EFFECTS OF SOLAR CUES ON BASIC DIRECTIONAL PREFERENCES OF YOUNG MALLARDS[1]

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The physical and biological factors associated with orientational capabilities of many avian species have been studied extensively. Most of this research has involved adult birds whose prior migratory experience might have modified their responses while in the test situation. Some recent studies (Emlen, 1969; Southern, 1967, 1969a, 1969b, 1971) have involved young (i.e., inexperienced) birds. These investigations were designed to show whether the species under study possessed a basic (i.e., unlearned) directional preference in response to certain environmental cues. Such basic headings are considered to be indicative of the initial course young Ring-billed Gulls (*Larus delawarensis*) will take to reach their population's winter range for the first time (Southern, 1969a).

Bellrose (1958a) demonstrated that wild-trapped adult Mallards (*Anas platyrhynchos*) upon release showed distinct preferences for north to northwest headings regardless of the season. Matthews (1961) later concluded that this same direction was preferred by adult Mallards from a largely sedentary population in southwestern England. Both Bellrose (1958a) and Matthews (1963) reported that Mallards use solar cues in their northwest orientation. However, almost nothing is known regarding the orientation behavior of the young of this species.

The purpose of our study was to determine, through orientation cage trials: (a) if game farm Mallard ducklings exhibit directional preferences comparable to those demonstrated by their wild adult counterparts; and (b) if so, what natural physical and biological parameters affect such orientation.

METHODS AND MATERIALS

The 1,277 trials reported in this study were conducted on the grounds of the Max McGraw Wildlife Foundation in Dundee, DuPage County, Illinois from 6 May to 15 June 1969. The Mallard ducklings used were from five strains (Fig. 1) raised commercially at the McGraw Foundation. Birds ranging from 1 to 14 days old were used in orientation cage trials. The ducklings were hatched in incubators and then reared in indoor brooders without exposure to the natural sky.

The test apparatus (Fig. 2) consisted of an octagonal frame 7.26 feet across and 3 feet high that was covered with 1.5 inch mesh chicken fencing. The cage floor, a sheet of black polyethylene, was marked off into 16 equal pie-shaped sectors. The lines between sectors corresponded to the 16 major points of a compass rose, with 0° corresponding to magnetic north, and the angles increasing in a clockwise direction to 360°. We observed the birds from behind a blind located 12 to 14 feet from the cage. A 12 x 12 x 8 inch card-board box was used to hold the duckling in the center of the cage

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prior to release for the trial. The box was connected to a rope strung along a board going from the cage to the blind. This apparatus enabled us to raise the box, thereby releasing the bird, without showing ourselves.

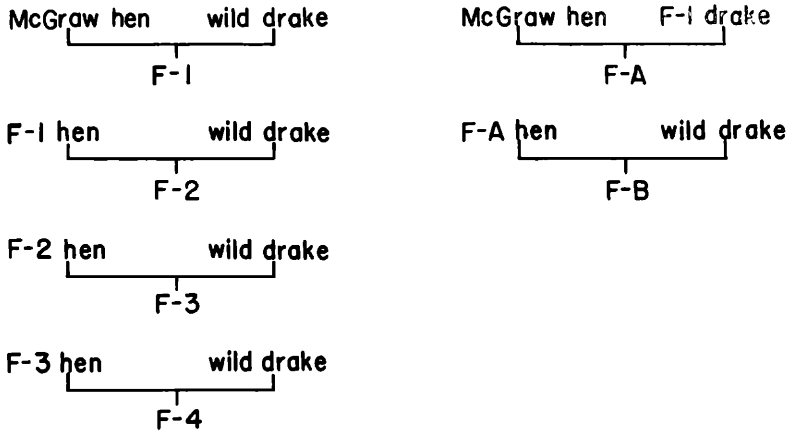

FIGURE 1. Derivation of McGraw strains. The McGraw Mallard is an inbred game farm bird. The other strains are obtained by back-crossing this bird with wild Mallards.

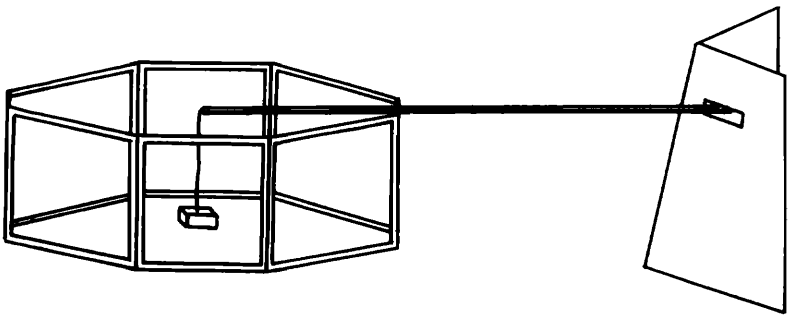

FIGURE 2. Orientation cage and blind.

A total of 1,277 ducklings was used in the various tests, and each bird was used only once. Each duckling was allowed 90 seconds of unrestricted movement within the cage. All of the bird's directional headings and its progress were recorded on a circular chart diagram of the cage floor. We also recorded the duckling's initial heading (the direction of first movement), final heading (the direction the bird was moving when and if it attempted to escape from the cage), or the direction faced if it failed to respond (i.e., move) during the 90-second trial. We recorded all headings as the vector direction of movement (or facing) rather than as the position of the bird in the cage. To reduce the possibility of providing the test birds with artificial cues for orientation, we rotated the cage arbitrarily on each successive trial date, turned each successive test bird 90° clockwise to the previous trial as it was placed in the holding container, and varied the location of the blind during the study period.

All of the trials discussed in this paper were conducted outdoors during daylight hours. The following environmental factors were evaluated with respect to their possible effects on the ducklings' responses: wind direction, time of day, sky condition (the amount of cloud cover), and disturbances in the earth's magnetic field. Our results for the latter parameter will be discussed in a separate paper. Consideration was also given to the possible influences of the duckling's age and genetic strain.

Wind direction was measured next to the cage and about 5 feet above the ground. The starting time of each trial was recorded, but during data analysis we grouped these into three time-periods: (a) 07:00 to 10:59 CDT, (b) 11:00 to 14:59, and (c) 15:00 to 18:00. We categorized sky conditions as clear (Sky 1), partly cloudy but with less than 50 per cent cloud cover (Sky 2), partly coludy with more than 50 per cent occlusion (Sky 3), and completely overcast (Sky 4).

The statistical methods for circular distributions used to analyze the trial data were described by Batschelet (1965). The computations were carried out using an IBM 360/50 computer and a Fortran IV Program (Zar, 1969). A mean angle was calculated and its significance was tested using Rayleigh's z test, wherein a significant mean angle indicated a preferred direction. The 1 per cent probability level was used throughout the analysis of our data. A mean angular deviation was also calculated. Each of the three types of headings (initial, final, or none) was first tested for a significant mean angle, and then the effects of the physical and biological parameters were considered.

RESULTS

Initially we combined our data for all the test dates and analyzed the three selected response categories (initial heading, final heading, and no heading) to determine if any of the groups showed a directional preference, i.e., non-random movement. No consideration was given at this time to variables created by different environmental factors or by the experimental design. A significant mean angle of 317° (NNW) was calculated for the 1,191 initial headings and a significant mean heading of 281° (WNW) appeared for the 907 final headings. The "no heading" group did not demonstrate a preferred direction. The initial and final heading groups were analyzed further to determine which environmental factor(s) affected orientation. Because of the similarities between the responses of these two groups, we have selected the initial heading group as being representative, and unless otherwise indicated, our comments refer to this group.

Solar cues.—The initial headings were separated for the four sky conditions and each subgroup was analyzed separately. The data for the 527 trials conducted under Sky 1 (clear) showed a significant mean angle of 327° (NNW); the 392 trials under Sky 2 had a mean of 296° (NW); the 82 Sky 3 trials and the 190 Sky 4 (overcast) trials did not demonstrate any preferred direction of orientation (Table 1 and Fig. 3). These results indicate that young Mallards have a northwest directional preference and that their heading is apparently based on solar cues, even though the test subjects had not been per-

TABLE 1. Results of testing the effects of sky condition on the initial responses recorded during the outdoor trials.

sky condition	n†	$\bar{x}$(deg)	s(deg)††	z	significant (1% level)
1 (clear)	527	327	74	15.1057	yes
2	392	297	75	7.9020	yes
3	82	278	79	0.1752	no
4 (overcast)	190	348	78	1.0523	no

†n = number of ducklings used in a particular test.
††s = standard angular deviation.

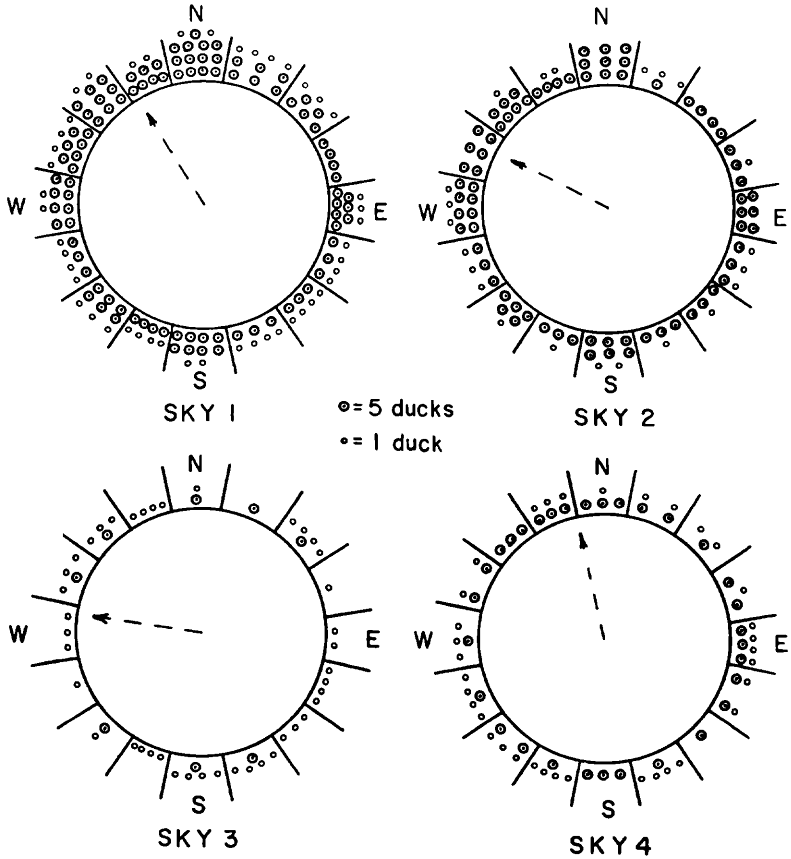

FIGURE 3. Distribution of initial responses around a compass rose for the four sky conditions. The values of the critical statistic, *z*, for the four sky conditions were: Sky 1, 15.1057; Sky 2, 7.9020; Sky 3, 0.1742; and Sky 4, 1.0523. The mean angle for each sample is indicated by the dashed line.

mitted to see the natural sky prior to the trials. Such a preference was not apparent until after the fifth day of age suggesting that some post-hatching maturation, possibly of the nervous system, is required before the ducklings have a directional preference or before they are able to select a particular heading on the basis of solar cues. Bellrose (1958a) and Matthews (1961, 1963) also found the sun to be the important cue for diurnal orientation by adults of this species. Furthermore, Matthews' (1961) conclusion that "nonsense" orientation might involve a sun-compass seems to be supported by our findings. These birds could have no memory of the sun's arc at home, which is required for Matthews' (1951, 1953) theory of sun navigation, since they never saw the natural sky prior to the trials. The quickness of their direction-finding process also suggests a sun-compass type of orientation.

Genetic strain.—In order to test the possibility that genetic make-up of the ducklings influenced their directional preferences and their response to environmental cues, we separated the data for the four sky conditions into strain subgroups (Table 2). Some differences are apparent: (1) the F-B strain showed no preferred heading under any sky condition; (2) the F-2, F-3 and McGraw Mallard samples had significant mean angles under Sky 1 and 2, but not under Sky 3 and 4; (3) the F-4 strain demonstrated a significant mean angle under clear and overcast skies. This latter group was represented by a small sample (16 birds) and so the results are subject to question. The amount of inbreeding or domestication (the number of generations removed from the wild) did not seem to have an effect on the ducklings' orientational ability although it could influence the degree of wildness and actual initiation of migration.

Other factors.—Wind direction and blind location had no apparent (or at least consistent) effect on the orientation responses of ducklings. When the initial headings were sorted for the nine wind directions encountered during the study, significant mean angles (321° and 263°) were found for only two groups (E and WNW winds). The means for the other seven data groups were not significant, but they were all within or near the 90° west to north quadrant. It appears likely that the clustering of headings toward the west and northwest is in response to cues other than wind. This is evidently true for adult Mallards as well since Bellrose (1958a) reported that wind direction and also low to moderate wind velocities had no effect on their orientation.

Bellrose (1958a) and Matthews (1961) found that time of release had no effect on the orientation of adult Mallards. Our results for ducklings do not coincide with their findings. A significant directional preference was found for ducklings tested between 11:00 and 14:59 (Table 3). Since this is the only time period for which a significant heading was recorded a possibility exists that the apparently innate ability to select a preferred directional heading on the basis of solar cues is initially most accurate during some part of this particular four-hour time span. Further maturation and perhaps experience is required to enable the birds to use accurately the sun at other times during the day. The importance of post-hatching development was discussed previously when it was mentioned that

TABLE 2. Results of testing the effects of strain differences and sky condition on the initial responses recorded during the outdoor trials.

strain	sky condition	n	x̄(deg)	s(deg)	z	significant (1% level)
4th	1	138	285	76	1.8887	no
4th	2	109	283	70	6.9652	yes
4th	3	36	295	72	1.5650	no
4th	4	83	180	78	0.3579	no
F–2	1	166	11	71	9.1650	yes
F–2	2	89	63	80	0.0367	no
F–2	3	19	105	73	0.6358	no
F–2	4	17	0	61	3.2656	no
F–3	1	61	303	66	6.8396	yes
F–3	2	31	356	61	5.6698	yes
F–4	1	91	286	71	4.9045	yes
F–4	2	73	281	72	3.3831	no
F–4	3	19	84	78	0.1233	no
F–4	4	16	1	53	5.1266	yes
F–B	1	71	351	71	3.5994	no
F–B	2	90	281	77	0.7598	no
F–B	3	8	223	66	0.8683	no
F–B	4	74	311	79	0.2397	no

TABLE 3. Results of testing the effects of time of day on the initial responses recorded for the outdoor trials.

time of day	n	x̄(deg)	s(deg)	z	significant (1% level)
07:00-10:59	337	284	76	4.4121	no
11:00-14:59	473	320	72	20.7349	yes
15:00-18:00	381	353	78	2.2668	no

ducklings younger than five days seemed to lack a directional preference.

DISCUSSION

The directional preference of 318° found for the initial headings of Mallard ducklings corresponded closely to results which Bellrose (1958a) and Matthews (1961) reported for their adult releases. The high mean for angular deviations (76°) was probably due primarily to the inexperience of the birds in relation to long distance orientation. Emlen (1969) reported similar angular deviations for orientation cage trials with hand-reared juvenile Indigo Buntings (*Passerina cyanea*). Bellrose (1958b) determined from band recoveries that approximately 67 per cent of the 475 adult drake Mallards which he trapped in Illinois and released in Utah returned to the Mississippi Flyway whereas 67 per cent of the 425 juvenile drakes remained in the Pacific Flyway. Therefore, experience seems to play an important part in orientation or in perfecting the use of cues during orientation, and a large mean angular deviation for these inexperienced ducklings was to be expected.

SUMMARY

Orientation cage trials were conducted using Mallard ducklings 1 to 14 days old to determine if an unlearned directional preference was present and also what physical and biological factors affected the choice of directions. An innate directional preference for the northwest was shown, and the direction of initial movement from the center of the orientation cage seemed to be indicative of this preference. It was shown that solar cues were used by ducklings in their orientation. The time of the trial seemed to affect the bird's ability to select a preferred heading. This might indicate that further maturation and experience are required before a Mallard can use the sun during other times of the day for orientation. It appeared that a critical age of about five days was required before ducklings were able to indicate a directional preference. Wind direction, strain differences, and blind location appeared to have no effect on the directional responses of young Mallards.

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