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Large-scale studies of marked birds in North America

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The first large-scale, co-operative, studies of marked birds in North America were attempted in the 1950s. Operation Recovery, which linked numerous ringing stations along the east coast in a study of autumn migration of passerines, and the Preseason Duck Ringing Programme in prairie states and provinces, conclusively demonstrated the feasibility of large-scale projects. The subsequent development of powerful analytical models and computing capabilities expanded the quantitative potential for further large-scale projects. Monitoring Avian Productivity and Survivorship, and Adaptive Harvest Management are current examples of truly large-scale programmes. Their exemplary success and the availability of versatile analytical tools are driving changes in the North American bird ringing programme. Both the US and Canadian ringing offices are modifying operations to collect more and better data to facilitate large-scale studies and promote a more project-oriented ringing programme. New large-scale programmes such as the Cornell Nest Box Network are on the horizon.

Geography and the distribution of human and avian populations provide the context for large-scale studies of marked birds in North America. The combined area of Canada and the USA covers more than 19 000 000 km^2, approximately 60 times the combined area of the UK and Ireland. Human populations, and hence ringers, tend to be concentrated in the eastern third of the continent along the coast and around the Great Lakes, and along the west coast. Bird populations on the other hand, cover all areas of the continent. During the early years of the North American bird ringing programme, the daunting challenges of geography and human population distributions limited the scale of studies of marked birds. Small, local, independent studies were the norm. The challenges of geography and population distributions were gradually overcome by several factors. The two countries' mutual interest in the conservation of shared populations of migratory birds was formalized with the signing by the USA and Canada of the 1916 Convention for the Protection of Migratory Birds. A uniform, jointly administered ringing programme commenced shortly thereafter, with the establishment of the US Bird Banding Laboratory (BBL) and the Canadian Bird Banding Office (BBO). Shared goals, a common language, similar cultures and an open border fostered long-lasting co-operation between the two countries. Advances in transportation and communication systems shrank distances, at

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least figuratively, and further enhanced possibilities for large-scale studies.

EARLY LARGE-SCALE STUDIES

Operation Recovery

The first co-operative ringing projects covering sizeable portions of the continent were attempted in the 1950s. Operation Recovery began in 1955 with the establishment of numerous ringing stations along the Atlantic coast from Nova Scotia to North Carolina.[1] The choice of location resulted from the relatively high density of ringers in the east and the prevalence of northwest winds that concentrate migrating birds along the coast. The objective of Operation Recovery was to learn about species composition, and magnitude and speed of migratory movements of passerines, particularly as related to weather. Operation Recovery continued informally for many years. Hundreds of thousands of migrating passerines were ringed. Few were recovered and there were no definitive analyses of the results. The value of Operation Recovery was that it demonstrated that large-scale, co-operative ringing projects were feasible in North America.

Preseason duck ringing

The pre-hunting season duck ringing programme, also initiated in the 1950s, was more successful in terms of applied results. Supported by state, provincial and federal governments, professional ringing crews were assigned annual quotas of ducks. Special emphasis was placed on the continent's principal duck breeding area, the prairie-pothole areas of North Dakota, South Dakota, Montana, Alberta, Saskatchewan and Manitoba. Ringing data complemented data from aerial surveys of breeding populations in the same area and data from surveys of the composition and size of duck harvests over a wider area.[2] The integration of data from these three sources has been the mainstay in managing (regulating) duck hunting in North America for more than 40 years.

Estimates of duck survival rates, ring recovery rates and harvest rates derived from the early (pre-1970) years of the preseason ringing programme may seem rudimentary but they served the needs of researchers at that time. Perhaps more important, the early success of the preseason duck ringing programme also demonstrated the feasibility of long-term, co-operative, large-scale ringing projects. It set in place a solid operational framework to support the more refined ringing projects that became possible following the revolution in statistical methods during the late 1960s and early 1970s.[3]

EXPANDING THE SCALE OF STUDIES THROUGH STATISTICS

In the 1970s, the use of ringing data to estimate survival and harvest rates expanded rapidly, concurrent with the development of analytical procedures. Anderson and Henny investigated the distribution and migration patterns of Mallard *Anas platyrhynchos* and developed ringing reference areas by examining patterns of recoveries in relation to ringing locations.[4] The goal in determining reference areas was to group birds having similar movement patterns.

In 1975, Anderson published an analysis of temporal and geographical variation in Mallard recovery, survival and harvest rates.[5] This was the first extensive use of ringing and recovery data utilizing the new ring recovery models of Brownie & Robson and Brownie *et al.*, who developed two groups of models, those for birds ringed as adults and those for birds ringed as young and adults.[6,7] The development of the computer programmes ESTIMATE and BROWNIE made utilization of these models easy, and the analysis of ringing data advanced greatly. With these new tools to estimate population parameters useful to management, the existing North American waterfowl ringing programme was expanded. The expansion continued in the 1980s and 1990s with the development of such tools as BAND2, a software package that considers power for ring recovery analyses.[8]

The development of sophisticated software, such as the programme SURVIV, raised the use of ringing data to new levels.[9] More complex modelling efforts looking at underlying biological processes such as the role of hunting were undertaken, e.g. the ultrastructural model of Burnham *et al.*, to investigate whether harvest was additive or compensatory to other sources of mortality.[10] Closed and open population models (Jolly–Seber models) were developed and software packages were written (for closed populations, CAPTURE; for open populations, JOLLY and JOLLYAGE, RELEASE, SURGE, POPAN and MARK).[11–16] These hold great promise for future utilization of ringing, recovery and observational data.

These models and programs, along with the advances in computing technology, have become a major factor driving the expansion of large-scale studies of marked birds in North America. The availability of bigger, more powerful tools for processing and analysing large data sets has enlarged the scale of thinking about bird studies. As a result, researchers and managers are refining and expanding existing large-scale projects and designing new ones. Public concern for declining populations and the need for demographic data have added impetus to this development.

CURRENT EXAMPLES OF LARGE-SCALE STUDIES

Monitoring Avian Productivity and Survivorship (MAPS)

MAPS is a volunteer-based monitoring programme that uses standardized, constant effort ringing to obtain data on productivity and survivorship of breeding land bird populations.[17–19] MAPS was established by the Institute for Bird Populations in 1989 and was based on the design of the British Constant Effort Sites (CES) Scheme. The number of stations participating in MAPS has increased remarkably from 17 in 1989 to 454 in 1997.

Aside from providing much needed demographic data, MAPS is significant in that it was deliberately designed to be a large-scale, continent-wide programme. It was designed through a rigorous peer review process that addressed both statistical and practical considerations. Estimable parameters were identified, spatial scales were defined, target species were identified, analytical models were selected and sample sizes were estimated. The practical considerations of recruiting ringers and managing large data sets were also addressed.

Analytical models were key considerations in the design of MAPS. Productivity indices (proportion of young in the catch) have been calculated using methods developed for CES.[20] Additional analyses of spatial and temporal variation in productivity indices have been modelled using logistic regression techniques.[21] Survivorship has been estimated using the familiar Cormack–Jolly–Seber models, along with a more recent refinement, that accounts for the effect of 'transient' birds captured at MAPS sites.[9,22]

After seven years of trial operation, MAPS has recently undergone a rigorous statistical evaluation and an extensive general evaluation of operations and results. Some results from these evaluations are included in this volume.[23,24] Additionally, their evaluations were reviewed by the US Department of the Interior which provided funding and other support for MAPS. General conclusions are as follows: MAPS is technically sound; its unique demographic data complement population trend data from other programmes such as the North American Breeding Bird Survey[25]; it provides a large-scale spatial framework for posing questions related to genetic, morphological or phenological characteristics of landbird populations; it provides useful ancillary data and excellent educational opportunities; its support and participation has substantially exceeded expectations.

MAPS is being refined based on review recommendations. More clustering of sites will improve the sampling strategy and help cope with sparse data at small spatial scales. A reduction of sampling periods should reduce the number of transients captured. Given adequate future support, MAPS should become one of the mainstays of avian monitoring programmes in North America.

Adaptive Harvest Management (AHM)

AHM, a specialized case of adaptive resource management, is a structured process by which managers gain knowledge about biological processes of waterfowl harvests from the regulation-setting process itself.[26] Despite the large volume of information available on hunter activity, duck harvest levels and population status, the annual process of setting duck-hunting regulations has been characterized by a lack of consensus among managers on an appropriate harvest strategy. AHM addresses this as a dynamic optimization problem, the problem being to recommend a regulatory package given knowledge of the following criteria: the current population and environmental status; a set of competing population dynamics models; one's relative faith in each model; and the objective of maximizing the harvest and maintaining the Mallard population at or above the North American Waterfowl Management Plan goal of 8.1 million birds. The problem is solved using discrete stochastic dynamic programming using the program SDP.[27] The predictions of the competing models are checked against estimates from subsequent monitoring efforts and the model weights are adjusted accordingly in an annual iterative process. Model probabilities are updated using Bayes' theorem. A restrictive, moderate or liberal set of hunting regulations is selected, depending on the outcome of the models. In 1995, the US Fish and Wildlife Service took the initial steps toward using AHM to guide the regulation setting process for ducks in the USA and, in 1996, a full-blown AHM process was adopted for Mallards.

Although AHM is not a ringing study *per se*, ringing data play an important role. The AHM models incorporate competing hypotheses about the processes determining Mallard population dynamics, especially survival and harvest rates, that are best estimated from ringing data. Recruitment processes are also modelled. The major uncertainty of the effect of exploitation on survival is addressed in two opposing models.[28,29] In the additive model, hunting mortality is completely additive to other sources of mortality, and the sex-specific survival of adults and young during the hunting season declines linearly with increases in harvest rate. In the compensatory model, hunting mortality is completely compensatory to other sources of mortality up to the threshold of the annual rate of non-hunting mortality. Annual survival is constant for kill rates below the threshold but, beyond the threshold, survival declines linearly with increases in harvest rate.[30] Natural mortality during the hunting season is assumed to be negligible in both models.

Two models of recruitment, a weakly density-dependent and a strongly density-dependent model, are used in conjunction with the survival models. Annual autumn age ratios (young females per adult female) are estimated from the age ratio of the harvest corrected for relative harvest vulnerability (the ratio of young per adult of the direct recovery rates from the preseason ringed sample). The age ratio is modelled as a linear function of Mallard population size and habitat conditions determined from the annual Breeding Waterfowl Survey.[2] Thus, the combination of the two survival and two recruitment models results in four alternative models of Mallard population dynamics.

Within the AHM models, survival is modelled as the product of survival from hunting and survival from natural mortality factors outside the hunting season for adult and young cohorts separately.[29] Survival out of the hunting season is estimated for the Canadian prairie-pothole banding reference areas using the ultrastructural model of Burnham *et al.*, $S = S_0(1 - \beta K)$, where S_0 is the survival in the absence of hunting, β is a slope parameter measuring the degree of compensation and K (hunting mortality) is kill.[4,10] This model is fitted to recoveries of normal preseason ringed Mallards using SURVIV.[9] Kill is estimated as $K = f/(1 - c)\lambda$ where f is the direct band recovery rate, c is the crippling loss ($c = 0.2$) and λ is the band reporting rate ($\lambda = 0.32$).[28,31] Estimates of annual survival from natural causes were 0.81 (± 0.02 se) for males and 0.64 (± 0.01 se) for females.[30] These survival rates were partitioned into winter and summer components using information from recent research and the literature: for males, $S_{summer} = 0.90$; for females $S_{summer} = 0.71$; for both sexes $S_{winter} = 0.90$.[32–34]

The efficiency of the survival models, and thus the success of AHM, is obviously dependent on ringing data. In recent years, Mallard ringing efforts have been expanded significantly to increase the amount of data, especially outside the prairie-pothole region which was the original focus of the preseason duck ringing programme. Up to 125 000 Mallards are ringed annually across their range in the USA and Canada, making AHM a truly large-scale endeavour.

AHM is gradually becoming recognized as a superior scientific approach to establishing waterfowl hunting regulations. Assuming eventual full acceptance by waterfowl technicians and senior agency officials, AHM will probably become the foundation of the next generation of the US Environmental Impact Statement governing the hunting of migratory gamebirds. Expanding the preseason waterfowl ringing programme and full development of the toll-free telephone number for reporting rings will contribute directly to the refinement of AHM.

FACILITATING LARGE-SCALE STUDIES

BBL and BBO recognize the need for sound, scientific ringing data, both in terms of quality and quantity. Both offices are actively adapting operations to facilitate large-scale studies and make the ringing programme more effective. As with developments in Europe, conservation-oriented research and electronic data management are being promoted.[35] These developments are being accelerated by a recent external review of the operations of BBL and the broader North American ringing programme.[36] The review made specific recommendations regarding the collection, management and dissemination of ringing data.

Improving the quality of data

The collection of data will be evaluated with a view towards facilitating the increased use of contemporary analytical methods and the improvement of the quality of data collected from large-scale studies. For example, hundreds of ringers collect thousands of recapture, resighting and radiolocation data for their specific studies. Approximately 56% of ringers use auxiliary markers (e.g. neck collars, radio-transmitters) in addition to numbered leg rings. A whole suite of tools is available to analyse these data, including versatile models that can use recovery and recapture data together.[37,38] At present these data are not reported to BBL, and so are not available for general use in meta-analyses. Exactly which and how much recapture data should be collected and stored centrally is still being debated. We expect that at least some recapture records will be incorporated into our already massive database.

Specific data fields within records will also be evaluated. Arcane fields only of use to the ringing offices will probably be eliminated from the records that a data analyst would receive. The accuracy of ringing location data will also be refined. Currently, locations are stored in degrees and minutes of latitude and longitude truncated to the 10-minute block (e.g. 43°16'N, 101°59'W is stored as 431-1015). Historically, such gross locations were deemed sufficient for waterfowl management when computer disk space was a limiting factor in large-scale data management. Today, disk space is not limiting and GPS technology yields accurate locations that will allow use of ringing data in GIS applications.

In the last 10 years, ringing projects across North America have increased in number and in scope, and it has become evident that there is need to improve and standardize ringing techniques. In 1996, the North American Banding Council (NABC) was formed to address this need. NABC consists of appointed members from the major ornithological and ringing organizations in North America. They represent the various groups of bird species being ringed in North America such as passerines and near passerines, shorebirds, seabirds, waterfowl and raptors. NABC's main objectives are to prepare and disseminate standardized training and study materials, and to establish standards of competence and ethics through a certification process at three levels: assistant, permittee and trainer. A North American Bander's Study Guide and a North American Syllabus for Trainers will be published in 1999, including some specialized materials for ringing passerines and near passerines, raptors and hummingbirds. It is expected that 1999 will see its first group of NABC certified ringers in North America. This certification will not be mandatory, but will be recognized by BBL and BBO as evidence of demonstrated competence in applications for ringing permits. The ringer training and certification programme will improve the quality of ringing data, increase the number of ringers participating in large-scale, co-operative studies, and enhance animal welfare.

Increasing the quantity of data

More data generally yield more precise estimates of parameters, allowing better inferences about populations, management actions and other matters of interest. BBL and BBO are making significant changes to the ways data are collected, stored and disseminated to users. For example, the waterfowl ringing and recovery database is now accessible on CD-ROM.

Ringers are being encouraged to submit data electronically and at present 35% of ringing data are submitted on computer disk. Improved software and network links will be developed to accomplish the goal of receiving all ringing data electronically within a few years.

BBL and BBO have established a toll-free telephone number for people to report ring recoveries more conveniently. The goal is to increase reporting rates, especially for Mallards, for which only 32% of recovered rings are reported.[31] A functional postal address and the toll-free telephone number are now stamped on larger-sized rings. Early results indicate that the toll-free telephone number prompts significantly more ring reports from the public and yields better data because specific and more complete information can be obtained by the operator. Record numbers of recoveries are being reported, with approximately 70% coming in via the telephone. Use of toll-free rings was expanded in 1997 and 1998 with the aim of stabilizing the Mallard ring reporting rate at some new, higher level that will be re-estimated in a few years.

Promoting partnerships

Co-operation and partnership among government agencies, academic research programmes and individuals or groups interested in bird population conservation and monitoring, are essential to ensure long-term success of large-scale studies of marked birds in North America. Long-standing partnerships among BBL, BBO and state and provincial governments, effected through the Waterfowl Flyway Councils, have contributed greatly to the success of the preseason duck ringing programme and in turn, to the success of AHM. Partnerships with the Institute for Bird Populations, with Bird Studies Canada, with the National Fish and Wildlife Foundation, and the NABC have fostered the MAPS programme and the development of a ringer training and certification programme. Concern from the general public for bird populations and willingness to support ringing and other science-based approaches to bird conservation represent an informal, but none the less important, partnership. BBL and BBO will continue to promote these partnerships to increase the effectiveness of the North American bird ringing programme.

International co-operation

Because the conservation of migratory birds requires the protection of species and their habitats on the breeding grounds, migration routes and wintering grounds, international co-operation throughout the entire western hemisphere must be expanded. The Western Hemisphere Shorebird Reserve Network (WHSRN) is a good example of a successful international co-operation. In the western hemisphere, many species of shorebirds migrate from breeding grounds in the Canadian Arctic to the most southerly parts of South America where they winter. WHSRN was established in 1985 with the rationale that many shorebird species depend on a series of specific sites to complete their annual migration, and for their conservation to be successful, the entire network at sites needs to be preserved. Data collected through ground and aerial surveys have provided important information on shorebird distributions and numbers on an international basis. Ringing, especially colour marking, has provided conclusive information linking species and populations to specific sites. WHSRN now includes 34 reserves in seven countries from Alaska to Tierra Del Fuego, protecting an estimated 10 million hectares and 30 million shorebirds.

Expanded international co-operation would encourage the ringing and stewardship of all migrating bird species in the western hemisphere and increase recoveries on their wintering or breeding grounds of birds ringed in North America. It is therefore envisaged that BBL and BBO will co-operate with other western hemisphere countries to collectively implement co-ordinated and integrated ringing standards and protocols.

FUTURE LARGE-SCALE STUDIES

The availability of versatile, powerful analytical methods, the exemplary successes of MAPS, AHM and WHSRN, and the power of partnerships encourage the further development of large-scale studies. A new large-scale study, the Cornell Nest Box Network (CNBN) is being developed by the Cornell Laboratory of Ornithology, with funding from the National Science Foundation and co-operation with BBL. CNBN will enlist volunteers to monitor three species of bluebird *Sialia* sp. and Tree Swallows *Tachycineta bicolor* that occur across the continent and take readily to nest boxes. Standardized data on productivity and survivorship will be collected by the volunteers and analysed and reported by Cornell. It is expected that the numbers of bluebirds and Tree Swallows ringed in North America will increase greatly from the approximately 50 000 ringed each year at present. The geographical breadth of the project and the planned intensity of ringing will provide a good framework for the study of dispersal, about which little is known.[39,40] CNBN operated in New York and adjacent states in 1997. It will be expanded to include parts of the western USA, and eventually to cover most of the USA and Canada.

The networking of autumn migration ringing stations across southern Canada is in the early stages of development. The objective is to monitor population trends of species not well covered by other survey methods. Analytical methods and criteria for joining the network are being developed by Bird Studies Canada and BBO. The potential exists for additional, co-operative large-scale studies, especially studies of particular species or groups of birds such as hummingbirds. Given the excellent operational and analytical models available today, and widespread public support for bird conservation, all that is needed are resourceful bodies to step forward and lead the developments.

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