojiang River, and west of the Shiwan Mountains in parts of the four counties (Fig. 2).

**Figure 1.** The topography and fragmentation of karst hills in habitat of white-headed langur.

The dominant trees of the forests in these areas are *Ulmus tonkinensis, Semiliquidambar cathayensis*, and *Parashorea chinensis*, and endemic plant species include *Camellia nitidissima*, *Camellia longggangensis*, *Cathaya argyrophylla*, and *Cyathea spinulosa* (Guangxi Forestry Department 1993; Huang 2002).

## Methodology and Data Analysis

We used Landsat 7 Thematic Mapper (TM) satellite imagery (resolution of 30 m per pixel) and relief maps (1:10,000) to The TM images were rectified to the Geographic Transverse Mercator coordinate system based on 1:10,000 scale relief maps, and were re-sampled using the nearest neighbor algorithm with a pixel size of 30 by 30 m for all bands. The resultant RMSE was found to be less than 0.5 pixel.

Using the TM imagery, we set 561 sampling points for ground-truthing the vegetation in the four habitats: 65 in NS; 155 in CZ; and 341 in F1 and F2 in order to collect sufficient information about the landscape categories. The location of each sampling point was recorded using a GPS (MAGELLAN 315). There were fewer sample points in the NS habitat because of the difficult terrain.

Using manual interpretation we achieved an overall accuracy of about 91%. We used the following landscape categories: Forest (karst hills covered with natural arboreal

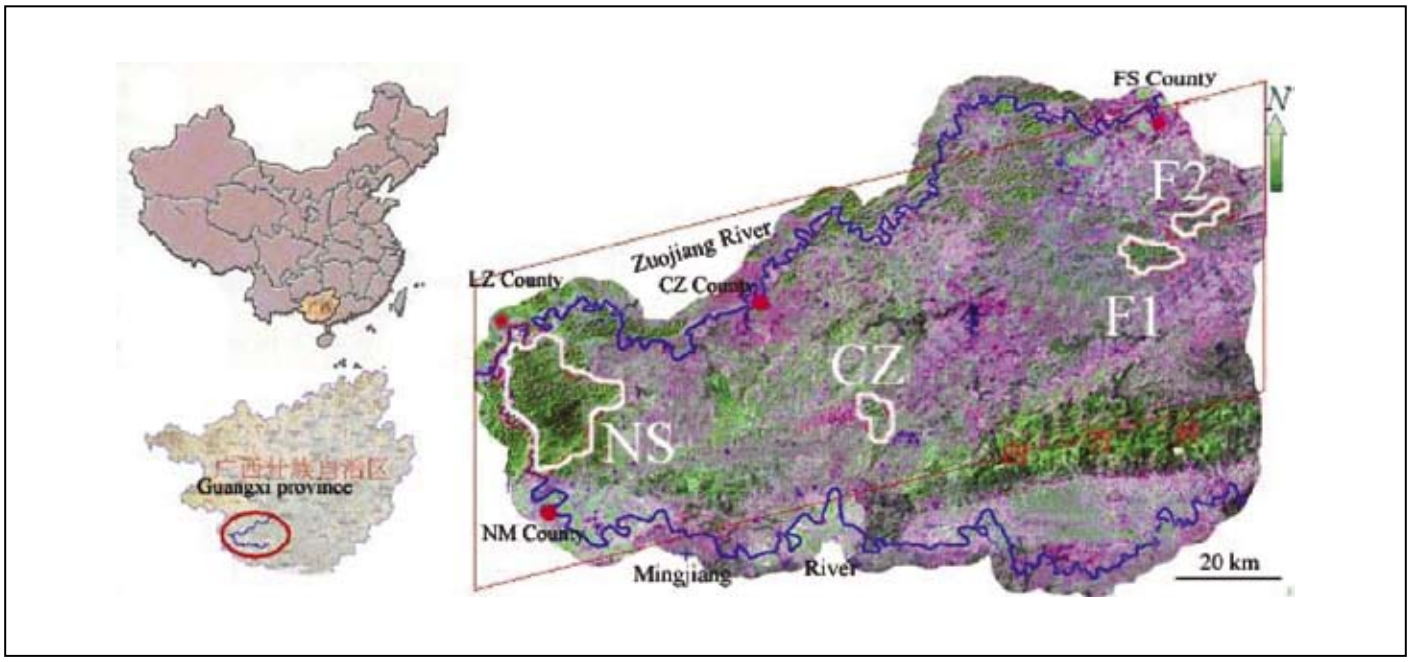


**Figure 2.** Location of the four karst habitats where the white-headed langur, *Trachypithecus leucocephalus*, survives. NS is in Longgang National Nature Reserve at the border between the counties of Longzhou and Ningming. CZ is in Chongzuo Banli Provincial Nature Reserve, in Chongzuo County. F1 and F2 fragments are in Fusui Papen Provincial Nature Reserve in Fushui County.

vegetation, shrubs and vines); meadows (plains of native grass); farmland (cultivated plains); villages and urban areas; bare rock (karst hills lacking vegetation); and water bodies (permanent pools and rivers near the habitat).

We used ARCGIS 8.0 (ERSI Inc., Redlands, CA) to create shape files of the results of the classification and relief maps. We then calculated the area and perimeter of each patch of each category, and the number of patches. We calculated indices of landscape pattern and habitat fragmentation with Fragstats 3.3 (Table 1).

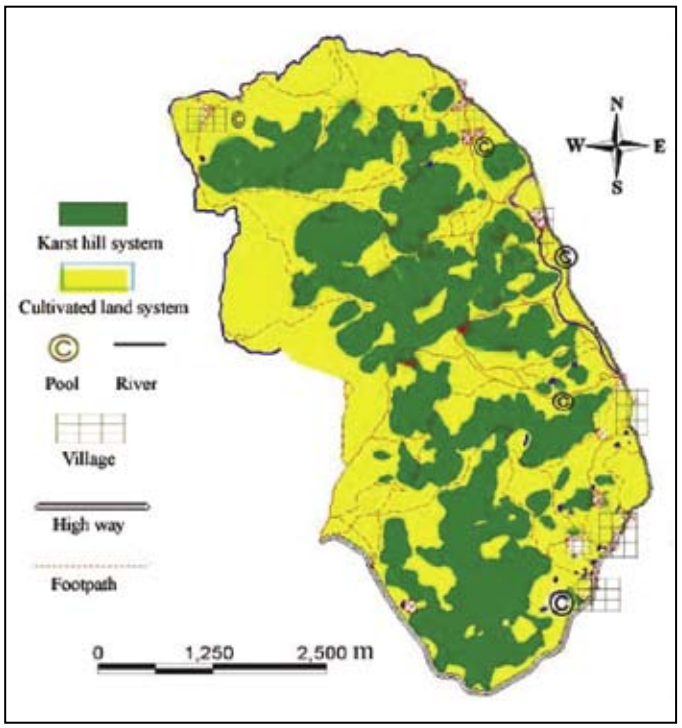


**Figure 3.** Composition of white-headed langur, *Trachypithecus leucocephalus*, habitat in CZ habitat, Chongzuo Banli Provincial Nature Reserve, Chongzuo County, Guangxi Province, China.

## Results

*Habitat composition*

Each of the four karst fragments were completely isolated from each other (Fig. 2). The distances between fragments ranged from 2 km (the edge of F1 to F2) to 100 km (edge of F1 to NS). Even between F1 and F2, the closest fragments, it was still difficult for the langurs to cross the large expanses of cultivation, rivers and villages because of a lack of natural vegetation to serve as a corridor. All four habitats consisted of karst hill systems, areas of agriculture, and water bodies, and all had roads passing through their core areas. There were people living around the habitats, using the core areas of the karst fragments to cultivate the plains and collect firewood—most particularly in CZ, F1 and F2 (Fig. 3).

The karst hill system is composed of karst hills and plains, the latter being cultivated by nearby villages in some areas. Of the four habitats, NS (20,167 ha) had the highest percentage of karst hill system (70.7%) and the least area given over to agriculture (24.5%), while CZ (2,084 ha) had the smallest area of karst hill system (43.3%) and highest given over to agriculture (56.2%) (Table 2).

*Vegetation composition and coverage in karst habitat*

Sugarcane (*Calamus thysanolepis*) is the most important cash crop in the southern counties of Guangxi Province. It has been planted over large areas of the plains in the core areas of the fragments CZ, F1 (2,935 ha) and F2 (2,338 ha). We detected two categories with eleven subcategories of landscape in the fragments. Water bodies, forest, grass, shrub and bare rocks were the natural categories, while areas denuded of vegetation, dry land cultivation, rice fields (wet cultivation), sugarcane and houses were artificial landscape subcategories. Combining the TM imagery and field samples indicated that the natural landscape cover was highest (41%) in NS and the lowest in CZ (28%), while the reverse was true in terms of the areas of human activities. NS had the most forest cover (34%) and CZ the lowest (4%) (Table 3). The factors indicate that

**Table 1.** The calculation of indices for fragmentation analysis of the habitats of the white-headed langur, *Trachypithecus leucocephalus*, in China.

| Index name | Formulation | Specification |
|---|---|---|
| Total area | $A_{sum} = \sum_{i=1}^{n} A_i$ | n is the number of patches, $A_i$ is the area of patch i. |
| Patchiness | $PT = \frac{1}{Nb} \sum_{i=1}^{T} \sum_{j=1}^{T} EE(i,j)DD(i,j)$ | Nb is total length of all patches, EE(i,j) is shared length of neighboring patches i and j; DD(i,j) is unshared length of patches i and j (Liu and Zhang 2004). |
| Fragmentation index | $F = (NF-1)/MPS$ | NF is the number of certain landscape types, MPS is the average area of patches (Liu and Zhang 2004). |
| Patches fragmentation index ($FN_1$\$FN_2$) | $FN_1 = (Np-1)/Nc$<br>$FN_2 = MPS(Nf-1)/Nc$ | Np is the number of patch type, Nc is the whole area of landscape($\times 10^5 km^2$), MPS is the average area of patches ($\times 10^5 km^2$), Nf is the number of karst hill patch (Liu and Zhang 2004). |
| Human disturbance index | $H_{DI}=A_h/A_n$ | $A_h$ the area of artificial landscape, $A_n$ is the area of natural landscape (Liu and Zhang 2004). |

NS provided the best quality habitat, followed by F1, F2 and then CZ (Table 2).

*Fragmentation and human disturbance*

Three landscape categories were defined in Forman's system (Forman and Gordon 1986) and (Liu and Zhang 2004). The "patch" is one of the basic landscape units, the other two are "corridors" and "matrices". We used patch units for the habitat analysis. In NS there were 203 patches of hills, cultivated land and water bodies, with a total patch density of 100.34/ha. NS had the lowest indices of patchiness and patch fragments compared with other fragments, indicating that, in these aspects, it is the best habitat for white-headed langurs. CZ, F1 and F2 had patch densities of 311.82, 258.96, and 265.19, respectively (Table 2).

Human disturbance (communities around the reserves, agricultural land, and roads inside and around the protected areas) constitutes a threat to the white-headed langur in these fragments. NS had the lowest density of people, roads, and cultivated land, and therefore the lowest index of human disturbance (0.323), while the CZ fragment had the highest (1.28) (Table 2).

## Discussion

The white-headed langur and other Indochinese limestone langurs (see Groves 2004) are endemic to karst hill forests, and their survival is, as such, closely linked to the preservation of these habitats (Huang *et al.* 1997; Huang and Li 2005; Nadler 2006). Deng (1987) divided the karst hills into peak cluster depressions and peak cluster valleys according to the densities of the hills. Peak cluster depressions are in karst hill ranges with more than 20 hills per km², with more hills and less flat land, which is less fragmented and suffers less human interference, while peak cluster valleys have less than 20 hills per km² with large areas of plains where agricultural activities are predominant. The NS area in Longgang National Nature Reserve fits the pattern of peak cluster depression (33.6 ± 19.2/km²), while the karst hills in CZ, F1 and F2 (19 ± 6.3/km²) are classified as peak cluster valleys. The two types have distinct characteristics in terms of their geology and the human activities that are degrading and destroying them. In NS, karst hills are dense, concentrated, and less fragmented; it has a higher percentage of karst hills, more extensive vegetation cover, and less fragmentation and human interference. It is possible to protect this area with just the one reserve (Longgang) created in 1980. The other two provincial nature reserves (Chongzuo Banli and Fusui Papen) consist of several widely separated fragments. The borders of these fragments were unclear, and the ownership of the land was also confused at the time the reserves were created. As it turns out, people living around the fragments have the right to access the land and to cultivate areas in and around the fragments. They also take firewood from the hills in the nature reserves: the reserve staffs have authority only to protect the animals. CZ, F1 and F2 have, therefore, a lower percentage of karst hills, less forest, and higher indices of fragmentation and human interference (Tables 2 and 3).

The forest and the karst hills are very important to the white-headed langurs. The hills have four distinct zones: the flat plains, the lower, middle slopes and the hill tops. All except for the plains in CZ, F1 and F2 are covered with forest. The valleys in CZ, F1 and F2 are cultivated. Our studies have indicated that the white-headed langurs spent 65.25% of their time on lower slopes, 22.25% on the middle cliffs and steep slopes, and 12.5% on the hill tops (Huang 2002). They do not use the valley bottoms due to the heavy human disturbance.

Large areas of the plains and valleys are planted with sugarcane and other cash crops. Agricultural activity reaches a peak during planting and harvesting seasons in Spring and Autumn when hundreds of people and dozens of trucks enter the core areas of CZ, F1 and F2, seriously affecting the activities of the white-headed langurs (Huang 2002; Li and Rogers 2004). Over the long-term it will be necessary to greatly reduce the levels of human activity for cultivation by developing alternative sources of income that will not only reduce disturbance to the langurs but improve the well-being of the local communities there. This could include eco-tourism (Huang *et al.* 2003b; Bleisch *et al.* 2006).

**Table 2.** Composition, fragmentation indices, and human disturbance in karst habitats of the white-headed langur, *Trachypithecus leucocephalus*, in China.

| Name of habitat | NS | CZ | F1 | F2 |
|---|---|---|---|---|
| Total area (ha) | 20167 | 2084 | 2935 | 2338 |
| Hill system (ha)/(%) | 14272/(70.7) | 903/(43.3) | 1613/(54.95) | 1204/(51.49) |
| Agricultural system (ha)/(%) | 4936/(24.5) | 1171/(56.2) | 1276/(43.5) | 1119/(47.86) |
| Water system (ha)/(%) | 1023/(5.1) | 100/(0.5) | 46/(1.6) | 140/(0.59) |
| No. of patches | 203 | 65 | 76 | 62 |
| Patch density (/ha) | 100.34 | 311.82 | 258.96 | 265.19 |
| Patchiness index | 0.472 | 0.737 | 0.713 | 0.773 |
| Fragment (F) index | 0.9289 | 0.9733 | 0.9665 | 0.9675 |
| Patch fragment (FN1/FN2) index | 0.0998/0.1133 | 0.3070/0.2923 | 0.2555/0.1974 | 0.2609/0.1935 |
| Density of residents (person/ha) | 0.74 | 5.8 | 5.0 | 3.5 |
| Density of cultivated land (patch/ha) | 0.41 | 0.83 | 0.49 | 0.59 |
| Density of roads (km/km²) | 0.244 | 0.562 | 0.434 | 0.479 |
| Index of human disturbance | 0.323 | 1.28 | 0.769 | 0.919 |

Firewood collection is an even greater threat than agriculture to the white-headed langurs in these areas. It not only interferes with their normal activities, but also destroys the vegetation and reduces their food sources. Most local households are poor and rely on firewood for energy: about 2.5 tons is used annually by each household. As the local population grows, the demand becomes more and more serious. Fortunately, local and provincial governments have initiated measures for the provision of methane gas as an alternative, with priority being given to families in the immediate vicinities of the nature reserves. To date about one-third of the households are already benefiting from this program (Huang *et al.* 2003b).

Local people have traditionally hunted the langurs, shooting them in order to make 'langur wine'; a concoction said to be effective in curing rheumatism. The white-headed langur was protected in 1980 (Lin 1980; Huang *et al.* 2002), and the government now seriously punishes illegal hunting, but there are still occasional incidents.

White-headed langur populations in each fragmented habitat are completely isolated from each other at distances of two to 100 km. This prevents the exchange of individuals and will predictably cause inbreeding depression to occur sooner or later. A fragmented population is the most dangerous of the metapopulation patterns that cause reduced gene flow (Frankham *et al.* 2003). The white-headed langur is believed to have originated in Southeast Asia, dispersing north to reside in the triangle between Zuojiang River and Mingjiang River two million years ago. It gradually occupied many karst fragments and there was undoubtedly frequent exchange of individuals between the fragments (Shen and Li 1981; Lu and Li 1991). However, hunting prior to the creation of the nature reserves extirpated the white-headed langurs from many of the smaller forests, and the increasing distance between populations has evidently reduced their capacity for recolonization (Lin 1982; Huang *et al.* 2003a).

The four isolated karst habitats in the southwestern Guangxi Province comprise the last refuge of the white-headed langur. In assessing the size, composition, vegetation cover, indices of fragmentation, and human interference, we find that NS has the best and largest habitat, followed by F1 and F2, and CZ has the worst and smallest (Tables 2 and 3). However, a recent survey showed that F1 and F2 in Fusui Nature Reserve together have the largest population (319 individuals in 42 groups), while CZ was in second place with 211 individuals in 21 groups). NS had the lowest population, with an estimated 86 individuals in eight groups (Huang *et al,* 2003b). Wang *et al*. (2004) considered the white-headed langur population of NS to be near extinction due to hunting from 1990 to 1998.

A number of white-headed langur surveys in the early 1980s indicated that NS had a population of about 240 individuals (Shen and Li 1981; Wu 1983). This would indicate that the population could increase considerably if the langurs were properly protected by the Nature Reserve Authority. However, it would seem that the population has remained low, at about 80 individuals over the last 10 years, despite the improved protection of the region. Z. Y. Li counted 80 individuals in NS in his survey in the mid-1990s (pers. comm.), and Huang *et al.* (2003b), with 30 people surveying the area for two weeks, recorded 86 in 2003. A survey carried out by local rangers of the Longgang National Nature Reserve in 2006 (unpublished), also came up with a total of about 80 individuals. The other populations in apparently in worse situations in CZ, F1 and F2 have, on the other hand, increased.

Studies of karst langurs—white-headed langur, Hatinh langur (*T. laotum hatinhensis*), and François' langur—have shown that they prefer to sleep on cliff faces (Huang 2002; Huang and Li 2005; Huang *et al.* 2004; Li and Rogers 2006; Nguyen 2006), and it may be that the availability of sleeping sites in the cliff faces is affecting population numbers in NS. The density of cliffs is much lower there ($0.5 \pm 0.85/km^2$), than in SZ ($1.6 \pm 1.8/km^2$) and F1 and F2 ($4.1 \pm 1.96/km^2$). The differences are statistically significant ($Z = -3.489$, $p<0.001$) (Huang *et al*. submitted).

There are two possible explanations for this contradictory finding that the smallest population of white-headed langurs is that in the largest and least fragmented forest of NS. One is that the lower population is real because of the lower density of cliffs. Sleeping sites as such being the limiting factor for

**Table 3.** Coverage of the landscape elements in the four karst habitats—areas of the surviving populations of the white-headed langur, *Trachypithecus leucocephalus*, in China.

| NS habitat | | | CZ habitat | | | F1 and F2 habitat | | |
|---|---|---|---|---|---|---|---|---|
| **Category** | **Subcategory** | **%** | **Category** | **Subcategory** | **%** | **Category** | **Subcategory** | **%** |
| Natural 41% | Water bodies | 2 | Natural 28% | Water bodies | 3 | Natural 32% | Water bodies | 5 |
| | Forest | 34 | | Forest | 4 | | Forest | 14 |
| | Grass | 3 | | Grass | 12 | | Grass | 7 |
| | Shrub | 2 | | Shrub | 7 | | Shrub | 6 |
| | Bare rock | 0 | | Bare rock | 2 | | Bare rock | 0 |
| Artificial 59% | Bare land | 2 | Artificial 72%` | Bare land | 2 | Artificial 68% | Bare land | 2 |
| | Dry land | 19 | | Dry land | 1 | | Dry land | 3 |
| | Rice field | 12 | | Rice field | 10 | | Rice field | 9 |
| | Sugarcane | 18 | | Sugarcane | 39 | | Sugarcane | 39 |
| | Fruit tree | 2 | | Fruit tree | 10 | | Fruit tree | 11 |
| | Resident | 6 | | Resident | 10 | | Resident | 4 |

population growth; and the survey in the early 1980s consequently had overestimated the population size. Another possibility is that hunting pressure in NS is much higher than in the other, more fragmented, habitats. Resolving which of the two is causing the lower population in NS, requires further study and, besides, more effective measurements to protect the population in NS.

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