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3 Title: The Movement Shortfall in bird conservation: accounting for nomadic,
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The Movement Shortfall in bird conservation: accounting for nomadic, dispersive, and irruptive species

Abstract

Efforts to prioritise conservation planning are undermined by several recognised knowledge shortfalls. Here we highlight a further shortfall, which we term the Movement Shortfall, in our knowledge of species movements, with particular reference to dispersive, irruptive, and nomadic birds. Despite one hundred years of ringing effort, the movement characteristics of these species are still poorly known, as the irregularity of their movements, and low human population densities in many parts of their range, impedes traditional methods. A lack of understanding of their movements, combined with an inappropriate conservation approach that relies on protected areas and out-dated international frameworks, which at best focus on regular migratory species, places several of these species under threat. We call for the application of new tracking technology and outreach initiatives to help formulate innovative conservation approaches that are better suited to species with irregular movement behaviours.

Keywords Citizen science; conservation planning; biogeography; knowledge shortfalls; migration; science communication

1. Introduction

To address the fundamental questions in conservation biogeography, we require an accurate and extensive knowledge of the basic units of study (Riddle *et al.*, 2011). Deficits in our biogeographical knowledge not only hamper our ability to understand patterns in biodiversity, but also constrain our ability to plan effective conservation

strategies. A particularly important area where limited biogeographical knowledge overlaps with conservation shortcomings concerns bird movements (Bauer & Hoyer, 2014). While migratory species are increasingly well studied, and are the focus of international conservation efforts (Faaborg *et al.*, 2010; Birdlife International, 2013a), the irregular movements of those species that exhibit dispersive, irruptive, and nomadic behaviours are poorly understood (Table 1). Furthermore, while migratory species are harder to conserve than sedentary species (Shuter *et al.*, 2011), species with irregular movement patterns are harder still to conserve, not least because of the reliance on protected areas in most conservation strategies. For too long our attempts to conserve mobile species have drifted, but with new technology and methods promising to overhaul the way we conduct research on species movements, it is time to galvanise ecologists and conservationists around this hitherto intractable conservation issue.

2. The Movement Shortfall

Improving our knowledge of birds that exhibit irregular movement behaviours should improve our ability to conserve them. We urgently need higher resolution and broader scale ecological data to equip conservation actors with the basic information needed to engage authoritatively with the range of stakeholders involved in conserving highly mobile species. To this end, we wish to highlight the lack of knowledge on bird movement behaviours to a wide audience (see Bauer & Hoyer, 2014), in particular for dispersive, irruptive, and nomadic species, by formally identifying it as the Movement Shortfall.

Other shortfalls include the Linnean, Wallacean, Extinction Deficit, Prestonian, Hutchinsonian, Eltonian, and Darwinian Shortfalls (Raven & Wilson, 1992; Cardoso *et al.*, 2011; Mokany & Ferrier, 2011; Riddle *et al.*, 2011; Diniz-Filho *et al.*, 2013;

Morales-Castilla *et al.*, *in press*; Table 2). Identifying and naming shortfalls in our knowledge of biodiversity is an increasingly important conservation tool (Riddle *et al.*, 2011). The practice helps to shape a problem, improve referral, and build momentum towards addressing it. The formal identification of earlier knowledge shortfalls, such as the Linnean or Wallacean Shortfall, have helped focus research efforts in conservation biology, and have been frequently cited (a Google Scholar search for the term Linnean Shortfall returns 107 citations since 2005, with 139 for Wallacean over the same period). The Movement Shortfall is distinct in that it accounts for short-term, temporary movements, rather than long-term adaptive dispersal in response to environmental change encompassed by the Hutchinsonian (Mokany & Ferrier, 2011). This shortfall is currently undermining our ability to conserve highly mobile species, but by identifying the problem and embracing modern technology, exciting opportunities to address this shortfall are now within reach.

3. Current conservation status of different movement groups

3.1 Migratory species

The importance of identifying the Movement Shortfall is underlined by the proportion of birds of conservation concern within each movement group, along with the inadequacies of our current conservation strategies (Koleček *et al.*, 2014). For migratory birds, which are the best studied, 11% of the world's migratory land and water birds were classified as threatened or near-threatened in 2008 (Kirby *et al.*, 2008). Some groups are under particularly high pressure, such as raptors that migrate between Africa and Eurasia (Goriup & Tucker, 2007), while 27 of 39 soaring birds (69%) that migrate along the Rift Valley/Red Sea Flyway are reported to have an unfavourable conservation status (Tucker, 2005). Despite the volume of work carried

out on migratory species, with 4,539 publications under the topic “Migratory Birds” found in the Web of Science (Somveille *et al.*, 2013), there is still little accurate knowledge about the status of breeding and wintering populations of some of the best studied species, including Africa-Eurasia migratory raptors (Kirby *et al.*, 2008).

3.2 Dispersive species

While the conservation status of a large proportion of migratory birds is worrying, the situation for the other movement groups is of even more concern. Dispersive species, which make movements from their breeding areas with no fixed direction or distance (Alerstam, 1990), present even greater monitoring and conservation challenges than species which conduct regular migratory movements. Examples of dispersive species include the critically endangered regent honeyeater (*Xanthomyza phrygia*; Higgins *et al.*, 2001), and many pelagic seabirds, with regular population aggregations at colonial breeding sites for part of the year, followed by long periods of maritime foraging (Newton, 2008). Their vulnerability to nest predation during the breeding season, coupled with their wide ranging non-breeding habits, are sufficient to place many dispersive species under a high level of threat (Wanless *et al.*, 2009; Cherel *et al.*, 2013). Of the 22 albatrosses, for example, 17 are listed as globally threatened, of which three are critically endangered (Birdlife International, 2013b). The situation for seabirds in general is not much better: 28% are globally threatened (Croxall *et al.*, 2012), and this group has experienced a faster decline than any other bird group in Red List Index scores over the last two decades (Butchart *et al.*, 2005; Birdlife International, 2013c). The conservation challenges and mitigation measures during the breeding season are well documented, such as controlling alien predators on islands, even if they are difficult to execute in practice (Nogales *et al.*, 2004; Howald *et al.*, 2007; Whittaker & Fernández-Palacios, 2007). Conserving dispersive species

throughout the rest of their life-history is more complicated, as they can have very large range areas, which in the marine realm are particularly difficult to monitor, making it hard to assess movement patterns and to carry out effective conservation work (Jouventin & Weimerskirch, 1990; Croxall *et al.*, 2012; Cherel *et al.*, 2013).

3.3 *Irruptive species*

Irruptive species, which make irregular seasonal movements where the number of individuals, timing, direction, and distance travelled varies greatly between years, present another case of limited knowledge restricting conservation action (Newton, 2008). Boreal finches, especially those that depend on fluctuating tree-seed crops (Newton, 2006a), and birds of prey that depend on cyclically fluctuating rodent populations (Fuller *et al.*, 2003), typically exhibit large scale irruptive movements with little breeding or non-breeding site fidelity (Newton, 2006b). Specific examples of long distance irruptive bird movements include common crossbills (*Loxia curvirostra*), where individual adults have been found in locations up to 3,200km apart in different breeding seasons (Newton, 2006a), and common redpoll (*Carduelis flammea*) where an individual that was ringed in Michigan, USA was later recovered near Okhotsk in Siberia, 10,200km away (Troy, 1983). While the occurrence of irruptions is apparent through observation, much of our scientific understanding of irruptive behaviour is based on ringing recoveries, which have limited data collection to “scraps of information collected over a long period” (Newton, 2006b:434). While the rarity of ring recoveries in the same area the year after an irruptive migration suggest dramatic geographical changes in population demographics, they do not provide an indication of movement patterns, alternative destinations, and population fluctuations.

3.4 *Nomadic species*

144 Nomadic species, which have no fixed spatial or temporal patterns in their
145 movements, present a major challenge to conservationists, as a conventional protected
146 area approach would require the creation of prohibitively large reserves (Andersson,
147 1980; Woinarski *et al.*, 1992). Nomadic birds are believed to respond to resource
148 fluctuations, ranging widely and breeding where food is locally abundant, leading to
149 obligatory changes in distribution (Dean, 2004). Nomadic species include many
150 dryland waterbirds, granivores, nectarivores, and carnivores, such as the black
151 honeyeater (*Sugomel niger*; Tischler *et al.*, 2013), grey-backed sparrow-lark
152 (*Eremopterix verticalis*; Dean, 1997), and Australian painted snipe (*Rostratula*
153 *australis*; Marchant & Higgins, 1993). The erratic movements made by many of these
154 species make it difficult to quantify their population sizes, or to design site based
155 conservation strategies (Woinarski *et al.*, 1992, 2005). The highly nomadic Princess
156 parrot (*Polytelis alexandrae*), for example, which occurs in Australia's interior
157 deserts, defies accurate population assessment due to its erratic occurrence at most
158 sites, and a lack of information on its movements (Higgins, 1999; Garnett *et al.*, 2011;
159 Forshaw & Cooper, 2002). Indeed, overcoming limited movement information is a
160 key challenge for bird conservation in Australia, where 93 out of 742 species of
161 resident land bird are considered to be primarily nomadic (Marchant & Higgins, 1993;
162 Higgins, 1999; Higgins *et al.*, 2001; Pizzey & Knight, 2007). Seven of these species
163 are considered threatened according to the Commonwealth Government listing, and
164 10 by Birdlife International, and in an analysis comparing movement behavior and
165 IUCN threat status, we found a significant association with Fisher's exact test ($P =$
166 0.001; FET; see Table 3 and caption for methods; Keast, 1960; Garnett *et al.*, 2011).
167 Our current knowledge of nomadic bird movements is based on chance observations
168 and inference, with few relevant ring recoveries, and a lack of detailed records

(Newton, 2008). As a result, many fundamental questions about their behaviour remain unanswered: how do nomadic species know where to go to find isolated resources in a vast desert, how far away can they detect suitable conditions, are there any directional patterns in their movements, and what is the primary reason for so many of them being threatened (Newton, 2010)?

4. 21st century conservation

While many of the basic questions of migratory biogeography are only beginning to be solved (Wikelski *et al.*, 2007), migratory birds have received a high level of scientific attention, and have been the focus of several international conservation agreements (for example, the Ramsar Convention in 1971, the EEC Directive for the Conservation of Wild Birds in 1979, and the Bonn Convention on the Conservation of Migratory Species of Wild Animal in 1983; Berthold, 2001). Dispersive, irruptive, and nomadic species, on the other hand, are often overlooked in these and other frameworks, despite the distinctive challenges they face. Their irregular movements place many of them beyond the capacity of conventional conservation approaches that use the protected area as their primary tool, while efforts to estimate their population sizes have low reliability due to their rapidly shifting distributions, which often occur in remote locations (Woinarski *et al.*, 1992; De Frutos & Olea, 2008; Garnett *et al.*, 2011; Burnham & Newton, 2011).

Improving our capacity to conserve dispersive, irruptive, and nomadic species first requires an improvement in our ability to gather better data on their movements. We need very precise data to see what resources they are tracking, uncover any movement patterns, and identify any hidden site dependencies (Wikelski *et al.*, 2007; Limiñana *et al.*, 2012). While this presents a challenge, the Movement Shortfall is distinctive in

that it has, until recently, largely been the result of limited technology rather than effort, funding, or public interest.

Previous attempts to address this shortfall in migratory birds have focused on ringing schemes. However, this technology provides limited information even for birds that have high site fidelity and follow regular migration routes (Schmaljohann *et al.*, 2012). It is not well adapted to species that make irregular movements, spatially or temporally, as recapture rates are very low (Newton, 2006b), due to both the nature of the movements and the low human population densities in the pelagic, boreal, and arid environments inhabited by many of these species (Newton, 2010). Furthermore, the data gathered do not help address many of the important questions surrounding dispersive, irruptive, and nomadic species (see Hays, 2013).

Instead, new tracking devices, using geolocators or satellite telemetry, can now provide high quality data over long time scales, and in some cases also remove our dependency on re-trapping tagged birds (Berthold, 2001; Robinson *et al.*, 2009). Stable isotope ratio analysis and the use of genetic markers can be used to identify both the breeding and non-breeding grounds of irruptive or dispersive birds (Coiffait *et al.*, 2009; Marquiss *et al.*, 2012; Cherel *et al.*, 2013), while the International Cooperation for Animal Research Using Space (ICARUS) Initiative is working towards establishing a platform to remotely sense animal movements on a global scale (<http://icarusinitiative.org>). While there is a clear need to improve the miniaturisation of tracking technologies, improve analytical techniques, and standardise data collection and reporting protocols, the increased roll-out of these technologies should ensure such advances are swiftly made (Baillie *et al.*, 2009; Fiedler, 2009).

217 Applying the methods of successful migration studies may also help raise public
218 awareness and improve engagement with the issues facing dispersive, irruptive, and
219 nomadic species. The use of Movebank (<https://www.movebank.org>) as a resource for
220 data storage, sharing, and visualisation may also be useful as a tool for wider public
221 engagement (Baillie *et al.*, 2009). Expanding satellite-tracking studies of sociable
222 lapwing (*Vanellus gregarius*) and Eurasian cuckoo (*Cuculus canorus*) to species with
223 irregular movements (Birdlife International, 2013d; BTO, 2013a), may highlight the
224 difficulties conservationists face in devising appropriate strategies for them. Finally,
225 initiatives such as Blogging Birds, which uses satellite tracking technology and
226 innovative software to provide automated updates of individual red kites' (*Milvus*
227 *milvus*) activities online (Ponnamperuma *et al.*, 2013), may help realise the power of
228 communicating real-time data to the public, stimulating interest and directing finance
229 towards conservation efforts.

230 The Integration of bird movement data collection, public engagement, and new
231 technology is perhaps best illustrated by the rise of eBirds in the United States. A
232 freely available web platform, eBirds allows users to input their bird observations as
233 electronic personal checklists, while also allowing them to share their records with the
234 scientific community (Bonney *et al.*, 2014; Supp *et al.*, 2014). Since launching in
235 2002, eBirds has grown rapidly, and by 2012 was receiving over 3 million bird
236 records in a month in North America (<http://ebird.org/content/ebird/about/>). Other
237 new approaches to citizen science and communication are already helping to address
238 the Movement Shortfall in the irruptive Bohemian waxwing (*Bombycilla garrulus*) in
239 the UK. The @WaxwingsUK Twitter feed gathers live information on Waxwing
240 sightings across the United Kingdom (<https://twitter.com/WaxwingsUK>), while the
241 television programme BBC AutumnWatch has promoted widespread online reporting

242 of Waxwing sightings to help identify irruption years and track their movements
243 (<http://www.bbc.co.uk/programmes/b0079t1p>). Some communication strategies have
244 also created new fundraising streams, such as sponsoring a tracked bird (BTO,
245 2013b), or betting on bird dispersal movements in the Big Bird Race of shy
246 albatrosses (*Thalassarche cauta*; Kirby, 2004).

247 Like many conservation programmes, schemes targeted at dispersive species have
248 required widespread public support and stakeholder engagement. In the Southern
249 Ocean, long line fisheries had been identified as the major driver of decline in
250 albatrosses and other seabirds (Croxall, 2008). By working with fishermen to identify
251 strategies that could minimise pelagic seabird by-catch, and introducing new fishing
252 technology, the Albatross Task Force has started to reduce by-catch mortality on long
253 line vessels (Birdlife International, 2012). Hopefully further technological innovation
254 will help modernise our approach to conservation while also helping to address the
255 Movement Shortfall.

256 The need to bring 21st century technologies and strategies to mobile species
257 conservation is particularly pertinent considering the age of many of the conservation
258 frameworks targeted at migratory birds (see above), which may be one reason why
259 species with irregular movements lie beyond the scope of the traditional protected
260 areas approach. New innovations, such as delimiting temporary protected areas or
261 micro-sites that reflect the dynamism of the species they are aimed at conserving, may
262 be one idea worth exploring.

263 The major international conservation organisations could also help address this
264 shortfall by implementing suitable strategies to help conserve mobile species with
265 irregular movements. While migratory birds and flyways is one of their nine
266 conservation programmes, Birdlife International, for example, are uniquely placed to

make real progress in this arena. They and other international conservation organisations could help by adopting a broader approach, recognising the plight of species with irregular movements along with more conventional migrants. These organisations could bring technology manufacturers, software programmers, and scientific researchers around the table to find ways to aggressively invest in driving tracking technology forward and cut costs.

It is also time for the conservation community to galvanise their response to the threats these species face. A major conservation organisation could consider dedicating a year to focus on mobile species and overhaul our failing approach to negotiating with stakeholders with radically opposed views (see for example Jepson, 2012). There is also scope for an individual champion of the cause to emerge, to set the agenda and act as a figurehead to drive the movement forward, much like Thoreau did as a voice for wilderness in the 19th century (Nash, 2014). After the media attention generated by the arrest of British wildlife presenter Chris Packham in Malta in 2014 (<http://www.theguardian.com/environment/2014/apr/28/chris-packham-malta-is-a-bird-hell>), such a strategy may be especially effective in this age of celebrity.

5. Conclusion

In reality, migratory, dispersive, irruptive, and nomadic behaviours are different configurations along the same movement axis (Newton, 2008). Different populations of the same species can exhibit migratory or irruptive behaviour (for example, the red-billed quelea *Quelea quelea* or Eurasian bullfinch *Pyrrhula pyrrhula*; Dingle, 1996; Newton, 2010). However this classification helps draw attention to the particular issues faced by species belonging to the more irregular movement classes, which are often overlooked within conservation agendas. Hopefully, outlining the

292 extent and dangers of the Movement Shortfall with this classification system will
293 highlight the particularly severe knowledge deficit in these species, accelerating the
294 application of new technology to help unravel the mysteries of their biogeography and
295 drive the innovative conservation strategies they need.

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Tables

Table 1 A typology of bird movement behaviours.

Name	Definition	Examples
Migratory	Species that perform regular, seasonal movements from breeding to non-breeding areas (Berthold, 2001; Newton, 2008).	Black-throated blue warbler (<i>Dendroica caerulescens</i> ; Townsend et al., 2013); greater white-fronted goose (<i>Anser albifrons</i> ; Ely et al., 2013)
Dispersive	Species that move with no fixed direction or distance from their breeding site (Newton, 2008).	Australasian gannet (<i>Morus serrator</i> ; Pyk et al., 2013), Western gull (<i>Larus occidentalis</i> ; Coulter, 1975)
Irruptive	Species that make seasonal movements where the number of individuals, timing, direction, and distance travelled varies greatly between years (Lack, 1968; Newton, 2008).	Common crossbill (<i>Loxia curvirostra</i> ; Newton, 2006a), snowy owl (<i>Bubo scandiacus</i> ; Fuller et al., 2003)
Nomadic	Species that move with no fixed spatial or temporal pattern (Newton, 2008).	Gouldian finch (<i>Erythrura gouldiae</i> ; Woinarski et al., 1992); Princess parrot (<i>Polytelis alexandrae</i> ; Pizzey and Knight, 2007)
Vagrant	An individual bird that appears in an area far beyond the limits of its normal range and migration routes (Newton, 2008).	American robin in Europe (<i>Turdus migratorius</i> ; Svensson et al., 2010); Amur falcon in the UK (<i>Falco amurensis</i> ; Hudson et al., 2010)

Table 2 Named knowledge shortfalls in conservation biogeography. Definitions

adapted from the source references indicated.

Name	Definition	Reference
Linnean Shortfall	The disparity between the number of formally described species and the total number of species in existence.	Lomolino <i>et al.</i> , 2010:775
Wallacean Shortfall	The inadequacy of our knowledge on the geographical distribution of species.	Riddle <i>et al.</i> , 2011:54
Extinction Deficit Shortfall	The uncertainty surrounding our knowledge of extinction rates.	Riddle <i>et al.</i> , 2011:58
Prestonian Shortfall	The scarcity of comparative species abundance data in time and space.	Cardoso <i>et al.</i> , 2011:2650
Hutchinsonian Shortfall	The lack of knowledge of species ecology and sensitivities to habitat change (including natal dispersion).	Mokany and Ferrier, 2011:375
Eltonian Shortfall	Uncertainty concerning the networks of interactions between organisms.	Peterson <i>et al.</i> , 2011:201
Darwinian Shortfall	The lack of relevant phylogenetic information.	Diniz-Filho <i>et al.</i> , 2013:689
Movement Shortfall	The limited knowledge of species movements.	

Table 3 The number of Australian bird species grouped by threat status and by their primary movement behaviours. Data on movement behaviours were collected from the Handbook of Australian, New Zealand, and Antarctic Birds (Marchant and Higgins, 1990) and Pizzey and Knight (2007). In cases where species displayed multiple movement behaviours, the primary movement behaviour was taken to be that undertaken by the majority of the adult population. Abbreviations are CR=Critically Endangered; EN=Endangered; VU=Vulnerable; NT=Near-threatened; LC=Least Concern, and the values in these columns refer to the number of species that are listed in these categories according to the IUCN Red List criteria, taken from Garnett et al., 2011. The values in the IUCN column refer to the total number of species in each movement group that are listed in categories other than LC. The values in the EPBC column refer to the total number of species listed under the Australian Government's Environment Protection and Biodiversity Conservation Act (1999) in each movement group. The percentage of threatened species in the final column refers to the IUCN listing. There was a significant association between the type of movement behaviour (due to issues of small sample size we grouped migratory, dispersive, irruptive and nomadic species into a single movement category) and IUCN threat status according to Fisher's exact test ($P = 0.001$; FET).

Category	CR	EN	VU	NT	LC	IUCN	EPBC	Total species	Percentage threatened
Dispersive	6	8	10	5	54	29	19	83	35%
Irruptive	0	1	0	1	27	2	1	29	7%
Nomadic	0	5	2	3	83	10	7	93	11%
Migratory	1	2	4	2	105	9	2	114	8%
Sedentary	2	10	8	12	391	32	16	423	8%