

Abstracts of ornithological masters' theses from Taiwan, 1977–2003

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Since the late 1970s, many masters' theses in Taiwan have investigated aspects of the island's avifauna, including a substantial number of studies on the endemic species. This paper presents abstracts of these studies, in some cases condensed from the originals, to bring this important body of data to international attention. In recent years, all Taiwanese masters' theses have been required to have Chinese and English bilingual abstracts, but this was not the case for those published before 1993. Thus, nine of the early theses have only Chinese abstracts, and I have translated these into English (as indicated after the title). Editing has been largely confined to clarity of expression rather than change of content. Taxonomy and nomenclature follow Inskipp *et al.* (1996) except for usage in thesis titles, where the researcher's original usage is also given (with Inskipp *et al.*'s nomenclature inserted in square brackets). This is to facilitate readers in tracing the thesis. The full theses are mostly in traditional Chinese, except for numbers 3, 7, 10 and 23, which are in English. Readers wishing to consult the full theses should contact the institutions directly. Some are also held in the National Central Library, Taipei, Taiwan (<http://www2.ncl.edu.tw/>).

Table 1 shows that more than half of the theses (57%) focused on single species. Among subjects, breeding behaviour and ecology accounted for almost half of the theses (48%), foraging behaviour and ecology accounted for 25% and community structure accounted for 16%. Many theses addressed more than one of the subjects listed in Table 1.

THESIS ABSTRACTS

1. Jai Peng (1977) **A study of ecological isolation of birds in Taiwan.** Department of Biology, Tunghai University, Taichung. Adviser: Lin Jun-Yi.

Ecological isolating mechanisms of 130 species of landbird breeding in Taiwan are described. Factors such as geography, altitude, horizontal and vertical habitat, foraging behaviour, body size, bill morphology and diet were analysed. Within each avian community, 'guilds' were defined to show functional structure. Only two species, Light-vented Bulbul *Pycnonotus sinensis* and Styan's Bulbul *P. taiwanus*, appeared to be completely geographically isolated. Altitudinal ranges varied according to local distributions; generally, species occupied specific ranges, especially during the breeding season. Most species did not show clear directional or seasonal migration along altitudinal gradients. Altitudinal ranges averaged 1,333 m, which is larger than in other similar studies. The greatest changes in avifauna occurred at around 1,000 m and 2,300 m. For practical purposes, three altitudinal zones of bird distribution were distinguished: low altitude (<1,000 m); intermediate altitude (1,000–2,300 m); and high altitude (>2,300 m). Bird species diversity increased from sea level, reached its peak (66 species) at 1,200–1,500 m, and then decreased to five species at high altitudes. The relative paucity of the forest avifauna at low altitudes was attributed to human disturbance of habitats and historical factors during colonisation of Taiwan by people in

Table 1. Subject matter of ornithological masters' theses from Taiwan (N=67).

Subject	Theses	No. (%)
Community structure, competition	1, 18, 19, 21, 25, 26, 29, 31, 35, 49, 65	11 (16%)
Morphology and plumage	2, 16, 17, 36, 42, 51	6 (9%)
Breeding behaviour/ecology, territoriality	2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 20, 24, 27, 38, 39, 41, 42, 46, 47, 48, 52, 54, 56, 58, 60, 61, 63, 66	32 (48%)
Foraging behaviour/ecology, diet	4, 6, 8, 9, 11, 22, 23, 33, 38, 43, 44, 48, 50, 55, 57, 59, 61	17 (25%)
Flocking	4, 8, 10, 27	4 (6%)
Vocal behaviour, vocalisations	8, 16, 17, 41, 62, 64	6 (9%)
General behaviour	45, 57, 67	3 (4%)
Conservation issues	9, 19, 35, 40, 48, 56, 65	7 (10%)
Genetics	28, 37, 63	3 (4%)
Flight	30	1 (1%)
Migration	51	1 (1%)
Distribution, population trends	9, 10, 19, 31, 32, 34, 40, 53	8 (12%)
Single species	4, 5, 7, 8, 10, 11, 14, 15, 16, 17, 22, 24, 27, 28, 30, 33, 36, 38, 39, 41, 42, 43, 45, 46, 47, 48, 50, 51, 52, 54, 57, 58, 59, 61, 62, 63, 66, 67	38 (57%)
Species pairs	2, 3, 12, 13, 32, 37, 49	7 (10%)
Seabirds	9	1 (1%)
Waterbirds/shorebirds	6, 11, 15, 20, 22, 24, 29, 31, 32, 40, 43, 45, 50, 51, 54, 55, 56, 57, 66	19 (28%)

the 18th century. In forest, species occupying the ground layer were most abundant at low altitudes, whereas the proportion of species occupying the shrub layer increased with altitude. Species occupying the forest understorey were reduced or absent in pure coniferous forest. The proportion of canopy species decreased with altitude. Foliage-gleaning and ground-foraging were the two most common foraging behaviours. Low altitudes, especially those near sea-level, supported more species of aerial foragers. Hover-gleaning species disappeared abruptly at c.2,400 m. Birds of prey were absent above 2,700 m. Only one species of bark-feeder occurred at low altitudes. The proportion of small-bodied (4–9 cm) species increased with altitude, whereas that of intermediate (9.5–17 cm) species decreased. No clear trend was observed for large-bodied (17.5–38 cm) species. Species with body sizes of 4–6 cm appeared to occur most frequently above 2,100 m. Within each altitudinal range, food resources were generally exploited uniformly, except in the case of vertebrates and larger invertebrates.

2. Hsu Jy-Minna (1984) **A biological study of Styan's Bulbul *Pycnonotus taivanus* and Chinese [=Light-vented] Bulbul *P. sinensis formosae***. Department of Zoology, National Taiwan University, Taipei. Adviser: Lin Yao-Sung; [translated by WHF].

Between September 1982 and August 1983, an 860-hour field study of Styan's Bulbul *Pycnonotus taivanus* and Light-vented Bulbul *P. sinensis* was conducted in Kenting and Taipei (botanic garden, zoo, youth park and NTU campus). In 1983, specimens of both species were purchased from Pingtung for external measurement and inspection of the sexual organs in order to compare their appearance, breeding biology and ecology. In total, 222 Light-vented Bubluls, 176 Styan's Bubluls and 15 'intermediate morphs' were obtained. The adult:juvenile and male:female ratios amongst the specimens were similar for both species. Males were larger than females, and Styan's Bulbul was larger than Light-vented Bulbul. Intra-specific size differences between the sexes were greater than inter-specific size differences between individuals of the same sex. The plumage and size of the 'intermediate' specimens were between those of the two species, and their geographical distribution was from the area of overlap between the two species' ranges. Hence, they possibly represented hybrids of the two species. The daily activity patterns of Styan's and Light-vented Bubluls were influenced by both time and season. Birds were generally active in the early morning and late afternoon. During breeding season, Styan's Bubluls remained active throughout the day, although this was apparently not the case for Light-vented Bulbul. Both species occurred in pairs throughout the year, although during the non-breeding season they could be found in flocks. In both species, threatening behaviour included supplanting, chases, alert and 'head forward' postures, which were all used in the establishment and defence of territories. Wing-lifting, song and aerial displays were used during territory advertisement, and combined with chasing, 'head forward' and pre-copulatory display, attracted females for mating. The breeding season of Styan's

Bulbul was from late March to early July, the peak being during April. Light-vented Bulbul bred later, with the peak in May. In both species, nest construction and incubation were carried out entirely by the female. Males guarded and defended the territory. Nestlings were fed by both parents. Females of both species laid at 24 hour intervals, and incubation began when the last egg was laid. The incubation period was 11–12 days. Nestlings required frequent brooding. The fledging period was 9–10 days. In Styan's Bulbul, average clutch size was 3.3 eggs and hatching success was 60%; the average number of nestlings per nest was 2.7. In Light-vented Bulbul, average clutch size was 2.9 eggs and hatching success was 65%; the average number of nestlings per nest was 2.6. Both species frequently had two broods. Styan's Bulbul was very selective with respect to nest-site: of 84 nests found in Kenting, 75% were in *Calophyllum inophyllum*, although the latter comprised just 34% of the trees locally.

3. Lin Lu-Shih (1985) **The breeding ecology of two wren warblers [=prinias]: [Plain Prinia] *Prinia subflava formosae* [=Prinia inornata] and [Yellow-bellied Prinia] *P. flaviventris sonitans* in central Taiwan**. Department of Biology, Tunghai University, Taichung. Adviser: Paul S. Alexander.

Populations of Plain Prinia *Prinia inornata* and Yellow-bellied Prinia *P. flaviventris* were studied between January 1984 and May 1985 in an area of c.2 km² covering parts of the Tunghai University campus and adjacent Taichung Industrial Zone. The breeding activity of 68 pairs of Plain Prinia and 27 pairs of Yellow-bellied Prinia was studied between April and September 1984. Most Plain Prinia breeding activity occurred between April and August, whereas breeding by Yellow-bellied Prinia occurred mainly between May and July. Habitats used by Yellow-bellied Prinia had denser vegetation than those used by Plain Prinia. Nesting sites of both species occurred principally in *Panicum maximum*, but also in *Miscanthus floridulus*. The height of nests in these two grass species was greater on average for Plain Prinia than Yellow-bellied Prinia. Average clutch size in Plain Prinia (4.35 eggs) was higher than in Yellow-bellied Prinia (3.87 eggs). Egg size was slightly smaller in Plain Prinia. In both species, egg weight was correlated with laying order. Hatching and fledging success were higher in Yellow-bellied Prinia than in Plain Prinia, but a greater number of clutches in Plain Prinia compensated for the lower productivity per clutch. These data suggest that the two species of prinia maintain their population levels by different adaptations.

4. Li Pei-Yi (1986) **The natural history of Black-naped Blue Flycatcher [=Black-naped Monarch] and why it joins mixed-species flocks**. Department of Biology, Tunghai University, Taipei. Adviser: Lucia Liu Severinghaus; [translated by WHF].

This study was on the behaviour of Black-naped Monarch *Hypothymis azurea*, the benefit individuals gain from joining mixed-species flocks, and how mixed-species feeding flocks form. Between June 1984 and April 1986, the behaviour of Black-naped Monarch was studied at Tunghai University campus,

Taichung. Foraging efficiency and incidences of predation were studied, both when feeding in flocks with Vinous-throated Parrotbill *Paradoxornis webbianus* or Japanese White-eye *Zosterops japonicus*, and when feeding alone. The species preferred *Acacia confusa* woodland with low human disturbance. Black-naped Monarchs were monogamous, with the pair bond lasting year-round. Both sexes defended the territory. They fed on insects captured by flycatching. The breeding season was from late April to late July, with one or two broods per year. The average clutch size was three eggs, and the incubation period was 14 days. The fledging period was 10 days, although fledglings stayed with the parents for 40–60 days before becoming independent. Both sexes shared the incubation, brooding and provisioning of chicks, although females did a greater share of chick provisioning. Males carried out nest-site defence duties. The species usually joined mixed-species flocks during the non-breeding season, most commonly during January. Although it fed in the canopy when on its own and when joining Japanese White-eye flocks, Black-naped Monarchs foraged in lower bushes when they joined Vinous-throated Parrotbill flocks. Foraging efficiency was higher when in mixed-species flocks: although individuals did not obtain more food, they saved energy when capturing prey. The benefits of joining mixed-species flocks varied according to the constituent species. Foraging efficiency increased when birds joined parrotbill flocks, whereas there was no significant difference when birds joined white-eye flocks. The incidence of predation was lowest in parrotbill flocks, second lowest in white-eye flocks, and highest when alone.

5. Yuan Hsiao-Wei (1986) **A behavioural and ecological study of Lesser [=Oriental] Skylark *Alauda gulgula* at Kenting Pasture.** Department of Zoology, National Taiwan University, Taipei. Adviser: Lin Yao-Sung; [translated by WHF].

Between April 1985 and March 1986, a 750-hour field study of Oriental Skylark *Alauda gulgula* was conducted in the pasture and surrounding hills of Kenting National Park, Pingtung county. The lark population was dependent on the vegetation status of the habitat. During August–September, before the pangola grass *Digitaria decumbens* had been harvested, and when average grass height was >80 cm, the larks moved to nearby grassland with shorter grass. Areas with livestock also contained higher numbers of larks. Daily activity was affected by the seasons, and started and ended within one hour of sunrise and sunset respectively. Birds were most active in the period between sunrise and 10h00, with another peak of activity shortly before sunset. In the breeding season, birds maintained relatively high levels of activity throughout the day. During the breeding season, a higher proportion of birds was in pairs, whereas during the non-breeding season, birds were mainly seen singly or in flocks. Individual behaviour included resting, alert, feeding, bathing and preening. Social interactions included agonistic behaviour such as supplanting, chasing, posturing and fighting, as well as singing from the ground and in flight. Alert, agonistic and vocal behaviour changed in frequency through the breeding season, which was from early March to late

June, with a peak in late April. Males began by establishing territories and attracting females for mating. Nest building and incubation were carried out exclusively by the female, while the male defended the territory. Eggs were laid during the early morning, and the average clutch size was 2.6 eggs. Eggs had an average weight of 2.8 g and average dimensions of 21.6×16.3 mm. Egg size was negatively related to clutch size, and varied significantly between nests. Incubation began soon after the last egg was laid. Females incubated eggs only when the temperature was below 26°C or above 37°C; most of the time they only turned the eggs. Long spells of incubation were not observed. The incubation period was 12 days, and the female brooded the nestlings for 3–4 days. Provisioning of nestlings was shared by both parents. Chicks fledged after 8–9 days, after which fledglings were provisioned by the parents for another 15 days. Hatching success averaged 59%, but was much higher earlier in the breeding season (95% before May) than later (8.3% after May). Fledging success averaged 68%; later nests were less successful owing to predation, and heavy rains after May. The growth curves of chick weight and tarsus length showed a close fit to logarithmic relationships. Growth of the tarsus ($K_L=0.59$) was faster than increases in weight ($K_W=0.35$). At 15 days old, fledglings were relatively capable of flight.

6. Chu Yueh-Li (1987) **A behavioural and ecological study of egrets.** Department of Biology, National Taiwan Normal University, Taipei. Adviser: Wang Ying; [translated by WHF].

Of the six species of egret occurring in Taiwan, only four are common. These include two winter visitors (Great Egret *Casmerodius albus* and Intermediate Egret *Mesophoyx intermedia*) and two resident species (Little Egret *Egretta garzetta* and Cattle Egret *Bubulcus ibis*). Feeding behaviour of these species was studied between September 1985 and March 1986 at Nan-Jen Mountain in Kenting National Park. A positive correlation was found between the number of cattle and the number of Cattle Egrets following them ($r=0.4$, $P<0.05$). The percentage of egrets foraging with grazing cattle increased as the ratio of Cattle Egrets/cattle increased. It appeared that egrets preferred to follow cattle when the cattle were grazing since 97% of grazing cattle were accompanied by egrets, while only 51% of cattle without attendant egrets, were grazing. There was no significant difference in feeding frequency between egrets following and not following cattle. However, the time distribution of feeding, watching, preening, and bathing between these two groups was very different. In winter, Little Egrets defended their feeding territories in streams from intruders. After chasing, the owner's behaviour was affected by the presence of the intruder. When the owner of a neighbouring territory was in sight, the incidence of intrusion was lowered. Neighbouring territorial egrets helped to drive intruders away. After a chasing incident, if the intruder entered a neighbouring territory when the neighbour was out of sight, the first territory owner increased its activity in the neighbouring territory. Little Egrets were most active in the centre of territories. The frequency of chasing incidents

was correlated significantly with the use of the territory boundary by the owner ($r=0.7$, $P<0.05$). Little Egret foraging techniques varied with habitat and food abundance, and hence indirectly affected the time spent in different habitats. The frequency of feeding attempts by young birds (3.0 attempts/min) was higher than for adults (1.4 attempts/min), but the success rates showed no difference. The frequency of feeding attempts was higher for territory owners (3.7 attempts/min) than intruders (2.5 attempts/min) (t-test, $P<0.05$), however, catching rate for owners (90%) was significantly lower than for intruders (99.6%; t-test, $P<0.05$). Little Egrets showed three major foraging techniques: walking, standing, and flycatching. Feeding frequency when walking was highest in the breeding season (3.4 attempts/min) and much lower in winter (0.8 attempts/min). Feeding when standing was rarest (0.06 attempts/min). Great and Intermediate Egrets winter in Nan-Jen area. Their feeding frequencies and movements showed significant differences (t-test, $P<0.05$). The use of feeding areas by Intermediate Egret fitted the feeding model by Charnov (1976).

7. Chen Hui-Chuan (1987) **The biology and breeding behaviour of [Eurasian] Tree Sparrow [*Passer montanus*] in central Taiwan**. Department of Biology, Tunghai University, Taichung. Advisers: Paul S. Alexander and Lucia Liu Severinghaus.

This represents the first study of the biology and breeding behaviour of Eurasian Tree Sparrow *Passer montanus* in Taiwan. Field observations were conducted between January 1986 and May 1987. In total, 565 bouts of male courtship display were observed and a flow-chart for courtship behaviour was constructed. Male courtship display peaked in late March and decreased gradually through to May. Nests were searched for during June–August in 1986 and April–May in 1987. The number of new clutches peaked at the end of June. Clutch size ranged from three to five eggs; the mode was four. Mean hatching success per nest (± 1 standard deviation) was 0.75 ± 0.23 . Both sexes appeared to make equal contributions to nest-building and parental care. Most individuals maintained monogamous pair bonds, but some males paired with two females and simultaneously defended and cared for two nests. Additional extra-pair courting was also observed.

8. Luo Liu-Chi (1987) **A biological study of [Steere's Liocichla] *Liocichla steerii* at Chitou**. Department of Biology, National Taiwan Normal University, Taipei. Adviser: Wang Ying; [translated by WHF].

From March 1986 to April 1987, a biological study of Steere's Liocichla *Liocichla steerii* was conducted at Chitou, Nantou county. Steere's Liocichla frequented the transition zone between two different vegetation types. About 77% of plants used as perches were bushes or undergrowth less than 4 m in height; 85% of perching sites were less than 2 m above ground. Daily activity peaks of the species coincided mainly with dawn and sunset. Steere's Liocichla is omnivorous, with a very varied diet that includes fruits, berries, insects, other invertebrates and a range of human-

made foods. In winter, when natural foods are scarce, food left by tourists was a major food source. In cases of severe food shortage, birds feed on the remains of dead conspecifics. The calls of Steere's Liocichla can be separated into nine types: male territorial call, female response call, two alarm calls, fighting call, escape call, distress call, social call, and chick begging call. Each call is distinctive and has a specific meaning. The male territorial call and female response are both sex-specific. The breeding season lasts almost five months, from mid-March to mid-August, during which birds sing, mostly in pairs, at dawn. The average weight of adult birds during the breeding season was significantly lower than in the non-breeding season. Both the male and the female defended the breeding territory. The average territory was 60x100 m in size, and in the shape of an irregular polygon according to the landscape. Nests were located to one side of the territory, not in the centre. Nests were cup-shaped and built by both sexes from bamboo leaves, bark, roots and leaves, lined with fine grass and plant fibres. The pair tended the nest for two days following the completion of building before the female laid the first egg. The average clutch size was 2.5 eggs. Eggs were generally pale green, speckled with dark reddish spots. On average, eggs measured 17.9x23.9 mm, and each weighed c.13% of the female's body weight. The incubation period was 16 days, with both sexes incubating by day, but only the female by night. Nestlings were brooded for eight days, with both parents sharing brooding, provisioning and nest-cleaning duties. Chick growth rate (body weight and tarsus length) was nearly exponential. The fledging period was 12 days, and the average weight of fledglings was 20.5 g ($n=3$), equating to c.68% of the female weight. Average tarsus length at fledging was 28.5 mm, which is about the same as that of adults. During the non-breeding season, between September–March, the species formed flocks. Flock size reached its peak during January, the coldest month of the year. Pair bonds lasted into the non-breeding season. Pairs joined flocks (of varying sizes) and began daily activities an hour after dawn. At the end of the day, flocks broke up into pairs again two hours after sunset.

9. Chen Tsuei-Lan (1988) **A biological study of seabirds at Mao-Yu islets**. Department of Biology, National Taiwan Normal University, Taipei. Adviser: Wang Ying; [translated by WHF].

The Mao-Yu islets lie south-west of the Penghu archipelago. With steep inaccessible terrain and abundant fish resources, the area has become one of the last traditional breeding sites for a number of tern species. However, owing to human disturbance, seabird populations have declined in recent years. To facilitate the future management of the area, a two-year survey of the avifauna and a preliminary investigation into the dependence of terns on local resources was conducted. The preliminary survey recorded 43 species of bird from 22 families, seven of which breed there: Great Crested Tern *Sterna bergii*, Roseate Tern *S. dougallii*, Black-naped Tern *S. sumatrana*, Bridled Tern *S. anaethetus*, Brown Noddy *Anous stolidus*, Pacific Reef Egret *Egretta sacra* and Oriental Skylark *Alauda gulgula*. Only Common Kingfisher *Alcedo atthis*, Pacific

Reef Egret and Oriental Skylark were resident year-round, with the rest of the species being migratory. Rarer species that were also recorded included frigatebirds *Fregata* sp., Streaked Shearwater *Calonectris leucomelas* and Brown Booby *Sula leucogaster*. The most abundant species were Brown Noddy and Bridled Tern, which comprised more than 90% of individuals recorded. The breeding season of these two species was from March to September. The average body weight (± 1 standard deviation) was 189 ± 10.8 g ($n=13$) for Brown Noddy, and 124 ± 7.9 g ($n=29$) for Bridled Tern. Half the individuals ringed had a brood-patch. Preliminary estimates suggested that 7,000–20,000 terns were present at the peak of the breeding season. A few terns were also found on nearby islets, but numbers were less than 10% of those occurring at Mao-Yu. Habitat use differed between the two species: 62–92% of Brown Noddy nests were among rock-piles, whereas 52–84% of Bridled Tern nests were on grass. The distribution of nests of both species was also affected by the slope of the terrain: as many as 260 nests/ha were recorded on steep cliffs, whereas fewer than 15 nests/ha occurred in flat areas. No species are known to be predators on the islet; although rats were seen, their impact on the tern colonies is not known. Differences in foraging technique were noted among four of the tern species. Diving was used most by Roseate Tern (90%) and Black-naped Tern (88%). Brown Noddy used four types of foraging technique, with foot-paddling and contact-dipping the most commonly used (90%). Bridled Tern employed five techniques, amongst which contact-dipping was the most frequent (70%). The area was also used heavily by fishermen from nearby islets throughout the year: interviews with them revealed that fish were abundant, and that more than 20 species could be caught in the area. Fishing occurred by day or night, depending on the target species. Clams, crabs and seaweed were also abundant at Mao-Yu, and were harvested year-round. The collection of eggs was the most obvious threat to the bird populations on the islets, but its impact was not determined. Disturbance by the increasing number of tourists visiting the islets is also a concern.

10. Li Shou-Hsien (1989) **The breeding biology and flocking in the non-breeding season of Japanese White-eye *Zosterops japonica* [=*Z. japonicus*]**. Department of Biology, Tunghai University, Taichung. Advisers: Paul S. Alexander and Lucia Liu Severinghaus.

The breeding biology and flocking behaviour of Japanese White-eye *Zosterops japonicus* were studied from September 1987 to February 1989 in an area covering c.50 ha on the campus of Tunghai University. In 1988, the breeding season began from mid-April and ended in mid-August. The average clutch size was 2.8 eggs. Incubation lasted 10–11 days and the young fledged 10–11 days after hatching. Both parents shared equally in feeding and brooding responsibilities. White-eyes were monogamous, and pair bonds may be maintained throughout the year. In the non-breeding season, white-eyes formed large foraging flocks of 20–50 individuals. Flock size and composition changed frequently throughout the day. Turnover rate of birds in a 1.5 ha area was high. Of 94 birds ringed

in the 1.5 ha area between November 1987 and February 1988, only eight were seen in this area one month after ringing, and only seven were sighted about one year later.

11. Chen Zhao-Jie (1989) **The relationship between breeding territory and stream habitat in Brown Dipper *Cinclus pallasii***. Department of Biology, National Taiwan Normal University, Taipei. Adviser: Wang Ying.

From November 1987 to April 1989, Brown Dippers *Cinclus pallasii* were studied in Taiwan. The breeding season, in December–May, was earlier than for most of the resident bird species. The early start of breeding in this species appears to be an adaptation to a food supply that is most abundant in winter and early spring. For about 90% of observation time, dippers foraged in riffles, which comprise 47% of the stream systems in the area, suggesting that dippers prefer this habitat type. Riffles were the most productive sites for aquatic insects. Three types of foraging techniques—submerge-wading, diving, and float-pecking—were observed; submerge-wading was observed most frequently in shallow riffles, and diving in deep riffles. Dippers were found to be monogamous. Pairs established linear breeding-season territories along streams. An average breeding territory was 1,045 m in length ($n=14$) and territory size was strongly correlated with food parameters. Nest-site availability was not a limiting factor. Detailed analysis of the relationship between territory size and stream habitat factors showed that territory size was significantly correlated with the percentage of slow, deep water. Altitude, percentage of area comprising riffles, and total wet-weight of aquatic insects were inversely correlated with territory size. There were no apparent correlations between territory size and other factors such as stream flux, slope and water pH. In multiple regression analysis, a model developed from the combination of riffle area percentage and total aquatic insect weight explained 74% of variance in territory size. The percentage riffle area related to available feeding area in the territory, while total wet-weight of aquatic insects related to food supply. The combination of these two factors related to the total food available in each territory. Thus, territory size was closely related to food availability.

12. Young Shuh-sen (1989) **The comparative biology of Sharp-tailed Munia [=White-rumped Munia] and Spotted Munia [=Scaly-breasted Munia]**. Department of Zoology, National Taiwan University, Taipei. Adviser: Chiu Tai-sheng.

Life histories of White-rumped Munia *Lonchura striata* and Scaly-breasted Munia *L. punctulata* were studied at the Kan-tou River bank, Hsinchu county, from January 1988 to January 1989. The research investigated differences between their life histories, and mechanisms favouring sympatry. There were several similarities in natural history. Both species fed on similar seed types year-round, and potentially affected crop harvests. Nests of both species had an elliptical shape with a tubular opening at the upper side hidden with long grass stalks. The eggs were pure white, and hatched after 12–13 days. The fledging period was c.18

days, and juveniles required about 100 days to gain adult plumage. There were several differences between the species. Scaly-breasted Munia was larger and bred from May to November, whereas White-rumped Munia bred from April to December. Scaly-breasted Munia showed highest activity in October whereas White-rumped Munia was most active in May, July, and October. Hatching success was 65% for White-rumped Munia but 36% for Scaly-breasted Munia. For the nest lining, White-rumped Munia used dry bamboo leaves, and Scaly-breasted Munia used green plant matter. White-rumped Munia nests were more widely spaced than those of Scaly-breasted Munia. The logistic growth curve of body weight was: $W=11.47/1+e^{-0.31(t-7.42)}$ for Scaly-breasted Munia and $W=8.21/1+e^{-0.38(t-5.06)}$ for White-rumped Munia.

13. Chang Chiung-Wen (1990) **Analysis of vocal repertoire of the bulbuls [Light-vented Bulbul] *Pycnonotus sinensis formosae* and [Taiwan Bulbul] *P. taivanus***. Department of Zoology, National Taiwan University, Taipei. Advisers: Lin Yao-Sung and Lucia Liu Severinghaus; [translated by WHF].

From March to August 1989, a total of 290 field-hours studying Light-vented Bulbul *Pycnonotus sinensis* and Taiwan Bulbul *P. taivanus* were conducted at Kenting and Taipei (NTU campus, botanic garden and Academia Sinica). From August 1989 to April 1990, the inter-species and intra-species differences in maximum frequency, frequency range, duration, and time interval of these two species' calls were analysed using a sonagram analyser (Kay 5500) to determine the call types used by each species. In total, 420 minutes from 175 calls of Taiwan Bulbul and 360 minutes from 89 calls of Light-vented Bulbul were recorded. Sounds were divided into four categories: songs, calls, harsh notes and alarm calls. Each category was subdivided into types: eight for song and harsh notes, four for calls and alarms. In total, there were 356 kinds of vocalisation. Among these 356 sounds, the songs were most varied, with 239 kinds; 57 specific to Light-vented Bulbul, 144 specific to Taiwan Bulbul, and 38 shared by both. Although they share some common vocalisations, there were differences between the species in the frequency with which they were given. Twelve harsh sounds were specific to Light-vented Bulbul, 14 to Taiwan Bulbul, and 40 were shared. Three calls were specific to Light-vented Bulbul, 21 to Taiwan Bulbul, and nine were shared. Two alarm calls were specific to Light-vented Bulbul, ten to Taiwan Bulbul, and six were shared. Both species gave shared harsh notes, calls, and alarms similarly frequently. Songs, calls, and harsh notes did not differ significantly between species in maximum frequency or frequency range, although they did in duration and time interval. Alarm calls of Light-vented Bulbul and Taiwan Bulbul differed significantly in all characters: maximum frequency, frequency range, duration and time interval. Statistical analysis of basic phrases showed that Light-vented Bulbul had significantly lower intra-specific variation in sound characters. While Taiwan Bulbul tended to add notes before or after its basic phrase, Light-vented Bulbul did not. In summary, the major differences between sounds of

Light-vented Bulbul and Taiwan Bulbul were in song notes, and there was much less difference in basic sound characters.

14. Liu Wan-Chun (1990) **Polygyny in the Pale-headed Fan-Tailed Warbler [=Bright-headed *Cisticola exilis*] of central Taiwan**. Department of Biology, Tunghai University, Taichung. Advisers: Paul S. Alexander and Lucia Liu Severinghaus.

The mating system of the Bright-headed *Cisticola exilis* was studied in shrub-grassland on Tatu mountain (180 m) in Taichung county. During April–September in 1989 and 1990, 14 male territories were observed regularly for breeding activities. Most males were bigamous, some were trigamous and others showed successive monogamy with up to four mates per male during the breeding season. Territorial behaviour (up to 25 minutes per hour) and the absence of paternal care by males were documented. It was not possible to draw conclusions about the factors influencing female mate choice. Harem size did not correlate significantly with territory size or male calling frequency. Brooding females regularly foraged outside the territory, suggesting that within-territory food abundance may not influence female choice. All nests were built on shrubs and herbs in dense vegetation, and suitable nesting sites may be a major factor in a female's mate choice. The breeding season began in early April and the last fledging occurred in mid-September. Clutch size was 3–5 eggs and tended to decrease later in the breeding season. The incubation period was 15–17 days, and the brooding period was 11–13 days.

15. Tu Ming-Lin (1991) **Nest site selection and hatching success of Kentish Plover *Charadrius alexandrinus* on Changhua coast, Taiwan**. Department of Environmental Science, Tunghai University, Taichung. Advisers: Chen Peter Ping-Huang and Wang Chung-Kuei.

From March 1990 to July 1991, nest site selection and hatching success of Kentish Plover *Charadrius alexandrinus* were studied at Hsien-Hsi, Lun-wei, and Lu-Kang, along the coast of Changhua county, Taiwan. A total of 167 nests with eggs were recorded during this period. Compared with randomly selected points, Kentish Plover nests were closer to water, roadside, and nests of conspecifics. Hatching success was much higher at Hsien-Hsi (65–68%) than in the two other areas (35–42%). Nests failed through human destruction, nest abandonment and inclement weather. In Lu-Kang, higher hatching success was correlated with greater distance from other nests, proximity to water, and proximity to roads. In Lun-Wei, hatching success was significantly correlated with vegetation cover surrounding the nest.

16. Liu Liang-Li (1991) **Biological study of [Collared Bush Robin] *Tarsiger johnstoniae***. Department of Biology, National Taiwan Normal University, Taipei. Adviser: Wang Ying; [translated by WHF].

From April 1990 to March 1991, the biology of Collared Bush Robin *Tarsiger johnstoniae* was studied at

New Central–Cross Highway and Yu-Shan Forestry Road in the range of Yu-Shan National Park. The study included ringing, breeding observations, population estimation and nest site measurement. In all measurements, males (n=10) were larger than females (n=7), except that females had longer bills than males. Ringed males stayed in fixed territories during the breeding season, and were monogamous. The breeding season was from late March to mid-August. Nests were cup-shaped structures of moss, grass roots, dead leaves, and nylon fibres, usually placed in a hole on a slope; they were built solely by females. Females incubated, and the incubation period was 14 days (n=2). Both parents shared feeding, nest cleaning and guarding. The fledging period was 18 days (n=2); fledgling wing and tail length reached only 72% and 53%, respectively, of that of adults. There were no differences between provisioning rates and food sizes provided by male and female parents. Most food items were animals (98%). The daily activity of Collared Bush Robin coincided with local daybreak and sunset times. Birds were most active between 07h00 and 08h00, with 6.75 sightings/day on average; by contrast, only 0.75 sightings/day were made at the lowest activity period, between 16h00 and 17h00. Sightings of individuals and pairs were significantly higher in the breeding season than at other times of year. Calls of females showed no seasonal differences. Males gave significantly more alarm calls in the breeding season, but other types of call showed no seasonal differences. The roadside slope was divided into seven types. Bamboo-soil slope was the most frequent nesting area (n=5), and all other types were used in proportion to area. The major factor affecting breeding success was the distance from nest to road surface. This might have been because of predation and/or disturbance effects.

17. Chung Yu (1992) **Ecological study of Chinese Bamboo Partridge *Bambusicola thoracica***. Department of Biology, National Taiwan Normal University, Taipei. Adviser: Wang Ying; [translated by WHF].

From March 1991 to June 1992, Chinese Bamboo Partridges *Bambusicola thoracica* were studied at Kenting National Park, Pintung county, Taiwan, to investigate vocalisations, roosting behaviour, foraging range, external characters and breeding biology. Sixty birds were caught (in 73 captures), including 30 males (39 captures) and 30 females (34 captures). Capture efficiency in open environments (1.2 captures per 100 days) was higher than that in closed environments (0.8 captures per 100 days). Calling peaked in the morning and in March. In total, 349 calls were recorded. Calls of males and females differ. Female calls followed males' most of the time. Pair duets were most frequent in March, and male solos were most frequent in early June. Radio-telemetry was used to investigate roosting behaviour. Birds roosted in trees, with no fixed sites. Roost sites were usually in dense foliage <3 m high. Individuals in a roosting group pressed together. Eight birds were tracked; the mean foraging area (± 1 standard error) was $7,909 \pm 4,011$ m², with significant individual variation. There was no significant sexual dimorphism in external appearance, but all measurements for males significantly exceeded those for

females, except for the lengths of the central toe and lower mandible. Partridges nested on well-drained slopes. Both sexes developed brood patches. Young grew very fast; by 80 days, their plumage was almost indistinguishable from that of adults, and their tarsus length reached more than 90% of that of mature birds.

18. Ding Tzung-Su (1993) **Avian community ecology of mature forests in Mt Yushan**. Department of Zoology, National Taiwan University, Taipei. Advisers: Lin Yao-Sung and Lee Pei-Fen.

I studied avian communities of mature primary forests in Mount Yushan along 1,400–3,700 m altitudinal gradients between January and October 1992. Fifty sample stations were selected along Shalishian valley and Nantzshian valley, located at western ridge of Mount Yushan. Breeding bird densities were recorded with a circular-plot method, and 30 habitat variables were measured at each sample station. The foci of this study were: (1) the composition and parameters of avian communities among these vegetation zones; (2) the classification and distribution of avian guilds; (3) altitudinal distribution and its processes, and habitat selection of bird species. Population densities of 59 bird species were collected. Six bird communities were discerned by cluster analysis based on bird densities observed at each sample station. This classification reflected vegetation types, with the broadleaf forests split into higher (>2,000 m) and lower (<2,000 m) types, and bird communities of hemlock *Tsuga chinensis* and fir *Abies kawakamii* forests not distinguishable. Broadleaf forests, mixed forests and spruce *Picea morrissonicola* forests had higher total bird density and diversity; the latter declined with increasing elevation. Hemlock and fir forests showed the highest similarity (80% of species shared), while broadleaf forest and juniper *Juniperus squamata* shrubs showed the lowest (no overlap). Similarity between forests declined with increasing altitudinal separation. Species' distributions are limited by (1) altitude, (2) ecotone, and (3) competitive exclusion. Of the 56 bird species, 27% seemed to be limited by altitude, 32% by a combination of altitude with ecotone, 25% by ecotone, 9% by obvious competitive exclusion, and 7% by uncertain factors.

19. Lin Ming-Zhi (1994) **The relations between landscape changes and avian communities in Guandu, Taiwan**. Advisers: Lee Pei-Fen and Chen Qing-Xia.

I studied the relations between landscape changes and avian communities in Guandu from 1979 to 1993, using remote sensing and a geographic information system. Habitat types used by each bird species were recorded from November 1992 to December 1993 to allow landscape types to be linked to avian guilds in the study area. There had been two distinct landscape changes. The area of mangrove had increased in the south, while the area of human disturbance had increased in the north. Landscape structure indices showed that landscape diversity and evenness increased, but that landscape dominance decreased. The area of building land, soil-dumping land, mixed grassland and mangroves increased, but the area of paddyfields, ponds, *Cyperus malaccensis* and mudflats

decreased. During the study period, the area of paddy-field was the highest, mangrove land increased from 0.17 ha to 17.3 ha, and land with *C. malaccensis* disappeared. Avian species richness showed a bimodal annual distribution, with the highest peaks in April and November. The species richness of migrants decreased between 1979 and 1993, but that of residents did not. Changes from year to year of the avian species richness were determined by the occurrence of migrants, especially through the significant decrease shown by both the spring and autumn migration peaks during the 16-year period. Seven avian guilds were clustered by habitat selection data. The annual species richness of the shoreline, mudflat and shore-high-grass guilds decreased, reflecting declining areas of these habitats. The annual species richness of the woodland, grassland and shoreline guilds showed only small changes, as did the areas of these habitats, except that the area of woodland increased. Landscape changes were the main cause of avian community changes. Habitat quality and quantity for migrants declined through human disturbance and natural succession. The management of waterfowl and their wetland environment is an urgent need.

20. Sheu Sheau-Hwa (1994) **Effect of egret flocking on the plants and soil of egrettries**. Department of Botany, National Chung-Hsing University, Taichung. Advisers: Chen Ming-Yih and Lin Jau-Yuan.

In Taiwan, Little Egret *Egretta garzetta*, Cattle Egret *Bubulcus ibis* and Black-crowned Night Heron *Nycticorax nycticorax* nest together at certain egrettries (heronries). The effects of egret crowding on the plants and soils below egrettries were studied. Egrettries usually have dense forests and good feeding environments. Dominant trees differ between egrettries, and include *Casuarina equisetifolia*, *Broussonetia papyrifera*, *Melia azedarach*, bamboos and mangroves. Some egrettries have moved to coastal areas, reflecting intensive land use and increasing disturbance inland, and rapid expansion of fish ponds in coastal areas. Egrettries in coastal areas are mainly in *Casuarina* and mangrove stands. Recently, a few more egrettries also have been established in southern Taiwan. Accumulating faeces produce soils below egrettries that have low pH values and are extremely rich in available phosphorus and organic matter. Plants less susceptible to contamination by faeces, such as *C. equisetifolia*, *Ficus microcarpa*, *Avicennia marina* and *Kandelia candel*, have a smooth epidermis (so that faeces are easily detached from the leaf) and protected stomata on the epidermis of the underside of the leaf. More susceptible plants, including *Broussonetia papyrifera*, *Achyranthes aspera* and *Lantana camara*, usually wither when coated by faeces because the stomata on both the upper and lower epidermis are not well protected and so are easily blocked. This retards leaf physiological processes.

21. Chen Te-Kang (1994) **Resource partitioning of avian communities in Hsitou**. Department of Biology, National Taiwan Normal University, Taipei. Adviser: Lue Kong-Yang.

We used multivariate analysis to study resource partitioning of avian communities in Hsitou from September 1992 to April 1994. A 6.7-km loop was set

along virgin broadleaf forest and coniferous plantations, and various time and space parameters of the community were measured. In total, 89 species of woodland bird were recorded, of which 30 were common enough for detailed analysis. Of these, 26 are resident all year in the study area. There were more bird species, contacts and guilds in virgin broadleaf forest than in coniferous plantations. Cluster analysis divided the 30 species into eleven guilds. Most congeners belonged to different guilds, except for two woodpeckers. DCA (detrended correspondence analysis) and cluster analysis showed that bird species within a guild were partitioned by vegetation type, perch site, vertical stratification and foraging style, and between guilds were partitioned by biome, vegetation type, perch height, foraging behaviour and food type (bill size). There was little evidence that inter-specific competition resulted in resource partitioning. Niche breadth of most of bird species changed with season.

22. Tsai Chia-Yang (1994) **Seasonal and spatial variations of abundance of the Dunlin in relation to their main prey (Crustacea: Amphipoda) at Tatu estuary, Taiwan**. Department of Environmental Science, Tunghai University, Taichung. Adviser: Chen Peter Ping-Huang.

Dunlin *Calidris alpina* is one of the commonest shorebirds on the western Taiwan coast. This study aimed to understand the mechanisms regulating its distribution and abundance in the southern part of the Tatu estuary, Changhua county, by analysing its feeding ecology. Exclosure experiments from March 1993 to March 1994 estimated the effects of Dunlin feeding on amphipod density. In March–April 1993 and February–March 1994, when amphipods were most abundant, Dunlin feeding rate ranged from 3,800 to 8,000 individual amphipods per hour at different feeding sites. There was a positive linear relationship ($r^2=0.82$) between the spatial distribution of Dunlins and amphipods: more abundant amphipods attracted more foraging Dunlins. The abundance of Dunlins and amphipods is also positively correlated temporally ($r^2=0.90$).

23. Lin Hsing-Yu (1995) **Seed dispersal of mistletoes by flowerpeckers at Lien-Hua-Chih area, Nan-tou county**. Department of Biology, Tunghai University, Taichung. Advisers: Paul S. Alexander and Chiu Shau-Ting.

From March 1994 to April 1995, seed dispersal of mistletoes *Scurrula* spp. by flowerpeckers *Dicaeum* spp. was studied in the oil camellia *Camellia oleifera* plantation at Lien-Hua-Chih (23°55'N 120°52'E). Over 95% of camellia plants were parasitised by the mistletoe *S. rhododendricolus*, which began flowering in March, peaked in May and ended in October. Fruiting began in April and ended in November. Plain Flowerpecker *Dicaeum concolor* appeared in the plantation from March to November, with an estimated population of 30–45 birds from late April to mid-August. Juveniles appeared in June, when ripe fruits were plentiful, and increased through July. Thus, breeding was synchronised with mistletoe flowering and fruiting times. Fire-breasted Flowerpecker *D. ignipectus* appeared in small numbers (c.15) in the plantation in mid-July,

decreased to six in early August, and further declined until none was found in mid-September. Flowerpeckers fed on mistletoe nectar and fruit. They dispersed mistletoe seeds. Birds defecated seeds as they perched on mistletoe (87% of observed defecations for both species) or oil camellia branches (12% for Plain Flowerpecker, 13% for Fire-breasted Flowerpecker) and pressed the strings of viscous seeds to the branch. Faeces of the two species of flowerpeckers could not be distinguished. Ten seeds germinated on uninfected oil camellia branches (1.6–8.1 mm diameter) and were successfully established with at least one shoot in approximately six months. This represented only 1.8% of an estimated 547 seeds dispersed by flowerpeckers and monitored from August 1994 to April 1995. The larger population size and greater efficiency in fruit foraging of Plain Flowerpecker makes it more effective in seed dispersal in the plantation than Fire-breasted Flowerpecker.

24. Chen Rong-Tzou (1995) **The research of asynchronous hatching in Little Egret.** Department of Biological Sciences, National Sun Yat-Sen University, Kaohsiung. Adviser: Chang Hsueh-Wen.

Hatching asynchrony, sibling competition and brood reduction of the Little Egret *Egretta garzetta* were investigated in the Linyun heronry in 1993 and 1994. Egg-laying intervals averaged 39 hours, and egg-hatching intervals averaged 28 hours. These intervals increased with position in the hatching order, but egg masses did not differ significantly with laying order. Mean clutch size was 4.0 eggs in 1993 and 3.8 eggs in 1994. Hatching success was 92% of all eggs laid in 1993 and 94% in 1994. Growth and survival probability of nestlings related to their hatching order. During days 0–18, size differences among siblings were clear. Growth and survival rates of the first and the second nestlings were similar, but higher than those of the third and the fourth chicks. Nestling survival rates in different sized clutches differed significantly. Parents came back to the nest 48 times per day, on average, to feed the young. When two siblings competed for food, the elder was more likely to be fed than the younger. Some chicks were exchanged between nests to create broods with no hatching interval ('pseudo-synchronous' broods). Asynchronous broods had a higher proportion of partial broods, but a lower proportion of complete nest failures compared with pseudo-synchronous broods. On these latter nests, parents provisioned the young 66 times per day, a higher rate than that for the asynchronous broods. The pseudo-synchronous broods had a parental efficiency 33% lower than the asynchronous broods. The results supported Lack's hypothesis that asynchronous hatching allows flexible, optimal brood size, corresponding to food availability. They also accord with Hamilton's hypothesis that asynchronous hatching reduces competition between siblings.

25. Fang Cheng-Yi (1996) **The bird community in the Tatachia area pine forest three years after a forest fire.** Department of Forestry, National Taiwan University, Taipei. Adviser: Yuan Hsiao-Wei.

From 6 January 1993, a six-day forest fire burned 90% of pine forests in the Tatachia area of Yushan National Park (2,765–2,865 m). From March to July 1996, I compared the vegetation, bird densities and arthropods in burned and unburned areas of pine forest. Compared with unburned forest, burned areas had decreased ground layer cover but a greater number of ground layer plant species and more snags, similar bird species but different bird guild densities, and fewer arthropods (potential prey for birds). A total of 27 bird species was observed, with 24 in unburned forest, 21 in burned forest and 18 species common to both. Fourteen species of birds were abundant enough to estimate densities. All 14 used unburned forest, where the total bird density was 10.8 birds/ha, but only nine occurred in burned forest, which had a total bird density of 6.8 birds/ha. Bird guilds in burned forest had one fewer species of bush insectivore, and two fewer of tree omnivore and of tree insectivore, compared to the guilds in unburned forest. Densities of bush insectivores, tree omnivores and tree insectivores were lower in burned than in unburned forest, although density of ground insectivores was greater in burned forest. Species richness and biomass of arthropods were lower in burned forest than in unburned forest, perhaps explaining the lower bird densities in the burned forest.

26. Fang Yun-Ju (1996) **The relationship between forest structure and bird community: a case study on the influence of the timber stand improvement programme in a mid-elevation area, northern Taiwan.** Department of Forestry, National Taiwan University, Taipei. Advisers: Su Horng-Jye and Lucia Liu Severinghaus.

Selective logging and silviculture practices modify forest structure. To understand their influences on bird communities, and relationships between forest structure and bird community, a mid-elevation area in northern Taiwan was investigated. I compared forest structure, bird community, and microhabitat use of birds in a site nine years after selective logging and replacement by cypress (presumed *Chamaecyparis formosensis*) plantation, with those in undisturbed forest. Breeding bird density was censused in 23 sample stations by a variable circular plot method. Microhabitats were investigated by recording each active bird with respect to the plant life-form, forest stratum, and perch position. Vegetation and habitat structure were censused with twenty 5×5 m quadrats in each sample station. Birds were divided into eight guilds by diet, foraging behaviour and activity strata, according to the information of previous studies and data from my microhabitat investigation. A total of 110 tree species was recorded. In the logged forest there were lower densities of small- to medium-sized trees, and reduced coverage in the shrub to sub-canopy layer. The coverage and height of the ground layer, increased, as did the vertical heterogeneity. Tree species diversity, total coverage, foliage height diversity, and the horizontal heterogeneity of under-storey were also reduced.

In total, 35 breeding bird species were recorded in undisturbed forest, of which 27 were abundant enough

for density estimation. This species richness was slightly higher than in the logged forest, where 32 species were found, with 25 of them common enough for density estimation. However, the difference in species composition was small. The total bird density in undisturbed forest was higher than in logged forest, but dominance was stronger in the former, thus rendering its species diversity index lower than in the latter. The number of species more abundant in the undisturbed forest equalled the number more common in the logged site, but the effect of logging differed significantly between guilds. Ground gleaning omnivores, upper-storey gleaning insectivores, and upper-storey hovering insectivores suffered more impacts from logging. Conversely, under-storey gleaning insectivores, upper-storey trunk-probing insectivores, and upper-storey gleaning omnivores were more abundant in the logged site. These diverse responses among guilds reflect differences in food resource and foraging microhabitat. In the logged site, microhabitat use of birds was significantly concentrated in the dominant tree canopy and in the ground-layer. The range of vertical strata used was reduced. The perch position of upper-storey birds tended to shift towards the outside of crowns. Patterns of microhabitat breadth followed those of density of each guild, but average microhabitat overlap among species showed a reverse pattern. The microhabitat breadth was not related to the density difference between the two sites, neither was the microhabitat shift. Detrended correspondence analysis was used to analyse bird species assemblages. The most important factor corresponding with bird community variation was the habitat structure difference resulting from logging. The second was altitude. Bird community variation among sample stations was highly correlated with vegetation and habitat structure differences. Most of the higher altitude species were more abundant in the undisturbed site, and the diversity index along the altitudinal gradient was higher there. The tree species diversity index, foliage height diversity, total coverage, and horizontal heterogeneity index were related to the vegetation differences underlying variation in the bird community, but all of them had low correlation with both the number of bird species and total bird density.

27. Lin Ruey-Shing (1996) **The breeding and flock ecology of Grey-cheeked Fulvetta *Alcippe morrisonia***. Department of Zoology, National Taiwan University, Taipei. Advisers: Lin Yao-Sung and Chou Liea-Siang.

Grey-cheeked Fulvetta *Alcippe morrisonia* is the most abundant bird in Fu-shan forest. Its breeding and flock ecology were studied in the Botanical Garden from January 1994 to March 1995. The breeding season ran from mid-April to mid-August, peaking in May–June. The mating system may be monogamous. Both parents shared nest-building, incubation, brooding and feeding. However, the effort of females and males varied between nests and stages. Nest-building usually took 3–4 days. The clutch size was 3–4 eggs per nest and each fresh egg averaged 2.3 g. The incubation period was 12–14 days, and the young fledged nine days after hatching. The young were fed for 40–65 days after fledgling. Feeding frequency and

food-item size correlated positively with age of the young. The commonest food types were Lepidoptera and Hymenoptera larvae (79%). During the non-breeding season, fulvettas formed flocks. The size of two monitored flocks peaked at 49 in August and 62 in November. The smallest sizes (27 and 37) occurred just before the breeding season. The natural mortality of flock members was 34% per year, mainly due to cold weather in January and February. Flock composition stabilised after August or September. Flock home ranges were 17.8–31.8 ha according to grid cells counts. Flocks showed no preference for different habitats within the home range. Home ranges of neighbouring flocks overlapped, with no obvious territory defence. The extent of overlap differed between areas.

28. Chen Chao-Sheng (1996) **Variation of mitochondrial control-region sequences and population phylogeny in Japanese White-eyes *Zosterops japonica* [= *Z. japonicus*]**. Department of Biological Sciences, National Sun Yat-sen University, Kaohsiung. Adviser: Chang Hsueh-Wen.

Japanese White-eye *Zosterops japonicus* is widespread in South-East Asia, with two subspecies in Taiwan: *Z. j. simplex* is common in mainland Taiwan and *Z. j. batanica* occurs in Orchid Island and Green Island. The two differ in bill width, body size and feather colour. Using PCR (Polymerase Chain Reaction), I amplified the variable control region of the mitochondrial DNA and sequenced different populations of Japanese White-eye from mainland China, Kaohsiung, Nantou, Taitung, Orchid Island and Green Island. The length of mitochondrial DNA control region is about 1034 bp. Based on the phylogenetic analysis (by PHYLIP) of the central region of control region, the China–Taiwan populations and the Orchid–Green island populations are distinct. Assuming an origin in South-East Asia, the species might have spread from there to mainland China and the Philippines.

29. Huang Li-Ming (1996) **The relationships between avian community structure and stream corridor patterns along the Fa-Tse river in Taichung city**. Department of Environmental Science, Tunghai University, Taichung. Adviser: Chen Peter Ping-Huang.

Relationships between stream bird community structure and stream corridor patterns were studied along the Fa-Tse river in Taichung city. Avian species' populations and stream corridor factors were surveyed in nine plots from summer 1995 to spring 1996. Of 37 species of birds recorded, 20 were distinguished as stream species, 13 as terrestrial species, and four as aerial species. Four stream corridor factors correlated with stream bird species richness and population abundance. Corridor width showed a strong linear relationship with both avian species richness and abundance ($P < 0.001$). The number of sand-bars showed a significant relationship with both stream bird population abundance ($P < 0.001$) and species richness ($P < 0.01$). The terrestrial bird abundance also showed a significant relationship with stream corridor width ($P < 0.01$). Of the 20 stream bird species, Black-crowned Night Heron *Nycticorax nycticorax* was the most numerous species, more than twice as common

as Little Egret *Egretta garzetta* and four times as abundant as Common Moorhen *Gallinula chloropus*. Individual bird species preferred different habitats, but stream birds were concentrated in the centre of the corridor transect.

30. Huang, Shian-Lin (1996) **Power consumption of flight at different speeds in Light-vented [=Chinese] Bulbuls *Pycnonotus sinensis* estimated from aerodynamics.** Department of Zoology, National Taiwan University, Taipei. Advisers: Chou Lien-Shiang and Sue Chin-Chia.

Flight speeds and kinematical parameters of three Light-vented Bulbuls *Pycnonotus sinensis* were recorded. Using these data and morphological parameters, I estimated power consumption of these birds in flight through aerodynamic theory. Wing-beat frequency and amplitude did not differ with flight speed or between individuals. Body inclination angle decreased with increasing flight speed through a simple linear relationship. Light-vented Bulbuls may vary flight speed simply by changing their body inclination angle. When flying slowly (almost hovering), the induced power of the bird was about 80% of its mechanical power requirements, and the profile and parasite power were about 5%. In fast flight, induced power was about 50% of mechanical power requirements, with profile and parasite power about 30%. Induced power generates lift, whereas profile and parasite power overcomes drag. Hence, at slow flight most power expenditure is to generate lift. At high speed, only 50% of power expenditure generates lift, whereas 28–30% overcomes drag. Inertial power was 15–17% of mechanical power at slow flight and 23–27% at fast flight. Inertial power should not be ignored in calculations of power consumption of flight. If the mechanical efficiency of flight muscle lies between 0.08 and 0.23, flight metabolic rate could be 7.12–18.4 times basal metabolic rate (BMR) in slow flight (effectively, hovering), and 4.57–11.08 times BMR in fast flight.

31. Lu Cheng-ern (1997) **A study of dynamics of communities and population trends of shorebirds, wildfowl and egrets at Tatu estuary.** Department of Environmental Science, Tunghai University, Taichung. Adviser: Chen Peter Ping-Huang.

The Tatu estuary is a very important stopover site for shorebirds migrating through mid-Taiwan. This study is based on data from the Taiwan Wildbird Information Service, collected in five sites in the Tatu estuary from 1988 to 1996. Birds were divided into four groups: waders, wildfowl, terns and egrets. I analysed the community dynamics in each group every year, and examined population indices for trends. There were no obvious variations in the number of species or community composition of the Tatu estuary from 1988 to 1996. However, numbers of certain species varied significantly. Egret numbers did not change much, whilst all other species decreased except Grey Plover *Pluvialis squatarola*, Grey-tailed Tattler *Heteroscelus brevipes*, Ruddy Turnstone *Arenaria interpres*, Little Tern *Sterna albifrons* and Grey Heron *Ardea cinerea*.

32. Chang Yen-Chyuan (1997) **A study of spatiotemporal distribution of Little Egret *Egretta garzetta* and Black-crowned Night Heron *Nycticorax nycticorax* in Fa-Tse creek, Taichung city.** Department of Environmental Science, Tunghai University, Taichung. Adviser: Chen Peter Ping-Huang.

Little Egret *Egretta garzetta* and Black-crowned Night Heron *Nycticorax nycticorax* are the most numerous wading bird species on Fa-Tse creek, Taichung city. To understand the spatio-temporal distribution of these two species, the bird populations, habitat, environmental factors and the relative density of the birds' primary food source, fish, were surveyed in seven sites along the creek from June 1996 to May 1997. The egret was more evenly distributed than the night heron. During the study, the site of a heronry shifted, but this did not influence relative abundance at feeding sites. Little egrets used both shallow, slow-moving currents and swift rapids, while night herons used mostly slow-moving currents, specifically between water depths of 5 to 15 cm. Night heron abundance was correlated with relative density of fish. Night herons can be seen locally 24 hours a day. During the day there are significantly more night herons in the creek in the breeding than in the non-breeding season. These two species tolerate noise, but the night heron is more sensitive to sudden noise.

33. Chen Yun-ju (1997) **Foraging ecology of the White-backed Woodpecker *Picoides leucotos* [= *Dendrocopos leucotos*], in the *Quercus* zone of Da-Hsuen-shan mountain area, Taiwan.** Department of Forestry, National Taiwan University, Taipei. Adviser: Yuan Hsiao-Wei.

I studied the foraging ecology of White-backed Woodpecker *Dendrocopos leucotos* in the *Quercus* zone of Da-Hsuen-Shan mountain area, Taiwan, from October 1995 to November 1996. The study focused on foraging habitat selection and intersexual and interseasonal foraging resource partitioning. During 180 observations of foraging, birds used 25 tree species. Foraging habitat showed characters of old-growth forest, the woodpeckers preferring stands with more partially dead trees. They preferred trees of the Fagaceae, and/or that were partially dead, meso- or mega-phanerophytes. Males foraged on trees 25–75 cm diameter at breast height (dbh), and those larger than 100 cm dbh, more than did females; but they foraged less on trees smaller than 25 cm dbh, and 75–100 cm dbh. In addition, males foraged on trunks or branches greater than 10 cm diameter more than females and less on trunks or branches smaller than 10 cm diameter. Males probed more than, and scaled less than, females. Males used foraging resources more evenly than did females. It is not known if these differences reflect sexual dimorphism or intra-pair dominance. During the breeding season, partially dead trees and snags were used more, and live trees less, than during the non-breeding season. During the breeding season the foraging height increased, with more observations above 15 m, and fewer below 15 m. Finally, feeding woodpeckers scaled more, and probed less, during the breeding season than at other times. This probably reflects seasonal changes in food avail-

ability or in endogenous physiological requirements of the woodpeckers. Further studies are needed on this species's diet and foraging to understand the intersexual and interseasonal resource partitioning observed during this study.

34. Liao Chien-Yu (1997) **The spatial distribution and predictive model of Timaliinae [=Garrulacinae + Sylviinae: Timaliini] in Taiwan.** Department of Zoology, National Taiwan University, Taipei. Adviser: Lee Pei-Fen.

Understanding species' distribution is important for wildlife management and biodiversity conservation. Based on presence/absence distribution data and environmental variables, spatial distribution models of 16 species of the former Timaliinae (= Garrulacinae + Sylviinae: Timaliini, *sensu* Inskipp *et al.* 1996) in Taiwan were established using logistic regression. Bird distribution data were compiled from literature published between 1978 and 1995. A 2×2 km grid system was used to record the bird distribution. Environmental data were mapped in a geographic information system (GIS). Environmental variables showed significant differences between areas of presence and of absence for certain species. The accuracy of prediction varied from 71% to 92%. Based on predicted distribution models, altitudinal distribution of birds, gap analysis of existing reserves and simulation of global warming were undertaken. The available literature data can predict the distribution of 'Timaliinae' in Taiwan through logistic regression, but more information on birds and environmental variables would improve the power of the distribution models. Spatial analysis using GIS methods can provide valuable insight into overall patterns of potential distribution of 'Timaliinae' and the results can be applied in conservation policy.

35. Lin Lee-jane (1999) **The relationships between avian communities and environmental factors in the urban parks of Kaohsiung city.** Department of Zoology, National Kaohsiung Normal University, Kaohsiung. Advisers: Liang Shih-hsiung and Shieh Bao-sen.

This study constructed a database of bird communities of urban parks in Kaohsiung city, and investigated relationships between their characteristics and environmental factors. Twenty-five urban parks were seasonally surveyed from April 1998 to March 1999. A circular-plot method was used to record bird species and their abundance. Characteristics estimated of bird communities included total species richness, density, evenness and family richness index $(=(F-1)/\ln N)$, where F = number of families in the sample, and N = total number of individuals in the sample). Environmental factors included the area and age of a park, human activity level, noise intensity, edge effect and vegetation diversity. Area had the most important effect on bird species richness, diversity and family richness indices, explaining 30–55% of their variation. Species richness, diversity and family richness indices of larger parks exceeded those of smaller parks. By contrast, vegetation diversity, human activity and park age explained only about 10% of variation in those indices. Density and evenness varied more between seasons (temporally) than between parks (spatially).

Bird density was mainly influenced by season, while the number of bird species varied more between parks. Among characteristics estimated, diversity and family richness indices seemed to be the two best indicators for monitoring bird communities of urban parks in Kaohsiung city, because they were the most sensitive to environmental changes. Recommendations to increase bird diversity in Kaohsiung city parks include: (1) increase area as much as possible, at least to exceed 1.5 ha; (2) increase vegetation diversity and cover, especially the cover of bushes; (3) plant more native species of vegetation to attract native bird species; and (4) create more water sources to attract more species of waterbirds.

36. Hu Meo-Fen (1999) **Age identification and population dynamic of Grey-cheeked Fulvetta *Alcippe morrisonia* at Fushan Experimental Forest.** Department of Zoology, National Taiwan University, Taipei. Adviser: Chou Liea-Siang.

To understand the population dynamics of Grey-cheeked Fulvetta *Alcippe morrisonia* and the variation resulting from seasonality and typhoons, 1,392 fulvettas were captured, marked and released during January 1994 to October 1998 in Fushan Experimental Forest station. In order to construct a standard for age determination, skull pneumatization, iris colour, and moult patterns were recorded, and nine external morphological characteristics were measured. Skull pneumatization was the most effective indicator of age from April to September: 93.0% ($n=243$) of individuals with the skull incompletely pneumatized (1st–4th stages) were juvenile, and 92.9% of those with skulls completely pneumatized (5th stage) were adult. Adults' irides were more reddish than juveniles', which were yellowish- or reddish-brown. No single external morphological measurement could discriminate adults from juveniles. Tarsus and wing length together in a discriminant analysis gave an error rate of 37% for 155 known-age individuals. A key for age identification was suggested, based on skull pneumatization, moult pattern, iris coloration and morphological discriminant function. The error rate was higher in adults (25%, $n=261$) and lower in juveniles (4.7%, $n=296$); the total was 11% ($n=551$). Grey-cheeked Fulvetta showed a type II survivorship curve. Annual disappearance rate after fledging varied from 53% to 86%. Population numbers at the start of the breeding season (April) declined by 35% between 1994 and 1998, largely owing to mortality caused by Typhoon Amber in August 1997. Winter and typhoons were the major non-biological factors limiting fulvetta populations. Most typhoons reduced juvenile numbers, while adult numbers remained stable except under Typhoon Amber. About 47% of adult mortality happened in winter (between November and March).

37. Hsu Yu-Teng (1999) **The evolutionary relationships of Chinese [=Light-vented] Bulbul *Pycnonotus sinensis* and Taiwan Bulbul *P. taiwanus* revealed by their population genetic structure.** Department of Zoology, National Taiwan University, Taipei. Adviser: Lucia Liu Severinghaus.

Geographical isolation and natural hybridisation between Light-vented Bulbul *Pycnonotus sinensis* and Taiwan Bulbul *P. taiwanus* provide a good opportunity for studying avian speciation. We chose the rapidly evolving mitochondrial DNA (mtDNA) control-region (CR) sequences as a genetic marker and used Polymerase Chain Reaction (PCR) and automated DNA sequencing techniques to analyse population genetic structure and phylogenetic relationships between four subspecies of Light-vented Bulbul and Taiwan Bulbul. A 1,110 base-pair (bp) mtDNA (including 1081 bp control region [CR] and 29 bp t-RNAPro) neighbour-joining tree for 27 individuals (of the four subspecies) revealed no strict phylogenetic relationships. In total, 123 haplotypes were detected in the 536 bp hypervariable segment of the CR of mtDNA for 258 individuals from 18 localities. Genetic diversity indices showed high haplotype diversity (h) in every population, averaging 0.925 (range: 0.725–1); but low nucleotide diversity (?), averaging 0.00906 (range: 0.00538–0.01208). Neutrality tests (Tajima's D , and Fu and Li's D test) suggested that the mtDNA evolves in a selectively neutral manner. Population differentiation indices, including d_A (Nei's standard genetic distance), NST (a population differentiation index) and AMOVA (analysis of molecular variance), showed no population genetic structure, and only little genetic differentiation between the two species. The results of the gene flow (N_m = the number of migrants per generation) and the identical haplotypes among populations, suggest that gene flow is the most plausible cause for the limited mtDNA differentiation between the two species. The haplotype relationship network showed that *P. s. shirogashira* (of Okinawa island) probably originated from southern Taiwan; it is morphologically close to *P. s. formosae*. In conclusion, combined results of both this and previous studies showed no reproductive isolation and no apparent differences in ecology, behaviour or genetics between the two species. The two were presumably in an early stage of speciation, but geographic isolation disappeared through recent ecological and environmental changes.

38. Yu Shu-chun (1999) **The breeding and foraging ecology of the Taiwan Laughing Thrush [=White-whiskered Laughingthrush] *Garrulax morrisonianus* in the Tatachia area, Taiwan.** Department of Forestry, National Taiwan University, Taipei. Adviser: Yuan Hsiao-Wei.

I studied breeding and foraging ecology of White-whiskered Laughingthrush *Garrulax morrisonianus* at Tatachia, in the mountains of central Taiwan, from April 1997 to December 1998. I examined the species's parental care, nest site selection, and intersexual and interseasonal foraging resource partitioning. White-whiskered Laughingthrush was monogamous, with a breeding season from March to August. Both parents shared nest building, incubation, brooding and feeding. All clutches were of two eggs, which averaged 31.3 ± 1.5 mm in length. Parental feeding frequency increased with nestling age; invertebrates were the most common food. Within breeding territories, nests were located in areas with the highest tree densities. Males foraged on branches higher than 8 m more often

than females, but on branches below 8 m less often than females. Compared with the non-breeding season, laughingthrushes in the breeding season foraged at lower (0–2 m) and higher (8–14 m) heights, on shorter (0–2 m) and taller (6–14 m) plants, on smaller (0–5 cm dbh) and larger (15–40 cm dbh) trees, on smaller (0–1 cm dbh) branches, and exhibited more glean, flake, pry, sally, and sally-strike behaviours, and ate more invertebrates, flower petals, and larger food items (1–6 cm). White-whiskered Laughingthrushes seem to be opportunistic foragers, with foraging behaviour influenced by food availability, plant phenology, weather and seasonal changes in their endogenous physiological requirements. Seasonal variation in foraging behaviour probably reflects changes in food availability.

39. Liu Mark (1999) **The cooperative breeding of Taiwan Yuhina *Yuhina brunneiceps* at Mei-Fung area, Taiwan.** Department of Forestry, National Taiwan University, Taipei. Adviser: Yuan Hsiao-Wei.

In 1938, Taiwan Yuhinas *Yuhina brunneiceps*, which are endemic to Taiwan, were found to breed cooperatively. Further research on their breeding ecology was conducted at Mei-Fung, in the mountains of central Taiwan, from January 1997 to April 1999. The research focused on territorial behaviour, pair relationships, dominance hierarchies, breeding cooperation, parental group formation and variation in group composition of the 8–9 parental groups in the study area. Yuhinas maintained territories and lived in parental groups year-round. I observed 17 parental groups, each of 3–7 adults. The most common group size was four birds (47%). Each parental group had 1–3 communally nesting, monogamous, pairs and some had a single unmated helper. Each parental group had a male dominance hierarchy in which the head, wing, and tail length of higher-ranking males exceeded those of lower-ranking males (Mann-Whitney U test; $P < 0.05$). Only the largest male, the alpha-male, engaged in territorial defence singing. Female rank in the dominance hierarchy related not to body size but to mate's rank. Male yuhinas had significantly longer heads, wings and tails than females (Mann-Whitney U test; $P < 0.05$). Each group member contributed to rearing the young in the communal nest. During nest building and incubation, the female worked harder than the male, but when feeding nestlings the amount of work by males and females was more variable. Each brood took about 70 days to rear to fledging. Parental groups could rear three broods each season. Nests used by two or three females showed 2–3 different spot patterns on the eggs, supporting earlier observations that egg spot pattern is unique for each female. At Mei-Fung, new individuals joining parental groups were either male offspring from previous breeding seasons with a non-relative mate, or an unrelated pair. From 24% to 30% of the Taiwan Yuhinas at Mei-Fung disappeared annually. One bird ringed as an adult in an earlier study has lived at least eight years.

40. Chou Yi-Fang (2000) **Waterfowl population, activity pattern, and management of the Wu-Wei harbour, Ilan.** Department of Forestry, National Taiwan University, Taipei. Adviser: Yuan Hsiao-Wei.

Wu-Wei harbour, in the southern half of the Ilan plain, Ilan county, Taiwan, was designated a wildlife refuge in 1993 to protect overwintering waterfowl. The Kan-Ko irrigation canal flows into the harbour from the north, forming a freshwater marsh. I studied the abundance, distribution and behaviour of overwintering waterfowl in and around the harbour, and documented habitat changes to evaluate the harbour's importance to waterfowl overwintering on the Ilan plain. I also reviewed papers about habitat and food management to help resolve management problems at Wu-Wei harbour. Finally, I provided suggestions for future management and development of the refuge. I surveyed waterfowl at Wu-Wei harbour, Chu-An, Lan-Yan river, and 52-Chia from September 1998 to April 1999. Common Teal *Anas crecca* was the most abundant species at each site. Waterfowl diversity was great at Wu-Wei harbour (Simpson diversity index = 0.43), but there were more birds and more species at Chu-An and 52-Chia. Thus, Wu-Wei harbour is the third most important site for waterfowl overwintering in Ilan county. From 1989 to 1996, the open water area of Wu-Wei harbour gradually decreased with expansion of emergent plants such as *Phragmites* sp. Waterfowl in Wu-Wei harbour spent 12% of their time feeding, less than they spent (>20%) in other studies in literature. Flocks did not fly to nearby paddyfields to feed at night. Many species of annual plants produced seeds that may be used by waterfowl. Food resources might be sufficient to support the waterfowl overwintering in the harbour. Wu-Wei harbour could be managed towards as an ecological refuge, both wildlife- and human-orientated. 'Moist-soil management', used for similar habitats in other countries, could improve habitat quality and food resources at Wu-Wei harbour. Monitoring of waterfowl, food resources and other important variables should continue.

41. Chang Sue-Ching (2000) **Songs and breeding behaviour of Maroon Oriole *Oriolus traillii***. Department of Biological Sciences, National Sun Yat-sen University, Kaohsiung. Adviser: Chang Hsueh-wen.

I divided the sounds of Maroon Oriole *Oriolus traillii* into five types (Types A–E) according to aural impression. Type A, a harsh 'a-', was given by both sexes all year. It was possibly an unformed call, related to Type E. Type B, a 'wu-wu' or 'wu', was a male song functioning in mate attraction and territory defence. Type C was a whistle, heard mostly from females in reply to the male's songs. Type D, 'ga-ga-ga...' or 'ga-ga-ga-a-ga-ga-ga...' repeated shortly, was heard from both sexes all year; its major function was alarm. There was greater variation within Type E calls, which sounded like 'au-wai', 'au-wa', 'a-a', 'wa-au' or 'wa-wa-gua-wa'. They were heard from both sexes and their function was unresolved. Maroon Orioles bred from mid-February to early July. Nest-building took about 7–12 days, and incubation about 20 days. Clutch size was 3–4 eggs. Nestlings stayed in the nest for two weeks. The female built the nest and incubated alone, but shared feeding young with the male.

42. Kuo Wei-Wang (2000) **Sex differences and breeding ecology of Grey-checked Fulvetta**

***Alcippe morrisonia* at Fushan Experiment Forest**. Department of Zoology, National Taiwan University, Taipei. Adviser: Chou Liea-Siang.

In order to understand morphological differences between the sexes, the sex allocation of parental care, the growth rate, and the sex ratio of Grey-checked Fulvetta *Alcippe morrisonia*, birds were captured and measured from January 1994 to December 1999 at Fushan Experimental Forest station. Germ feather and blood samples of 328 birds collected from August 1997 to December 1999 allowed sexing by PCR (Polymerase Chain Reaction). Breeding behaviour at four nests was observed from April to May 1999. Among morphological measurements, only wing length and body mass differed significantly between sexes. Wings of adult and juvenile males were significantly longer than those of females. Adult males weighed significantly less than adult females and juvenile males. Fulvettas were heaviest in September and lightest in December. Body-mass changes during the non-breeding season did not differ significantly between sexes. During the early breeding season (March), females gained more weight than did males. Daily changes in weight were similar between sexes: lightest in the morning; heaviest in late afternoon. Sexes shared incubation, brooding and feeding young, but with different weights. Females incubated more often than males by day, and were totally responsible for incubation at night. Parents fed young one item each time. Food item size showed no significant difference between sexes. Males fed more frequently than did females, and older nestlings were fed more often than were young ones. Body mass and tarsus length of 8-day-old fledglings and their growing patterns showed no significant difference between sexes. No significant sex-ratio bias was detected among fledglings, juveniles or adults.

43. Chen I-Ling (2000) **Prey choice of Kentish Plover *Charadrius alexandrinus* in winter at Tatu estuary, Taiwan**. Department of Environmental Science, Tunghai University, Taichung. Adviser: Chen Peter Ping-Huang.

Kentish Plover *Charadrius alexandrinus* is one of the most common shorebirds on the western coast of Taiwan, but its feeding ecology is little studied. This study looked at the species's diet, foraging behaviour and net energy intake, through optimal diet theory. Laboratory study investigated the role of prey crab species (*Mictyris brevidactylus*, *Scopimera longidactyla*, *Uca lactea*) and size (each species divided into three classes) in prey choice of captive plovers from November 1997 to January 1998. Field studies of foraging behaviour of plovers were conducted in October and November 1998 at the Tatu estuary. Results of the laboratory study showed that *S. longidactyla*, small *M. brevidactylus* and small *U. lactea* were preferred ($P < 0.05$). In the field, Kentish Plover rarely foraged on *U. lactea*. This difference to the laboratory study was attributed to the escape capability of *U. lactea*. Low-profitable *M. brevidactylus* is as important a prey as the highly profitable *S. longidactyla*, because its overall profitability exceeds the energy intake rate of plovers specialising on *S. longidactyla*. Kentish Plovers hunting for *M. brevidactylus* seemed to search more

slowly and with less aggression than did birds hunting *S. longidactyla*. Energy cost–benefit calculations showed similar net energy intake for foraging plovers specialising on either of the two crabs, and maximum intake while foraging on both.

44. Tsai Jo-Szu (2000) **Fruit removal pattern on Formosan sassafras *Sassafras randaiense* by wildlife in Chilan area.** Department of Forestry, National Taiwan University, Taipei. Adviser: Yuan Hsiao-Wei.

I studied fruit removal from Formosan sassafras *Sassafras randaiense* (Lauraceae) to estimate relative importance of different animals to this species's dispersal. In 1998 and 1999, I collected data at Compartment 20 (1,100 m asl) in the Taiping work circle, I-lan county, and Compartment 94 (2,000 m) in the Tachi work circle, Hsin-chu county, Taiwan. I counted the number of fruits taken from infructescences over time to estimate the rate of fruit consumption, and I determined the species of diurnal dispersers and seed predators through direct observation. I used infrared cameras to assess secondary dispersal of fruits and seeds. In 1998 and 1999, 4.5% and 12% of all mature fruits dried out and 0.1% and 0% fell to the ground, respectively. Most fruits were consumed by wildlife, including one mammal species (Pallas's Squirrel *Callosciurus erythraeus*) and 11 species of birds. The bird species that ate sassafras fruits at the two sites were totally different, reflecting differences in elevation. Squirrels were seed predators and destroyed fruits (89% and 18% of the fruits taken by birds or mammals at Taiping and Tachi, respectively). Birds swallowed fruits and defecated or regurgitated intact seeds. Although the effects of these processes on sassafras seed viability are not known, they remove the pulp and probably do not harm the seeds. Thus, birds probably act more as seed dispersers than as seed predators. Taiwan Yuhina *Yuhina brunneiceps* consumed more fruit than any other species. Black-browed Barbet *Megalaima oorti* was probably the least effective seed disperser, because it spent longer periods in sassafras trees than did any other species of bird, and defecated most seeds under the parent tree. Steere's Liocichla *Liocichla steerii* and White-whiskered Laughingthrush *Garrulax morrisoniana* usually defecated in open habitats, aiding seed dispersal and germination. Because most (98.3%) fruits and seeds that fell on the ground were eaten or damaged by the Formosan Field Mouse *Apodemus semotus*, Formosan White-bellied Rat *Niviventer culturatus* or Père David's Vole *Eothenomys melanogaster*, there was little opportunity for secondary dispersal.

45. Wang Chia-Chi (2001) **Diurnal activity patterns of wintering Black-faced Spoonbills *Platalea minor* in Chigu, Tainan county.** Department of Zoology, National Taiwan University, Taipei. Adviser: Wang Ying.

From September 1998 to May 1999, diurnal time-budgets of Black-faced Spoonbills *Platalea minor* were recorded at the wintering area in Chigu, Tainan county. Communal and individual behaviour, and impact of disturbance on behaviour, were studied. Activities were classed into seven categories. Resting (80% of all

observations) was the predominant diurnal activity, followed by maintenance (10%), transitional behaviour (5.7%), locomotion (3.2%), foraging (0.93%), social interaction (0.45%) and others (0.13%). Observations were grouped into 'early population stable period' (mid-November–mid-January) and 'late period' (mid-January–mid-March). Only the proportion of time devoted to social interaction differed significantly between periods ($P=0.027$). Individual rests lasted 1–35 minutes, mostly (57%) less than five minutes. The major maintenance activity was preening (76% all maintenance activity observations), which often (in 43% of preening bouts) lasted fewer than 10 seconds. Most transitional behaviour was standing (95% all transitional behaviour observations), and most locomotion was walking (91% all locomotion observations). Diurnal foraging in the main roosting area was very rare (0.9% of time). Social interactions included friendly and agonistic activities. Friendly activities were classified into four types. The major type was allopreening (69% of all friendly activities), mostly confined to the neck-to-neck region (80% of preening observations). Agonistic activities were classified into four types, and mainly composed aggression (61% of all observations of agonistic activities). Social interactions occurred mostly between sub-adults. Overall activity increased after 15h00, peaking around 18h00 (75% of all the activities observed in a day). Amounts of maintenance activity, transitional behaviour and social interaction differed significantly with time of day ($P<0.001$). Spoonbills were disturbed on average 4.3 times per day, mostly by other waterbirds and fisherman. The predominant response was to fly and land some distance away from the disturbance. Activities after disturbance differed significantly from those before disturbance ($P<0.001$). Maintenance activities, transitional behaviour, locomotion and social interaction were significantly increased after disturbance. Four radio-tagged birds with 24-hour continuous monitoring spent more time in the main roosting area (62–66%) than in other areas (34–38%). The main roosting area was important to this species, and needs an effective management plan.

46. Wu Tsai-Yu (2001) **Nest-site selection of Lanyu Scops Owl [=Elegant Scops Owl] *Otus elegans botelensis*.** Department of Zoology, National Taiwan University, Taipei. Advisers: Lucia Liu Severinghaus and Lin Yao-Sung.

'Lanyu Scops Owl' *Otus elegans botelensis*, a subspecies of Elegant Scops Owl *O. elegans*, occurs only on Lanyu island. The population is c.1,000 birds. This owl is a secondary cavity-nester; it cannot excavate a hole for itself. Breeding success depends on cavity availability. The current study investigated possible criteria of cavity selection. Elements of trees and cavities were measured during the 2000 breeding season, in a region with a high density of breeding pairs. Owls seemed to select cavities for nesting on the basis of the cavity's size, interior moisture, flatness of the bottom, smoothness of surface and height above ground. They preferred high, large, dry and smooth cavities, which provide a safe and comfortable environment.

47. Lin Wen-lung (2001) **Insect residual, pellet analysis and hunting behaviour of the Brown Hawk Owl [*Ninox scutulata*] in Da-ken and Lien-hwa-chi areas.** Department of Entomology, National Chung-Hsing University, Taichung. Adviser: Yeh Chin-Chang.

This study investigated insects hunted by the Brown Hawk Owl *Ninox scutulata* in Da-ken, (Taichung) and Lien-hwa-chi (Puli) areas, in terms of their numbers and estimated biomass, and frequency of remains in regurgitated pellets. Lepidoptera, Coleoptera, Homoptera and Orthoptera were most frequently taken prey, making up 90% and 92% of total prey items in the two areas respectively. Numbers of Lepidoptera and Coleoptera taken remained constant with season, but those of Homoptera and Orthoptera varied. Scarabaeidae (17% and 25% in the two areas) was the most frequently taken family, followed by Sphingidae (11% and 14%), Cicadidae (11% and 12%) and Noctuidae (8.4% and 11%). Individuals of these four families constituted 50% and 60% of total insects taken. The same four orders also represented the largest biomass, accounting for 95% and 95% of the total. Scarabaeidae comprised the highest percentage of biomass (14% and 23%), followed by Cicadidae (17% and 18%), Acridiidae (13% and 19%) and Sphingidae (8.9% and 10%). The biomass produced by these four families represented 61% and 61% of the total insect biomass consumed by owls. Remains of Lepidoptera, Homoptera, Odonata, Phasmida, Megaloptera and Neuroptera were all found in >96% of pellets, with Mantodea, Blattaria and Orthoptera and Coleoptera found in 90%, 86%, 82% and 69% respectively. The weight of individual insects is highest in Acridiidae, Lucanidae and Saturniidae; the remaining 39 families have individual insects weighing 0.03–1 g. Analysis of pellets showed that small birds formed the largest proportion of food items, c.35% and 47% respectively at the two sites, with small mammals forming 25% and 33% of food items. Among foraging behaviours, hawking was most frequent in spring at Da-ken (25 occurrences per hour) and in winter at Lien-hwa-chi, and flycatching in the autumn at both areas (16 occurrences per hour at Da-ken and 22 occurrences per hour at Lien-hwa-chi). The food niche breadth and evenness at Da-ken were 11.6 and 0.74 [unknown units] respectively, those at Lien-hwa-chi were 8.9 and 0.55 [unknown units] respectively, and the food niche overlap at both sites was 93.9%.

48. Zong-Jiann Lin (2001) **Feeding and reproductive adaptation of Philippine Glossy Starling *Aplonis panayensis* in Kaohsiung city.** Department of Biology, National Kaohsiung Normal University, Kaohsiung. Advisers: Liang Shih-Hsiung and Shieh Bao-Sen.

Observations of feeding and reproductive adaptations of Philippine Glossy Starling *Aplonis panayensis*, an exotic bird species in Taiwan, were conducted in the Chiang Kai-shek Cultural Center and National Kaohsiung Normal University, Kaohsiung city, from January to December 2000. Possible impacts of the glossy starling on native species of Taiwan, and its projected population expansion were also evaluated.

Thirteen plant species were eaten by starlings in this study. The number of native and exotic species was almost equal. Glossy starlings fed mostly on fruit, followed by nectar and petals. Protein for nestlings comes partly from snails and caterpillars. Glossy starlings bred from mid-March to mid-September in 2000. They retained cavity-nesting habits after introduction into Taiwan. Nest sites were used up to three times in a single breeding season. Nest materials included native and exotic plant species, and artificial materials. The egg-laying period was 3–8 days. Clutch size was 1–4 eggs, mostly three. Incubation lasted 11–15 days, with a hatching success rate of 62%. The nestling period was 15–24 days, with a fledging success rate of 43%. On average, 39 days were needed from laying to fledging. Based on the Mayfield method, survival rate and reproductive success rate were 44% and 52% respectively. More singles were observed than were any larger group sizes. Daytime activity levels were influenced both by the time of day and season. Activity of starlings was observed mostly during one hour before or after sunrise or sunset. The largest numbers of this species were observed during 16h00–18h00 in January and February 2000. The population size of glossy starlings is projected to increase, based on characteristics of feeding, reproduction and daily activity. This species also possibly presents a direct and negative impact on Taiwan's native birds, such as Light-vented Bulbul *Pycnonotus sinensis*, Japanese White-eye *Zosterops japonicus*, Eurasian Tree Sparrow *Passer montanus* and House Swift *Apus affinis*.

49. Chen Chih-hao (2000) **A study of niche relationship between Red Turtle [=Red Collared] Dove *Streptopelia tranquebarica* and Spotted Dove *Streptopelia chinensis* on Tung-hai University campus, Taiwan.** Department of Environmental Science, Tunghai University, Taichung. Adviser: Chen Peter Ping-Huang.

Red Collared Dove *Streptopelia tranquebarica* and Spotted Dove *S. chinensis* are common native species in Taiwan, and coexist on Tunghai University Campus. According to the competitive exclusion principle, if two competing species coexist in a stable environment, their resources will be partitioned, or one species will become extinct. Birds reduce competition by spatial, temporal, and dietary isolation. This study aimed to identify niche relationships between the two doves. These two doves coexist by differences in their feeding and activity habitats. In the breeding season, requirements of nest sites and food resources increased, so niche overlap indices also did so. More detailed dietary data would be needed to identify the degree of competition, if any, between the two species.

50. Cheng Pei-Rong (2002) **The diet and foraging habitat requirements of Painted Snipe [=Greater Painted-snipe] (*Rostratula benghalensis*) during the breeding season at Ham-bow wetland area.** Department of Biology, National Changhua Normal University, Changhua. Advisers: Lee Shu-Wen and Jiang Ling.

Han-bow wetland, located on the boundary between Fu-Xing village and Fang-Yuan village in

Changhua county, is typical of coastal areas. Farms, horticultural lands and pasture have all commonly been abandoned. Owing to the salinisation of land, transformation of economic activities, and joining the World Trade Organisation (WTO), yet more farmland is being abandoned. To address agricultural loss and to achieve ecological conservation, the Han-bow Ecology Park is planned. Greater Painted-snipe *Rostratula benghalensis* is a resident bird listed in Category 2 on the Taiwan Wild Animal Conservation List. This research aimed to document basic painted-snipe feeding ecology to allow set-up and management of a reserve for it. Painted-snipe numbers were investigated from April to September in 2000 and in 2001. In 68 investigations, 780 individuals were found, but this total includes repeat sightings. Average sex ratios in both years were unity. Painted-snipes were found mainly in newly sown paddyfields (27%), followed by growing paddyfields (18%), harvested paddyfields (24%), swamps (11%), ridges between fields (5%), forage grass (5%), ditches (4%), abandoned or fallow lands (4%), and others (2%). Statistical analysis showed a significant preference for paddyfields (in any cultivation stage). Analysis of droppings and extracts from stomachs showed that painted-snipes mostly fed on polychaete worms, dipterans and beetles before rice grains were produced. After this, painted-snipes fed mostly on the golden apple snail *Pomacea canaliculata*, rice grains and other plants in the grass family. In the breeding season, *P. canaliculata* and rice grains were the dominant food items. In the non-breeding season, Capitellidae was the most numerous prey for painted-snipes. There were significant positive correlations between painted-snipe numbers and those of *P. canaliculata* ($r=0.91$; $P<0.001$), and with the number of rice grains ($r=0.77$; $P=0.03$). This suggested that *P. canaliculata* and rice were the major foods in the breeding season. Before rice grains are available, the diversity and abundance of prey were high. After rice grains are available, harvest reduced the diversity and abundance of prey. Therefore, painted-snipes fed on the dominant food items available. Painted-snipes may have moved to nearby paddyfields for food because the responsibility of brooding limits opportunities for longer-distance foraging.

51. Li Chih-An (2002) **The fat load shift and migratory strategy of Dunlin (*Calidris alpina*) at south Ta-Tu estuary.** Department of Environmental Science, Tunghai University, Taichung. Adviser: Chen Peter Ping-Huang.

Dunlin *Calidris alpina* is a common shorebird breeding in high latitudes of the northern hemisphere, and visiting Taiwan as a winter resident and double passage migrant. Shorebird conservation requires an understanding of migratory routes and the protection of stopover sites. Studies of migratory routes and strategies, and of fat load shifts of migratory shorebirds, are badly needed in Taiwan. During September 2000–March 2001 and September 2001–April 2002, fat load shifts of autumn and spring passage, and wintering, Dunlin populations at Ta-Tu estuary were recorded using total body electric conductivity (TOBEC). These data were used to suggest possible

migratory strategies and stopover sites for different populations. For the two seasons, maximum fat deposition rate of autumn passage birds was $42\pm 11\%$ ($n=8$) and $35\pm 13\%$ ($n=13$), of wintering birds was $41\pm 18\%$ ($n=4$) and $23\pm 4.3\%$ ($n=14$), and of spring passage birds (recorded only during 2002) was $29\pm 7.7\%$ ($n=11$). Fat load of autumn birds declined upon arrival at the estuary and accumulated rapidly before departure. Possible reasons for fat load decline are primary moult and the search for suitable habitat. The fat load of wintering birds also declined upon arrival. Average fat load in the second season was lower than that of the first season; both rainfall and disturbance were lower in the second season. Wintering Dunlins started to accumulate fat 20–30 days before departure to their breeding sites. Daylight period differed significantly before and after the start of accumulation of fat load ($P<0.01$). Temperature and wind speed and direction did not differ significantly before and after the wintering population left the estuary. In spring passage, birds did not moult primaries at the estuary and their fat load did not decline when they arrived. The migratory strategy of autumn populations is possibly energy selected and that of spring populations is possibly time selected. The estimated energy expense of autumn populations is 50% lower than the energy expense actually recorded. Estimated and recorded time expenses of spring populations are similar. Southbound populations in autumn can arrive in the Philippines directly, but would need one more stopover to reach Hainan island. Wintering and passage populations migrating north during spring may use Chun-Min island (Chongming Dao; in the Yang-Tze river mouth) as a first stopover if their route is along the south-east China coast, or Okinawa if they pass through Japan. Sakhalin island breeders probably need 4–5 stopover sites, northern Siberian ones 6–7, and Alaskan ones 7–8, to complete migration after Taiwan.

52. Shen Sheng-Feng (2002) **The ecology of cooperative breeding Taiwan Yuhina (*Yuhina brunneiceps*) in Mayfeng area.** Department of Zoology, National Taiwan University, Taipei. Advisers: Lee Pei-Fen and Yuan Hsiao-Wei.

We studied Taiwan Yuhina *Yuhina brunneiceps*, the only joint-nesting passerine in Taiwan, in the mountains of central Taiwan, from June 1999 to September 2001. The male incubation hypothesis and the costs and benefits of joint-nesting were investigated. Alpha females performed most incubation both by day (67%, $n=27$) and by night (73%, $n=11$), contrary to the male incubation hypothesis. Yuhinas inhabited a subtropical fluctuating environment with high nest predation and frequent typhoons. Larger groups did not have higher nest success rates or more fledglings. Instead, they reduced their investment to each single nest attempt by laying fewer eggs in the nest, lightening the workloads of incubation and provisioning in joint-nesting groups. Individuals in larger groups except alpha males had higher survival probabilities, especially for the females who lightened their incubation load in larger groups. Larger groups may have also built nests and re-nested faster than solitary pairs, and had better home ranges in terms of possible

nest sites, food availability and tree cover. Therefore, joint-nesting behaviour may possibly represent a bet-hedging strategy for a fluctuating environment.

53. Lin Chu-Ji (2002) **Analysis of the biodiversity of birds at county level in Taiwan.** Department of Forestry, National Taiwan University, Taipei. Advisers: Yuan Hsiao-Wei and Chiou Chyi-Rong.

Biodiversity is a critical issue in conservation research, yet the concept is so broad that it causes problems in application to the real environment. Birds are sensitive to changes in habitat and they are positioned at the higher levels of the food chain; and, compared with other species, they are more easily sampled. Hence, they are a good biological indicator for larger-scale biodiversity research. This study analysed the quality of the database from Wild Bird Federation Taiwan (WBFT) for each county, and investigated distribution patterns of bird diversity with place, elevation, season etc. It also examined distribution of protected birds and of bird hotspots. Existing sample effort reflects, roughly, current bird diversity for most counties. There are commonly more data from low-elevation counties and fewer data from certain counties from the period of June to August. In each county, bird diversity has a significant positive correlation with county area and elevation range. The diversity of migratory birds showed no significant correlation with any factor. In each county, breeding bird diversity shows a bell-shaped curve with elevation, peaking at about 1,000–2,000 m. Diversity of breeding birds shows little fluctuation with season, but diversity of migratory birds is lower from June to August. Analysis of hotspots found significant correlations among breeding birds, protected species and endemic species. The distribution of protected species in Taiwan is significantly localised. This study's results for bird diversity of each county can serve as a reference for bird protection planning and nature conservation zoning for each county. Besides, although the database of WBFT is built from counting sites and frequencies that are not evenly distributed, it reflects well enough actual patterns of bird diversity for it to be a most important link to promote a future Taiwan Biological Resources Inventory.

54. Yao Cheng-te (2002) **The breeding ecology of the Malayan Night Heron (*Gorsachius melanophus*) [= *G. melanolophus*] in central Taiwan.** Department of Biology, Tunghai University, Taichung. Advisers: Lin Liang-kong and Yo Shao-pin.

Malayan Night Heron *Gorsachius melanolophus* inhabits lowland wooded areas in Taiwan. I studied its reproductive success in the urbanised areas of Taichung, Nan-tao, Yun-lin, and Chia-I counties, in central Taiwan. A total of 67 nests was monitored in 2000 and 2001. The breeding season lasted 210 days in 2000 and 220 days in 2001. Clutch size was 2–6 eggs (3.4 ± 0.8 , $n=67$); brood size was 0–4 nestlings (2.5 ± 1.5 , $n=67$; all \pm figures refer to one standard deviation). Of 67 nests, 46 successfully fledged at least one young. The mean number of young fledged per nest was 1.9 ± 1.5 chicks. Incubation period lasted 30.4 ± 1.2 days, and nestling stage 36.0 ± 2.1 days. Nesting success measured by the Mayfield method was

65% in 2000 and 62% in 2001. There was no difference between pooled-interval success rate of first nests (61%) and of second broods (69%; $Z=0.57$; $P>0.05$). Pooled interval success rate of yearlings' nests was 21% ($n=17$), whereas it was 74% ($n=50$) for nests of older birds ($Z=6.02$; $P<0.05$). Mean number of young fledged per nest by older birds was 2.2 ± 1.5 ($n=37$), while it was only 0.9 ± 1.3 ($n=15$) by pairs with at least one yearling. Reuse of old nests was common (50% of active nests observed had already been used at least once). Breeding success of re-used nests was 80%, while it was 47% for new nests ($Z=-2.82$; $P<0.05$). Among nests in four categories of land-use, nests in rural landscapes had pooled-interval success rates (85%) significantly higher than those in managed landscapes (49%; $Z=2.79$; $P<0.05$) or agricultural land (49%; $Z=2.01$; $P<0.01$). Comparing estimated daily survival probabilities of nests categorised in two groups of structural stability index (SS-1, those damaged or destroyed one year after breeding; and SS-2, those not damaged within one year), no significant difference was found ($Z=-0.89$; $P>0.05$). Predation, starvation, infertile or addled eggs and inclement weather were identified as major sources of mortality during incubation and nestling stages. The main factors affecting reproductive success of Malayan Night Heron are age of breeders, nest predation, inclement weather, land-use type and reusage of old nests.

55. Chang Chia-Wei (2002) **The impact of migratory shorebirds' (Scolopacidae and Charadriidae) feeding on prey abundance with exclosure experiment in Su Tsao Wild Life Reserve.** Department of Biology, National Changhua University of Education, Changhua. Adviser: Jiang Ling.

The Su Tsao Wildlife Reserve is very important for winter migrant birds in south-west Taiwan. Feeding is the main activity of wintering shorebirds. Exclosure experiments and stomach content analysis were undertaken to assess the impacts of winter shorebird feeding on prey abundance in the reserve. Other than water depth, environmental factors showed no significance differences between days on which experiments were carried out. Feeding shorebirds reduced invertebrate numbers, but if numbers of birds were few, numbers of invertebrates showed no significant decline. The reduced quantity of invertebrates was positively correlated with the numbers of shorebirds. Stomach contents showed that shorebirds consumed *Thiara riqueti*, *Neanthes glandicincta*, and Capitellidae sp(p.); exclosure experiments produced the same result. At night, shorebirds still fed and reduced the numbers of invertebrates. The distribution of shorebirds did not affect invertebrate numbers, suggesting that invertebrates were abundant enough to meet shorebird needs. Feeding rates of shorebirds might be over-estimated by mathematical magnification. More information about resident invertebrates, such as life cycle and activity times, would inform understanding of feeding ecology of winter shorebirds.

56. Liu, Wei-Ting (2002) **Habitat selection, reproductive success and management of waterbirds breeding in Changhua Coastal Industrial Park.**

Department of Environmental Science, Tunghai University, Taichung. Adviser: Chen Peter Ping-Huang.

Very high proportions of the coastal zone in western Taiwan have been converted to industrial use. Changhua coastal industrial park (3,643 ha) is the second largest such area. About 90% of the area was not in use, and provided suitable habitat for waterbirds roosting in winter and breeding in summer. Breeding Little Terns *Sterna albifrons* and Kentish Plovers *Charadrius alexandrinus* in Changhua coastal industrial park form the biggest colonies in Taiwan. Greater Painted-snipe *Rostratula benghalensis*, Oriental Pratincole *Glareola maldivarum* and Little Tern are Category 2 conservation species in Taiwan. I studied breeding habitat selection of ground-nesting waterbirds in Changhua to identify factors causing breeding failure, and to provide suggestions for future management. I found 33 Little Tern nests, four Kentish Plover nests and two Oriental Pratincole nests in a 13.2 ha area in Lungwei in 1998, and 117 Kentish Plover nests and one Oriental Pratincole nest in eight sites totalling 22.7 ha in Shengshi. Black-winged Stilts *Himantopus himantopus* and painted-snipes also bred in the study area. Kentish Plovers and Little Terns nested on the gravel substrate provided by land fill. Little Tern nests were significantly closer to the nearest road and nearest nesting terns than were random points. Kentish Plover nest sites showed no difference from random points in the distance to the nearest road, distance to nearest vegetation line and distance to nearest plover nest. Hatching success in 1998 was very low: only 25% of Little Tern nests and 50% of Kentish Plover nest hatched, but in 1999, 89% of Kentish Plover nests hatched. Artificial nests set in May 1999 estimated 26% hatching success of Little Tern and 19% of Kentish Plover. Flooding through heavy rain in spring and summer was the main reason for nest failure: 26 nests in 1998 and six Kentish Plover nests and 10 artificial nests in 1999 were flooded. Clutch predation was rare: only two Kentish Plover nests and nine artificial nests in 1999 were taken, mainly by dogs. Garbage dumping and researcher activities (attracting dogs into breeding sites) were the only human disturbances recorded. The gravel habitat in Changhua provides suitable breeding habitat for ground-nesting waterbirds. Development of the industrial park and the increase of vegetation cover are the main factors reducing habitat, and flooding is the main factor causing breeding failure. To protect breeding waterbirds, a 26 ha reserve should be legally designated in Shangshi West-2 area.

57. Liu Chao-Kuo (2002) **A study of diurnal activity patterns by Eurasian Curlew (*Numenius arquata*) at Ta-Du estuary, Taiwan.** Department of Environmental Science, Tunghai University, Taichung. Adviser: Chen Peter Ping-Huang.

Eurasian Curlew *Numenius arquata* is an uncommon wintering shorebird in Taiwan, with the biggest population at the Da-Tu estuary. Construction of the Tai Power Generator displaced this population south from the rivermouth. For the last five years (1996–2000), birds have wintered on the coastline at the Changhua coastal industrial park. Counting data

show this population is decreasing. Increase of coastal land conversion and human disturbance make conservation issues for this population urgent. This research investigated the daytime activity pattern of Eurasian Curlew and its relation with abiotic factors. The census took place on 25 days from 5 October 2000 to 25 March 2001. Scanning was used to record behaviour, and tide height, wind speed and temperature were the abiotic factors recorded. Eurasian Curlews stood near the tide edge and moved with it during the high-tide period. The flock did not move with the tide during the low-tide period, but each individual moved from the group to the tide edge 3–4 times. Rest was the predominant daytime activity (80% of time). The pattern was obviously much more correlated with the tidal cycle than with the day-night cycle. Both preening (Spearman's $r=-0.53$) and resting ($r=0.24$) levels showed significant correlation ($P<0.01$) with wind speed. Spatial, maintenance and feeding behaviour showed significant differences ($P<0.01$) between high- and low-tide periods. Human disturbance was mainly a result of aquaculture, tourism and fishing, and birds appeared gradually to get used to noise. Feeding behaviour and temperature were positively correlated ($r=0.20$, $P<0.01$). The proportion of time spent feeding showed significant variation ($P<0.01$) with temperature between the early-, mid- and late-winter. The proportion of time spent feeding at low tide was higher than at high and mid-tide. The low proportion of time spent feeding during daytime suggests that Eurasian Curlew may feed mainly by night at the Da-Tu estuary.

58. Wang Lee-ping (2003) **Breeding habitat selection and breeding biology of Blue-tailed Bee-eaters (*Merops philippinus*) on Kinmen island.** Department of Forestry, National Taiwan University, Taipei. Adviser: Yuan Hsiao-Wei.

I studied breeding habitat selection and breeding biology of Blue-tailed Bee-eaters *Merops philippinus* on Kinmen island from 2000 to 2002. Blue-tailed Bee-eaters only dug nest holes in the Kinmen geological layer and on sandy soils, which both have characteristically low clay contents. From the 822 bee-eaters observed, 84% dug nest holes on natural cliffs and 16% on artificial farmland. Only 8% of nest holes were dug in radial colonies, the remaining 92% being on one-sided open colonies. Scan observations revealed that the diet of bee-eaters comprised mainly insects, mostly Odonata (49%), Homoptera (17%), Diptera (13%) and Lepidoptera (12%). Water quality tests of nearest water bodies to six nest colonies showed no significant differences between retained and abandoned nest colonies in dissolved oxygen, BOD, pH and some nutrients (PO_4^{3-} , NO_3^- , N, Cl, SO_4^{2-} , NH_4^+ , HCO_3^- , CO_3^- , Ca, Mg, Na, K). The nearest water bodies of abandoned nest colonies had lower electro-conductivity than did those for retained colonies, which positively correlated with species richness and abundance of dragonflies, the main diet of the bee-eaters. Blue-tailed Bee-eaters mainly dug nest holes on cliffs with no or little vegetation, and with low vegetation structure in front of the colony. This might increase detection of nest predators, and thus reduce nest predation. Bee-eaters were mainly colonial

breeding and monogamous on Kinmen. In the 2001 breeding season, 83% of the chicks hatched within a nine-day period, suggesting the bee-eaters were breeding in synchrony. Sixteen nests had more than two adults feeding chicks, suggesting cooperative breeding.

59. Wu Shih-Hung (2003) **Territory and habitat use of Formosan Rufous-backed Shrike [Long-tailed Shrike] (*Lanius schach formosae*) in Hualien.** Institute of Nature Resources, National Dong Hwa University, Hualien. Adviser: Wu Hai-Yin.

I studied the relationships between vegetation structure and habitat use of Long-tailed Shrikes *Lanius schach*. I assumed that food availability for shrikes, a perch-hunting predator, is determined by perch density and understorey cover, and hypothesised that shrikes would concentrate foraging in habitat patches with high food availability. The study was conducted on farmland along Hualien river from January to May 2002. The study area was divided into five habitat types according to perch density and understorey cover. Ringed shrikes were followed and their perch locations and behaviour were recorded. Observations were divided into three stages: pre-nesting, pre-fledging and post-fledging. Territories of individual shrikes were determined by perch locations. Shrikes had stable territories, the area of which correlated with the ratio of the area of low-perch-density habitat type to total territory size. Compositional analysis revealed that shrikes used habitat types with high perch density and low understorey cover more than the other types. There was no significant difference among the areas of territories in the three breeding stages. However, searching time decreased from pre-breeding stage to post-breeding stage. This suggested that, instead of extending territory size, shrikes increased their prey attack rates to cope with the increasing energy demand through the breeding season.

60. Wu Jeng-Wen (2003) **A study on the effects of altitudes and habitats on nest predation risk.** Institute of Tropical Agriculture and International Cooperation, National Pingtung University of Science and Technology, Pingtung. Advisers: Yeh Ching-Long and Sun Yuan-Hsun.

Nest predation is one of the major causes of reproductive failure among birds, suggesting a close correlation between birds' reproduction rate and nest predator abundance. Composition and foraging behaviour of nest predators should determine patterns of nest predation. It would inform understanding of bird reproduction to study population dynamics of nest predators. Shell remains in artificial nests and an automatic camera system were used in this study to evaluate the nest predation risks of ground-nesting birds at different altitudes and in different habitats. This study found that the highest predation rate at medium altitudes (about 2,000 m), an intermediate rate at low altitudes (about 1,000 m), and the lowest rate at highest altitudes (about 3,000 m). Predation rates were higher in both medium- and low-altitude forests, than in grasslands of similar altitude. There was no difference in predation rate between forest and grassland at high altitude. Species composition of nest

predators varied with altitudes and habitats. Most nest predators were mammals, some were birds and snakes. Nest predator species richness was higher in forest at medium and high altitude than at low altitude. To sum up, altitudes and habitats were two major factors affecting the nest predation rates of ground-reproducing birds. Different environmental conditions in different habitats may be the reasons for different nest predation risks.

61. Li Pei-Ying (2003) **An analysis of habitat selection for foraging, singing and nesting of the Grey-cheeked Fulvetta (*Alcippe morrisonia*) at Fushan Experimental Forest.** Department of Forestry, National Taiwan University, Taipei. Advisers: Chen Chao-Jie and Wang Li-Chih.

To investigate the ecological significance of differences in habitat selection among foraging, singing and nesting Grey-cheeked Fulvettas *Alcippe morrisonia*, we investigated the habitat use during breeding season (March–July) 2002 at Fushan Experimental Forest. Fulvettas used Lauraceae and Fagaceae mostly, and their foraging and singing macrohabitat (10x10 m) and microhabitat (in the canopy) were similar, but not at the same height and position. Comparing foraging or singing habitat with nest-sites, most habitat characteristics showed significant differences. Nest-site macrohabitat differed from foraging and singing macrohabitat. Fulvettas nested in shrubs but used mostly trees when foraging or singing (where trees and shrubs were defined as differing in shape, height, diameter at breast height and other characters).

62. Tu Hsiao-Wei (2003) **Geographic variation of the Hwamei (*Garrulax canorus*) songs.** Department of Zoology, National Taiwan University, Taipei. Adviser: Lucia Liu Severinghaus.

Taiwan Hwamei *Garrulax canorus taewanus* and Chinese Hwamei *G. c. canorus* are found, respectively, only in Taiwan, and in central and southern mainland China. Their drab appearance and dense habitat make their long and complex vocalisations extremely important in social behaviour. This study compared 229 Taiwan Hwamei songs (from 20 birds) and 227 Chinese Hwamei songs (from 20 birds) at the note, syllable, songs and syntax levels, both micro- and macro-geographically. Geographic variation occurred mainly at the syllable level. Taiwan Hwamei songs from the three sampling locations differed in diverse ways, while in Chinese Hwamei songs, there was a fair overlap of syllables and syntax between sampling locations, but the extent of sharing decreased with distance. Chinese Hwamei songs were more complex than Taiwan Hwamei songs, containing significantly more syllable types, more syllable changes, larger syntax combinations and fewer syllable repeats per song. Most syllable types, ways of syllable changes and syntax patterns in Taiwan Hwamei songs were also present in Chinese Hwamei songs, but not vice versa. This could reflect founder effects or locations of past refugia. Taiwan has not been isolated from China for very long, hence songs of these two Hwamei subspecies are still similar.

63. Hung Hsin-Yi (2003) **Identifying the paternity within the breeding group of Taiwan Yuhina (*Yuhina brunneiceps*) by DNA microsatellite at Mei Feng area.** Department of Forestry, National Taiwan University, Taipei. Adviser: Yuan Hsiao-Wei.

Taiwan Yuhina *Yuhina brunneiceps*, endemic to Taiwan, exhibits cooperative joint nesting behaviour. Parental groups comprise 2–7 adults with monogamous pairs, some with helper(s). I examined 12 broods, totalling 46 nestlings, using DNA microsatellites to identify paternity and the genetic mating system. More than one female from the group laid eggs in the nest. Genetic monogamy was the major mating system, but 20% of offspring were from inter-group EPF (extra-pair fertilisation), 20% were from intra-group EPF, 50% of broods involved inter-group EPF and 67% involved intra-group EPF. Bigger groups had higher proportions of EPF. Compared to other plural breeding bird species, the inter-group EPF of Taiwan Yuhina was higher. Each group had a linear hierarchy of socially monogamous pairs. I compared morphology, residency and breeding behaviour between alpha and beta males and females. I also investigated the effect of hierarchy on reproductive fitness. Alpha males had a longer natural and maximum wing length, a longer residency and sang more than beta males, but alpha and beta females did not differ in size or residency. In four-member groups, alpha females had significantly more offspring than beta females, but there was no difference between alpha and beta males. Alpha females also incubated, both diurnally and nocturnally, more than other group members. Group members contributed equally during the nestling provisioning period. The skew index among females was 0.29 for groups with only two females; it rose with increasing number of females in the group, indicating a higher skew towards to alpha female in larger groups. Adults in the breeding group were not full siblings.

64. Chang Yung-Fu (2003) **A study on corpus-based analysis for a bird sound recognition system.** Institute of Electrical Engineering, National Dong Hwa University, Hualien. Adviser: Sun Tsung-Ying.

This paper develops a bird sound recognition system based on corpus analysis, a system usually applied in computational linguistics. Each kind of bird sound has a special frequency sequence. Feature segmentations of bird sound were found through voice-print analysis, so that the frequency sequence, called the corpus, was obtained. We created a corpus database for over 90 kinds of corpus of birds in Taiwan. This provides the knowledge base for a bird sound recognition engine. Three successive processing stages, bird sound preprocessing, corpus analysis, and target bird sound searching, occur in the bird sound recognition system. First, the sound of the as-yet unrecognised bird (URB) is preprocessed by a fifth-order Butterworth filter to eliminate environment noise. The corpus analysis stage performs automated feature segmentations of bird sound, partitioned into frequency sequence. The URB is then searched through the corpus database by a recognition engine. The result of this system is a list of candidate target birds, ranked by sound similarity in frequency sequence. Adopting the corpus database by using

frequency sequence reduces the database capacity, speeds recognition and gives a high correction ratio. Next steps are to transplant the system to personal digital assistant (PDA), smart phone etc. In future, it could also be extended to human natural language recognition.

65. Chen Cheng-Chung (2003) **The landscape resource of avifauna of Tali river, Taichung Hsien—the section from Tawei bridge to Chungtou highway bridge.** Department of Geology, National Taiwan Normal University, Taipei. Adviser: Cheng Sheng-Hua.

To study landscape resources for avifauna in a Taiwan riverbank, fieldwork was conducted at ten sites along the bank of Tali river, from Tawei bridge to Chungtou highway bridge, four times monthly from March 2001 to February 2002. A total of 51 species in 26 families were recorded. In total, 15,518 individuals were recorded, comprising 73% residents (of 27 species), 21% summer or winter visitors (20 species), 5% cage birds (3 species) and 1% species which occur only on passage (1 species). Simpson's Index of bird diversity exceeded 0.9 in every month, except August (0.83) and September (0.86). Bird diversity peaked in spring and summer. Species richness was highest in winter and spring (48 species), and lowest in summer (20 species). Grassland (Japanese or manyflower silvergrass *Miscanthus floridulus*) and bushes were more important habitats for birds than were farmland, artificial lawns and leisure areas. People and their leisure activities displaced most birds. The Tali riverbank, an area integrating fresh water and land ecosystems, is good habitat for resident and migrant birds. Public and private authorities of Tali city should pay more attention to ecological planning of the river and its bank for sustainable management.

66. Chen Chen-jung (2003) **Territorial behaviour and habitat use in Plumbeous Water Redstart (*Rhyacornis fuliginosus affinis*).** Department of Biology, National Taiwan Normal University, Taipei. Adviser: Wang Ying.

From November 2001 to April 2003, the behaviour and the habitat use of 13 Plumbeous Water Redstarts *Rhyacornis fuliginosus* were observed in Wulai, Taipei. Playback and male models were used to test relationships between habitat selection and territorial maintenance by the male owners. Available stream bank habitat (81%) far exceeded that of stream surface (19%). The species spent equal time in both habitats, indicating that it preferred surface to bank. Males spent more time foraging on the stream surface (67% of observed foraging time), spending 53% of total time on big rocks, which composed 21% of the total area; hence, they favoured this microhabitat type (1-way ANOVA, $P < 0.001$). Furthermore, male singing was also observed more frequently on big rocks (57% of singing observations). Use of big rocks may be related to territorial maintenance, because during playback, males first appeared on big rocks on 69% of occasions, and 82% of male song responses to playback were performed on big rocks. Compared with randomly-selected sites, big rocks had wider viewing area (1,872 m², N=39; vs. 374 m², N=29), which may help male

owners to detect intruders earlier. Male models were found more easily on big rocks than on other microhabitats by a group of tested people, suggesting that a male owner perched on a big stone will be more easily detected by an intruder. The big rock microhabitat seemed to be important for males during territorial defence.

67. Yeh Yu-Ling (2003) **Grouping and vigilance behaviour in Ring-necked [= Common] Pheasant (*Phasianus colchicus formosanus*)**. Department of Zoology, National Taiwan University, Taipei. Advisers: Lin Yao-Sung and Wu Hai-Yin.

Vigilance helps feeding animals defend themselves from predators. Individuals in a group might benefit from cooperative vigilance. To study factors affecting

vigilance behaviour of Common Pheasant *Phasianus colchicus formosanus*, we recorded group size and composition, environmental factors, auditory signals and human activities using five-minute focal sampling in National Dong Hwa University from July 2002 to March 2003. Biological factors such as group size and composition, rather than environmental factors, significantly affected vigilance levels of pheasants.

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