TECHNIQUES AND METHODOLOGY USED TO STUDY RAPTOR MIGRATION

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ABSTRACT

The techniques used to study raptor migration are: direct visual observation, aerial observation, capture and marking, radar and radio-tracking. Each yields a different type of data. Much has been learned from use of these techniques, although inherent advantages and disadvantages make some more suitable than others for answering particular questions. For future raptor migration research, it is important to pose specific questions prior to collection of data. The lack of a rigorous approach is evident from the tremendous amount of field work that has resulted in a paucity of generalized results.

INTRODUCTION

Although raptor migration was described by Frederick II as early as the Middle Ages, it is only within the last 40 years that research has resulted in quantitative data. Studies of raptor migration have included a variety of field techniques, including ground counts, aerial observations using aircraft, capture and marking, tracking using radio transmitters attached to the raptor, and radar tracking.

Direct visual counts have dominated the published results on raptor migration, and only recently have results from other methods broadened our knowledge. These new results have sometimes confirmed and sometimes contradicted theories based on direct observation.

This paper reviews the methods, data collected, and information resulting from each technique, together with its limitations. A plea is made to initiate new studies that integrate the various research techniques, and some questions are posed for further work.

METHODS

Raptor migration research studies were categorized according to methodology:

Ground observations. Researchers counted raptors passing a fixed point. Included are studies when the counting location moved in response to the movement of the line of migrants with differing winds or time of day.

Aerial observations. Observers studied migrant raptors from an aircraft. Usually the aircraft moved with the birds over a portion of their route.

Capture and marking. Raptors were captured and ringed (banded), sometimes marked. Includes data from raptors ringed in the nest and recovered after migrating, and raptors ringed on migration and reported from wintering or breeding grounds.

Radar. Researchers used a stationary or mobile radar device to follow the movement of migrating raptors.

Radio-tracking. Researchers followed migrants whose locations were revealed by radio signals from a small transmitter attached to the bird.

For each study method, information resulting, advantages, equipment required, and need for special personnel were noted.

RESULTS

Ground observation studies

Most consist of a brief description of local area and a tabular account of raptors counted from the observation point. Many include a short statement on the seasonal timing by species, occasionally by different age groups. Some accounts correlate flights with weather (Alerstram 1978; Haugh 1975); others deal with theoretical aspects of migration (Murray 1964; Mueller & Berger 1967a; Alerstram 1978), with wet season/dry season movements (Thiollay 1978), with the use of special optical equipment (Smith 1980), or with aspects of migration biology, such as fasting (Skutch 1945, 1971; Smith 1980). Another study has used long-term count data to reveal population trends (Nagy 1977). In America, the proliferation of hawk counting has resulted in the formation of an organization to co-ordinate field studies.

Aerial observation studies

Little has been published on the use of aircraft to study raptor migration. Stearns (1948, 1949) used a dirigible (blimp) and Pennycuick (1975) indicated how a motor-glider could be used. The New England Hawk Watch (Hopkins *et al.* 1979) also used a motor-glider as part of their study, while Smith (this volume) observed raptor migration in various weather conditions from motor-glider and single-engine aircraft. Aircraft have also been used for radio-tracking (see below).

Capture and marking studies

Most of the studies based on ringed nestlings are of single species (Broley 1947; Henny & Van Velzen 1972; Olsson 1958; Saurola 1981; Ward 1975), mostly from Europe and N. America. The migration capture studies are from N. America, and range from progress reports (Field 1971; Clark 1976; Soucy 1976), to in-depth studies (Mueller & Berger 1961, 1967a; Mueller *et al.* 1977; Rosenfield & Evans 1980) and include those incorporating results from different locations (Bildstein *et al.* in press). Some reports are of unusual occurrences beyond their normal range (Clark 1973, 1974); others deal with colour-marking techniques or results (Dunne & Clark 1981; Hamerstrom 1975; Ward 1975).

Radar studies

Two papers report results using fixed location radar (Evans & Lathbury 1973; Richardson 1975). Some new works using a portable radar have been reported recently (Kerlinger 1980; Gauthreaux, in press).

Radio-tracking studies

The few reports are either in difficult-to-locate sources, exist only as unpublished progress reports (Cochran 1972, 1975; McClelland 1982), or are very recent (Holthuijzen *et al.*, and Hunt, both this volume).

DISCUSSION

Ground observation studies

Although great effort has been expended on ground observations, little has been learned. The question most often posed is: 'How many individuals of a species can be counted at a specific location during a migration season?' Some studies have been very successful in answering this question, but have not helped much to answer broader questions about raptor migration.

Although Nagy (1977) used long-term count data to assess population trends, caution is needed to interpret count data. Correlations of counts with weather variables have used only the *visible* migration (Haugh 1975; Alerstram 1978). Smith (1980) and others point out that the visible birds may be only a fraction of the total number migrating overhead. Hussel (1981), however, used counts of migrant songbirds with weather variables to estimate population parameters, so that data from various count areas can be compared and analysed statistically.

The Hawk Migration Association of North America has standardized some data collection procedures (Fuller & Robbins 1979; Roberts & Fuller, this volume).

In an innovative use of ground observation, the New England Hawk Watch (Anon. 1982) stationed raptor counters at various locations throughout southern New England for two days during the peak of the Broad-winged Hawk migration. The results, while still in report form, give a better understanding of how this long-distance migrant moves through that region.

Other studies have concentrated on some aspect of migration, such as water-crossing behaviour (Kerlinger, in press), or variations in the local counts as the number of observers and their position is varied (Kochenberger & Dunne, in press).

In some localities where ground observation counts were made, the raptor tally spot was moved in response to the movement of the bird's flight line (Christensen *et al.* 1982; Dovrat 1981; Thiollay 1980). An advantage of using this technique is that a few observers using only binoculars can identify and count migrating raptors (*Table 1*). Usually volunteers are available, especially if the number and variety of raptors to be counted is large.

Aerial observation studies

Aircraft use has allowed researchers to fly with migrating raptors and determine flight direction, altitude and speed, as well as sink rate during glides (Hopkins *et al.* 1979; Stearnes 1949). Smith (this volume) used a motor-glider to investigate the use of 'cloud streets' by migrants.

One limitation of motor-gliders is that their stall speed is much greater than that

Table 1: Methods used to study raptor migration.

Method of study	Information resulting	Frequency of use	Equipment required	Advantages	Disadvantages	Published
Ground observation	Counts, species, flight direction	Widespread, increasing	Optical	Inexpensive, mobile, volunteers	Human error, weather variable local	Much, mostly count totals
Aerial observation	Mode of flight, sink rate, species	Infrequent	Aircraft, glider or blimp	Mobile, species-selective	Expensive	Little
Capture, ringing, marking	Origin, path and destination, mortality, individual details	Some, N. America and USSR	Capture and measuring equipment	Volunteers, long term data	Immobile, species selective, recovery bias, trained personnel	Some
Radar	Actual flight path, altitude, speed	Infrequent	Radar	Broad view, recorded, some mobile	Expensive, immobile, highly trained personnel	Little
Radio-tracking	Actual flight path, behaviour, flight speed	Infrequent	Transmitters, receiver antennae	Detailed information on individual migrants	Expensive, small sample size, trained personnel	Little

of the raptors, hence it is difficult to stay with a specific raptor or group. The cost of using aircraft is high and a highly-trained and licensed pilot is required (*Table 1*).

Capture and marking studies

The ringing (banding) of raptors on migration is being conducted largely in N. America, but ringing of raptors as nestlings is more widespread. Bub (1968) described the capture techniques used by Mueller and Berger at their pioneer migration ringing station at Cedar Grove, Wisconsin. USA. The many ringing stations operating now in N. America are all similar and consist of some combination of mist-nets and bow-nets, using live lures to attract the raptors into them (Clark 1970; Field 1971; Soucy 1976). Such work is labour-intensive, but volunteer help is readily available for capture, measurement and data analyses.

Data obtained consist of standard ornithological measurements, age, sex, feather moult, subcutaneous fat, eye colour and wing area measurement (*Table 1*). Analyses of data have provided information about relative timing of migration for a species' different age and sex classes (Rosenfield & Evans 1980; Bildstein *et al.*, in press).

After sufficient ring recoveries of a species have been accumulated, one can map the breeding range, migration path and winter range (Clark, in press). Causes of mortality can also be tabulated, but interpretation must be cautious because reported returns are biased toward man-caused deaths (Evans & Rosenfield, this volume; Mueller & Berger 1976b; Saurola 1981).

Radar studies

Most radars have the advantage that they can cover a large cross-sectional area (about 50km, Richardson 1975); hence they monitor a fairly wide swathe of raptor migration at all altitudes. A disadvantage is that one cannot distinguish raptors from other birds, or identify species (*Table 1*). Most radars lend themselves to easy recording of displays for subsequent playback and analysis. The equipment is expensive and requires highly-trained operators and maintenance personnel. Portable (hand-held) radars are available, but frequently break down (Kerlinger, pers. comm.).

Most radar equipment used had been installed for other purposes but was made available to migration researchers. However, Gauthreaux (in press) has assembled a mobile radar.

Radar seems likely to answer many questions about raptor migration. For example, Evans & Lathbury (1973) compared radar with visual counts at Gibraltar to estimate the fraction of the flight counted visually under different wind conditions. More recently, Kerlinger (1983) used a mobile radar to show that migrating hawks at Cape May Point, New Jersey, flew lower on westerly than on other winds. These results were discussed in the context of counting biases.

Radio-tracking studies

Although this technique is used widely on a variety of animals to study behaviour and migration, little has been published about its application to raptor migration. Radio-tracking is labour-intensive, with much time needed to track each individual migrant. This requires trained personnel and high travel costs, sometimes including aircraft rental. The next logical step with radio-tracking is to follow migrant raptors using receivers in satellites (Craighead & Dunstan 1976).

Modern equipment is generally lightweight, reliable and inexpensive compared to other costs (*Table 1*).

Radio-tracking data include migration direction and speed, and behaviour, including habitat use and feeding ecology (Cochran 1972, 1975; Holthuijzen *et al.*, this volume).

MULTIPLE TECHNIQUES STUDIES

Some recent efforts have used more than one method to obtain new types of data or to better evaluate data already collected. Marking has been used with ground observation to better understand local raptor movements, particularly to find whether or not some birds were passing a count station more than once (Dunne & Clark 1981). Dunne & Clark (1977) compared counts by observers in ringing blinds (hides) to counts by a ground observer with a clear view of the surrounding area.

S. Benz (pers. comm.) estimated the distance travelled by migrating raptors along a continuous mountain ridge in eastern N. America by observing raptors at Hawk Mountain, Pennsylvania, which had been colour-marked at ringing stations up-flight from the count site. The New England Hawk Watch has used observations from a motor-glider to determine how far ground observers are able to detect and identify flying raptors (Welch 1980).

Kerlinger & Gauthreaux (pers. comm.) used a visual backup to their height-finding radar for species determination. They used a video camera with light intensifier and telephoto lens at night, and regular optics during the day.

FUTURE RESEARCH

To obtain better results from the use of these techniques, we should first pose specific questions that will lead to a better understanding of raptor migration. Research programmes can then be designed using the techniques available.

Some possible topics for future study include work on whether migrants fast and, if so, under what circumstances. Capture and inspection, including weighing, at various locations, and radio-tracking along the migration, can all provide relevant data. The nature of raptor migration away from known concentration areas is largely unknown. Radar may provide insight and direct observers to previously unknown areas. The causes and extent of mortality on migration could be studied by use of radio-tracking.

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