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FLOCKING AND COOPERATIVE BREEDING OF FORMOSAN BLUE MAGPIES

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L. L. Severinghaus (1987) Flocking and cooperative breeding of Formosan Blue Magpies. *Bull. Inst. Zool., Academia Sinica* **26**(1): 22-37. The Formosan Blue Magpie (*Urocissa caerulea*) is the only species known on Taiwan to breed with helpers at the nest. This species maintained stable flocks year round. Seventy percent of the nests found in a preliminary study had helpers. All the members of a flock participated in nest construction and in feeding of young. Females alone incubated the eggs and brooded the nestlings. Clutch size was 6 eggs. Hatching success in undisturbed nests was high. Fledging success was very low due to poaching. The frequency of nestling feeding probably varied with the resource conditions of each territory. Nestlings tended by two adults only were not fed less than those with helpers.

The rituals and patterns of reproduction in birds have always attracted the attention of naturalists. Birds are known to breed in pairs, in colonies, in flocks, polygynously, polyandrously, promiscuously, and cooperatively. Current theories suggest a close relationship between the mating system of a population and the ecological conditions this population lives under (Orians 1969, Emlen and Oring 1977, Oring 1981). Corvids are known for their diverse mating systems. Rooks, *Corvus frugilegus* (Ogilvie 1951), and Jackdaws, *C. monedula* (Lorenz 1952) breed colonially. Florida Scrub Jays, *Aphelocoma coerulescens* (Woolfenden 1975), and most other jays in North America have helpers at the nest. The Japanese Mapie *Cyanopica cyana* breeds primarily in monogamous pairs, with one record of a bird helping an unrelated pair once (Hosono 1983). These cases suggest corvids may have evolved breeding strategies along taxonomic lines instead of purely as an adaptation to ecological constraints. Thus, it is important that the mating system of other species in Corvidae be examined in detail in order to elucidate the relationship between the evolution of mating systems and environmental conditions.

The Formosan Blue Magpie (*Urocissa caerulea*) is an endemic species of Taiwan (Hachisuka and Udagawa 1951). It occupies mid to low elevation broadleaf forests and adjacent fields, orchards, and plantations. There have been no previous studies of this species, although it is one of the most conspicuous residents of the island. This paper reports the first study of the species' flocking behavior and breeding system.

METHODS

This study was carried out from May to September and November of 1983 and January, March, and May to July in 1984. My field assistants and I searched for magpies and

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their nests in Taipei, Miaoli, Taichung, and Pingtung counties. After locating an active nest, we monitored the feeding, incubation, rearing of young, and nest defense by the adults through binoculars and a spoting scope. We also observed the process of nest contruction whenever possible.

Formosan Blue Magpies are sexually monomorphic. In order to identify individuals, an effort was made to capture the adults using bird nets and baited traps so they could be color marked. None of the trapping efforts was successful. Adult identification was thus limited to a few individuals separable by plumage characteristics, such as specially worn tail feathers. Nestlings were banded with colored leg bands before fledging whenever possible.

Field observations of magpies by other biologists and bird watchers were compiled for the analysis of flocking behavior in this species. One third of the data came from northern Taiwan in 1983 and 1984 when a monthly survey was conducted. The rest of these observation records span seven years in time and cover the entire island, thus providing a broad coverage of the species as a whole.

RESULTS

Flocking

In seven years, Formosan Blue Magpies were sighted 86 times. They were seen singly,

TABLE 1

Number of Formosan Blue Magpies encountered by month and flock sizes

(1a) Island Wide

	1 bird	2 birds	3+ birds	
Jan	0	2	7	
Feb	1	1	4	
Mar	0	3	2	
Apr	1	3	4	
May	4	5	8	
June	3	1	1	
July	3	1	6	
Aug	0	0	1	
Sept	1	0	0	
Oct	1	1	7	
Nov	1	0	6	
Dec	2	1	5	Grand Total
Total	17	18	51	86
%	19.8	20.9	59.3	100
No. individuals per category:				
Total	17	36	274	327
%	5.2	11	83.8	100
If only April-August is considered:				
Total	11	10	20	41
%	26.8	24.4	48.8	100
No. individuals in April-August:				
Total	11	20	97	128
%	8.6	15.6	75.8	100

(1b) Near Taipei (1983-1984)

	1 bird	2 birds	3+ birds	
Jan	0	1	2	
Feb	0	1	3	
Mar	0	1	0	
Apr	0	2	0	
May	1	2	3	
June	0	1	2	
July	1	1	2	
Aug	0	0	1	
Sept	0	0	0	
Oct	1	1	2	
Nov	1	0	0	
Dec	1	1	0	Grand Total
Total	5	11	15	31
%	16.1	35.5	48.4	100
No. individuals per category:				
Total	5	22	98	125
%	4	17.6	78.4	100
If only April-August is considered:				
Total	2	6	8	16
%	12.5	37.5	50	100
No. individuals in April-August:				
Total	2	12	50	64
%	3.1	18.8	78.1	100

in pairs, or in flocks of 3 to 18 birds. Encounters of flocks comprised 59.3% of all sightings. When considering the breeding season only, 48.8% of the encounters were with flocks (Table 1a). Only 16.2% of all the birds were seen singly or in pairs. For the breeding season, only 24.2% of the birds were seen alone or in pairs. Analyzing only the sightings of 1983 and 1984 in the Taipei region, flocking occurred in nearly 50% of all the observations including those of the breeding season (Table 1b), and only 21.6% of the birds were not in flocks of three or more individuals. For the breeding season the proportion was 21.9%. These data indicate that flocking is a general and common phenomenon in this species.

When Formosan Blue Magpies travelled over long distances in flocks, they usually flew in single file. When travelling slowly, one bird often flew to the next perch first, then the other birds followed one at a time, landing on what appeared to be the same branch as the previous bird, in a regulated sequential manner.

Birds of a flock seemed to remain together through the year, including during the breeding season. A flock of three individuals identifiable by feather characteristics in the Kukuan area, and a flock of six birds near Hsiaoyi in the Wulai area were seen repeatedly through the year. From a vantage point, I observed the flock of three magpies at Kukuan utilizing at least 22.6 ha of a valley in mountainous terrain during their daily foraging activities from April to September 1983. Within this area, I never saw more than three magpies at any one time. No territorial defense was ever witnessed.

Nesting

Fifteen nests were found in 1983 and 1984. Among these, we monitored the 11 active nests but, because of poaching and other disturbances, have behavioral data from only five nests. All together, we obtained 312 hours of behavioral observations. Four of the 15 nests were already finished when

TABLE 2
Breeding statistics of Formosan Blue Magpies

Nest No.	No. Adults	Clutch size	Number hatched	Brood size	Number fledged	Remarks
1a	3	6	4	4	0	1 egg collected Nestlings poached
1b	3	6	4	4	0	Nestlings poached
1c	3	—	—	1	1	
2a	2	—	—	4	0	Nestlings poached
2b	2	6	0	0	0	Nest robbed
3	5	—	—	4	0	Nestlings poached
4a	5	—	—	2	0	Nestlings poached
4b	5	—	—	1	0	Nestlings poached
5a	2	6	0	0	0	1 egg collected Nest disturbed
5b	2	6	6	6	5	Nest protected
6	4	—	2 YIE	2	2	
7	4	—	—	4	0	Nestlings poached
8	3	—	—	0	0	Nest robbed
9	2	5	0	0	0	Nest robbed
10	3	—	—	1	0	Nestlings poached
Total	33			33	8	Fledging success =24.2%

we found them. We determined their original clutch and brood sizes from local people and bird watchers' reports.

Formosan Blue Magpies start breeding activities in April. The 15 nests we found belonged to 10 groups of birds, which included 3 pairs, three 3-, two 4-, and two 5-bird flocks (Table 2). All the individuals of a group usually participated in breeding activities together. If the first clutch was lost, the group would nest a second time. One flock even nested a third time when the first two attempts both failed before the nestlings fledged.

Nest 1a, 1b, and 1c (Table 2) belonged to the same 3 adults. The sex of the third bird was unknown. After seeing two copulations, we could identify the female by her very worn tail. The pair seemed to move together more frequently than either adult

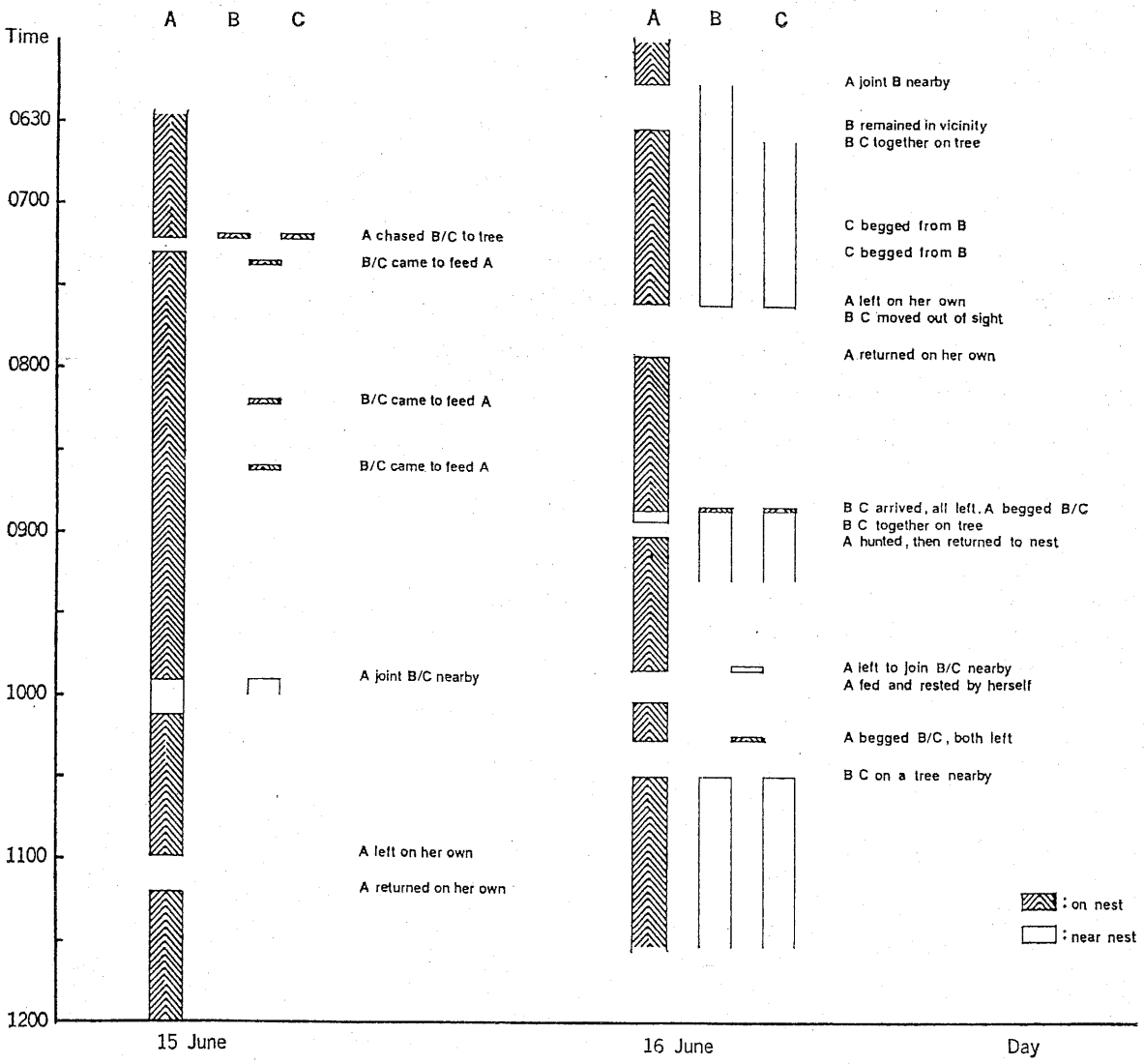

Fig. 1. The incubation regime of Nest 1b at Kukuan. Nest construction started on 27 May 1983, and eggs hatched on 26 June. A=female, B=male, C=helper. When the identity of male and helper could not be positively identified, it is denoted as B/C, and the bar placed in between the two birds on the graph. B, or C on nest refers to the time they actually landed on the rim of the nest.

with the third bird. The pair also preened together while the third bird preened farther away. I saw the male and the third bird feed the female many times, but never saw them feed each other or be fed by the female, even though the third adult was seen to beg unsuccessfully from the male.

Nest Construction

All flock members participated in nest contruction. During the contruction of Nest 1b, birds returned to the nest site 19 times in 6 hours. Among these, 10 were single-bird visits, 8 were two-bird visits, and one time all three birds arrived to fix the nest. In these 19 visits, they brought back 5 branches; the other times they returned only to re-arrange the branches. When two birds returned together or overlapped on the nest, one of them always gave the branch it was carrying to the other and then departed. The remaining one did the wedging and the fitting. The one time when all the birds returned simultaneously to the nest, each took turns sitting in the nest and fixing it.

Incubation

Nest 1b was observed during incubation

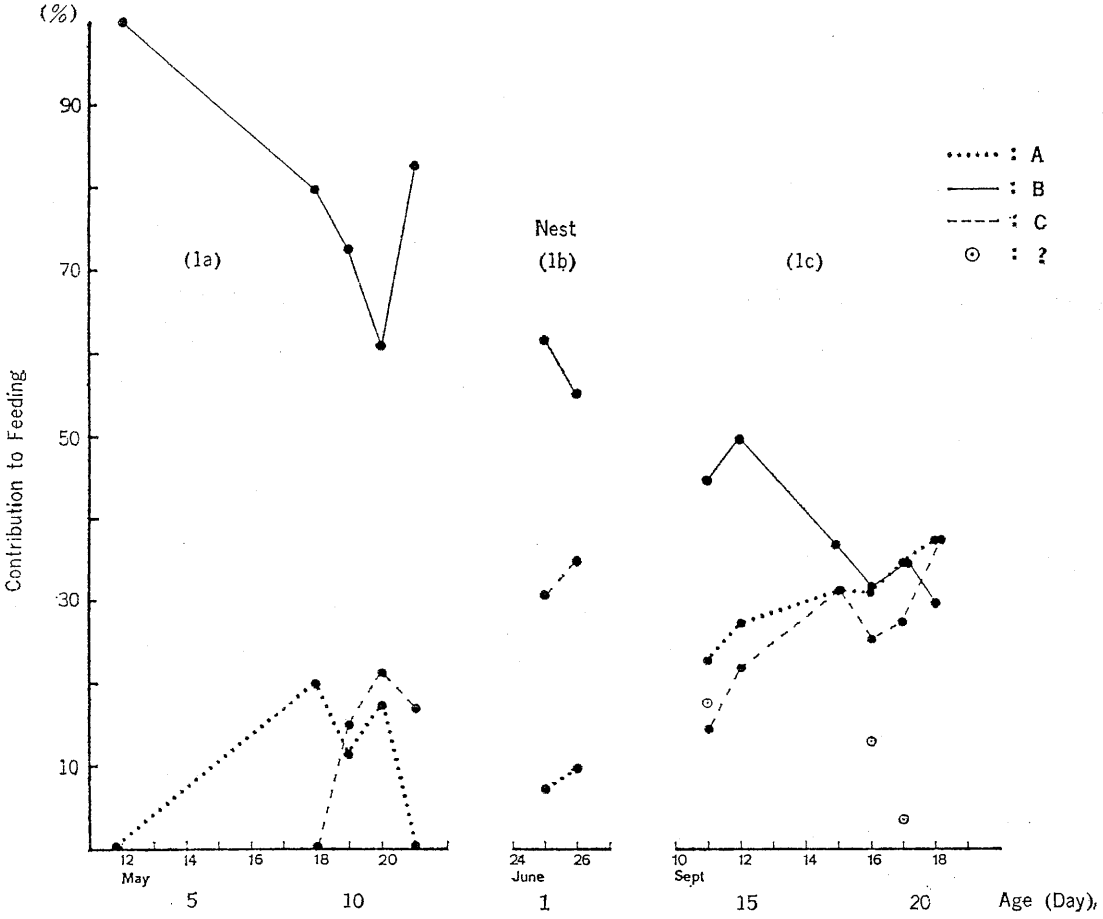

Fig. 2. Individual contribution to the feeding of young in the Kukuan flock. Data included all three nesting efforts by the same flock in one season. A= female, B=male, and C=helper. Age refers to the age of nestlings. Note that male did all the feeding at first. The female and the helper's contribution increased with the progress of the season. By mid September, all three adults contributed equally to the feeding of young.

for two days (Fig. 1). As nearly as I could tell, the female did all the incubating day and night. At night the other two birds roosted in a dense patch of woods nearby. During the day, they brought her food periodically (Fig. 1). At times when the female was left on the nest for a long time, she would leave to perch on a high branch, and make loud contact calls repeatedly. If the other two adults did not return or respond by call, she would depart to feed herself. These magpies often left excess food on favored feeding trees. The female often went to these trees and ate whatever was left there, thus permitting her to return to the nest quickly. Her absence from the nest was usually less than 15 minutes at a time (Fig. 1).

Reproductive Success

Hatching success was quite high for the magpie nests left alone by poachers. Among the six nests of known clutch size (5-6 eggs), three were robbed. The remaining three had an average hatching success of 83.4% (Table 2). Nest 1a had six eggs, among which one was collected and made into a specimen, four hatched, and one did not. Fledging success, however, was low. Two of the four nestlings in Nest 1a died on the third day after hatching. Among the other 9 nests, only three had 4 young when they were found. The rest had fewer young. Poaching by hunters resulted in even lower fledging success. Only 8 young fledged from the 15 nests in two years (Table 2). The effect of poaching made it impossible to analyze the relationship between fledging success and the number of adults caring for the young.

Rearing of Young

All the adults of a flock participated in brooding and bringing food to the young (Fig. 2). The female seemed to do most of the brooding. Young were brooded 50–70% of the time until they were about two weeks old in May, but only for about one week in September. During brooding, the other two birds brought food to the nest. The female often waited on or near the nest and begged when the other adults approached. When away from the nest, she often returned and begged for food from them when they came to feed the young. Early in the brooding period, the other birds gave her food when she begged. She either transferred the food to the young or swallowed it herself. Toward the end of the brooding period, they stopped giving her food. She stayed on the nest less and less then and started foraging on her own. The contribution of the three adults toward the feeding of the nestlings is given in Fig. 2.

Feeding Frequency

Nests 1a, 1c, and 5b were observed at length during the nestling period. Among these, 1a and 1c had three adults and 5b had two adults in attendance. Feeding frequencies differed from day to day for all three

TABLE 3
An analysis of mean feeding frequency per hour by the Age of Young

Age of Young (days)	Nest 1a (2Y)	Nest 1c (1Y)	Nest 5b (6Y)
3	0.17	—	—
7	—	—	0.35
9	1.74	1.13	—
10	2.29	—	—
11	1.78	—	—
12	1.67	—	—
15	—	—	3.05
16	—	—	6.08
17	—	—	4.86
18	—	0.75	5.75
19	—	2.62	—
20	—	2.68	—
23	—	2.54	1.10
24	—	1.65	1.30
25	—	2.23	3.89
26	—	4.24	2.59
27	—	—	3.36
33	—	0.62	—
Mean	1.66	3.19	3.67
Mean/young	0.83	3.19	0.61

TABLE 4
A comparison of feeding frequency by time of day

(A) Nest 1c

Observation	Dawn	Day	Dusk
1	7	2.4	5
2	—	—	2
3	5	2.2	4
4	4	2.5	—
5	—	—	1
6	3	0.8	—
7	5	1.7	—
8	7	2.2	2
Total	31	11.8	14
Mean	5.2	2.0	2.8

ANOVA:
F=9.02
P (one tailed)=0.009

(B) Nest 5b

Observation	Dawn	Day	Dusk
1	0	6.3	8.5
2	8.6	4.5	5.3
3	3.1	6.0	—
4	—	1.2	0.8
5	1.0	1.1	3.1
6	3.5	2.5	2.9
7	2.1	4.2	—
Total	18.3	25.8	20.6
Mean	3.1	3.7	4.1

ANOVA:
F=0.23
P (one tailed)=0.81

nests, varying between 0.17 and 6.08 times per hour (Table 3). For 1a and 1c, feeding frequency tended to increase slightly with the development of the young. No similar trend was detected for Nest 5b. On average, Nest 1a had 1.66 feedings per hour, 1c had 3.19 feedings per hour, and 5b had 3.67 feedings per hour. When brood size is taken into consideraton, Nest 5b had the least number of feedings per young per hour and Nest 1c the highest.

Street lamps at Kukuan remained lit all night long and attracted insects. Every morning at dawn, the three magpies of 1c went over all the lights one by one, searching systematically from the top down. They examined all the electrical connection, insulators, wire boxes, cross bars, and finally the ground around the light pole. The number of feedings they gave to the young for the first hour after around the ground dawn was significantly higher than during the rest of the day and the last hour before darkness (Table 4a). For nest 5b, no difference existed in the feeding frequency between time periods (Table 4b).

Nest defense

All the adults of a group participated in nest defense, taking turns to mob the intruders. In the Kukuan flock, I noticed that the helper mobbed less than the parents.

DISCUSSION

Intraflock relationship

No intraflock aggression was seen between or among adults in the wild. Mapgies kept in cages demonstrate strong hostility to unfamiliar individuals. Aviculturists warn against introducing new individuals to a cage already occupied by other magpies. Magpies unfamiliar to each other must be introduced to a new cage simultaneously. Late arrivers will get killed by the flock, or if only two birds are involved, the weaker member will get killed during severe fighting.

Four magpies I observed in a cage demonstrated what appeared to be a lineal hierarchical relationship. They changed perches in a predictable manner and order. One bird would take over the branch of another bird at the exact spot the second bird was perching, making the second bird leave. The second bird would take over the place of a third bird in the same manner, and so on.

Magpies in the wild flew in single file and changed perches in a regulated fashion. Bird watchers reported that when a flock of

wild Magpies fed on a papaya, they fed one by one. Those not feeding were on the alert. Thus, it is possible that there is dominance hierarchy among wild magpies. Dominance hierarchy has been found in other helper species such as the Florida Scrub Jay (Woolfenden and Fitzpatrick 1977).

Helper's Contribution to Breeding

All three individuals of the Kukuan flock contributed to breeding. The division of labor among the three birds was not always equal (Fig. 2). The female did all the incubation, and was fed by the other birds on or near the nest. This fits the pattern of all the corvids whose behavior is known except the *Nucifraga* spp. (Goodwin 1976). For the first few days after the young hatched in May, the male bird did most of the feeding. As the season progressed, the female and the helper contributed progressively more toward the feeding. By the end of September, the three adults contributed almost equally. The female apparently needed a transitional period from incubation to brooding to feeding of young. The helper's participation in assisting the breeding pair increased with time. This suggests that the helper needed time to learn how to take care of nestlings, or that the approaching termination of the breeding season and repeated breeding efforts induced it to participate more.

The two adults tending Nest 5b fed nestlings more frequently than the three-bird flock tending Nest 1a and 1c at Kukuan. This could be the result of a larger brood with higher energy demands (Nest 5b, 6Y), or more easily available food in a rich environment. Nest 5b was placed on a fruiting litchi nut tree (*Litchi chinensis*) in an orchard with high concentrations of insects. Unlike the Kukuan flock, neither adult of 5b ever went far from the nest when hunting for food during the time of our observation. Nest 5b fledged more young than all other nests known, even though it had the lowest amount of feeding per young. This demonstrates that a pair can breed successfully without helpers if other factors are suitable. Brown and Brown (1981) found in Grey-crowned Babblers (*Pomatostomus temporalis*) that the difference between breeding with helpers vs without was not in breeding success, but that pairs with helpers produced more clutches, had shorter intervals between clutches, and had earlier dates for the first clutches. Woolfenden (1981) found that adult Florida Scrub Jays with helpers had lower mortalities and helpers also survived better on territories. The situation is unknown for the Formosan Blue Magpies and more studies are needed.

All members of a flock participated in nest defense and the mobbing of enemies in varying degrees. In numbers alone, helpers can make a difference during crucial times of enemy attack.

Mating system

Helper-at-the-nest is one form of cooperative breeding. Current evolutionary principles emphasize the significance of individual fitness. Therefore great efforts have been devoted to the studying and explaining of this phenomenon (eg. Alexander 1974, Brown 1974, Gaston 1976, Axelrod and Hamilton 1981, Emlen 1978, 1981, 1982, Woolfenden and Fitzpatrick 1984). Many behaviorists have also discussed kin selection as an explanation for some individuals to forego breeding but assist others to gain higher fitness (Alexander 1974, West-Eberhard 1975, Ligons 1981, Woolfenden 1981, Among the species known to breed with helpers, some live in stable environments like Florida Scrub Jay (Woolfenden 1975) and Grey-crowned Babbler (Brown and Brown 1981), while others live in harsh fluctuating environments like Green Woodhoopoe (*Phoeniculus purpureus*, Ligon and Ligon 1978a,) b and Acorn Woodpecker (*Melanerpes formicivorus*, MacRoberts and MacRoberts 1976). These species share a common mating system but do not live under the same ecological conditions. Emlen (1982) proposed

an ecological contraints model to explain the existense of this breeding system, postulating the saturation of breeding openings and difficulty in rearing young as two reasons for young adults to postpone breeding for a limited number of years.

Flocking is a prominent phenomenon in Formosan Blue Magpies. More than three quarters of all the birds seen appeared in flocks. In terms of sighting frequencies, around half of all sightings were with flocks. Based on our observations, birds that flock together during the nonbreeding season remained together during the breeding season. This means around 50% of the nests had helpers. If considering only the nests and bird flocks we located, 70% of the flocks had helpers and two thirds of the nests had helpers.

The helpers of most species of birds studied by biologists are offsprings of a pair from previous broods. For blue magpies, the relationship of the helper to the breeding pair is not yet known. Nevertheless, I suspect the helper phenomenon is age related. The young of blue magpies fledged at two thirds the size of the adults. Bird watchers also reported seeing magpies in two sizes in one flock, although their plumage looked the same. It is possible that fledglings take a long time to reach sexual maturity and that subadults stay as helpers.

Regarding Emlen's (1982) model of ecological saturation as a cause for the helper system, Formosan Blue Magpies may be slow maturing and a young inexperienced pair may have difficulties in defending the nest and young against predators. Common predators of the magpie young include people, snakes, dogs, feral cats, predatory birds, and possibly other magpies. I have seen magpies bring back dead nestlings to feed their young and also to eat their own nestlings that have died. Slow maturation, however, may well be a side effect of the helper system instead of its cause (Koenig and Pitelka 1981), thus leaving only difficulties in rearing young as a possible causal factor for the development of this reproductive strategy.

Koenig and Pitelka (1981) postulated that the lacking of marginal habitat with regard to access to or amount of some limiting resource could lead to habitat-forced cooperative breeding. It seems unlikely that the physical aspect of Formosan Blue Magpie's environment poses much direct constraint. The highly omnivorous Formosan Blue Magpies inhabit mid elevation forests on a subtropical island, which is rich with fruits and animal life. Although their food types no doubt show an annual cycle, the quantity of food did not seem to wane. There should be no shortage in suitable nesting sites for they seem to have no special nesting requirement (Severinghaus 1986). There should be no shortage of food either especially because Blue Magpies seem good at using unusual local food sources, as seen in the Kukuan flock which learned to search around street lights at dawn. For the Grey-crowned Babblers, Brown and Brown (1981) found that helpers could breed as successfully as breeding pairs. They hypothesized that helpers probably could not easily gain dominance in a flock, or obtain control of suitable space for breeding. It is possible that many young Formosan Blue Magpie adults also have difficulties in gaining dominance or control over resources; therefore they stay in parental flocks to help their parents.

Blue magpies are highly aggressive birds capable of killing another Blue Magpie, as aviculturists reported. Magpies are expected to be relatively long lived in the wild, and their flocks have fairly stable home ranges. If this is true, a helper system can result in reduced flock numbers and decrease the chances that young adults encounter unfamiliar magpies in neighboring flocks and be killed. It may also reduce the possibility that nestlings get eaten by neighboring magpies during the absence of both parents. I suspect the aggressiveness of Blue Magpies may be another kind of constraint young

birds face, and thus a cause for the development of the helper system.

CONCLUSION

This preliminary study of the Formosan Blue Magpie's breeding system discovered that the helpers-at-the-nest phenomenon is common for this species. Much remains to be learned before this breeding system is understood. Further study with larger sample sizes is necessary to confirm the findings of this study. In addition, a long term study with marked birds in protected areas without human disturbance is essential, in order to understand the relationship between the helpers and the breeding pairs; the age of sexual maturation; the dominance hierarchy (if any) within the flock and how it is determined; the pattern of dispersal; the relationship between the size of dispersal units and formation of new flocks; and whether interflock aggression exists.

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臺灣藍鵲的羣性及合作生殖

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臺灣藍鵲是臺灣鳥類相中，至今惟一確知在生殖期有其他鳥協助親鳥繁殖者。大部份藍鵲維持全年性鳥羣，全羣參與生殖。尋見之巢中，70%均有他鳥幫忙，僅30%是兩隻親鳥獨立生殖。全羣鳥分擔築巢及育雛工作，雌鳥負擔全部孵卵及大部份之幼雛保溫工作。藍鵲每巢6個蛋，無人爲干擾時，卵之孵化率高達 83.4%，但幼雛存活率，因遭人類捕捉與干擾，於野外甚低。各巢成鳥每小時餵養幼雛之次數不等，可能與各羣鳥棲息環境中之食物量有關，但有他鳥協助之巢中的幼鳥所獲得的食物，並不較親鳥獨立餵養者多。