Stars in their eyes: iris colour and pattern in Common Mynas *Acridotheres tristis* on Denis and North Islands, Seychelles

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Summary.—An examination of Common Mynas *Acridotheres tristis*, trapped during eradication attempts on Denis and North Islands, Seychelles, revealed a wide variety of background colours and patterns of silvery white spots (which we named 'stars') in the irises. Explanations for the variation were sought via comparison of iris colour and pattern with the birds' age, sex, body condition, primary moult score and gonad size, and a sample of live birds was kept in captivity to examine temporal changes in iris colour and pattern. Juveniles initially had grey irises without stars, but through gradual mottling stars developed and other colours, especially brown, developed as bands within the iris. These changes took place within 3–7 weeks of capture; no major changes were observed in the irises of a small sample of adults over 17 weeks in captivity. No sex differences in colour or pattern were detected, but seasonal differences were apparent, particularly in that multiple bands of stars were more common in the breeding season, and grey irises were more prevalent in the non-breeding season. There was no association between iris colour/pattern and body condition index or primary moult score, but only in females was there a suggestion of a relationship between gonad size and two of the colour/star categories. The functional significance of iris variation in Common Mynas is uncertain and requires further study.

Following deliberate introduction by man, Common Mynas (hereafter 'mynas') have become established on many tropical oceanic islands where they can cause agricultural, human health and environmental problems (Feare & Craig 1998), and are commonly regarded as invasive aliens. During recent assessments as to the feasibility of eradicating introduced populations, mainly due to their adverse impacts on indigenous fauna and flora (Feare & Saavedra 2009, Feare 2010), large numbers have been handled and extensive variation in iris colour and pattern noted.

Common Starlings *Sturnus vulgaris* are members of the family Sturnidae to which Common Mynas belong. Iris colour in Common Starlings varies with age and sex (Feare 1984), as it does in some African starling species (Craig 1988, Sweijd & Craig 1991). In the genus *Acridotheres* most of the nine species are described as having dark irises, but in Jungle *A. fuscus* and White-vented Mynas *A. javanicus* it is conspicuously bright yellow. Most passerines have a dull brown iris, but in some groups, including starlings, many species have a conspicuously pigmented iris, the possible functions of which remain unresolved (Craig & Hulley 2004). In some species, iris colour can change transiently over very short time periods (McCulloch 1963, Britton & Britton 1970, Rowley 1978) and in Black-bellied Starlings *Lamprotornis coruscus* the colour changes seasonally (Chittenden & Myburgh 1994). Craig (1998) reported that in Pied Starlings *Lamprotornis bicolor* pupil contraction during some social activities led to an apparent increase in size of the pale iris. These changes might be indicative of a social signalling role of iris coloration.

No study has focused on iris variation and its possible functions in Common Mynas. However, the colour and pattern of the iris have been variously described. Feare & Craig (1998) and Craig & Feare (2009), following Ali & Ripley (1974), described irises as 'brown or reddish-brown mottled with white'. Roberts (1992) noted that the iris was brown, while Cramp & Perrins (1994) described the adult iris as 'brown to brown-red, often with white specks' and that the iris of juveniles is brown. Sengupta (1982) did not mention iris colour in his monograph on the species.

In an attempt to understand variation in iris colour in Common Mynas and to look for age and sex differences, birds caught during eradication attempts on Denis Island (03°48'S, 55°39'E) and North Island (04°23'S, 55°15'E), Seychelles, in 2010–2012, were examined in detail. A further aim was to search for correlates that might indicate a relationship between iris variation and health status or behaviour.

Methods

The eradication attempt on Denis Island was undertaken in two phases, May–July 2010 (non-breeding season, when most birds were in wing moult—see Results) and October 2010–March 2011 (breeding season, adults not in wing moult), and the North Island attempt was in October–November 2012 (early breeding season, adults not in wing moult).

Some 1,455 mynas were caught alive, 1,307 of them in decoy traps, using a living myna in a central compartment as an attractant (Feare 2010), the rest in traps or mist-nets without decoys. Iris features, background colour and the presence or absence, and pattern if present, of small white or silver-white spots (hereafter 'stars') of trapped birds were recorded while alive. Bill colour, body mass (measured with a Pesola balance), combined head and bill length (using Vernier callipers), wing length (flattened chord measured with a wing rule), primary moult score (Ginn & Melville 1983—determined only for the right wing and, as members of the Sturnidae possess only nine large primaries, the maximum moult score of one wing with all primaries renewed is 45), and gonad size (ovary length and left testis length measured with callipers) were recorded following humane dispatch.

Description of irises.—Background iris colours included uniform grey, mottled grey, brown, reddish brown and red. Two or three concentric bands of these colours, varying in width, commonly occurred. Embedded within the colour bands were patterns of 'stars', recorded as no stars, single ring of stars or multiple stars (a broad band of stars, usually in the centre of the iris, encircling the pupil). If present, the stars generally formed complete rings around the iris, but occasionally formed a partial ring, e.g. as a semi-circle.

Full descriptions of the colour and pattern of each bird were recorded; all co-authors participated in this, following instruction from CJF. Descriptions were converted into numerical scores by CJF as follows: 1 = grey with no stars, 2 = grey with stars, 3 = grey + brown with stars, 4 = grey + red with stars, 5 = brown with stars, 6 = brown + red with stars, and 7 = red with stars. These categories were ordered according to intensity of colour; in the absence of information on the development of iris colour, the scoring system excluded any assumption of progression from one category to another.

Iris colour categories were compared between ages and sexes within the three phases of eradication, as were the presence / absence and abundance (single or multiple bands) of stars. Colour categories and star distribution were also compared between breeding and non-breeding seasons on Denis Island.

Age and sex.—Birds were aged as adult or juvenile based on two criteria. Juveniles were separated on the basis of brown feathers without gloss on the crown (Ali & Ripley 1972, Feare & Craig 1998), and the presence of an all-yellow bill, lacking the dark, slate-grey mark at the base of the lower mandible of adults (CJF pers. obs.). Birds were sexed by dissection,

which was possible for most adults, but proved impossible in a proportion of juveniles because their gonads could not be located.

Iris colour change in captive juveniles and adults.—To determine the extent and rate of change with age in young birds, and to determine if changes occurred in colour or pattern in adults over time, seven juveniles and four adults were kept in captivity from late October 2010 to early March 2011, i.e. *c*.17 weeks. They were given *ad lib* water and food: bread, fruit and proprietary pet bird food. Each individual could be identified from colour rings. The precise age of the juveniles was unknown, but they were selected on the basis of the age characters mentioned above. Iris colour and pattern of all birds were recorded and photographed at approximately weekly intervals.

Statistical analysis.—Relationships between iris colour category and pattern with age, sex and season (breeding / non-breeding) were explored using chi-square tests. A multinomial model was then run in nnet (Venables & Ripley 2002) using the function multinom with a binomial distribution and log link in R version 3.0.1 (R Core Team 2013). The dependent variable was iris category (seven factors as described above) and the independent variables were body condition (body mass / length of head and bill), gonad size (mm) and primary moult score (0–45).

Results

Timing of eradication attempts in relation to breeding and primary moult.—On Denis Island, two phases of trapping occurred, May–August 2010 and November 2010–March 2011. During the former, adults were in active primary moult (mean moult scores for females and males respectively: May 26.9 (n = 18), 28.6 (n = 18); June 31.0 (n = 118), 32.2 (n = 115); July 36.6 (n = 54), 38.2 (n = 52); and August 39.9 (n = 74), 42.0 (n = 79). During this phase, seven of 257 females had large oocytes; four of these were in active primary moult. Mean left testis length of 272 males was 4.95 ± 0.11 (S.E.) mm.

During the second phase on Denis Island, the mean primary moult score of 84 females was 44.93, all but one individual having complete sets of new primaries; all 95 males had fully grown primaries. Seven of 79 females had enlarged oocytes (three of them with eggs in the oviduct). The proportion of females with enlarged oocytes was significantly greater during this phase than during the first phase (χ^2_1 = 5.08, P = 0.028). Mean left testis length was 7.27 ± 0.17 mm, significantly greater than in phase one (t_{160} = 11.32, P < 0.001).

On North Island, trapping occurred in October–December 2012. Of 252 females, just one was in active primary moult and mean moult score was 44.96, while all of 242 males had completed moult. Eighteen of the females had enlarged oocytes, but none had eggs in the oviduct. Mean left testis length was 6.69 ± 0.18 mm, significantly greater than that of phase one birds on Denis (t_{505} = 8.51, P < 0.001), but the difference from phase two birds was not significant (t_{321} = 1.84, P = 0.067).

The larger testis length in males, and presence of more enlarged oocytes in females, during the October–March trapping on Denis Island and October–December trapping on North Island, compared to the May–August trapping on Denis, indicated that the main breeding period for Common Mynas on these islands falls within the wetter north-west monsoon in October–March. The lack of primary moult during this breeding season indicates that breeding and moult are usually mutually exclusive, but four of the seven females trapped in May–August with enlarged oocytes were in active primary moult. This suggests that some breeding might occur during the drier south-east trade wind season and that the division between breeding and primary moult is not absolute.

Age-related iris colour and pattern.—Over the three phases of the eradication attempt, 70 of 82 (85.4%) birds identified as juveniles had grey irises (iris colour categories 1 and 2;

Table 1), while 195 of 726 (26.9%) adults had grey irises ($\chi^2_1 = 43.43$, $P < 0.001$), indicating that a grey iris is a predominantly juvenile characteristic, while the irises of adults have more brown and red pigmentation (categories 3–7). The distribution of colour categories of mynas caught on Denis Island during the non-breeding (March–July) and breeding seasons (October–March) differed significantly ($\chi^2_6 = 121.75$, $P < 0.001$), with a higher proportion of birds having grey irises in the former (Table 1). The same was apparent when comparing the Denis Island non-breeding sample with North Island birds during the early breeding season ($\chi^2_6 = 194.33$, $P < 0.001$).

During the non-breeding season on Denis Island 98.8% of adult mynas had stars in their iris (i.e. iris categories 2–7, Table 1), while in both breeding-season samples (Denis and North Island) all adults had stars in their irises. In contrast, most juveniles (70.0%, 74.4% and 55.6%, respectively, Table 1) lacked stars. As samples of juveniles were small, the analysis data for the three periods were combined, as were categories 3–7. The resulting 3 × 2 matrix showed that the differences in the colour patterns of adults and juveniles were significant ($\chi^2_2 = 504.38$, $P < 0.001$), with juvenile irises predominantly grey, while adult irises were more likely to contain two or more colour bands of brown and red, and also stars.

Sex-related iris colour and pattern.—Small sample sizes in some colour categories of adult female and male mynas (Table 2) necessitated the combination of categories 1 and 2 in all time periods, and of 6 and 7 in the two breeding-season samples. There were no differences in the resulting patterns of colour categories between the sexes ($\chi^2_5 = 9.80$, $P = 0.081$; $\chi^2_4 = 4.74$, $P = 0.315$; $\chi^2_4 = 3.95$, $P = 0.413$, respectively).

Seasonal differences in iris colour of adults on Denis Island.—The patterns of iris coloration in mynas caught during the non-breeding (March–July 2010) and breeding seasons (October 2010–March 2011) on Denis Island differed ($\chi^2_6 = 123.99$, $P < 0.001$).

TABLE 1
Numbers of juvenile and adult Common Mynas *Acridotheres tristis* showing iris colour / pattern categories 1–7 (see text) in samples obtained during the non-breeding and breeding seasons on Denis Island, and during the early breeding season on North Island, Seychelles.

	Age	1	2	3	4	5	6	7
Denis, May–Jul 2010 (non-breeding)	Juv	21	5	0	1	1	1	1
	Ad	4	166	54	63	21	6	21
Denis, Oct 2010–Mar 2011 (breeding)	Juv	32	4	7	0	0	0	0
	Ad	0	9	63	69	12	12	3
North, Oct–Nov 2012 (early breeding)	Juv	5	3	1	0	0	0	0
	Ad	0	16	127	15	46	14	5

TABLE 2
Numbers of adult female and male Common Mynas *Acridotheres tristis* showing iris colour / pattern categories 1–7 (see text) in samples obtained during the non-breeding and breeding seasons on Denis Island, and during the early breeding season on North Island, Seychelles.

	Sex	1	2	3	4	5	6	7
Denis, May–Jul 2010 (non-breeding)	Female	3	77	24	31	13	5	18
	Male	1	89	30	32	8	1	7
Denis, Oct 2010–Mar 2011 (breeding)	Female	0	2	25	35	7	7	1
	Male	0	7	38	34	5	5	2
North, Oct–Nov 2012 (early breeding)	Female	0	6	56	7	20	11	2
	Male	0	9	55	7	18	3	2

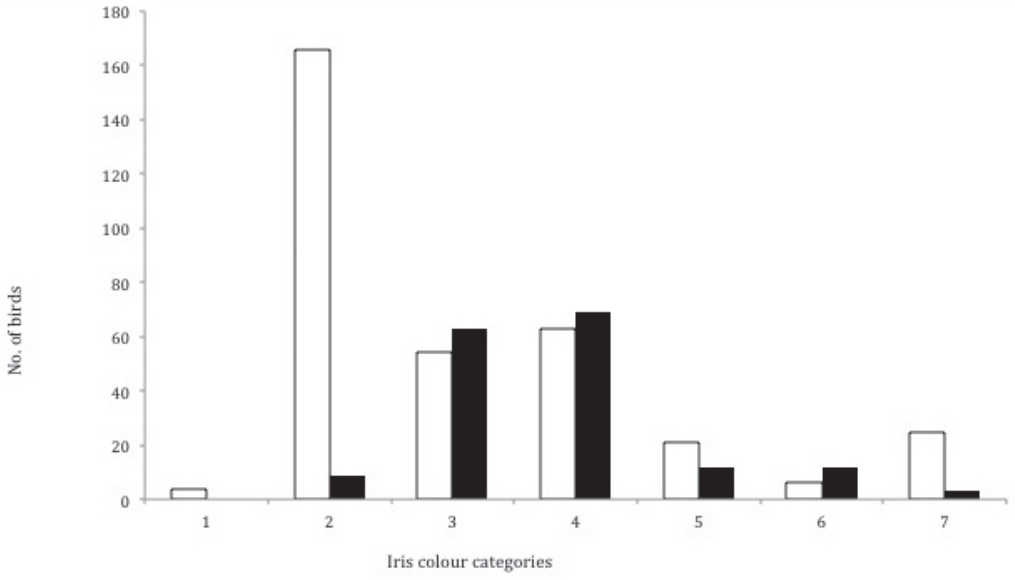

Figure 1. Distribution of iris colour categories in adult mynas on Denis Island during the non-breeding (open bars, n = 339) and breeding (black bars, n = 168) seasons. See text for definition of the categories.

During the former, category 2 (iris grey with stars) predominated, whereas in the latter the predominant categories were 3 (grey + brown with stars) and 4 (grey + red with stars) (Fig. 1).

Seasonal differences in star patterns of adults.—In the early breeding-season sample from North Island, there was no difference in the proportion of birds with single or multiple rows of stars (χ^2_1 = 0.03, P = 0.879, NS; n = 122 males, 145 females). On Denis Island, however, during the breeding season significantly more adults of both sexes combined had multiple stars than during the non-breeding season (χ^2_1 = 97.22, P < 0.001; n = 177 breeding, 339 non-breeding). There were also differences between the sexes in the non-breeding and breeding seasons, with a higher proportion of males (12 of 168) with multiple stars than females (three of 171) in the non-breeding season, although the samples of both sexes with multiple stars were small (χ^2_1 = 5.82, P = 0.016). During the breeding season the sex bias was reversed, with a higher proportion of females (40 of 83) than males (27 of 94) possessing multiple stars (χ^2_1 = 7.10, P = 0.008).

Iris colours of adults in relation to primary moult score, body condition index and gonad size.—In the multinomial model data from Denis Island, breeding and non-breeding seasons were combined because moult and breeding were confined to the non-breeding and breeding seasons, respectively, and thus were not contemporaneous. In males, the model produced no statistical significance of gonad size (n = 167, P > 0.05), moult (n = 167, P > 0.05) or body condition index (n = 167, P > 0.05) with iris category. In females there was no significance of body condition index (n = 164, P > 0.05) or moult (n = 164, P > 0.05), but significant associations were found between iris stages 3 (grey + brown with stars) (n =164, P = 0.03, SE = 0.1) and 5 (brown with stars) (n = 164, P = 0.04, SE = 0.1) with gonad size.

Iris change in captive juveniles and adults.—The unknown age of the mynas brought into captivity and the small samples dictate that only descriptive statements can be made concerning changes in iris colour and pattern over the observation periods. Five of the seven juveniles had grey irises when brought into captivity; in one the iris was grey with a brown outer ring (juvenile 5; Table 3), that of juvenile 7 was brown. Two had no stars at

TABLE 3
Eye colour categories (see text), recorded each week, of seven Common Mynas *Acridotheres tristis* caught as juveniles and kept in captivity for up to 17 weeks: 'm' = mottling or indistinct stars in the iris.

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Juv 1	1	1m	1	1m	3m	3m	3m	3	3m	3	3	3	3	3	3	3	3
Juv 2	1	1	1m	3m	3m	3m	3m	3m	3m	3	3	3	3	3	3	3	3
Juv 3	1m	1m	1m	3m	3m	3m	3	3	3	3	3	3	3	3	3	3	3
Juv 3	1m	1m	1m	1m	2	2	3	3	3	3	3	3	3	3			
Juv 3	3m		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Juv 6	1m	3m	3m	3m	3m	3	3	3	3	3	3	3	3	3	3		
Juv 7	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

the time of capture; four had mottled markings in the grey iris suggesting an early stage of star formation and one bird, juvenile 7 with a brown iris, already had stars. Juveniles 1 and 2 initially had grey irises without stars. They developed mottling in the iris within three weeks of capture and these birds, along with the three that had mottling at the time of capture, progressed to form initially indistinct stars and finally discrete stars within 3–7 weeks. During the same period, the five birds that initially had grey irises developed brown rings around the pupil, around the outer margins of the iris, or both. In two of these, red mottling began to appear within the brown rings, while in a third the brown outer ring became dark grey.

Throughout the 17 weeks in captivity, all of the juveniles retained a completely yellow mandible, with no signs of development of a dark patch typical of adults.

The four adults retained the same basic colour patterns throughout the study, but with minor variations in the distribution of colour and possibly intensity of brown, red-brown and red; apparent colour intensity can, however, vary with ambient light, especially in photographs. In two birds the pattern of stars remained the same, but in one with very few stars, the number varied between three and four during the first eight weeks of recording, then settled at four for four weeks and then five stars for the last six weeks. The final adult had multiple stars on 1 November 2010–3 January 2011, a single row of stars on 12–31 January, multiple stars on 7 February and single stars from 14 February until the last observation on 2 March.

Discussion

The data collected on iris appearance in Common Mynas on Denis and North Islands revealed considerable variation in colour and its distribution, and in the pattern of stars within the iris. The objective of the analyses was to attempt to determine whether any of this variation was attributable to age, sex, reproductive state or body condition.

All-grey irises were almost confined entirely to juveniles. Similarly, lack of stars in the iris was largely a characteristic of juvenile mynas. Observations of the small sample of captive birds showed that juveniles with initially grey irises gradually developed mottling within the grey, and the acquisition of brown and / or red coloration and some stars (Table 3). In all of the captive juveniles, these changes occurred while the all-yellow bill remained devoid of any darkening at the base of the mandible, indicating that the latter characteristic of young birds persists for at least 17 weeks (the max. duration that birds were held in captivity), while the all-grey iris changed within this timescale.

However, associations between iris colour / pattern and breeding status, moult stage and body condition proved non-significant. There is thus no clear indication of functionality

for the variation in iris characteristics. During the first phase of the eradication attempt on Denis Island, we obtained circumstantial evidence that some individual mynas proved more attractive than others when used as live decoys to lure mynas into traps. If iris characters could be used to identify potentially attractive decoy birds, this could be used as a tool to aid future eradication attempts. Further studies on the significance of the changes in star pattern in myna behaviour, possibly facilitating individual recognition or hormonal status, represents an avenue to explore if the hypothesis that some individuals make more attractive decoys than others is confirmed.

Among the captive juveniles both brown and red pigmentation became apparent during the early stage of change in iris colour. However, from this study we are unable to state when fully grown birds develop their full eye coloration or whether it persists for life. The four captive adults retained the same basic colour pattern during their 17 weeks in captivity, but longer term observations on a larger sample are needed to address these points, and especially to determine whether iris colour and pattern in juveniles can be used to estimate their age, as is the case in some other passerines (e.g. Bearded Tits *Panurus biarmicus*: Wilson & Hartley 2007).

The captive juveniles showed that stars begin to appear in the iris during the first few weeks of life. In one of the birds, the number of stars varied during the period in captivity, and in later life variability in star pattern was indicated by the significantly greater proportion of adults with multiple stars in the samples collected on Denis Island in the breeding than in the non-breeding period. This could indicate that star pattern might be influenced by hormone cycles, a possibility also suggested by the significant association between two of the iris colour and pattern stages and gonad size in female mynas. However, this possibility requires substantiation via long-term studies of captive birds and experimental studies involving manipulation of hormone levels. Unlike flecks in the irises of several species of oystercatcher *Haematopus* spp., which are sex-linked (Guzzetti *et al*. 2008), the stars observed in myna irises and their apparent seasonal variation occur in both sexes, but what the stars are, in terms of pigmentation or lack of it, is unknown.

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