



## The value of ringing for bird conservation

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Ringling has been an important research tool for the conservation biologist over the last 100 years. Effective conservation of wild bird populations requires understanding of bird ecology and of the factors driving population change, and evidence that proposed conservation measures can be effective. Bird-ringing studies can provide a wide range of data types to aid and inform this process, and in many cases these data are not available without the capture and marking of individual birds. We review the range of information available from bird ringing, and illustrate this with case studies where ringing has made a key contribution to the knowledge and subsequent conservation action applied to a particular bird population. The value to bird conservation is typically higher where a ringing study is well designed and targeted to answer specific questions of relevance to conservation. Therefore, there is potential for the conservation value of ringing to be improved in future through the development and encouragement of structured and targeted ringing projects, the integration of different data types collected from ringing, and increased collaboration between groups of ornithologists, including ringers and non-ringers.

During the last 100 years, ringing has been an important research tool in ornithology, but to what extent has it helped bird conservation efforts? For effective conservation action to be identified, it is necessary, first, to understand the environmental factors that have negative impacts on bird populations and, second, that the proposed action is effective in directly countering, or otherwise mitigating, those negative population impacts. For birds, ringing is one tool, or more accurately a whole toolkit, which can help to provide the evidence to identify and test effective conservation measures.

Catching, marking and following individual birds can provide information on movements (at a wide range of scales), survival rates and annual breeding success. Birds in the hand can also provide a range of additional information of potential value to the conservation biologist: data on diet, morphology, body condition, genetic relationships and geographical origins. Catching and marking wild birds with numbered metal rings, but also colour rings, visible tags and radio tags (all included within the definition of 'ringing' studies here), have thus helped identify causes of population decline and have informed conservation management aimed at achieving population recovery.

Categories of information from ringing that are of use to bird conservation can be considered under three headings: geographical, demographic, and biological status. Geographical data (data on the location of birds) can vary in scale from a single territory (eg knowing which habitats within a breeding territory a bird preferentially selects

for foraging) to global (knowing migration routes and stopover sites). Demographic data (data on the population processes of productivity, survival and immigration/emigration) can assist diagnosis of population changes by associating changes or differences in demographic rates with environmental changes or differences. Biological status data can reveal information on environmental conditions experienced by the individual bird, or its ancestors, over a range of timescales, from the very short (eg the diet composition of a bird over the few hours prior to trapping) to the very long (eg what genetic information from biological samples tells us about evolutionary relationships and current taxonomy).

The conservation uses of bird ringing data, particularly the obtaining of demographic information from marked populations, have been discussed thoroughly elsewhere (Baillie *et al* 1999, Green 1999a, b, Peach *et al* 1999a, Baillie 2001). We do not attempt to repeat these summaries but to illustrate the main types of data obtainable from bird ringing that are of direct relevance to bird conservation by case studies where such data have led, demonstrably, to conservation action for the species concerned.

### GEOGRAPHICAL DATA

#### Home ranges

Radio tracking Bitterns *Botaurus stellaris* has helped determine what type and what area of wetland habitats these secretive birds need for foraging in different seasons (Gilbert *et al* 2005). By revealing that Bitterns need wet

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reedbeds with extensive interface between reeds and open water for successful foraging on preferred fish species, this study informed the management of reedbeds that has led to local population increases in the UK (Smith *et al* 2000). Radio tracking also showed the area of habitat each Bittern requires at different times of year (Gilbert *et al* 2005), informing conservation work to expand the area of suitable breeding habitat for Bitterns in the UK away from their stronghold in East Anglia. Habitat creation and improved management has helped increase the UK breeding population and number of breeding sites occupied from a low point of 11 booming males on seven sites in 1997 (RSPB data), to 51 booming males on 33 sites in 2007 (Eaton *et al* 2008).

Similarly, the radio tracking of nocturnal-feeding Stone-curlews has shown that they forage up to 3 km from their nest site, preferring short grasslands as foraging sites (Green *et al* 2000). This has helped determine that the best location for agri-environment measures designed to provide nesting sites for Stone-curlew on arable land is close to areas of short grassland. Arable nesting plots targeted in this way are successful in attracting breeding Stone-curlews and have made a major contribution to the recent UK population increase in this species (Aebischer *et al* 2000, Evans & Green 2007).

In contrast, the foraging 'home ranges' of albatrosses can be enormous. Mortality from long-line fisheries was first recognised as a serious threat, to many of the world's albatross species, from observations on fishing boats of birds being killed on baited hooks (Brothers 1991). However, it was necessary to map the areas where the fisheries and the albatrosses coincide to identify priority areas for remedial conservation action – a huge challenge due to scale. Tracking data for 16 species of albatross, using both satellite and geolocator tags, have highlighted these key areas of concern (Birdlife International 2004). For example, during the breeding season the critically endangered Tristan Albatross *Diomedea dabbenena* has been tracked over 3,000 km from its breeding grounds on Gough Island, Tristan da Cunha (UK), in the South Atlantic. Feeding areas recorded by satellite tracking coincide with areas of high long-line fishing activity, providing evidence that low adult survival rates for this species, estimated from ringing data, are due to mortality from long-line fishing (Cuthbert *et al* 2004). Satellite tagging has also revealed that differences in mortality rates between the sexes of Wandering Albatross *Diomedea exulans* breeding on South Georgia arise because females spend more time than males foraging in areas used by long-liners (Croxall & Prince 1990). By informing conservation efforts on priority areas for action, these data have assisted in reducing the numbers of albatrosses being killed by long-line fisheries each year (Croxall 2008, Albatross Task Force 2009).

### **Movement between seasons in resident species**

Studies on Cirl Buntings *Emberiza cirius* in southern England in the 1980s suggested that population decline and range contraction had been caused by agricultural intensification, removing both winter seed food and summer invertebrate food from their farmland habitats. Colour ringing and resighting showed that individuals rarely moved more than 2 km between their breeding territories and wintering areas (Evans 1997). Therefore, to be effective in assisting population recovery, separate conservation measures to provide winter seed food (weedy stubble fields) and suitable invertebrate prey for chicks in the breeding season (extensively managed grassland or rough grass field margins) had to be located close to each other. Ensuring that these measures were provided in close proximity, through targeted agri-environment scheme payments, has resulted in a fivefold increase in the UK Cirl Bunting breeding population in 15 years (Wotton *et al* 2000, Peach *et al* 2001). Analysis of similar colour-ringing data, and radio-tracking data (Calladine *et al* 2006), from other farmland species in the UK is ongoing and should also help inform the optimum spatial arrangement of agri-environment scheme options for these species (BTO and RSPB unpublished).

### **Dispersal**

Resighting information from wing-tagged individuals has provided valuable information on dispersal, home-range size and survival rates for Red Kites *Milvus milvus* and White-tailed Eagles *Haliaeetus albicilla* in the UK. In both cases, the information has guided reintroduction programmes, on how and where to release birds, and how many to release, to give maximum chance of population viability and future growth (Green *et al* 1996, I.M. Evans *et al* 1999, Evans *et al* 2009).

Colour ringing has also shown that within an agricultural landscape, first-year Tree Sparrows *Passer montanus* preferred to colonise new nesting sites next to invertebrate-rich wetland, rather than those surrounded by intensively managed farmland (Field & Anderson 2004). Analysis of faecal samples from broods in nestboxes showed that these birds fed a wide range of invertebrates, both terrestrial and aquatic in origin, to their chicks, providing further clues about small-scale movements between habitats on foraging trips. These data help explain the breeding season association of Tree Sparrows with water bodies in the UK (Gregory 1999), and provide evidence to support the development and promotion of conservation measures aimed at restoring and enhancing invertebrate diversity and abundance on farmland.

### **Migration routes and strategies**

Understanding causes of population change and hence

how to achieve effective conservation of migrant bird populations often requires knowledge of the whole migratory pathway: the breeding and non-breeding areas of individuals and subpopulations and the routes and stopover areas between them. Much of our existing information on this has been obtained from bird ringing. The importance of migration flyway networks of wintering and stopover sites for waterbirds has been highlighted by ringing studies (Davidson *et al* 1999, Baillie 2001). Such ringing data have been central to many international efforts to create networks of key protected areas along these flyways (Rehfishch *et al* 1996, Davidson *et al* 1998), and has helped establish the principle that such migratory populations can be adequately protected only by coordinated multinational conservation action. The case for protecting key foraging sites for waterbirds is also supported by direct evidence from colour-ringing and radio-tracking studies showing that loss of intertidal feeding habitats can result in measurable and significant reductions in body condition and in increased mortality (Burton *et al* 2006).

The location and finding circumstances of ring recoveries can also identify key conservation problems faced by migrant species. A ringing study on Roseate Terns *Sterna dougallii*, initiated in response to the observed decline in the British and Irish breeding population, produced significant numbers of recoveries from coastal West Africa, particularly Ghana and Senegal. These directly revealed a significant cause of tern mortality: trapping for food or sport (Ntiamoa-Baidu *et al* 1992, Stientien *et al* 1998, Ratcliffe & Merne 2002). This direct evidence from the ringing study led to community-based conservation and education projects being established in Ghana and Senegal in the 1980s and 1990s, with considerable success in reducing the numbers of terns being trapped (BirdLife International 2002). Since the 1990s, the UK breeding population of Roseate Terns has shown an encouraging increase (Eaton *et al* 2007), although mortality on the wintering grounds may not be the only factor of importance for this population (Mitchell *et al* 2004).

There is still much to learn about many migrant bird species due to the difficulties of locating ringed birds in remote regions with little or no ornithological capacity. Recent developments in electronic tracking technology can allow birds to be followed throughout the world without the need for recaptures or resightings (Fiedler 2009). Satellite tracking of Sociable Lapwings *Vanellus gregarius* from their breeding grounds in Kazakhstan has revealed key staging areas in the Middle East, where flocks larger than the numbers previously thought to exist globally were discovered. It has also led to the discovery of hunting as a potential limiting factor, leading to conservation efforts to address this (BirdLife International 2009a, b).

## DEMOGRAPHIC DATA

### Survival rates

The use of marked individuals is often the most practical way to estimate survival rates of fully grown birds. A major decline of many seed-eating farmland birds in north-west Europe in recent decades is thought to have been a result of reductions in overwinter seed food resources caused by widespread changes in farming practice (O'Connor & Shrubbs 1986, Anderson *et al* 2001, Newton 2004). Analysis of data from the BTO ringing scheme revealed that population decline in one of these species, House Sparrow *Passer domesticus*, was associated with reduced annual survival rates (Siriwardena *et al* 1999). A colour-ringing study on rural populations of House Sparrows also showed that annual survival rate and local population stability were dependent on winter seed food supply, suggesting lack of winter seed food as a possible contributing factor to the observed national decline (Hole *et al* 2002). Similarly, analysis of constant-effort ringing data, in combination with data on population change and productivity from nest visit data, suggested that the population decline of the Reed Bunting *Emberiza schoeniclus* was also most likely to have been driven by changes in survival rates (Peach *et al* 1999b). Such evidence has helped contribute to the development of agri-environment scheme options in the UK, which are designed to provide winter seed food to farmland birds, and are successful in doing so (Bradbury *et al* 2004). While it is not yet possible to ascribe a direct cause, this may have contributed to the recent partial population recovery of Reed Buntings in the UK (Eaton *et al* 2009).

### Productivity

Ratios of the numbers of juvenile and adult birds caught during standardised ringing programmes can provide a consistent and useful index of whole-season productivity for a wide range of species, a key benefit of 'constant-effort' ringing (Robinson *et al* 2009). However, as capture probabilities may differ for juvenile and adult birds, estimating absolute annual productivity per adult bird using this method may be problematic.

For species that are capable of multiple nesting attempts per year, the only reliable way to obtain true measures of annual productivity per adult is to follow marked individuals between successive nesting attempts. Data on the number of nesting attempts per adult, and the required interval between nesting attempts, were obtained for Black-tailed Godwits *Limosa limosa* from a colour-ringing and resighting study. This formed the basis of a mathematical model predicting population trends in the face of periodic flooding at one of the two key UK breeding sites for this species (Ratcliffe *et al* 2005). This study concluded that the only ecologically and economically viable method

of maintaining this breeding population was probably through the creation of alternative breeding habitat nearby, which was not subject to flooding risk. This habitat is now in the process of being created.

Data from radio-tracking female Corncrakes *Crex crex* were instrumental in demonstrating the importance of the timing of grass mowing in determining the scale of losses of nests and chicks in Britain and Ireland (Green *et al* 1997) and the effectiveness of delayed mowing and alternative 'Corncrake-friendly' mowing techniques (Tyler *et al* 1998). In addition, the importance of this and other measures to increase Corncrake productivity in achieving future population recovery was highlighted by an intensive ringing and recapture study, which revealed low annual survival rates of adult birds (Green 1999c, 2004). Studies of the adult age structure of museum skins also showed that adult survival had been similar when the species was abundant and widespread in the 19<sup>th</sup> century (Green 2008). Population modelling showed that a reversal of the observed population decline should be achievable with modest increases in annual productivity, but was relatively unaffected by changes in adult survival rate (Green 1999c). As predicted, the adoption of 'Corncrake-friendly' mowing techniques, and provision of habitats to allow adults to rear more broods per year (both delivered through agri-environment schemes), have been successful in increasing the UK Corncrake population (Aebischer *et al* 2000, O'Brien *et al* 2006).

## BIOLOGICAL STATUS DATA

### Diet

An important addition to the case study of Bittern, described above, was knowledge of which fish species were important in the diet and key to successful breeding. Regurgitated food, collected while handling chicks at the nest, revealed the particular importance of eel *Anguilla anguilla* and rudd *Scardinius erythrophthalmus* at the UK breeding sites (the UK being islands of relatively depauperate freshwater fish faunas). Ensuring that habitat management encouraged the development of appropriate fish communities has been a key element to the conservation successes so far observed for Bitterns (Gilbert *et al* 2003).

### Body condition

Body mass, when corrected for body size and age, can give a useful index of body condition. Corn Bunting *Emberiza calandra* chicks were found to have lower body mass than expected for their age when the abundance of chick food invertebrates in the surrounding landscape (within the foraging range of the provisioning adults) was lower (Brickle *et al* 2000). In addition, nest visit data showed

that lower fledging success was also associated with less chick food. A significant predictor of the abundance of key invertebrate chick-food taxa in arable farmland in this study was the number of herbicide applications within the crops, which killed plants of importance to the invertebrates. This type of evidence has supported the development of measures within European agri-environment schemes aimed at enhancing invertebrate populations on farmland.

Ringing and recapture studies on Red Knot *Calidris canutus rufa* on their spring staging grounds in Delaware Bay, USA, showed that individual birds can achieve rapid mass gains, potentially doubling their body weight within three weeks, when feeding on the eggs of horseshoe crabs *Limulus polyphemus* (Baker *et al* 2001). In years of lower crab-egg availability, mass gain rates and departure mass were lower. Individuals departing Delaware Bay at lower weights had lower subsequent survival probabilities than higher-weight individuals (Baker *et al* 2004). Recent declines in the total Knot flyway population have followed a protracted period of high rates of commercial harvest of horseshoe crabs, lower availability of crab eggs to waders, and lower mean departure weights of staging Knot (Baker *et al* 2004, Niles *et al* 2009). The importance of this food resource to these waders, revealed by the ringing and biometric data, was key to a recent moratorium on crab harvesting (Niles *et al* 2009), and demographic and biological status data from ongoing wader-monitoring programmes are being incorporated into a 'Structured Decision Making' model to manage both wader and horseshoe crab populations sustainably in the future (Breese *et al* 2007).

### Genetic relationships

Prioritising bird populations for conservation effort relies on a good understanding of the taxonomic relationships and gene flow between different populations. The taxonomic unit that is conventionally of greatest importance to bird conservation is the species, and hence the definition of species limits has considerable impacts on the degree of conservation concern and the management effort applied to a population. Ringing recaptures and ring recoveries can reveal the degree of both temporal and geographical population separation or mixing. Birds in the hand can provide DNA (from blood or tissue samples) and biometrics, and morphological details which may allow differentiation between distinct taxa. A good example of the integration of all of these techniques, together with the use of timing of breeding and moulting to distinguish temporally isolated breeding populations, comes from a recent study of *Oceanodroma* storm petrel species in the Atlantic, resulting in the discovery of a new species, Monteiro's Storm Petrel *O. monteiroi* (Bolton *et al* 2008).

### Geographical origins

Stable-isotope analysis (SIA) of feather samples taken from birds in the hand is increasingly being used to determine geographical regions and habitat types in which birds breed or moult, and is discussed thoroughly elsewhere (Coiffait *et al* 2009). This technique is currently being used in an attempt to discover the historical (and hopefully still current) breeding grounds of the critically endangered Slender-billed Curlew *Numenius tenuirostris*, using samples taken from museum specimens and live individuals of related wader species (BirdLife International 2009c).

### HOW TO IMPROVE THE VALUE OF RINGING FOR CONSERVATION GAIN?

It cannot have escaped the notice of the reader, especially if they are an active ringer, that a high proportion of the case studies discussed here are intensive studies on a single species, often conducted by professional ornithologists and often involving marking techniques beyond simple metal ringing. Such studies are typically designed from the outset to answer specific questions relevant to conservation and so their success at informing conservation action is both unsurprising and reassuring! Simple ringing techniques used as part of less intensive or less targeted studies still have the potential to provide data of high value to conservation efforts, however, as demonstrated by several of the examples given above. In general, however, the value of ringing to conservation management of bird populations is likely to be greater when that ringing is conducted as part of a well-planned study designed to produce high-quality information on bird movement, demography or ecology. The Constant Effort Sites (CES) and Retrapping Adults for Survival (RAS) projects coordinated by the British Trust for Ornithology are good examples of these and should be encouraged and promoted wherever possible.

In many of the case studies discussed here, the conservation value of the information provided is greatly enhanced by the combination of different types of data, for example survival rates in combination with breeding success, home range data or biometric data. The potential for bird ringing to provide a wide range of different types of information, and to be carried out in combination with other methods of data collection, should be fully exploited, and ringing programmes designed to achieve this. For example, ringing studies could be combined with standardised nest monitoring on a local scale. Opportunities to maximise the collection of potentially useful data from birds trapped for ringing should also be taken. Biometrics, chiefly body size and mass, and data on moult and breeding status can be collected rapidly from most birds, and could provide key insights into interpreting

future population changes (A.D. Evans *et al* 1999). As population changes of significance to the conservation status of birds may occur over extended periods (several to many years), the importance of particular data collected from birds now may not necessarily be revealed until an appropriate temporal comparison can be made in the future. Similarly, although ringing effort may be profitably directed towards species of current conservation concern, to increase the amount of information gained for these birds, at the complete expense of other species would be unwise. The lesson of the pre-1976 restrictions on House Sparrow ringing in the UK tells us this. How much would conservation biologists give now for survival-rate estimates for House Sparrows in different regions and habitats in the UK pre-1976 to compare with more recent data?

Colour-marking projects have the potential to increase the amount of information returned per marked bird significantly, compared with simple metal ringing, as resighting the marked individuals can be much easier than recapturing them. In most cases, the value of colour-marking projects is dependent on the quality and quantity of resighting effort invested. Colour-marking projects where resighting protocols are considered and properly designed from the outset are much more likely to generate high-quality data, of greater value to conservation biology, than projects where resighting is left to chance. Colour-marking projects also provide an opportunity for collaboration between ringers and non-ringer ornithologists, who can provide resighting data, with a common interest in bird conservation. Such projects could involve volunteer ringing groups working closely with local birdwatching clubs.

The potential for volunteer ringers to have more collaboration with professional ornithologists, based in academic or other research institutions, should also be explored. Research institutions may have difficulty finding appropriately trained and qualified ringers for short-term intensive research projects, a situation made more difficult by the long-term nature of training required to produce safe, skilled and qualified ringers. While the time commitment required for intensive research projects may be well beyond that possible from individual volunteer ringers, well-coordinated ringing groups with a large pool of active ringers may be able to provide significant and very valuable contributions to such studies.

Despite 100 years of ringing in the UK, we still have little knowledge on the movements and wintering areas of many of our summer-visiting long-distance migrant species, a group of considerable current conservation concern in Europe as a whole (Sanderson *et al* 2006). However, there is much to be gained in the future from the miniaturisation of electronic tagging devices which can potentially provide data on bird location and activity anywhere in the world

(Fiedler 2009). The lower limit to the size of birds that can be safely and reliably tracked around the globe is reducing fast. Exciting new insights are already being gained from studies on American long-distance migrant passerines using data loggers (Stutchbury *et al* 2009) and studies on similarly sized species in Europe are under way. An alternative and complementary approach would be to instigate standardised bird-ringing programmes in potential wintering areas of long-distance migrants. Although logistically challenging, this is a high priority and initiatives are under way in several African countries.

The contribution of information gained from ringing to bird conservation efforts over the last 100 years has been significant and wide ranging. Effective conservation action will continue to rely on good understanding of bird ecology and of the causes of population change. Ringing studies, involving an increasing range of technologies and analytical techniques, will continue to provide this information, in many cases without alternative methods being available.

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