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WINTERING HABITAT CHARACTERISTICS OF BLACK-FACED SPOONBILL (*PLATALEA MINOR*) AT CHI-KU, TAIWAN

PEI-FEN LEE[1], JIA-EN SHEU[1] AND BOR-WEN TSAI[2]

[1] *Department of Zoology, National Taiwan University, Taipei, Taiwan, Republic of China*
[2] *Department of Geography, National Taiwan University, Taipei, Taiwan, Republic of China*

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Wintering habitat characteristics of the endangered black-faced spoonbill (*Platalea minor*) at Chi-Ku, Taiwan was studied by remote sensing and geographic information system (GIS). A series of aerial photos and a SPOT image were obtained to generate a land-use and land-cover map which was overlaid with a bird distribution map, digitized using a GIS, to show the habitat characteristics of *P. minor*. Tidal mudflats and shallow water are the major components that P. minor used as the resting grounds (core area), and adjacent fish ponds and estuaries provide food sources. The average traveling distance for *P. minor* from the core area to foraging grounds was 3.18 km (SD = 1.22, Min. = 0.72 km, and Max. = 5.54 km). Those fish ponds close to the core area received the most intensive visit. Because the current resting and foraging grounds have been zoned to construct a new industrial park, a neighboring area is proposed as an alternative reserve. The proposed alternative reserve is about 233.3 ha with 70.6%of mudflats and 29.4%of windbreak forests. The distance between the centers of the reserve and the proposed industrial site is about 1 km. However, there is no buffer zone between them. No bird was found in this area. Other areas in Taiwan where *P. minor* was spotted do not provide all the habitat requirements or possess similar landscape pattern as Chi-Ku. Thus, it is highly suspected that large flocks of *P. minor* will ever switch to this new reserve or other areas in Taiwan if the habitat at Chi-Ku is destroyed.

Key words: Endangered species, remote sensing, GIS.

The black-faced spoonbill (*Platalea minor* Temminck and Schlegel) is one of the six species of spoonbills currently found in the world. They are migrants and mainly distributed in East Asia (Yamashina, 1941). They stay in Korean Peninsula, northern China and Japan for summer breeding and go down south to Taiwan, Vietnam, Hong-Kong, the Philippines, southeastern China, and Thailand for wintering ground (Kobayashi, 1967; del Hoyo *et al.*, 1992; Hancock *et al.*, 1992). Habitats for *P. minor* include marshes, rice fields, mangroves, fish ponds, tidal mudflats and estuaries (del Hoyo *et al.*, 1992). The birds usually eat fish, shellfish,

insects, crustaceans (crabs and shrimps), and vegetation (Yamashina, 1941; del Hoyo *et al.*, 1992). A recent survey indicated that the worldwide population of *P. minor* was lower than 300 (Kennerley, 1990; Ueng and Kuo, 1991). Although this survey may not include all the countries that provide suitable habitats, it did show *P. minor* population is extremely rare and under stress. Due to its rarity, in 1992 it was designated as an endangered species in Taiwan.

In Taiwan, approximately 200 individuals of *P. minor* were found every winter at Chi-Ku (23 ° 05′N, 120 ° 05′E) between 1988 and 1992 (Ueng and Kuo, 1991). This is by far the largest wintering population found in the world for *P. minor*. Chi-Ku, located in southwestern Taiwan, is an estuary where Tseng-Wen River emptys to Taiwan Strait. Wintering period ranged between October and May, with the largest flock occurred between December and February (Ueng and Kuo, 1991). The wintering habitats of *P. minor* at Chi-Ku are basically tidal mudflats and fish ponds that are subjected to increasing land-use conflicts recently. The dominant species in the fish ponds is milk-fish (*Chanos chanos*). They are harvested in fall-winter period and regenerated in spring. This particular harvest cycle provides important food sources for many avian species, including *P. minor*. Recently, local county government planned to establish an industrial center at the location where *P. minor* uses as wintering ground. Besides, there is a plan to construct an international airport at the nearby areas. An alternative reserve was proposed to substitute these areas, but no detailed analysis was performed.

Remote sensing offers methods to assess wildlife habitat at large scales. The high altitude approach has several advantages over traditional methods for analyzing habitat over large spatial scales. The combination of remote sensing and geographic information system (GIS) can be used to link fine-scale selection of structural and compositional attributes of habitat assessments (Homer *et al.*, 1993).

To better design a comprehensive conservation plan for this species, it is essential to understand how birds use these areas. We used remote sensing and GIS to evaluate the habitat characteristics of wintering grounds of *P. minor* at Chi-Ku, Taiwan. Particularly, we compared the land-use pattern in coastal areas of Taiwan and tested the hypothesis that the landscape pattern at Chi-Ku is a unique combination that attracts large flocks of *P. minor*.

MATERIALS AND METHODS

Database

We compiled several data sets for this study. To understand the distributions of *P. minor* in Taiwan, we extracted the information from the data bank of Lee at al. (1994) which, in turn, was compiled from several reports, i.e., Yamashina (1941), Hachisuka and Udagawa (1951), Chen (1990), Wu (1990, 1991), Ueng and Kuo (1991) and Lin (1994).

A series of black and white aerial photos of approximately 1:20,000 scale acquired between 1981 and 1993, and a SPOT XS image provided by the Center for Space and Remote Sensing Research of National Central University at Chung-Li, Taiwan and taken on October 3, 1986, were used to study the habitat characteristics of *P. minor* at Chi-Ku. The SPOT image has a

spatial resolution of 20 x 20 m (a pixel, picture element). Light reflectance for each pixel is measured in each of the 3 spectral bands (green, 0.50-0.59 μm; red, 0.61-0.68 μm; and infrared, 0.79-0.89 μm) and assigned a digital value from zero to 255. The aerial photos were used as ground check, and showed trends of habitat changes, while the digital data were processed and analyzed to produce a land-use and land-cover map using Earth Resources Data Analysis System (ERDAS Inc., Atlanta, Georgia, USA) programs, an image processing software. An unsupervised isoclustering classification was performed to delineate the land-cover pattern. These classifications were then checked with aerial photos and ground survey data, and assigned to respective land use. A field check on the accuracy of classification was conducted in August 1994, and the accuracy was estimated to be about 95%. The classified land-use and land-cover map was then transferred to a GIS, i.e. ARC/INFO (Environmental Systems Research Institute, Redlands, California, USA).

A bird distribution map at Chi-Ku was digitized using ARC/INFO. It was collected by the members of Tainan Bird Club in 1992-1993 and submitted to the Council of Agriculture, the Republic of China for management policy decision. Two types of usage were distinguished: core areas where the birds rest and take shelter at night, and foraging areas where the birds were observed feeding. The areal size of the foraging grounds represents the foraging intensity of *P. minor* at Chi-Ku. Based on the size of these foraging grounds, we identified four intensity classes: less than 5 ha, between 5 and 10 ha, between 10 and 15 ha; and above 15 ha. To show the relation between industrial development plan and bird distribution, we also created two data layers for the proposed alternate reserve and industrial site.

Digital data on the land-use and land-cover for areas where *P. minor* had occurred in Taiwan were obtained from Chang *et al.* (1994) and Chu *et al.* (1992). There are 16 land-use types identified. The distribution pattern of water, estuary, wetland, tidal mudflat, and fish ponds are important in accessing the potential habitat for *P. minor*.

Data Analysis

To determine the habitat characteristics of *P. minor* at Chi-Ku, we overlaid the bird distribution map with the land-use and land-cover map, identified the habitat types, calculated the areas where birds were sighted, and measured the distance of the proposed reserve to the industrial site.

In addition to the regional statistics, the proximity of the potential *P. minor* foraging grounds to the rest area was determined from the land-use and land-cover map. To determine the traveling distance of *P. minor* from rest area to foraging grounds, we used a raster-GIS (i.e., IDRISI) to calculate the linear distances. Vector data were rasterized to grid data with 5 x 5 m per pixel. The distance of each pixel to the rest area was computed using Euclidean distance in IDRISI (Eastman, 1987). Then the map was clipped by the bird distribution map. The average distances from the rest area to the foraging grounds were calculated. To determine if the traveling distances differ among four foraging intensity classes, we used an F-test since our data met the statistical requirements. All statistical analyses were performed using SAS software (SAS Institute Inc., 1989).

The habitat characteristics pattern was determined by generating several isocircles around the rest area. All data were aggregated into 1-km class intervals from the resting site. Statistics for each zone were summarized.

We used a matrix approach (Westman, 1985) to compare the landscape pattern among the areas in Taiwan where *P. minor* visited, and qualitatively evaluated the potential of these areas as alternate site for hosting large flock of *P. minor*. Since detail location of *P. minor* occurring at these areas were unavailable, we think this approach offers an easy and quick way to assess the status of these areas.

RESULTS

The population of *P. minor* occurred in most of the major wetlands in Taiwan, but with limited individuals (Fig. 1). The general habitats are marshes, estuaries, and wetlands. Except at Chi-Ku, most the sightings were sporadically with less than 12 individual birds were recorded at one site during a particular winter. Historic review (in 1930s) shows that there were about 50 *P. minor* seen at the coast close to An-Ping harbor of Tainan (Yamashina, 1941), approximately 10 km south of Chi-Ku.

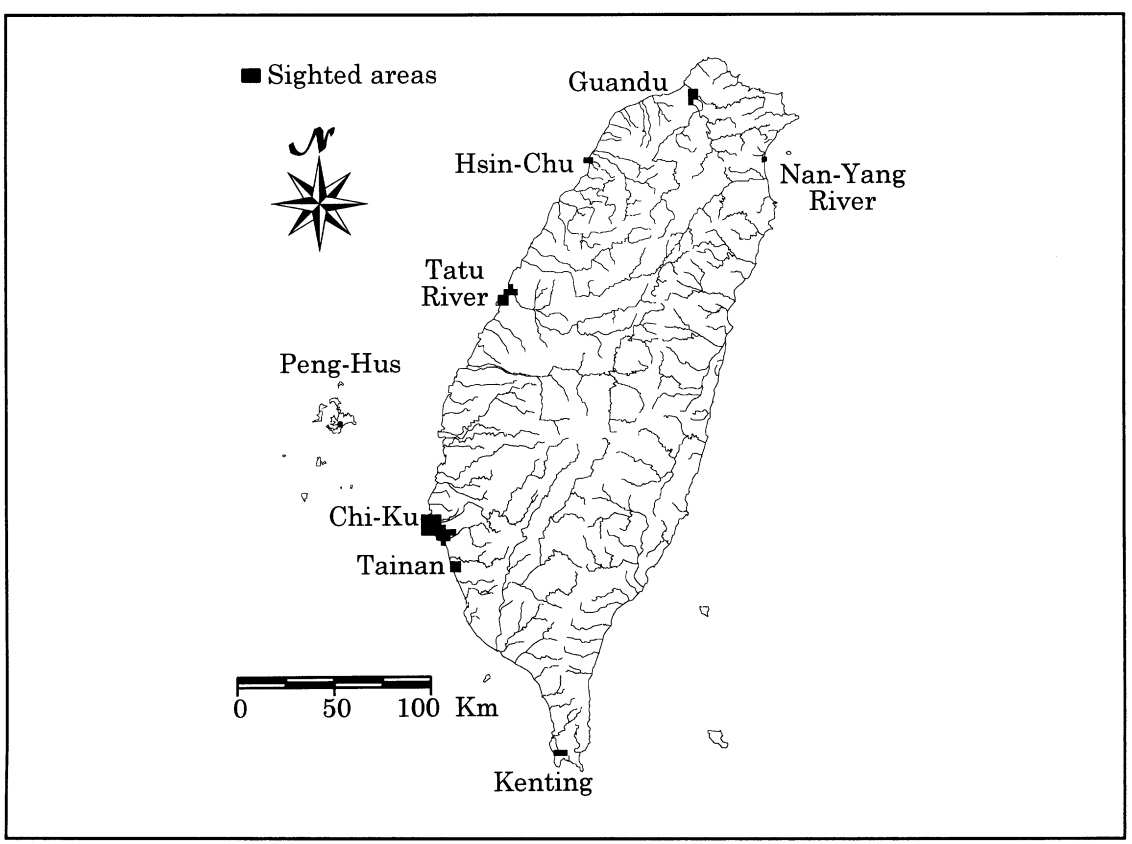

Figure 1. Distribution records of black-faced spoonbill (*Platalea minor*) in Taiwan. Data were based on various published reports (see text for details).

The distribution of *P. minor* at Chi-Ku is shown in Fig. 2 with the overlay of the SPOT image. Major land-use types at Chi-Ku include mudflats, fish ponds, water (ocean and estuary), and scattered vegetation. The main habitat (rest area or core area) that the birds used is shallow water (flooded area, approximately 20 cm deep) and mudflats, and is about 285.3 ha. Formally intertidal areas, these areas were created by construction of several water-controlling structures, beginning in 1984 and finished in 1987. This isolated area provide an important shelter for the birds. It is suspected that the site was chosen by spoonbill because it combines shallow water and mudflat, and possibly received less windy disturbance than the other sites as a result of the windbreak forest (*Casuarina equisetifolia* L.) located at the north-western direction. This core area is mainly used as rest site where hundreds of bird gathered together during the night. There are 26 foraging sites recorded. Most of the foraging grounds are the nearby fish ponds, with the exception of three mudflat sites located close to Tseng-Wen estuary. Our data show that *P. minor* did not visit on the alternate reserve proposed for the birds by local county. The bird distribution appeared in Fig. 2 can be regarded as the group home range which includes about 2875 ha.

The average traveling distances for *P. minor* from the core areas to various foraging grounds are shown in Table 1. Generally speaking, the traveling distances are inversely related to the usage intensity (Fig. 3). The birds seem to favor some of the most closest fish ponds for food and explored less on the northern sites. The average traveling of *P. minor* from the rest area to the foraging areas is about 3.18 km (SD = 1.22, Min. = 0.72 km, and Max. = 5.54 km). About 50% of the foraging sites are within this range (Fig. 4). No significant difference was found among the mean distances of the four foraging intensity classes ($F = 2.04$, $df = 3, 22$, $p = 0.14$; Table 1). In general, visiting frequency is not affected by the traveling distance. But the distance of the most frequent foraging sites was significantly close to the rest area than the other classes combined ($F = 5.27$, $df = 1, 24$, $p = 0.03$).

An examination on the proposed alternate reserve showed that it is located west of the proposed industrial site and has about 233.3 ha; 29.4% is a 2-m high windbreak forest (*C. equisetifolia*) planted no longer than 10 years ago and 70.6% is tidal mudflats. Winds are very strong at

Table 1. Average traveling distances (in km) of *Platalea minor* to foraging areas, classified based on the occurrence intensity, at Chi-Ku, Taiwan.

Foraging intensity class	n	Average distance (km)	Standard deviation	Minimum distance (km)	Maximum distance (km)
1	10	3.62	1.25	1.88	5.54
2	9	3.17	1.18	1.14	5.12
3	4	3.03	0.74	2.16	3.78
4	3	1.75	1.01	0.72	2.70

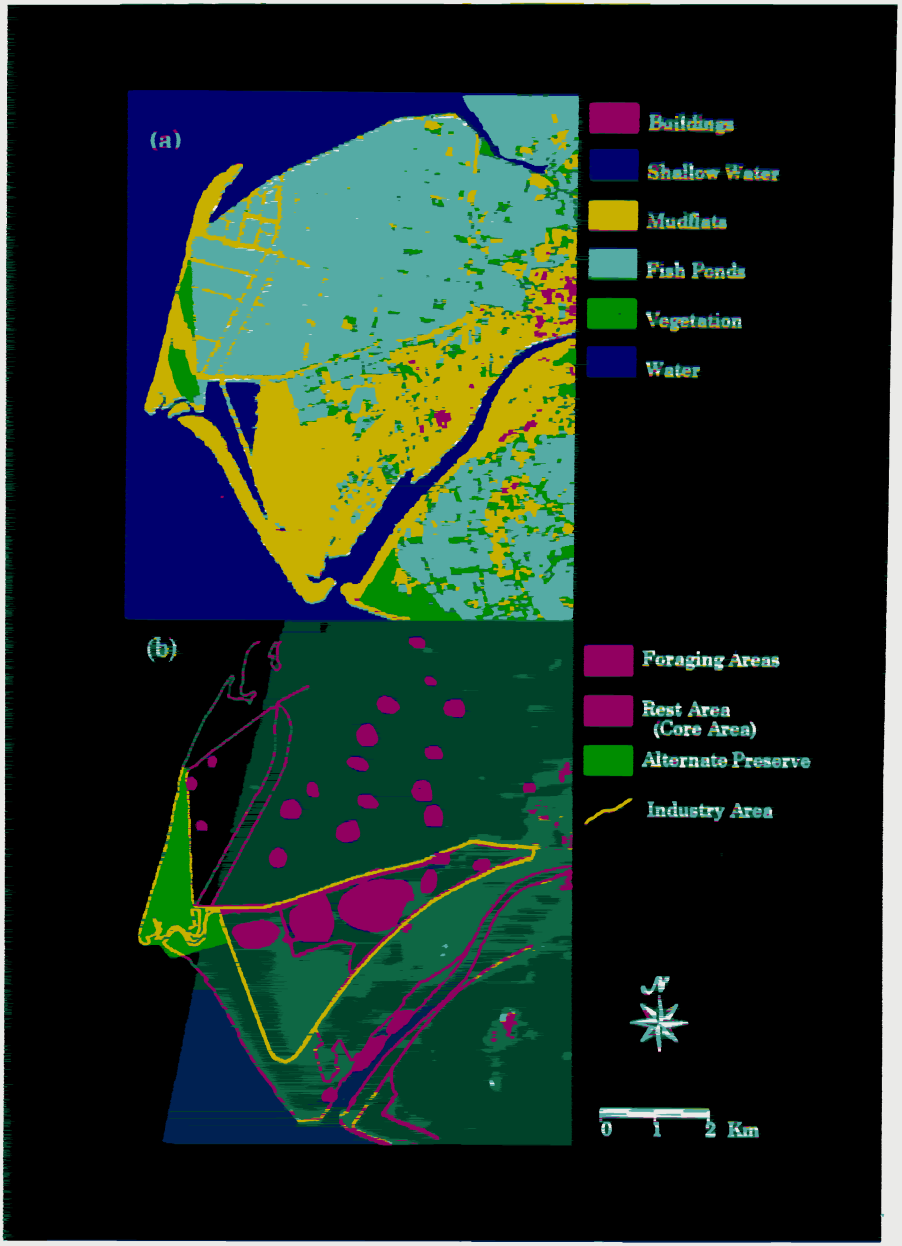

Figure 2. Distribution and landscape pattern of black-faced spoonbill (*Platalea minor*) at Chi-Ku, Taiwan. (a) A classified land-use map based on a SPOT image and aerial photos. (b) The original satellite image overlaid with bird distribution data compiled by members of Tainan Bird Club, boundary map, and the proposed alternate reserve map. Due to the satellite operation, the SPOT image shown in (b) did not cover the entire study areas. The missing parts were filled by photointerpreting the 1992 aerial photos.

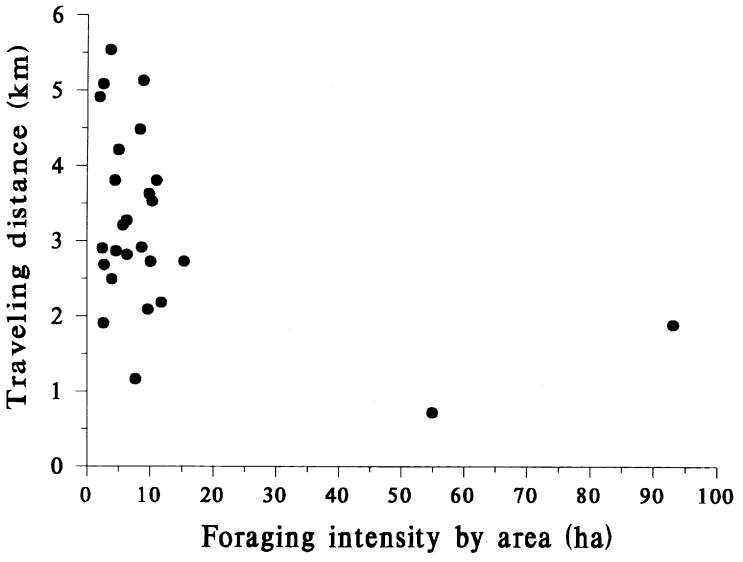

Figure 3. The relation between the traveling distance from the core area to the foraging grounds and the visiting frequency as determined by the areal sizes of the foraging grounds.

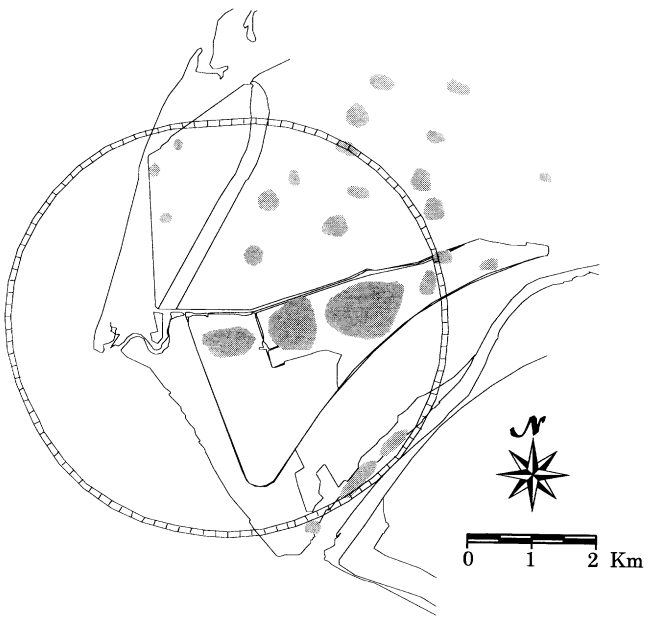

Figure 4. The potential protection area (circled) for the black-faced spoonbill (*Platalea minor*) at Chi-Ku based on a traveling distance of 3.18 km from the core area.

this area during the winter period. The shortest distance between the centers of the reserve and the proposed industrial area is about 1 km. The shortest distance between the boundaries of these two sites, however, is less than 10 m, i.e. these two areas are very closed.

Table 2 shows the spoonbill foraging cover statistics to the core area based on the proximity analysis of the land-use and land-cover map of Chi-Ku. Shallow water, mudflat, and fish pond are the major component in the first 1-km range. Fish pond, mudflat, and water are the dominant land-use/land-cover types for areas over 1-km range. In each 1-km zone they are the major component, while urban lands are relatively few. Thus, the characteristic pattern for *P. minor* at Chi-Ku is the combination of shallow water and mudflat for rest area, and mudflat and fish pond for food source, and the fish pond should be fairly large with sufficient small fishes to support the entire population of *P. minor*. Human disturbance is relatively low.

Based on the analysis at Chi-Ku and since *P. minor* is mostly carnivorous, we selected four critical habitat requirements to evaluate the coastal areas in Taiwan that have been visited by *P. minor* (see Fig. 1) to see if they can host large flock of population. These criteria are sufficient food sources (possible complex of estuary and fish ponds), presence of rest area (shallow water and mudflat), similar landscape pattern to Chi-Ku (overall similarity to Chi-Ku), and human disturbance (current human activities and development projects). It is clear from the land-use and land-cover maps of the areas studied that none of these sites possesses all the requirements or similar landscape pattern to support large population of *P. minor* (Table 3). Nang-Yang River (I-Lan County) has three sites, i.e. Chu-An, Nan-Yang estuary, and Wu-Shih-Eh-Chia, being

Table 2. Habitat size (in %) for each isocircle (in 1 km) of *Platalea minor* at Chi-Ku, Taiwan as determined by proximity analysis using a geographic information system (GIS).

Characteristics	Distance from the core area (km)					
	0–1	1–2	2–3	3–4*	4–5*	5–6*
Number of foraging site	2	4	7	7	3	3
Fish pond	40.0	33.0	28.2	27.7	29.2	40.2
Mudflat	32.1	33.8	23.1	17.7	10.2	9.1
Water	10.0	23.0	39.1	45.8	42.1	28.9
Vegetation	7.4	9.7	8.4	8.5	16.5	17.7
Shallow water	10.1	0.0	0.0	0.0	0.0	0.0
Urban	0.6	0.5	1.2	0.9	2.1	4.0
Total area (ha)	567.8	1159.2	1649.4	1859.9	1914.5	1249.8

* some areas were not included, most of them are water and urban lands.

Table 3. Habitat requirements evaluation on the sites that had been visited by *Platalea minor* for possibly hosting large flock of population.

Habitat requirement	Locality						
	Nan-Yang River*	Guandu	Hsin-Chu	Tatu estuary	Tainan	Kenting	Peng-Hus
Enough food source	Yes	Yes	No	Yes	Yes	No	No
Rest area	No	No	Yes	Yes	No	Yes	Yes
Similar landscape pattern	Yes	No	No	No	Yes	No	No
Human disturbance	Moderate	High	High	High	High	Low	Moderate

* generalized from three sites' characteristics. See text for explanation.

visited by *P. minor*. Chu-An is dominated by fish ponds, but with few mudflats. Nan-Yang estuary has the most similar land-use and land-cover pattern, but is lack of potential rest areas. Wu-Shih-Er-Chia is a marsh, but is short of sufficient food sources. Guandu (Taipei City) has undergone drastic changes recently (Lin, 1994) and may not be able support P. minor. The habitats at Hsin-Chu (Hsin-Chu City), Tatu estuary (Chang-Hua County), and Tainan (Tainan City) are facing very high human disturbance, and various economic development plans were proposed (Chang *et al.*, 1994). The wetland of Kenting (Ping-Tung County) is well protected by national park system, but it may be lack of enough food sources and rest area since it is not close to estuary. The condition at Peng-Hus (Peng-Hus County) may not support large flock of *P. minor* due to its limited food sources.

DISCUSSION

Our goal is to use remote sensing to assess large areas of habitat of an endangered species, black-faced spoonbill (*P. minor*). By incorporating remote sensing information into a GIS, we showed the unique landscape patterns at Chi-Ku for the wintering birds. The current study reveals the general distribution pattern of *P. minor* at their wintering site.

The mean traveling distance from the rest area to foraging grounds for *P. minor* is about 3.18 km. This suggests that a minimal protection areas for *P. minor* must include at least this distance to ensure sufficient food sources (Fig. 4). Although this boundary does not cover the entire foraging areas, it represents an essential area (about 3791.7 ha) that should be preserved and can be regarded as the core area in terms of the biosphere reserve model (Gregg and McGean, 1985). Additional buffer and transition zones should be considered to ensure sound protection of this endangered species.

The potential threats to *P. minor* at

Chi-Ku are the habitat destruction by industrial construction, pollution of Tseng-Wen River from surrounding urban discharges, and future sea-level rise caused by global climate change. The proposed industrial plan will have the greatest, immediate impact to this habitat. It is not clear how the proposed new international airport and river pollution will affect the *P. minor* population at Chi-Ku at this moment. Research work should be conducted on this aspect. Sea-level rise is expected to have deleterious effects to the coastal wetland where *P. minor* used, principally by changing the areal extent and configuration of available habitat, and the invertebrate food resources (Ray *et al.*, 1992).

Since some of these threats are inevitable, the most practical measure at this stage is to maximize the extent of habitat available in the future. Based on our initial study, to protect the wintering grounds for *P. minor* it is necessary to protect the entire areas where they were sighted, similar to the area shown in Fig. 2. Any further habitat destruction must be prevented. The new reserve for *P. minor* should also be designed to accommodate sea-level rise, including provisions for the formation of new intertidal mudflats at sea levels above current (Myers and Lester, 1992). Buffer zones should be protected to ensure above-tide resting sites that would be still available once current ones were submerged.

The design of a comprehensive protection plan for the endangered species requires interdisciplinary efforts and is only possible when more information becomes available. Continued work with the black-faced spoonbill is being conducted to gather more species-specific information. Various researchers have focused on the feeding ecology, behavior, and habitat requirements of the species by ground survey. These data and the information on the temporal population dynamics and seasonal spatial distribution pattern of *P. minor* at Chi-Ku, are necessary to show (1)how the birds utilize this areas in details, (2)the association of bird and habitats, and (3) the distribution of food and shelter resources. Temporal landscape changes detected by remote sensing are also important to monitor these resources, and provide a holistic view that is not available from the ground survey.

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黑面琵鷺在臺灣七股度冬區之棲地利用

李培芬[1]　許嘉恩[1]　蔡博文[2]

[1] 國立臺灣大學動物學系

[2] 國立臺灣大學地理學系

本文報導全球性瀕臨滅絕的黑面琵鷺在臺灣曾文溪口七股度冬區之棲地利用情行。利用各年份之航空照片與SPOT人造衛星影像資料，經由影像處理與地理資訊系統之分析，得到本區之土地利用圖，配合已知之鳥類分布圖，分析棲地利用情行。結果顯示黑面琵鷺主要是利用一塊潮間帶地區爲休息場所，並利用臨近之魚塭和河口區作爲攝食區，休息區與攝食區之平均距離3.18爲公里，一般而言，黑面琵鷺較常至距離較近之區域覓食。臺南縣政府擬議在本區設立工業區，並提出替代保護區方案，經由地理資訊系統分析，顯示替代保護區主要爲沙灘地(29.4%)和木麻黃防風林(70.6%)，本區之核心區域與工業區之間相距一公里，但兩區相臨，缺乏緩衝區，且黑面琵鷺從未出現於這區域，此外，由海岸地區土地利用資料評估，臺灣地區沒有類似七股地區之環境，可以提供大量之黑面琵鷺棲息，因此，若七股地區一旦遭受破壞，則黑面琵鷺可能將無法利用這個新保護區，或是臺灣地區的其他地點。

關鍵詞：瀕臨滅絕動物、遙測、地理資訊系統