RADAR TRACKING OF EXPERIMENTALLY RELEASED MIGRANT BIRDS

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INTRODUCTION

During the past two decades, much attention has been directed toward understanding the navigational systems used by migrating birds. Surveillance and radar tracking studies of bird migration have provided descriptive information on the behavior of birds in flight. Experimental studies on captive animals have investigated the types of sensory cues that animals can use, at least in caged situations. These studies indicate the probable existence of a hierarchy of redundant, multiple cues available for orientation and navigation. Rather than search for *the* mechanism of orientation, one must perform experiments that will separate various component cues and provide insights concerning their relative weighting and importance for orientation (Emlen, 1975). In this report we outline a new technique that allows one to manipulate experimentally the navigational system of a free-flying bird as it travels along its migratory route.

In our studies we use a lightweight cardboard box, suspended beneath a helium balloon, to carry an individual passerine migrant aloft to migratory altitudes. At a prescribed height above ground, the trap-door floor of the box falls open and the bird flies out. As the bird selects its departure direction and continues its migratory flight, it is "observed" or tracked from the ground. It thus becomes possible to exercise a degree of manipulative control over the orientational information available to a free-flying migrant in a way not previously possible. For example, one can release migrants under a variety of naturally occurring meteorological conditions, including some when birds normally choose not to go aloft. One can deprive birds from viewing local landmarks, sunset cues, or other celestial sources of information. And one can experimentally alter various aspects of the orientational system. By observing and comparing departure orientations under different conditions, it becomes possible to study the relative importance of, and the interactions between, the different directional information sources used by migrants aloft.

TECHNIQUE

The experimental bird is placed in a lightweight cardboard box (Fig. 1). For small- to medium-sized passerines, our standard box measures 7 × 5 × 5½ inches. This box is closed on all but one side and, after the bird has been placed inside, a separate piece of cardboard is attached to form the trap-door bottom of the box. This is attached at one end by two pieces of masking tape that serve as hinges. The other, or free end of the floor is held shut by a loop of nylon monofilament that is drawn up tight and taped securely to the box front. The box opens when a piece of slow-burning fuse ("caw-caw rope," J. E. Fricke Co., Philadel-

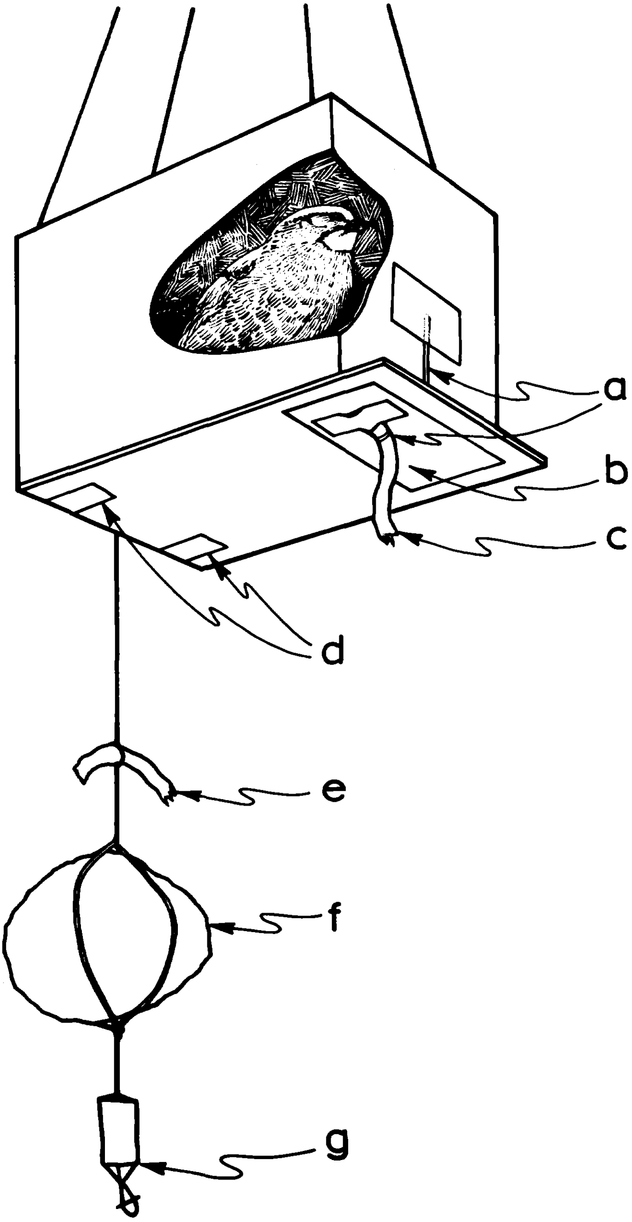

FIGURE 1. Diagram of box for releasing birds aloft. a = monofilament loop holding floor of box closed; b = fireproof tape; c = primary fuse; d = hinges; e = secondary fuse; f = aluminum foil sphere (for radar acquisition); g = battery and light bulb (for nocturnal visual acquisition).

phia) burns up to the monofilament and melts the loop. The weight of the bird is sufficient to cause the floor to swing down, releasing the bird into the airspace. Fumes from the burning fuse are minimal and are carried off by the wind. Duct tape on the underside of the floor "fireproofs" the box.

The box, with bird inside, is suspended beneath a helium-filled 100-g weather balloon inflated to about five feet in diameter. When released, the balloon can be tracked as it ascends through migratory altitudes. In this way, important information on local winds can be obtained. As the balloon/box rises, the wind carries it (and the bird) farther and farther from the tracking site. The rate of ascent must be a compromise between a gradual rise (that minimizes rapid pressure changes felt by the bird, but maximizes drift of the bird away from the tracking location) and a more rapid rise (that has opposite effects). We use a rate of rise of 400 ft/sec. This is achieved by inflating the balloon until it just lifts a standard counterweight (in our case, 200 g). Potential trauma associated with turbulent buffeting or swinging of the box is minimized by suspending it beneath the balloon by a long (40 ft) piece of string. This effectively dampens out most motion, thus ensuring a smooth ride.

The fuse system is designed to release the bird at any preselected altitude. Three variables determine at what altitude a bird is released: burn rate of the fuse, fuse length, and rate of rise of the balloon. The first can be measured empirically; the last two are under the control of the investigator. A strand of "caw-caw rope" burns at a rate of 3 min/in, so for a desired release altitude of 3,000 ft and a given rate of rise of 400 ft/min, the fuse should measure 2.5 in. As the box floor opens and the bird is released, the balloon and box continue to rise, and the bird is left alone in the airspace.

The technique as described is suitable for visually observing bird migrants (with binoculars, for example), for tracking with radiotelemetry equipment, and for radar tracking. The relative merit of the three systems is one of increasing precision in the information obtained. Visual tracking allows one to determine a departure bearing, only, whereas tracking radars provide an accurate 3-dimensional description of each departing bird's behavior.

METHODS

During the spring and fall migration seasons of 1970, we radiotracked Swainson's Thrushes (*Catharus ustulatus*) and Gray-cheeked Thrushes (*C. minimus*) in Ithaca, New York. The birds were captured on migration, held in captivity, and re-released in the airspace using the balloon/box technique. William Cochran kindly provided the circuit diagram from which we built the transmitters (see also Cochran et al., 1967). The transmitters weighed 3.0 g and transmitted in the 148 MHz range (Fig. 2). For the thrushes, the transmitter package represented roughly 10 percent of body weight. We found it necessary for the birds to wear "dummy" transmitters on their backs for several days prior to release,

FIGURE 2. Photograph of Swainson's Thrush (*Catharus ustulatus*) wearing radio transmitter. Transmitter weights 3.0 g and is attached by a single-wire harness knotted around the bird's body and from which the bird can peck free after two to three days.

in order to become adjusted to the added weight. Releases were made at night, and we tracked the birds using a Drake model R-4B receiver and a double Yagi antenna mounted atop a 40-ft high tower located adjacent to Cornell University.

Our radio-tracking results pointed to the initial success of the method, but radiotelemetry studies only provide data concerning the bird's departure direction. The speed associated with that track is not measured.

Likewise, since the altitude at which the bird is flying is unknown, it is impossible to describe accurately the wind situation a bird encounters. Any detailed analysis of orientational capabilities and strategies requires information on the wind vector at bird altitude, the vector describing the bird's flight path (termed heading and its associated air speed), and the resultant of the two, that vector described by the bird's departure bearing (track) and ground speed. Precise quantitative measurements of all important flight parameters can be obtained only with tracking radars.

Unlike surveillance radars, a tracking radar is a narrow-beam radar designed to acquire and stay with a single target. We sought the aid of the National Aeronautics and Space Administration at Wallops Island, VA and were given radar support, on a time-available basis, for part of three migration seasons: spring and fall 1971 and spring 1972.

A bird, without any artificial devices attached, makes an excellent, natural target for a tracking radar. In contrast, the release box (constructed from essentially radar-transparent materials) provides a minimal radar echo. Thus, when the radar is tracking the box and bird, it is, in fact, tracking the bird. When the fuse melts the monofilament and the floor of the box drops open, the box and balloon continue to rise and the radar automatically stays with the bird.

Since most passerine migration occurs at night, nocturnal radar tracking of the balloon/box presents some unique acquisition problems. First, the radar operator must be able to sight the box in order to aim the radar beam in the appropriate direction. Second, the returning echo from the target must stand out against ground clutter which, at low altitudes, often obscures bird echoes. We solve the first problem by attaching a small but bright light (pibal) below the box, enabling the radar crew to locate the specific area where the balloon/box is rising in the night sky. The second is solved by attaching a sphere of crushed aluminum foil below the box, enhancing its signal echo. Once the radar has locked onto the target and the target has risen above the clutter, the light and sphere are no longer required. In fact, if retained, the sphere will mask detection of the bird's exit from the box. A secondary fuse, shorter than the original (primary) fuse, rids the box of these now-unwanted devices (Fig. 1e–f).

In the spring of 1971, we tracked White-throated Sparrows (*Zonotrichia albicollis*) with the SPANDAR radar at Wallops Station, VA. The SPANDAR is a 10 cm wavelength, 5 Mw peak power radar with a 0.39° beam width. Its extreme high power enabled us to follow individual birds out to distances of 22 miles. Analyses of these long-distance tracks inceased our confidence that our experimentally released birds had actually initiated migratory flights and that the direction and altitude taken initially were maintained for long periods of time. For the fall 1971 and spring 1972 migration seasons, NASA assigned us the shorter range FPS-16 radar (Fig. 3). This is a 5 cm wavelength, 1 Mw peak power radar with a beam width of 1.2°. The radar is capable of tracking

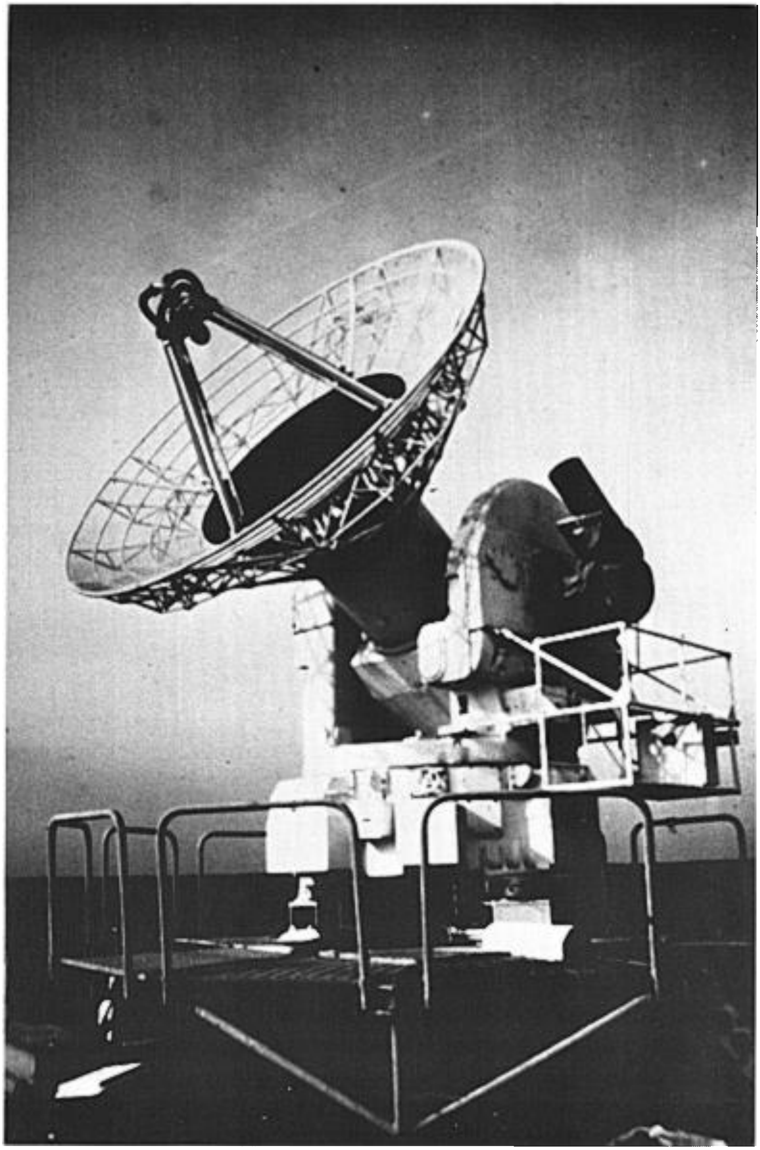

FIGURE 3. FPS-16 tracking radar at NASA Wallops Station, Wallops Island, VA. The radar dish measures 12 ft in diameter.

individual sparrows for distances of 8–10 miles, more than adequate for obtaining initial departure information.

Flight behavior was plotted on an analog plotboard that gives accurate position information in the three spatial coordinates (Fig. 4). Two dia-

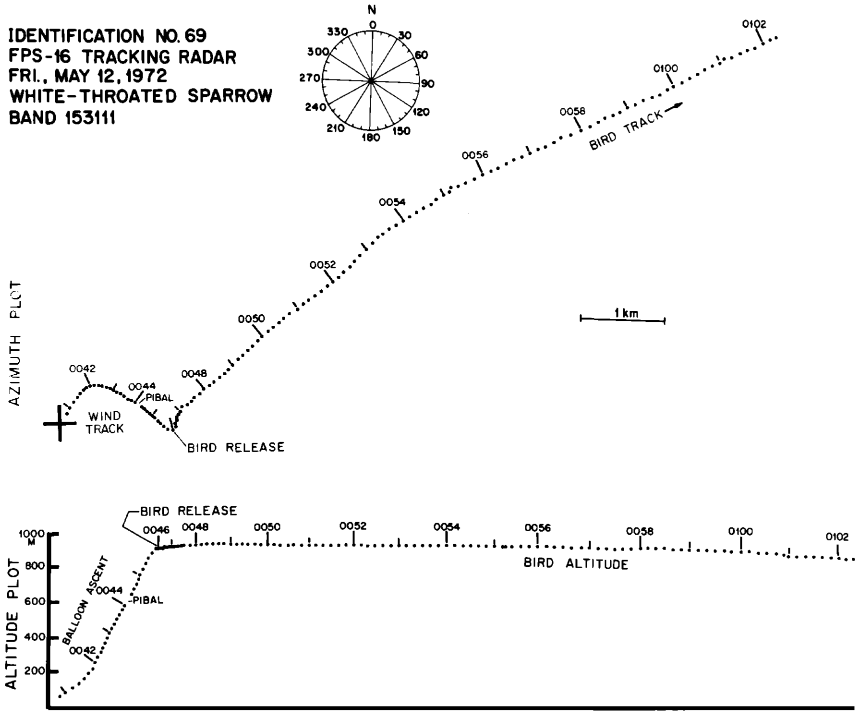

FIGURE 4. Position or azimuth (top) and altitude (bottom) plots for a White-throated Sparrow released at 2,500 ft on the night of 12 May 1972. Dots give the bird's location plotted at 10-sec intervals. Numbers adjacent to plots are hour and minute times in GMT. + signifies location of the radar. Pibal denotes the time at which the light used for nighttime acquisition was dropped. Data collected between the time of initial launch of the balloon and actual release of the bird provide accurate information of local wind conditions, and are used to derive the bird's heading and airspeed (see text). In this experiment, note the marked change in wind direction at approximately 700–1,000 ft altitude. This bird maintained nearly level flight and flew to the northeast-east-northeast in a constant crosswind. It covered approximately 5½ mi in 16½ min before tracking was discontinued.

grams of a bird's location are obtained. One gives the bird's geographic (azimuth) position over the ground, from which departure direction and ground speed can be calculated. The other provides altitudinal information showing whether a bird descended, climbed, or maintained level flight. Since data are collected beginning with the initial release of the balloon, the information obtained up to the time of bird release allows accurate determination of wind direction and speed at various altitudes aloft. Whenever a bird climbed above its release altitude, the next balloon was tracked to a correspondingly higher altitude. In this way, accurate wind information was obtained for all altitudes of bird flight. From these values, we could calculate the actual air speed and heading of each bird by vector analysis.

RESULTS

The major assumption of this technique is that a bird, after being subjected to the potentially traumatic and unnatural treatment of being carried aloft at night and released from a box into the airspace, is still properly motivated and behaves in a manner consistent with that of a normal migrant. To investigate this, we compared the behavior of our artificially released birds with the known behavior of naturally occurring migrants. If the birds tolerate our attempts to bring their flight departures under experimental control, we should expect the following predictions to hold true: (1) a large percentage of the birds released aloft should maintain altitude and initiate long-distance flights, rather than come to the ground. (2) The proportion of released birds that initiate such migratory flights should correlate with the internal physiological state of the bird. (3) The proportion of artificially released birds initiating flight should be greatest on nights when general weather conditions are stimulatory. (4) The flight behavior of experimentally released birds should show the alternating "flap-pause" pattern that is typical of passerines during migration (see below). And (5) the flight directions of the artificially released birds should be meaningfully and appropriately oriented in the migratory direction.

In order to discuss either the influence of weather on bird migrants or meaningful orientation directions, it is necessary to distinguish between spring and fall migration seasons. In this paper we shall discuss these two topics as they relate to spring migration only. Fall orientation studies will be discussed elsewhere. For points 1, 2 and 4 above, seasonal differences are not expected and all radar data have been analyzed together.

1. *Maintaining Altitude.* Not all birds that we put aloft chose to fly. Some descended directly to the ground. Others climbed or descended gradually before selecting an altitude band and leveling their flight. Figure 5A contains a frequency histogram of the climb or descent rates of the last mile tracked for all sparrows experimentally released aloft. The figure is roughly bimodal, with a clumping of birds with rates-of-altitude change between +2 and −4 ft/sec, a small hiatus in the −4 to −5 ft/sec range and a steadily increasing number of birds with rapid descent rates of from −5 to −27 ft/sec. On the basis of this distribution, we established the following criterion: a bird is presumed to be motivated to migrate and its track is included in later analyses if its descent rate does not exceed −4 ft/sec. All birds whose descent rates exceed this value are considered nonmigratory (most were tracked all the way down to the ground) and their tracks are excluded from analysis.

Figure 5B plots the climb and descent rates of naturally migrating passerines that were tracked with the FPS-16 radar between releases of our experimentally manipulated sparrows. The mean value ($\bar{x} = -0.04$, SD = 1.79) is more level than the mean of our experimentally released "migratory" sparrows ($\bar{x} = -0.89$, SD = 1.32). Even though the distri-

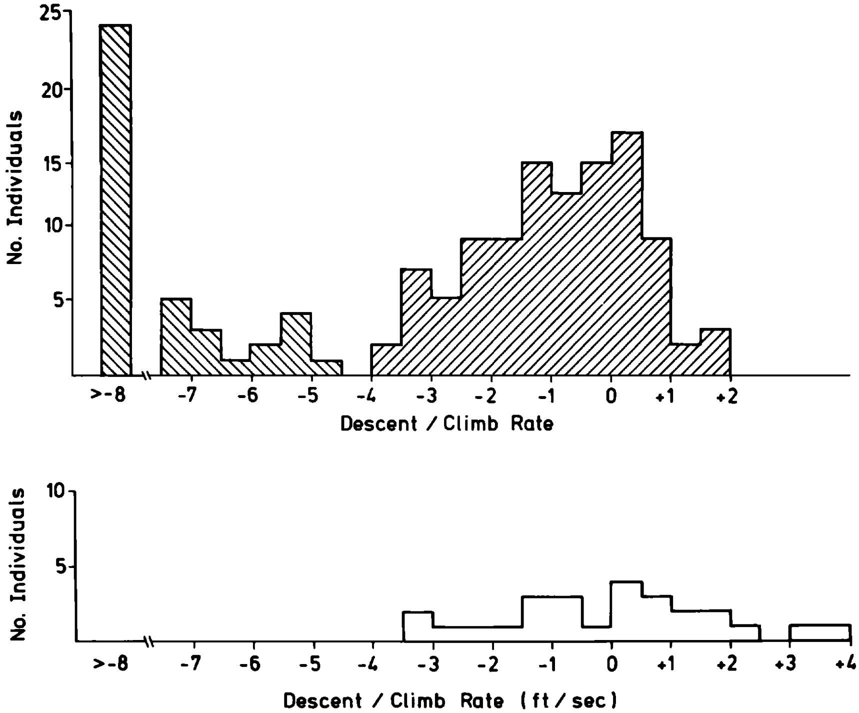

FIGURE 5. (Top) Histogram of altitudinal velocity (descent/climb rates) for all experimentally released birds acquired by radar during our three tracking seasons. (Bottom) Altitudinal velocity histogram for naturally occurring passerine migrants tracked by the FPS-16 radar.

butions differ significantly ($F_{1,126} = 7.3$; $.05 > P > .01$), they overlap almost totally. This, coupled with the natural frequency hiatus at −4 ft/sec, gives us confidence that (a) we can objectively separate migratory from nonmigratory flights, and (b) migratory flights by our criterion are similar to normally occurring migratory flights in terms of levelness of flight.

Of 141 White-throated Sparrows released aloft during 1971 and 1972, 102 maintained altitude and departed on "migratory" tracks while only 39 descended steeply to the ground. Thus over 70 percent "tolerated" the release procedure and departed on apparently normal migratory flights.

2. *Internal Physiological State.* It is well known that during periods of migration, nocturnal fliers lay down heavy deposits of subcutaneous fat and exhibit intense nocturnal activity, or *Zugunruhe* (Wagner, 1930; Palmgren, 1944, 1949; Farner, 1955; Helms, 1963; Dolnik and Blyumenthal, 1964; King and Farner, 1965; King, 1972; Berthold, 1975). In 1972, we housed our sparrows in individual activity recording cages and

all birds released aloft showed intense nocturnal activity on the nights immediately prior to being tested.

Prior to being boxed for release, each sparrow was examined and its level of subcutaneous fat reserve was recorded according to the method of Helms (Helms and Drury, 1960; Helms, Ms). This method sums the visible fat deposits from the abdominal and furcular areas into a 1 to 5 ordinal scale, with a scale of "1" indicating minimal, and "5" indicating massive, fat reserves. Using fat levels as a presumed indicator of internal physiological state, we plotted the percentage of released birds that flew as a function of fat index (Fig. 6). The increase in percentage of birds flying as a function of increased fat stores is apparent. As a second test, the fat indices of the 84 birds initiating flights (for which we have fat data) were compared to those of the 32 birds that came to the ground. The "migrators" were significantly fatter ($F_{1,114} = 4.12$; $.05 > P > .025$).

3. *External Motivational State.* It has been known since the work of Bagg et al. (1950) that the volume of passerine migration is highly dependent

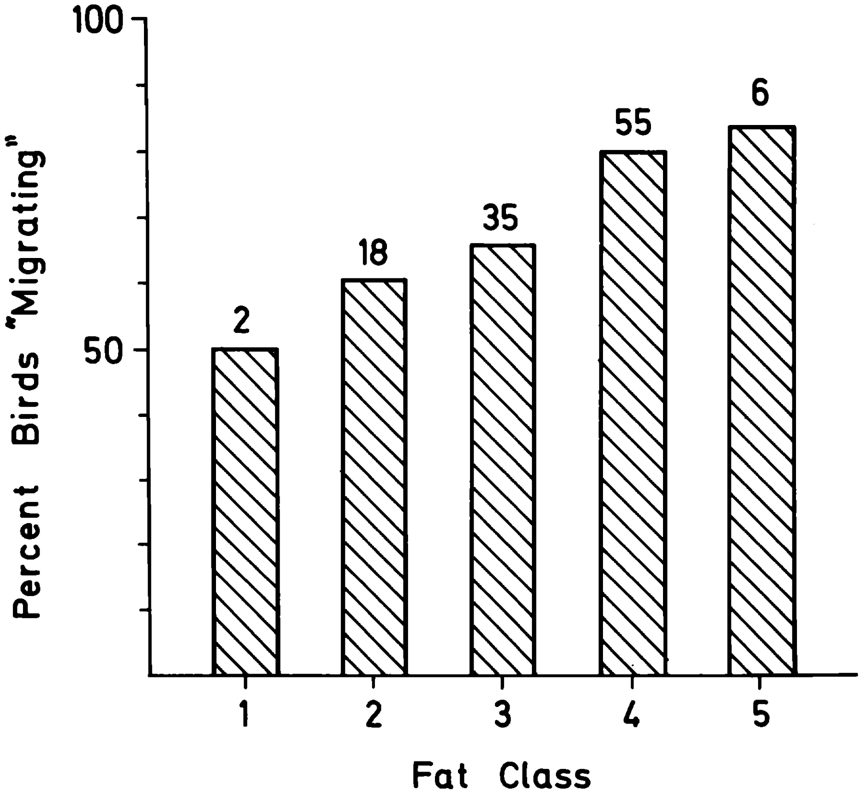

FIGURE 6. Relationship between percentage of experimentally released birds initiating "migratory" flights and fat level (scored on the basis of visible, subcutaneous fat reserves). Numbers above each histogram denote sample size.

upon meteorological conditions. Along the Atlantic coast in spring, the dominant direction of movement is to the northeast, and most such movements take place when a high pressure cell is located to the east and a low pressure cell is to the west (Lowery and Newman, 1955; Nisbet and Drury, 1968; Richardson, 1971; Able, 1973). These are precisely the conditions that produce favorable following winds from the south, southwest, or west.

We investigated the importance of meteorological conditions for our experimentally released birds by analyzing the proportion of birds that initiated a migratory flight as a function of different synoptic weather conditions. The weather patterns were categorized according to the generalized weather map first introduced by Richardson and Haight (1970) and modified by Muller (1976). Such a map represents an idealized picture of the common weather situations that can occur in an area. For each night that we performed experiments, the meteorological "position" of Wallops Island was determined in relation to pressure systems, winds aloft, and fronts, and plotted on the map. All releases conducted in each of the five general categories were then pooled, and the percentage of sparrows released that initiated actual flights calculated. These proportions are plotted in their appropriate meteorological "positions" on the generalized weather map in Figure 7. Weather category II (on the west

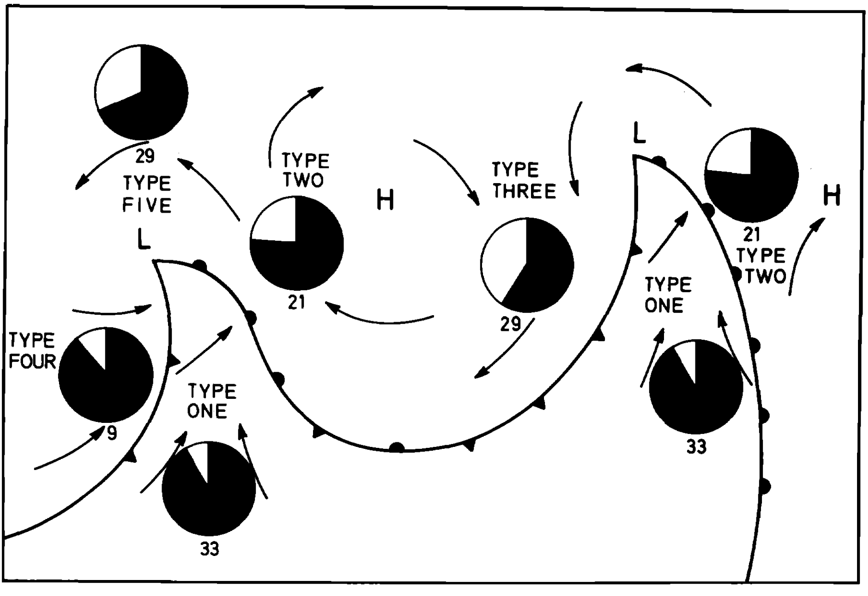

FIGURE 7. Generalized weather map showing percentage of experimentally released birds (shaded portion of each circle) that initiated "migratory" flights under weather conditions characterizing each of the five major synoptic weather categories. Categories I, II and IV are generally stimulatory for spring migration; categories III and V are inhibitory (see text).

side of a high pressure cell, ahead of an advancing warm front), and Type I (on the south of a low pressure cell and behind an advancing warm front) represent the classic conditions for heavy spring migration. The same is true for Category IV which was described by Richardson (1971) as follows: "By the time some lows reach the Maritimes, the associated cold front has swept counterclockwise around the depression such that it extends south or even southeast from the low. The wind behind these cold fronts is from the southwest or west . . . . Behind such fronts northeast migration usually occurred and was sometimes intense." Weather Categories III and V are generally considered inhibitory, and normal migration at these times is low in volume and occasionally reversed in direction. Figure 8 presents a histogram of the percentage of artificially released birds initiating flight under the three "stimulatory" and two "inhibitory" conditions. The experimental birds behaved in accordance with the predictions from surveillance radar studies of unmanipulated passerine migrants. "Migration" was significantly more frequent under "stimulatory" than under "inhibitory" conditions ($\chi^2 = 6.64$; df = 1; $P < .01$).

Analyses using local, rather than general synoptic, weather conditions yielded similar results. Experimentally released birds were more prone

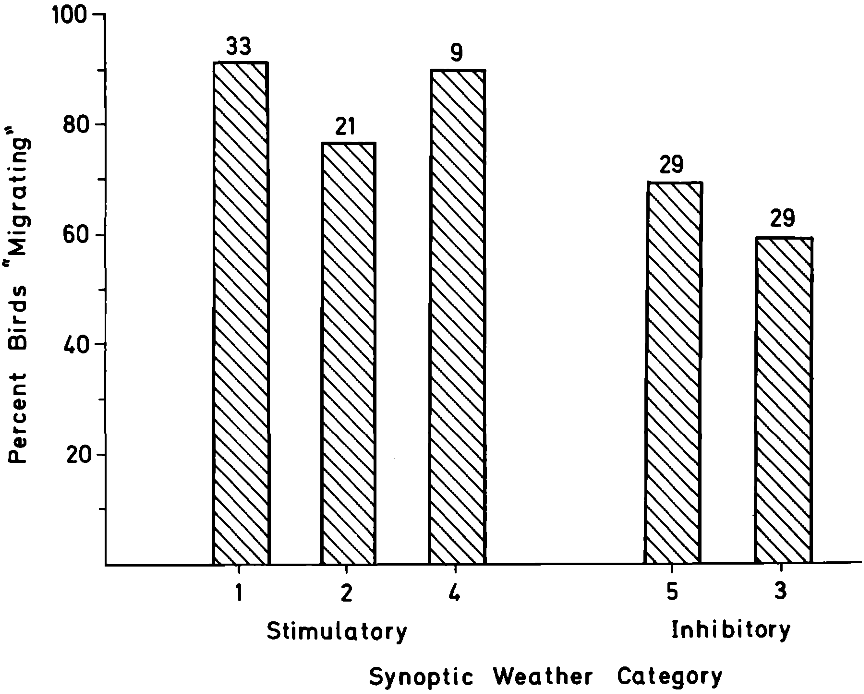

FIGURE 8. Comparison of the tendencies of experimentally released sparrows to initiate flights under stimulatory and inhibitory meteorological conditions (see text).

to fly when released under clear than under solid overcast conditions ($\chi^2 = 5.04$; df = 1; $P < .025$) and were strongly inhibited by rain.

4. *Aerodynamic Flight Strategy.* By using tracking radars, it is often possible to obtain a record of the wing beat pattern of a bird in flight. This is possible because the signal strength of the returning echo from the target (the bird) changes as a function of changes in the shape of the body induced by the changing positions of the wings. Tracking radars possess a circuitry that attempts to maintain a constant echo strength, and the compensatory changes in the AGC (Automatic Gain Control) circuitry provide the ornithologist with a record of wing beat patterns.

Migrating songbirds almost universally show a unique aerodynamic flight pattern, consisting of a regular series of alternations of periods of rapid wing beat separated by short pauses (Houghton, 1964; Schaefer, 1968; Bruderer, 1969; Bruderer and Steidinger, 1972; Bruderer et al., 1972; Emlen, 1974; Vaughn, 1974). Figure 9 shows such a wing beat record taken from one of the artificially released White-throated Sparrows. This regular "flap-pause" pattern is unlike the flight behavior exhibited by most songbirds during their daily activities outside of the migration season. The "flap-pause" pattern appears to represent a specialized aerodynamic strategy for migration, one that has been hypothesized to be adaptive in reducing the energetic cost of long-distance flights (Emlen, 1974). It thus can serve as a "marker" typical of songbirds engaged in actual migratory flights. Of the 102 sparrows artificially released aloft that did not rapidly descend to the ground, *all* exhibited regular alternations of flapping and pausing periods (for a more detailed discussion, see Emlen, 1974).

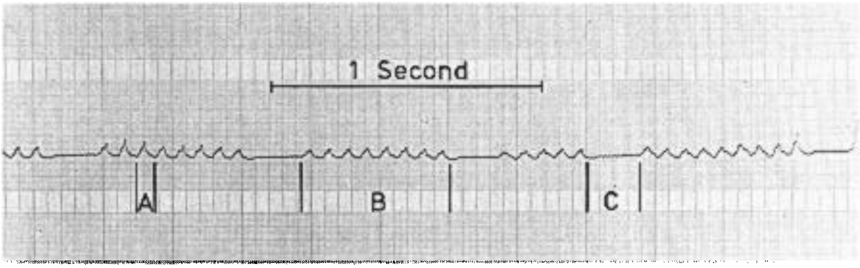

FIGURE 9. Typical "flap-pause" wing beat pattern of an experimentally released White-throated Sparrow. A = one complete wing beat cycle; B = flapping period; C = pause period. Figure shows the AGC signature pattern from the FPS-16 tracking radar.

5. *Orientation of Artificially Released Birds.* The final prediction is that artificially released birds should orient their flights in seasonally appropriate migratory directions. Orientation diagrams from the three spring migratory seasons are shown in Figure 10. Each symbol represents the flight direction of a bird released under clear, night skies when the speed of the winds aloft (at bird altitude) was less than the bird's average

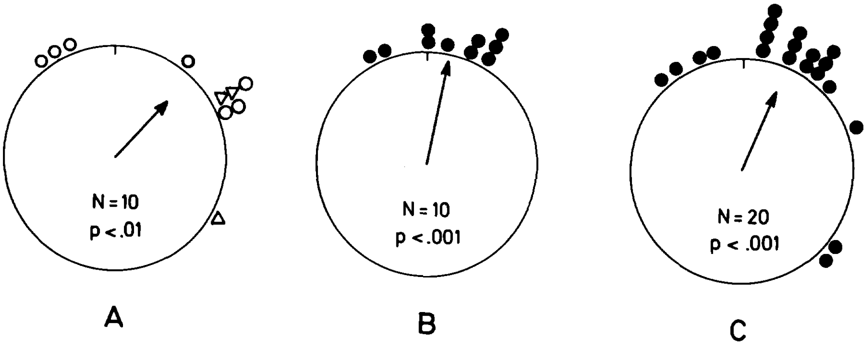

FIGURE 10. Orientation (departure tracks) of birds artificially released during favorable meteorological conditions during three spring migratory seasons. (A) Radio-tracked releases of *Catharus* thrushes from Ithaca, NY. Open circles represent Swainson's Thrushes; open triangles represent Gray-cheeked Thrushes. (B) Track directions (of the final mile of each flight) for White-throated Sparrows artificially released at Wallops Island, VA, during the spring of 1971 and tracked by the SPANDAR radar. (C) Track directions (final mile) of White-throated Sparrows artificially released at Wallops Island, VA, during the spring of 1972 and tracked by the FPS-16 radar. For each diagram, the arrow points to the mean direction of the data distribution and the length of the arrow is a measure of the consistency of orientation (= r, the length of the mean vector). The sample size (N) and the significance of orientation by the Raleigh test (p) are also given.

air speed of 30 ft/sec. (Stiff wind situations, when it would have been impossible for a bird to control its track direction, have thus been eliminated.)

Figure 10A shows the departure behavior of Gray-cheeked and Swainson's thrushes radio-tracked in Ithaca, NY during pilot experiments in the spring of 1970. Each symbol represents the mean (cumulative) track direction of the departing bird, where the average track length is 7–8 miles. Each dot in Figure 10B and C represents the track direction during the last mile of flight of a White-throated Sparrow radar-tracked at Wallops Island, VA during the spring of 1971 or 1972, respectively. In each case there is a significant orientation to the northeast or north-northeast, in agreement with the expected direction of spring migration of thrushes over upstate New York, and sparrows along the coast, respectively.

In summary, in each season the behavior of the artificially released birds is consistent with predictions based upon the behavior of natural songbird migrants. This supports the hypothesis that released birds do show actual migratory motivation and are making meaningful orientational decisions and departing on actual migratory flights. Of anecdotal interest, three of the individual sparrows that were artificially released during our experiments returned and were recaptured the following year in precisely the same overwintering location where they had originally been netted for use in our experiments (S. Gauthreaux, pers. comm.).

DISCUSSION

The importance of this technique lies in allowing one to conduct orientational studies on individual free-flying migrants, and to have the potential of manipulating various aspects of the orientational system. For example, birds can be released under different wind conditions to test the hypothesis of Gauthreaux (Gauthreaux and Able, 1970) that wind direction is an important orientational cue for songbirds. Migrants can be "dropped" below, or even within, a dense cloud, to test the importance of noncelestial and even nonvisual orientational information. By releasing migrants above a low cloud, one can examine the ability to orient, as well as to compensate for wind drift, when all visual input from the ground is lacking. Finally, the sensory systems of the individual migrants can be manipulated prior to release aloft by attaching miniature ceramic magnets to the wings or back or by clock-shifting to alter the bird's sense of time. By comparing the orientation behavior of birds released under differing meteorological conditions and after exposure to different experimental manipulations, finally it becomes possible to begin to separate the different components, and to determine the relative weighting of different cues as they are actually used by a freely migrating songbird. Preliminary results from some of our orientation experiments were presented by Emlen and Demong (1978) and will be discussed more fully in a later publication.

We wish to emphasize that although most of the tracking experiments mentioned were conducted with extremely sophisticated tracking radars made available by NASA, the release technique itself, and its potential value to orientational studies, need not be linked to the availability of such equipment. The release technique has been adopted for use with smaller, portable, tracking radars by Bruderer in Switzerland (pers. comm.) and Able in New York (1978, pers. comm.) and was also used successfully by us when the birds were equipped with miniature radios similar to ones that are commercially available. It also should be feasible to use the technique to release birds at lower altitudes where it would be possible to follow the birds' departures visually. S. Gauthreaux (pers. comm.) has experimented with the use of a chemical light (Cyalume, American Cyanamid Co.) which, when painted directly on both surfaces of the tail feathers, makes a flying songbird visible for a distance of ¼ mile or more at night. When vision is enhanced through the use of a light-gathering or night-vision scope, the tracking distance is greatly increased. It thus seems quite possible that, under appropriate conditions, nocturnal migrants could be released and visually tracked at night for distances sufficient to determine orientation behavior.

The release method itself is simple, inexpensive, and highly reliable. It does not appear to have a long-lasting traumatic effect on the birds, and their behavior seems comparable, in all ways, to that of normally migrating songbirds. At the moment, artificial releases are our only means of bridging the gap between controlled but artificially constrained laboratory studies and descriptive but nonmanipulative field observations. For the first time we have a technique that successfully allows experimental control and manipulation of the directional information available to an actual, free-flying migrant.

SUMMARY

We describe a new technique that makes it possible for a researcher to exercise manipulative control over the orientation systems of free-flying migrant birds. As such, it bridges the gap between descriptive (but uncontrolled) field observations of migration and controlled (but unnatural) laboratory investigations of orientation. The technique involves sending a migrant aloft in an especially designed release box, suspended beneath a helium-filled weather balloon. At a predetermined altitude, the box opens and the bird is released, free to continue its migratory journey. The migrant can be followed by visual observation, by radio-tagging, or by radar tracking.

Potential orientation cues can be controlled either (1) by choosing to release birds under different meteorological conditions (when high overcast obscures celestial information; when low fog blocks visual landmarks on the ground; when winds are from inappropriate directions for migration, etc.), or (2) by subjecting birds to various experimental manipulations prior to release (phase-shifting the bird's time sense; attaching miniature body magnets, etc.).

The flight behavior of artificially released birds was compared to, and found consistent with, the known behavior of naturally occurring passerine migrants. Specifically: (1) more than 70 percent of all birds released maintained altitude and initiated long flights; (2) the tendency to migrate correlated with internal motivational state, with fatter birds being more prone to initiate flights; (3) the proportion of birds initiating flights was greatest when released under stimulatory synoptic weather conditions; (4) all birds that initiated migratory flights exhibited the "flap-pause" wing beat pattern typical of nocturnally migrating songbirds; and (5) the departure bearings selected by the artificially released birds were consistent with expected migratory directions in each of three spring migration seasons.

We present initial results gathered from radio-tracking of Swainson's and Gray-cheeked thrushes in Ithaca, NY, and from radar tracking of White-throated Sparrows at Wallops Island, VA.

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