OnLine Journal of Biological Sciences 2 (10): 662-665, 2002
ISSN 1608-4127

Causes of Morphological Variation in the Hill Mynah Population in Thailand

Manee Archawaranon
Department of Biology, Faculty of Science, Ramkhamhaeng University, Bangkok, Thailand

Abstract: Study of the morphological characteristics of 749 living Hill Mynahs *(Gracula religiosa)* from throughout Thailand revealed a cline between distinct populations of the two subspecies recognized in this area *(G. r. intermedia, G. r. religiosa)*. A previous study classified morphological variants into five groups, including one that matched each recognized subspecies and three that showed intermediate characteristics. Mean values of most morphological measurements increased toward the south between 5° and 20°N. Studies of mating behavior in nature and in captivity showed that interbreeding occurred among all morphological groups. The morphological variation of Hill Mynahs in Thailand indicated that two distinct subspecies evolved at a time when they were separated from each other by geographical barriers. Since reestablishing contact, they have freely interbred.

Key words: *Gracula religiosa*, Hill Mynah, interbreeding, morphological variation

Introduction

It has been known for years that two subspecies of Hill Mynahs, *Gracula religiosa intermedia* and *G. r. religiosa*, occur in Thailand (Lekagul and Round, 1991), among the ten subspecies of *G. religiosa* found in southeastern Asia from India to China, Indonesia and the Philippines (Peters, 1962). A previous study of 749 living Hill Mynahs throughout Thailand showed that there were five morphological groups, namely northern (N), modified northern (MN), intermediate (I), modified southern (MS) and southern (S), with N and S corresponding to the two recognized subspecies and the others intermediate between them (Archawaranon and Wongwasana, 1998; Archawaranon and Techatraisak, 2002 unpublished). N group had continuous yellow connection line between the anterior and posterior wattles, MN group had yellow connection line approximately 90% of the length between the anterior and posterior wattles, I group had yellow connection line approximately half way, MS group had yellow connection line approximately 10% and S group had no yellow connection line between the anterior and posterior wattles. The five groups differ significantly in morphology and the mean size increases toward the south. Between 16° and 20°N all birds belonged to the N group, *G. r. intermedia*. However, birds belonging to the N group were also found with other groups (MN, I, MS) between 9° and 16°N. Only birds of the S group, *G. r. religiosa*, were found between 5° and 6°N. From about 6° to 9°N, birds belonging to the S group were found with those of the MS group. The zone between 6° and 16°N was thus a transitional zone in which three new morphological groups of Hill Mynah were found along with the two original subspecies (Archawaranon, 2002).

The occurrence of three new morphological groups in the wild poses a question of possible interbreeding of the two original subspecies in the contact zone. If two populations are not reproductively isolated, interbreeding is likely to occur in a contact zone and gene flow between the populations is possible (Well *et al*., 1978; Grant and Grant, 1992; Grant, 1994). The present study examined mating behavior in nature and in captivity in order to understand the causes of variation in the Hill Mynah populations in Thailand.

Materials and Methods

In the wild

Breeding season: The study was carried out in natural Hill Mynah habitats in 33 localities throughout Thailand during the breeding seasons, January to July, 1997 to 1999 (Fig. 1). Binoculars were used to determine the characteristics of yellow wattles from a distance. Two people in each locality estimated the morphological group for each bird based on the connection between anterior and posterior wattles. Percentage of assortative mating was calculated to show mate selection (Archawaranon, 1999). Pairs that produced nestlings were recorded as fertile regardless of any subsequent loss of young as a result of human interference. Because of the frequent loss of young before fledgling, data on characteristics of the wattles of offspring were incomplete. Nesting, egg-laying, incubating and feeding of young were also observed.

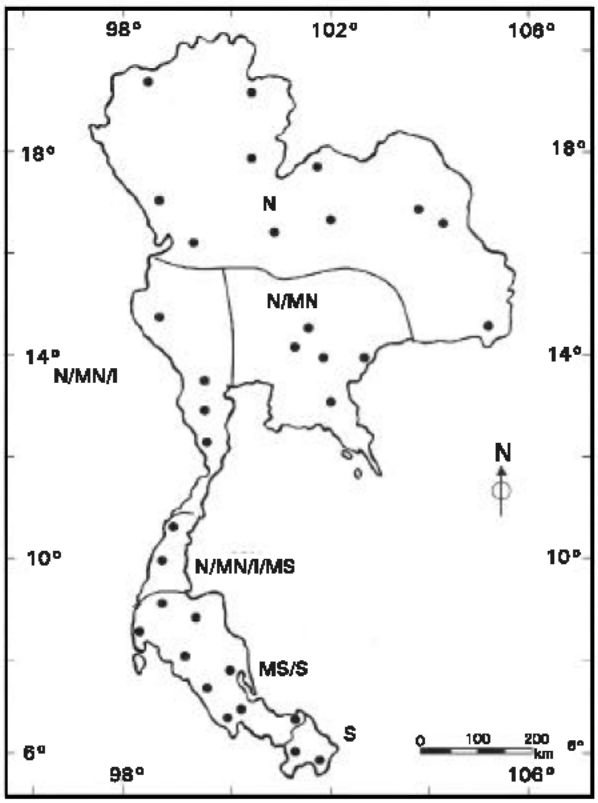

Fig. 1: Six parts of Thailand divided according to the habitats of five different Hill Mynah groups (● = 33 study sites)

Nonbreeding season: During August and December 1997 to 1999, flocks of nonbreeding Hill Mynahs were observed in 33 localities (Fig. 1). Percentage of flock with different combination of five morphological groups was calculated. Observations by two people were made at feeding sites between 06.00 and 11.00 and at roosting places between 11.00 and 15.00. Binoculars were used from distance to avoid disturbing the birds.

In captivity

Pairing behavior: In 1999 Mynahs were observed in six aviaries: 4x5x3 m^3 in dimensions at the Zoological Research Station, Ramkhamhaeng University, Bangna Campus, Bangkok, Thailand. Individuals of all five morphological groups (N, MN, I, MS, S) were mixed in an aviary, two birds of each group and each sex

(Archawaranon and Mevatee, 2002), or a total of ten birds per aviary. All birds used in this project were confiscated by the Forest Department from illegal captures by nest poachers. Courtship included flying, eating, bathing, preening and perching together. Preening each other was the clearest indication of pairing. Observations by two people occurred everyday from 07.00 to 10.00 and 15.00 to 18.00 for a month.

Breeding in captivity: In 2000 those couples from the six aviaries which successfully paired were separated in breeding cages, 1x 2x 2 m^3 in dimension, one pair per cage. Nest boxes and nest materials were provided freely and mates were allowed to breed without disturbance. The morphological characteristics of all offspring were recorded in order to categorize them into the five morphological groups.

Results

Mate selection in the wild: Thailand was divided into six parts according to the habitats of five different Hill Mynah groups (Fig. 1). In the first zone (Table 1), only the N group was found so the only possibility for pairing was N x N. In the second zone, groups N and MN occurred, so there were three possibilities for pairing, N x N, N x MN and MN x MN. In the third, groups N, MN and I occurred, allowing six possibilities of pairing, N x N, N x MN, MN x MN, N x I, MN x I and I x I. In the fourth, four different groups occurred, N, MN, I and MS, giving ten possibilities of pairing, N x N, N x MN, MN x MN, N x I, MN x I, I x I, N x MS, MN x MS, I x MS and MS x MS. In the fifth, birds of groups MS and S occurred. As in the second zone, three possibilities of pairing would occur, MS x MS, MS x S and S x S. The last zone had only birds of group S. In all cases, the proportions of each pairing closely matched expectations for random mating. For example, where N and MN groups were found, N paired with N in 72.4% of all cases, whereas N paired with MN in 27.6% and no MN was found paired with MN. Thus 86% of all birds belonged to group N and birds of the two morphological groups paired essentially randomly (expected frequency of N X N pairings = 0.86 X 0.86 = 0.74).

The reproductive behavior of different morphological groups were not different. Their breeding season was January to July. They were all monogamous and cavity-nesting birds and both parents showed reproductive activities together. Males and females built nests, incubated and fed the young. They flew from their nest in order to find nest materials or food and came back together. One parent took turn to go into the nest while the other kept watch outside. The incubation period was 15 days and parents fed young for 35-45 days. Most had 1-3 eggs per clutch and 2 clutches per breeding season.

Association of morphological groups in flocks: In six parts of Thailand where various Hill Mynah groups were found together, combinations of different groups occurred in flocks (Table 2). In the zone with N and MN groups, 72.2% of flocks included only N birds, while 27.8% contained both. In the western part of Thailand where N, MN and I groups occurred together, only 14.3% of flocks included only N birds, whereas flocks with birds of all three groups occurred in 52.4% of cases and N and MN birds were found together in only 33.3% of flocks. In the area where four different morphological groups were found together, three different types of flock composition occurred. Birds in group I were found in the same flocks with MS birds 50.0%. Flocks with four groups, N, MN, I and MS accounted for 37.5% of the total, followed by 12.5% of N birds in the same flocks. When MS and S birds occurred together, it was found that 57.9% of all flocks were mixed, while the remainder included only S birds.

Table 1: Mate selection (%) in six parts of Thailand according to the habitats of the combinations of five different Hill Mynah groups

Zone	Hill Mynah groups	n (Pair)	Pairing (%) NXN	NXMN	MNXMN	NXI	MNXI	IXI	NXMS	MNXMS	IXMS	MSXMS	MSXS	SXS
1	N	37	100 (37)											
2	N/MN	29	72.4 (21)	27.6 (8)	0									
3	N/MN/I	25	20.0 (5)	36.0 (9)	0	28.0 (7)	8.0 (2)	8.0 (2)						
4	N/MN/I/MS	16	0	18.8 (3)	0	0	12.5 (2)	0	25.0 (4)	6.3 (1)	18.7 (3)	18.7 (3)		
5	MS/S	32										15.6 (5)	34.4 (11)	50.0 (16)
6	S	7												100 (7)

Table 2: Flocks (%) of the combination of five different Hill Mynah groups during nonbreeding season in six parts of Thailand

Zone	Hill Mynah groups	n (Flocks)	Flocks (%) composed of N with N	N with MN	N with MN and I	N with MN, I and MS	I with MS	MS with S	S with S
1	N	25	100.0 (25)						
2	N/MN	18	72.2 (13)	27.8 (5)					
3	N/MN/I	21	14.3 (3)	33.3 (7)	52.4 (11)				
4	N/MN/I/MS	8	12.5 (1)	-	-	37.5 (3)	50.0 (4)		
5	MS/S	19						57.9 (11)	42.1 (8)
6	S	6							100.0 (6)

Table 3: Mate selection (%) in six aviaries. Expected possibilities of each pairing type was equal (6.7%) in an aviary

Hill Mynah groups in six aviaries	Pairing (%) NXN	NXMN	NXI	NXMS	NXS	MNXMN	MNXI	MNXMN	MNXS	IXI	IXMS	IXSM	SXMS	MSXS	SXS
N/MN/I/MS/S	5.9 (1)	11.7 (20)	11.7 (2)	5.9 (1)	23.5 (4)	0 -	5.9 (1)	5.9 (1)	5.9 (1)	0 -	5.9 (1)	5.9 (1)	0 -	5.9 (1)	5.9 (1)

Numbers in parentheses are the numbers of pairing

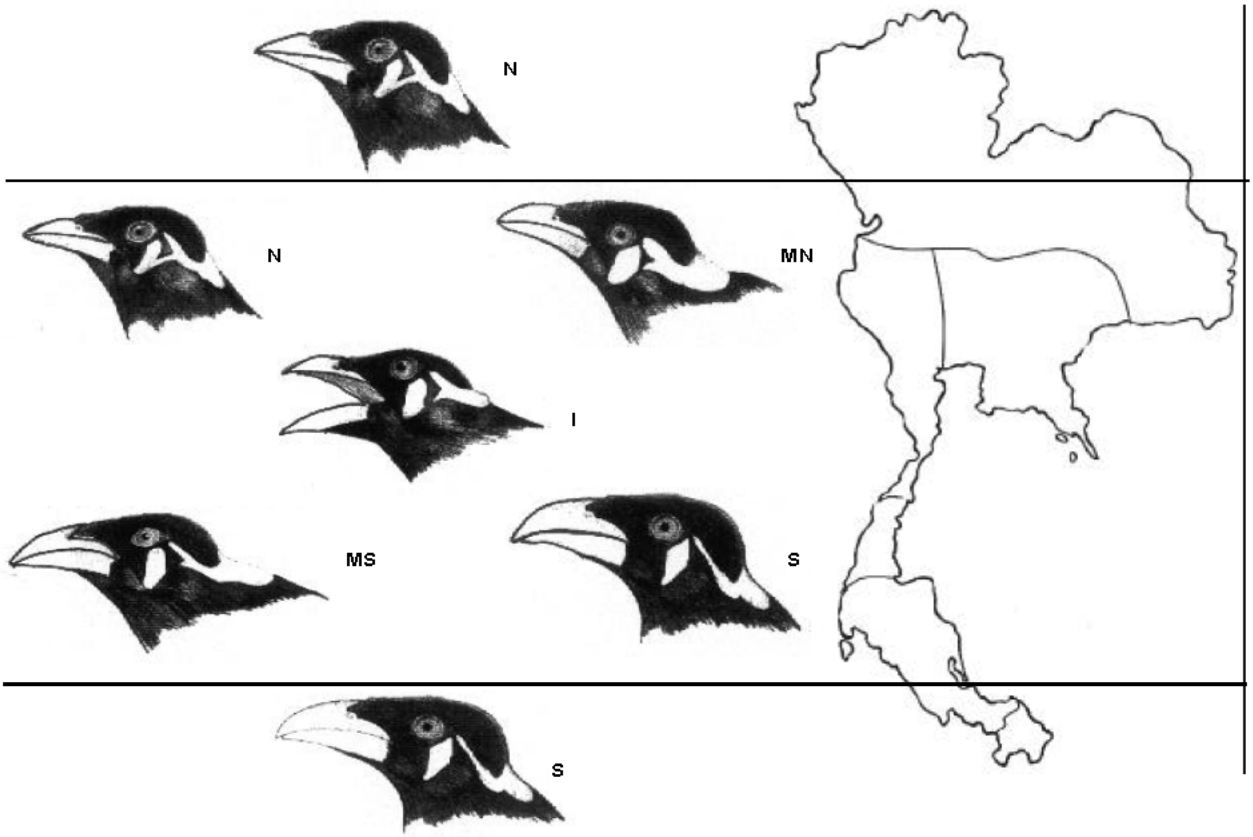

Fig. 2: Map of Thailand showed the location of Northern and Southern group's habitats and contact zone of both subspecies

Table 4: Groups of breeders and offspring in captivity according to the character of yellow connection line between the anterior and posterior wattles

		Offspring	
Pair No.	Breeder groups	Clutch size	Characters
1	NXN	3	N, N, MN
2	NXMN	3	N, MN, MN
3	NXMN	-	-
4	NXI	2	MN, I
5	NXI	-	-
6	NXMS	2	I, I
7	NXS	3	MN, I, MS
8	NXS	2	I, I
9	NXS	2	I, MS
10	NXS	-	-
11	MNXI	2	MN, I
12	MNXMS	-	-
13	MNXS	-	-
14	IXMS	2	I, MS
15	IXS	-	-
16	MSXS	3	MS, MS, S
17	SXS	2	S,S

Mate selection in captivity: In captivity, each aviary contained equal numbers of all five morphological groups (N, MN, I, MS, S). The numbers of each sex in each group were equal, therefore, each of the fifteen different combinations of pairings between morphological groups would occur equally frequently by chance (Table 3). The results showed that the most frequent pairing was N x S (23.5%), a combination never observed in the wild. The pairing N x MN and N x I were the second most frequent (11.7%). There was equal numbers of N x N, N x MS, MN x I, MN x MS, MN x S, I x MS, I x S, MS x S and S x S pairings (5.9% each), which pairings each occurred once. Birds of the three intermediate morphological groups (MN, I, MS) did not pair with birds of their own groups (no MN x MN, I x I, MS x MS) in captivity.

Breeding in captivity: There were seventeen pairs which showed courtship behaviors to each other. They were thus placed in seventeen breeding cages. Eleven of these pairs produced young: four pairs had clutch size of three and seven pairs had clutch size of two (Table 4).

When N birds bred together, offspring included MN bird. On the other hand, S birds paired to each other produced only the S characters. When N birds mated with S birds, the offspring belonged to the three intermediate groups found in the wild. When birds of one of the two original subspecies bred with adjacent groups (N x MN or MS x S), the offspring had both original and modified groups. However, when N birds mated with intermediate groups (N x I, N x MS), only intermediate characters occurred in their offspring. When birds of group MN, I and MS bred with each other, all offspring belonged to morphological groups MN, I and MS.

Discussion

Variation in morphological characters has been intensively studied in many bird species (James, 1970, 1983; Johnston and Selander, 1971; Gibson and Kessel, 1989; Aldrich and James, 1991; Martin, 1991; Peterson, 1991; Wiedenfeld, 1991; Benitez-Diaz, 1993; Johnston, 1994; Twedt *et al*., 1994). For instance, one-third of all North American bird species show geographical variation in morphology (Gill, 1998). Adaptation to local conditions promotes and maintains character variation among populations within different geographic areas (Zink, 1989). Consequently, geographic variation often involves ecotypic adaptation or phenotypic responses to different habitats. However, the habitats occupied by Hill Mynahs in Thailand do not differ markedly. The latitudinal span is only 15°. The temperature and humidity of the north and south are not substantially different. Rainfall associated with

monsoons play an important role in differentiating seasons and climates. Nevertheless, geographic variation in response to climatic differences seems like an unlikely explanation for variation in morphology of Hill Mynahs in Thailand.

In Thailand the ranges of two widespread subspecies meet. *G. r. intermedia* occurs from India and southern China southward to northern to central Thailand; *G. r. religiosa* occurs from southern Thailand southward through Malaysia and Indonesia. These two subspecies are not reproductively isolated (Archawaranon, 1994) and interbreed in a broad transition zone between latitudes 6-16°N within Thailand. Like many other hybrid zones, the area of intergradation is actually narrow in relation to the overall ranges of the subspecies. Where two subspecies meet, intermediate or hybrid populations may combine the characters of both subspecies (Mayr and Ashlock, 1991).

Although the results showed that the mean size of Hill Mynahs in Thailand increased gradually toward the south, these two subspecies were probably originally distinctly different in size and morphology, particularly in body size and in the connection between anterior and posterior wattles. The southern race, *G. r. religiosa*, is larger than the northern race, *G. r. intermedia* and there is no connection between anterior and posterior wattles in southern birds. In contrast, these wattles are fully connected in northern ones. Intermediate or hybrid populations often combine characters of two well-defined subspecies (Mayr, 1976). Moreover, the transitions in characters occur across the contact zone (Wells *et al.*, 1978; Lein and Corbin, 1990). The results indicated that morphology of the populations of Hill Mynahs in the area of intergradation consisted of a variety of pure and intermediate characters (Fig. 2) with a trend for each character to change gradually from north to south.

The experiments in captivity confirmed a lack of barriers to unrestricted interbreeding in the contact zone. It was striking that the most frequent pairing in captivity occurred between northern with southern (N and S) birds, a combination that, because of geographical separation, was never found in the wild. Results in captivity also confirmed the occurrence of pairing between N x S, MN x S and I x S, additional combinations never found in nature. On the other hand, in the wild there was no MN observed paired with MN and in captivity no MN, I, MS paired with their own kind, so it is possible that birds of these hybrid groups prefer to pair with the original subspecies than with other intermediates, although sample sizes are too small to be sure.

All offspring of northern and southern birds in captivity showed intermediate characters between these two original subspecies. When intermediate individuals (MN, I and MS) mated with one of the original groups, offspring showed both original and intermediate characters. When intermediate birds mated within the same group, only intermediate characters appeared in the offspring. The study on karyotypes among five different groups of Hill Mynahs showed that there was no difference in diploid chromosome numbers, size or shape of chromosomes (Archawaranon and Mevatee, 2002). Therefore, whenever different groups met, they paired and reproduced freely.

In natural populations of Hill Mynahs with highly variable morphology, there were no indications that birds tended to mate disproportionately with similar birds. The proportions of each morphological group in these areas during the breeding season corresponded in general with their proportions in flocks during the nonbreeding season. Thus it could be concluded that pairing and mating in nature between morphological groups was more or less at random and depended upon the number of birds of each group in the area.

The intermediate or hybrid populations of Hill Mynah in Thailand are distinctive in their own right. Although highly variable, they might well meet the requirements of 75% rule for recognition of subspecies (Mayr *et al.*, 1953), which specifies that 75% of the individuals of intermediate populations should differ from all individuals of the adjoining populations. In Hill Mynahs, intergradation has occurred between such distinct parental populations that the intermediate parts of the cline now have populations that are close to being recognizably different in their own right. The question if populations in the center of the hybrid zone are separable from N and S populations by the 75% rule or not is still to be studied.

Acknowledgments

I thank, R.H. Wiley, Department of Biology, University of North Carolina at Chapel Hill for the suggestion of this manuscript. I also thank B. Techatraisak for helping with the preparation of the manuscript and P. Wongwasana for field work. This research were supported by the Thailand Research Fund (BRG/07/2540) and Ramkhamhaeng University.

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