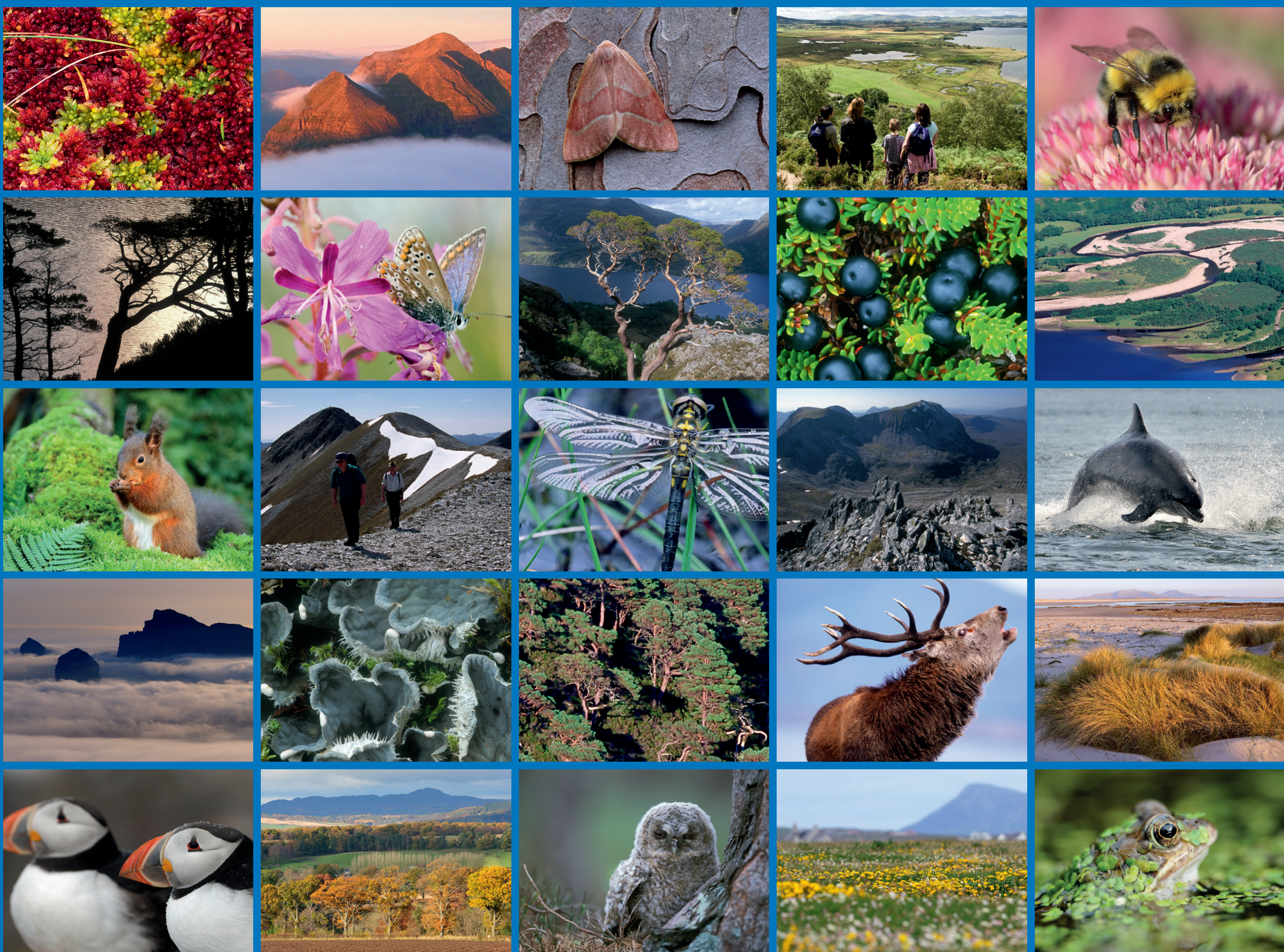
Scottish Natural Heritage
Research Report No. 1152

Conservation strategy for red-billed choughs in Scotland: Assessment of the impact of supplementary feeding and evaluation of future management strategies



RESEARCH REPORT

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Conservation strategy for red-billed choughs in Scotland: Assessment of the impact of supplementary feeding and evaluation of future management strategies

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This report should be quoted as:

Trask, A.E., Bignal, E., Fenn, S.R., McCracken, D.I., Monaghan, P. & Reid, J.M. 2020. Conservation strategy for red-billed choughs in Scotland: Assessment of the impact of supplementary feeding and evaluation of future management strategies. *Scottish Natural Heritage Research Report No. 1152.*

RESEARCH REPORT

Summary

Conservation strategy for red-billed choughs in Scotland: Assessment of the impact of supplementary feeding and evaluation of future management strategies

Research Report No. 1152
Project No: 115669, 117001
Contractor: Professor Jane Reid, University of Aberdeen
Year of publication: 2020

Keywords

supplementary feeding; parasites; habitat management; inbreeding; conservation translocations; Population Viability Analysis; red-billed choughs

Background

The red-billed chough (*Pyrrhocorax pyrrhocorax*) is a Species of European Conservation Concern (Annex 1, EC Birds Directive) and a Schedule 1 species in Scotland and the UK (Wildlife & Countryside Act 1981), with the UK *Pyrrhocorax pyrrhocorax pyrrhocorax* subspecies listed as Amber. Consequently, there is a special importance attached to conserving choughs and the habitat on which they depend. However, Scotland's chough population has decreased in size and range markedly over the last 30 years and is currently restricted to the islands of Islay and Colonsay.

The key demographic process causing this recent decrease is known to be low first-year survival (from fledging to age one year, Reid *et al*., 2011). This low first-year survival has been attributed to low food abundance and/or availability (Reid *et al*., 2008). Ideally, the increases in food that are required to ensure population persistence would be achieved through effective grassland habitat management that increases availability and abundance of the chough's invertebrate prey. Options that attempt to promote such habitat management have consequently been included in the Scottish Rural Development Programme 2014-2020. However, given the urgent need to increase first-year survival to ensure short-term population persistence, emergency supplementary feeding of choughs was undertaken on Islay during 2010-2019. Additionally, in response to observations of pathologically significant parasite infections in sub-adult choughs, targeted antihelminthic treatments were carried out during 2014-2018.

Alongside these ecological threats (i.e. food, parasites), recent research highlighted that the Scottish chough population is also facing genetic threats. Molecular genetic data suggest that the Scottish chough populations are isolated from other UK chough populations, and have relatively low genetic diversity (Wenzel *et al*., 2012). This isolation coupled with small population size means that inbreeding is inevitable, and is likely to decrease survival and/or reproductive success (i.e. 'inbreeding depression'). Indeed, a genetic disease causing blindness and consequent mortality of chough nestlings is already emerging (Trask *et al*.,

2016). Furthermore, Islay's chough population has a critically small 'effective population size' (equivalent to ~30 individuals), meaning that the population will lose further genetic diversity and rapidly become increasingly inbred over future generations (Trask *et al*., 2017).

This situation of simultaneous ecological threats from food shortage and parasites, and genetic threats from low genetic diversity and increasing inbreeding, presents substantial challenges to the development of an effective conservation strategy. If chough survival and/or reproductive success are limited by inbreeding depression, then resources invested in grassland management, supplementary feeding and parasite treatments (i.e. 'ecological management') may not have the desired effect of ensuring the persistence of choughs in Scotland. Management to reduce inbreeding (i.e. 'genetic management', through population reinforcements) therefore needs to be considered alongside ecological management. However, genetic management may itself be ineffective, and indeed wasteful, if ecological conditions more favourable for survival are not restored.

This report therefore has two primary goals. First, we provide an overview of the demographic monitoring, supplementary feeding and parasite treatments carried out on Islay during 2010-2019 under contract to SNH, and provide a preliminary assessment of the efficacy of these interventions in increasing key demographic rates. Second, we present a population viability analysis (PVA) undertaken to evaluate the likely efficacy of different potential ecological and genetic management strategies in achieving medium-term population persistence. Given the chough's current perilous state, and in light of these analyses, we highlight key management decisions that now urgently need to be taken by SNH and the Scottish Government.

Main findings

- Demographic monitoring was successfully carried out on Islay during 2010-2019, thereby extending the full available demographic dataset through 1983-2019. This allowed detailed assessments of demographic constraints on population persistence and effects of supplementary feeding, and underpins rigorous population viability analyses.
- Supplementary feeding was carried out at up to three sites on Islay during 2010-2019: Arnave, Sanaig and Coull, by Eric & Sue Bignal (Scottish Chough Study Group) and Donald Jones (Coull Farm). There was high uptake of supplementary food by sub-adult and adult choughs: on average ~82% of colour-ringed individuals known to be alive on Islay were observed attending the supplementary feeding during 2010-2018.
- Analyses show that the supplementary feeding has successfully increased key demographic rates. First-year survival was consistently higher for choughs that attended the feeding than for choughs that did not attend. Second-year survival of fed individuals was comparable to the high rates observed up to 2006. Adult survival increased significantly in areas where supplementary feeding was carried out. The proportion of breeding attempts that were successful remained stable or increased in these areas, but decreased elsewhere. More detailed analyses of the effects of feeding are being carried out as part of a NERC iCASE PhD studentship (supported by SNH), and will be completed in 2020.
- Post-mortem examinations of choughs found dead on Islay showed evidence of pathologically significant parasite burdens (58% of individuals examined from 2004-2018 (14/24). This suggests that parasites may be a contributory factor to chough mortality, possibly exacerbated by poor nutrition and low genetic diversity. Some birds showing symptoms of parasite infection were treated with antihelminthic drugs; subsequent first-year survival rates were comparable to the rest of the population. Sub-adults showing symptoms of parasite infections ceased showing symptoms within 2-3 days after receiving antihelminthic treatments.
- Population viability analysis (PVA) suggests that ceasing supplementary feeding will result in a rapid decrease in chough population size (unless habitat management that equivalently increases food abundance and/or availability can be rapidly implemented). This provides

evidence that the supplementary feeding and associated parasite treatments carried out during 2010-2019 are likely to have prevented a larger decrease, and hence to have been an effective and beneficial short-term conservation intervention. PVA also suggests that continuation of current supplementary feeding levels is unlikely to result in a long-term viable population, due to increasing inbreeding. Simultaneous population reinforcements, achieved by translocating additional choughs into Scotland to alleviate the problem of low genetic diversity, will also be required. However, such reinforcements would not lead to a viable population in the absence of either continued supplementary feeding, or an effective programme of habitat management that successfully increases natural food.

Recommendations

- Given the perilous status of the chough population in Scotland, its status on the Scottish Biodiversity List should be changed to ‘conservation action needed’.
- To prevent the disappearance of choughs in Scotland, ecological management (supplementary feeding and/or rapidly implemented habitat management), is urgently required on Islay. Since it is unlikely that the level of habitat management required can be implemented quickly enough, supplementary feeding should be continued until appropriate grassland management policies are in place (see Sections 3 & 8.3).
- Appropriate grassland management policies need to be agreed and implemented (see Section 8.2).
- Parasite treatment of juveniles should be continued until favourable ecological conditions, and the genetic health of the population, are restored (see Section 4)
- In tandem with these food availability and parasite treatment measures, a programme of genetic management (translocations to alleviate inbreeding), should be urgently developed to ensure medium-term population persistence (see Section 8.4)
- Since the current funded programme of supplementary feeding and parasite treatment has now ended, policy and management decisions based on the above scientific findings and recommendations must now be urgently taken and actions put in place to prevent the extinction of choughs in Scotland.

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Acknowledgements

We thank Sue Bignal for her substantial long-term contributions to the chough study on Islay, including help with survey, nestling ringing and organising and carrying-out the recent supplementary feeding. The population monitoring and nest site visits for ringing would not have been possible without help from the numerous farmers and landowners that generously allowed access to their land. Particular thanks to Donald Jones, Pat Jones and Andrew Jones for carrying-out the supplementary feeding of the choughs at Coull, and to Robert Epps and Tom Epps for allowing the supplementary feeding at Ardnave. Islay Estates and the Trustees of Coull Farm were very supportive of the work on their land.

On Colonsay, thanks to David Jardine and the late Mike Peacock for providing survey results there. We thank members of the Scottish Chough Forum, particularly Rae McKenzie, Jess Shaw and Des Thompson of Scottish Natural Heritage for facilitating our ongoing work.

We also thank RSPB staff for their support throughout the project, and particularly for accommodating JMR, AET and SRF on Islay, for providing chough survey data from the Oa, and for funding contributed to AET's contract. We thank Michal Sur for his work on the 2014 chough census, and for computerising recent chough re-sighting data.

1. INTRODUCTION TO THE PROJECT

1.1 Background to the project

The red-billed chough (*Pyrrhocorax pyrrhocorax*) is a Species of European Conservation Concern (Annex 1, EC Birds Directive), and is a Schedule 1 species in the UK (Wildlife & Countryside Act 1981). Chough as a species were until recently Amber listed and have only been down-listed due to a change in assessment criteria, as opposed to a change in numbers or range (Eaton *et al.,* 2015), but the British subspecies remains Amber listed. In Scotland, choughs are listed on the Scottish Biodiversity List and thus are considered to be of principal importance for biodiversity conservation. Furthermore, choughs in Scotland have considerable socioeconomic value due to eco-tourism, cultural significance and links to traditional pastoral farming systems, which are themselves of high biodiversity value (Bignal & McCracken, 1996). Consequently, the Scottish Government and hence Scottish Natural Heritage have a responsibility to conserve choughs and the habitat on which they depend.

In Scotland, the chough population has decreased from ~88 breeding pairs in 1986 to less than 50 breeding pairs in 2018 (Figure 1.1, Monaghan *et al*., 1989). The species has become locally extinct from historical breeding areas on Jura and in Kintyre and is currently restricted to the islands of Islay and Colonsay (Hayhow *et al*., 2018).

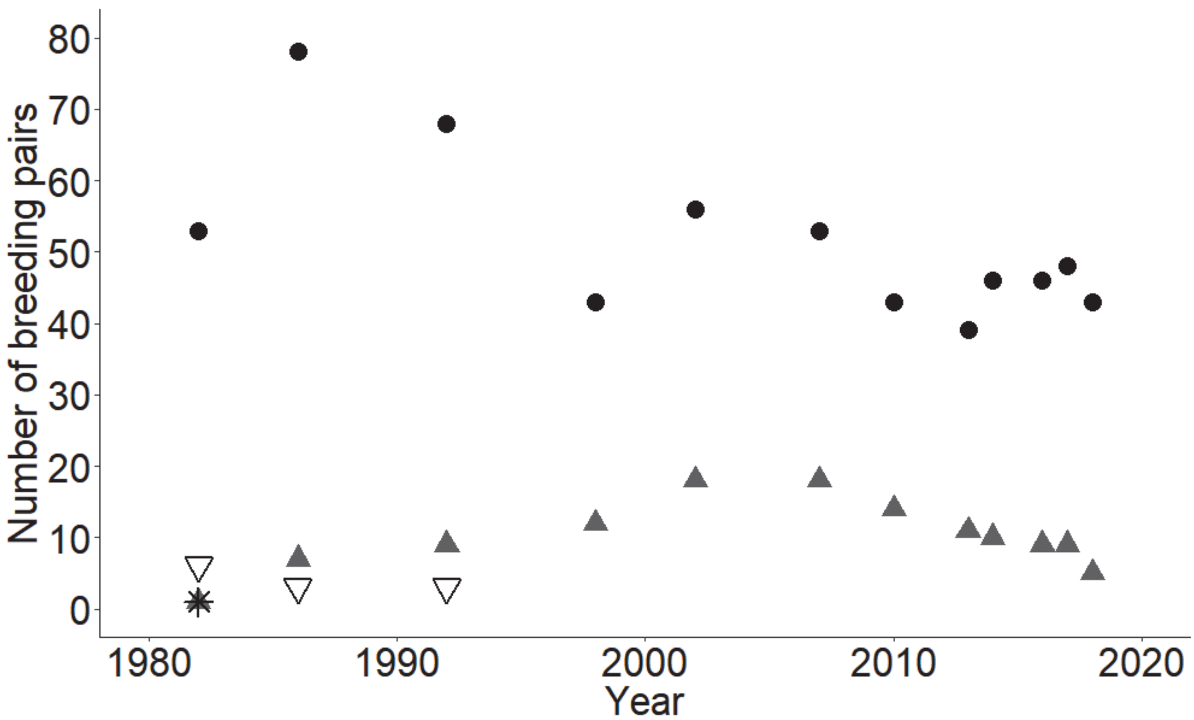

Figure 1.1. Number of breeding pairs of choughs on Islay (black circles), Colonsay (grey triangles), Jura (open diamonds) and Kintyre (star) in years where full censuses of the Scottish chough population were carried out. The Islay population size increased up to 1986 (following a reported reduction to a very small size during the hard winter in 1963), but has decreased subsequently. The Colonsay population size peaked around 2002 and has decreased subsequently. The Jura and Kintyre populations are now locally extinct.

One key process causing the recent decrease in population size is known to be low first-year survival (from fledging to age one year, (Reid *et al*., 2004; 2011). This decrease in first-year survival has been attributed to low abundance and/or availability of food for fledged choughs (Reid *et al*., 2008). In response, habitat management options that aim to improve grassland foraging habitat for choughs by increasing the abundance and/or availability of their main invertebrate prey have been included in the Scottish Rural Development Program 2007-2013 and 2014-2020 contracts. These options have been taken up in key areas on Islay.

However, during 2007-2009 first-year chough survival rates on Islay were substantially lower than the long-term average (~0.10 compared to ~0.42 for 1983-2006, Figure 1.2), with particularly high mortality in late summer and early autumn (Reid *et al*., 2011). Meanwhile, on Colonsay, sub-adult survival was so low that zero sub-adult choughs were alive in 2010. Population projection modelling showed that these survival rates would result in a rapid decrease in the number of breeding pairs of choughs in Scotland (Reid *et al*., 2011). These data and analyses revealed the need for urgent management action to rapidly increase food availability.

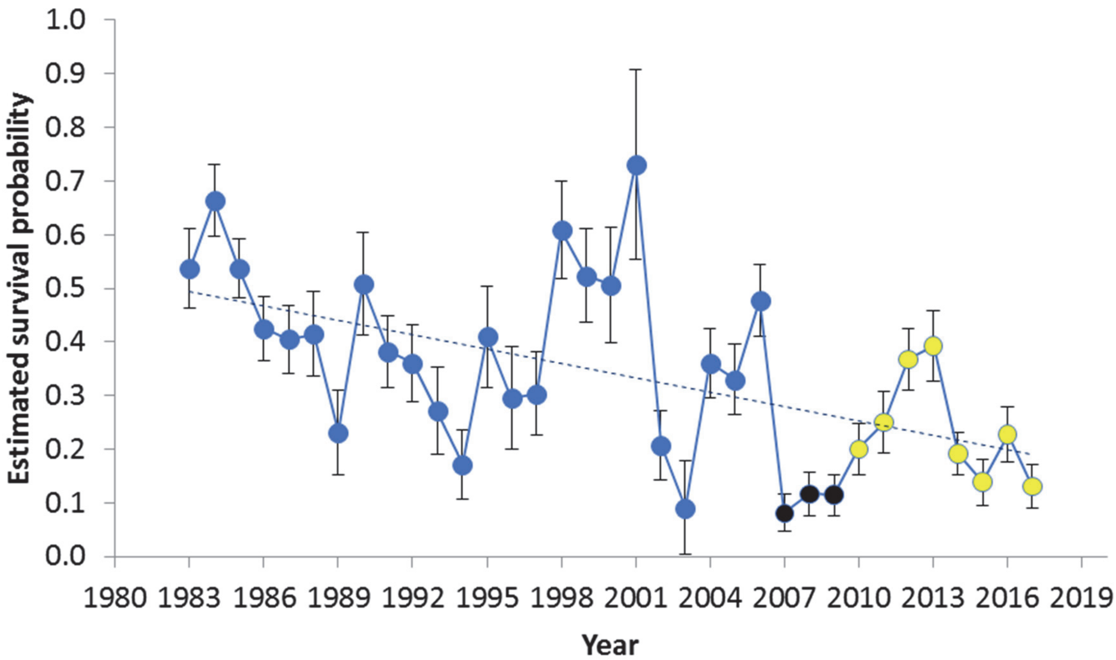

Figure 1.2. Estimated first-year (fledging to age one year) survival probabilities of choughs fledged in Islay, calculated from ring-resighting data. Survival varies markedly among years and is positively correlated with tipulid larvae abundance (Reid et al., 2008), but has decreased on average across years (dotted line). Black points highlight three consecutive cohorts that experienced very low survival, in 2007-2009. Yellow points highlight cohorts that received supplementary feeding (but note that not all fledged individuals received feeding). Blue points denote previous years.

Through discussions within the Scottish Chough Forum (involving representatives from Scottish Natural Heritage, local Chough Study Groups, Royal Society for the Protection of Birds, Universities of Aberdeen and Glasgow, and Scotland's Rural College), it was decided to initiate a programme of supplementary feeding targeted at the sub-adult choughs on Islay (Bignal & Bignal, 2011). Supplementary feeding was initially trialled in the 2009/10 winter. Supplementary feeding was then implemented at one feeding site from June 2010 and at two additional sites from July 2011, and carried out to date (i.e. spring 2019). Funding for this feeding program up to spring 2019 was primarily provided by Scottish Natural Heritage (Section 3).

During this time, veterinary post-mortem examinations of choughs found dead on Islay during 2004-2018 revealed parasite burdens high enough to have caused mortality (Pennycott, 2016, Section 5). In particular, choughs have been found to be affected by the respiratory and alimentary tract parasites gapeworm (*Syngamus* sp.), hairworm (*Eucoleus* sp.), thorny-headed worm (Genus *Plagiorhynchus*) and gizzard worm (*Streptocara* sp.). Parasite infections may therefore be another ecological factor contributing to the low survival of sub-adult choughs. A program of trapping individual choughs displaying signs of parasite infection and treating them with an antihelminthic (under SNH licence) was therefore started in 2014.

Alongside the ecological threats stemming from food shortage and parasites, recent research highlighted that the Scottish chough population is also facing genetic threats to its persistence. The Scottish populations are known to be isolated from other British Isles chough populations, as evidenced by high genetic differentiation, lack of observations of the exchange of colour-ringed birds between populations, and functional extinction of neighbouring chough populations (e.g. in Northern Ireland and Kintyre, Wenzel *et al.,* 2012; Hayhow *et al.,* 2018). The Scottish chough populations also have low genetic diversity compared to the larger continental European chough populations (Wenzel *et al*., 2012). The small size of the Scottish chough populations and their isolation mean that inbreeding is inevitable. High levels of inbreeding commonly leads to decreased survival and/or reproductive success (known as 'inbreeding depression') and can thereby decrease population viability (Keller & Waller, 2002). Furthermore, Islay's chough population has a critically small 'effective population size', meaning that the current population is genetically equivalent to only ~30 individuals. This means that the population will lose further genetic diversity, and become increasing inbred, relatively rapidly over future generations (Trask *et al*., 2017). Indeed, the population is already experiencing detrimental effects of inbreeding, including genetic effects that cause developmental abnormalities resulting in blindness and consequent mortality of chough nestlings (Trask *et al*., 2016).

This combination of ecological and genetic threats to the persistence of the Scottish chough population generates challenges for conservation management. If chough survival and/or reproductive success is limited by inbreeding depression, then resources invested in grassland management, supplementary feeding and parasite treatments (i.e. 'ecological management') may not have the desired effects of reversing the population decrease and ensuring the persistence of choughs in Scotland (Figure 1.3). Management to reduce inbreeding through population reinforcements, where choughs from other populations are translocated into the Scottish chough population (i.e. 'genetic management') therefore needs to be considered alongside ecological management. However, genetic management may itself be ineffective, and hence a waste of resources, if inbreeding is in fact a minor contributor to the population decrease compared to ecology.

Given the current perilous state of the Scottish chough population (small and decreasing population size and highly restricted geographical range), evaluation of the efficacy of different potential ecological and genetic management strategies to increase population size and viability was recognised as essential. This would then provide the evidence base required to inform conservation management and policy decisions and enable Scottish Natural Heritage, and hence Scottish Government, to fulfil their statutory commitments to conserving Scottish biodiversity.

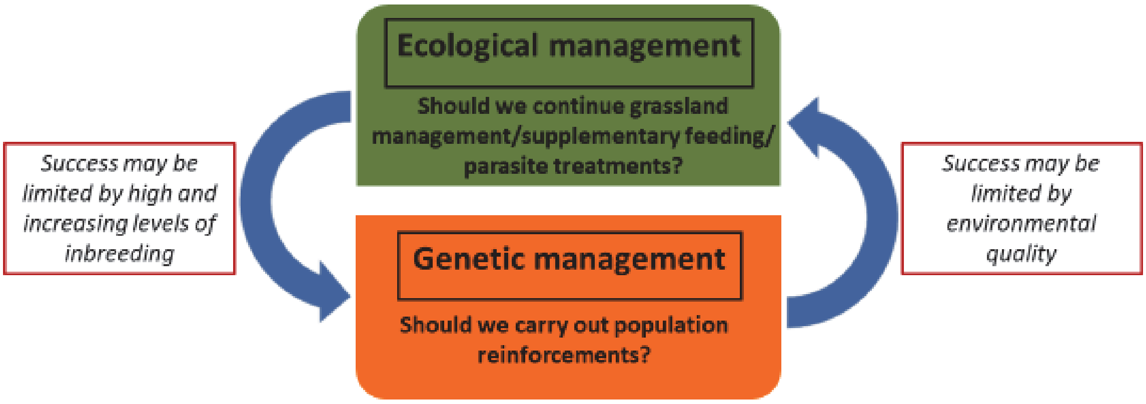

Figure 1.3. A conservation challenge: continuation of current ecological management strategies (i.e. grassland management, supplementary feeding and parasite treatments) may fail to achieve management goals of increasing the size and persistence probability of the Scottish chough population if the population is experiencing high levels of inbreeding and resulting inbreeding depression. Conversely, initiating genetic management through population reinforcements to reduce inbreeding may also fail to achieve management goals if inbreeding is a minor constraint on population persistence compared to ecological threats.

1.2 Overview of the project

This project involved work carried out as part of three separate contracts from SNH to Scottish Chough Study Group (SCSG) and University of Aberdeen:

1: Demographic monitoring and supplementary feeding (2010-2014)

Trialling and then implementation of a supplementary feeding program for choughs on Islay, in response to the unsustainably low first-year survival rates observed in 2007-2009 (Reid *et al*., 2011, Fig. 1.4).

Annual demographic monitoring of Islay's chough population, comprising continuation of the long-term monitoring of population size, breeding success and age-specific survival, and initiation of additional intensive monitoring of individual use of the supplementary feeding.

2: Demographic monitoring and supplementary feeding (2015-2019)

Continuation of the supplementary feeding program for choughs on Islay (Fig. 1.4), and continuation of both annual demographic monitoring and monitoring of individual use of the supplementary food (as above).

Initial analysis of the demographic data, to provide preliminary evaluation of the efficacy of the supplementary feeding in increasing key demographic rates and population viability.

3: Population viability analysis and evaluation of future management strategies (2018-2019)

Construction and analysis of a population model that incorporates both ecological and genetic threats to the Scottish chough population. Use of the model to evaluate the efficacy of different potential management strategies to achieve medium-term viability of the Scottish chough population, including scenarios of (1) ceasing current supplementary feeding, (2) ceasing supplementary feeding and initiating population reinforcements, (3) continuing supplementary feeding, (4) continuing supplementary feeding and initiating population reinforcements.

To summarise these results in the context of informing next steps for chough conservation and evaluating the case for population reinforcements.

In addition, a *NERC iCASE PhD studentship* supported by SNH is ongoing *(2017-2021)*. The aim of this studentship (awarded to Sarah Fenn, University of Aberdeen) is to use all available demographic data to quantify the full effects of supplementary feeding on the demography and dynamics of Islay's chough population.

The purpose of this report is therefore to fully summarise all work undertaken under the three contracts from SNH. This includes initial analyses of the effects of supplementary feeding, with full analyses to be delivered on completion of the PhD studentship.

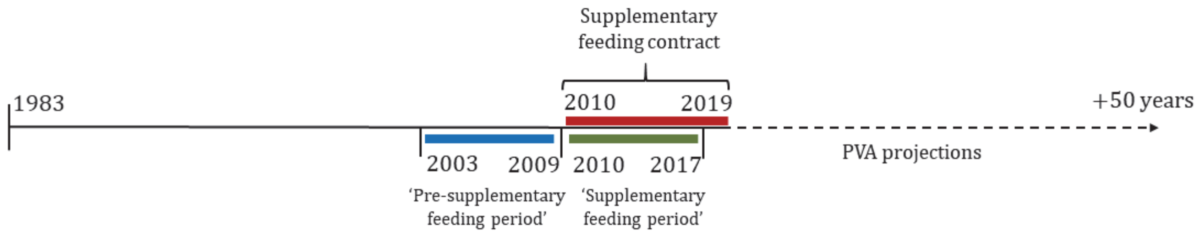

Figure 1.4. Schematic of the timeframe of the Islay red-billed chough study. Demographic monitoring of Islay's chough population has been on-going since 1983 (solid black line). Supplementary feeding was started in winter 2009/2010, and continued to 2019 (red line). Analyses of the effects of supplementary feeding (Section 4) use data from the designated feeding years 2009/2010 to 2017/2018 ('supplementary feeding period', green line) in comparison to designated pre-feeding years 2003/2004 to 2009/2010 ('pre-supplementary feeding period', blue line). The Population Viability Analysis (PVA, Section 7) projects 50 years into the future (dotted black line). The PVA 'baseline model' uses data from the pre-feeding period. Effects of supplementary feeding used in the PVA's 'ecological management scenario' are estimated from the feeding period compared to the pre-feeding period.

1.3 Objectives of the report

This report provides an overview of the contracted work for conservation of the Scottish chough population from 2010-2019 (Section 1.2). This work focused on the chough population on Islay. However, the chough population on Colonsay is also declining, and overall management recommendations will likely also be highly relevant to this population.

Specifically, the report addresses the following six aims, to:

- Summarise the annual demographic monitoring that was carried out on Islay during 2010-2019;
- Summarise the supplementary feeding programme that was carried out on Islay during 2010-2019;
- Summarise the parasite treatment program that was carried out on Islay during 2014-2018;
- Provide an assessment of the combined effects of the supplementary feeding and parasite treatments on key demographic rates of Islay's chough population;
- Evaluate different ecological and genetic management strategies to increase population size and support long-term population persistence, using population viability analysis; and
- Provide recommendations for key next steps in Scottish chough conservation policy and management strategy, which are vital to ensure persistence of choughs in Scotland.

2. ANNUAL MONITORING

Summary:

- Demographic monitoring of Islay's chough population has been successfully undertaken each year during the supplementary feeding programme (i.e. 2010-2019), thereby extending the long-term demographic dataset.
- Overall, 320 breeding attempts have been monitored (~81% of those made) and 779 fledglings were colour-ringed. Individuals in all age-classes were resighted with high efficiency, yielding an annual resighting probability close to one.

Islay's chough population has been the focus of a long-term demographic monitoring study, run primarily by the SCSG and with input from RSPB, since 1983 (Figure 1.4). Each year during the breeding season (March – July), a sample of accessible nest sites across Islay have been visited to monitor breeding success and ring nestlings with unique combinations of coloured rings. These individuals can then subsequently be identified by their colour-rings, allowing survival probabilities to be estimated from resighting data (e.g. Reid *et al*., 2004). During 1983-2018, >2000 nestlings have been colour-ringed on Islay and >1700 breeding attempts have been monitored. Each year a complete population census has also been undertaken, supported by complete geographical surveys in the national chough census years (Hayhow *et al*., 2018). This has included identifying virtually all surviving adult and sub-adult individuals with high intensity, such that re-sighting rate of ringed individuals each year is close to one. Unusually high-quality demographic data consequently exist for the population, allowing detailed analysis of population demography, ecology and dynamics (e.g. Reid *et al*., 2003a, 2004, 2008). Nest site visits are carried out under SNH licence, following protocols designed to minimize disturbance to breeding pairs.

Additionally, DNA samples were collected during 2012-2014 by collecting naturally moulted feathers, carcasses from natural mortalities, and blood sampling of nestlings (under Home Office licence PIL60/14021), allowing molecular genetic analyses.

The resulting demographic and molecular genetic datasets provide critical and highly valuable resources from which to assess population viability and consider potential management strategies. Furthermore, this system and dataset has broader value to conservation science by providing a rigorous case-study of the processes contributing to a population decline and potential routes to recovery.

This annual demographic monitoring was successfully carried out during 2010-2019, thereby fulfilling the current contract. A summary of total numbers of nest sites surveyed, nest sites where egg laying occurred that were monitored, and nestlings ringed, and of chough breeding success, is shown in Table 2.1. Detailed annual monitoring reports are in Annex 1.

Table 2.1. Summaries of the annual survey of occupied and unoccupied breeding sites, annual breeding season monitoring effort, and annual chough breeding success on Islay. Totals number of nest sites from which egg laying was recorded/reported/assumed, and number of nestlings ringed across all the monitored sites are shown. Total number of fledged young (observed directly or reported by others) across all sites where breeding was attempted, mean number of fledged young per visited site, and mean number of fledged young per site where egg-laying was recorded directly are also shown.

Year	Annual survey of total breeding pairs		Annual breeding season monitoring effort		Annual chough breeding success		
	Total number of occupied sites	Total number of unoccupied sites	No. sites from which egg laying was recorded/reported/ assumed	No. of nestlings ringed	No. fledged young across sites where breeding was attempted	Mean no. fledged young per visited site	Mean no. fledged young per site with recorded egg-laying
2010	43	21	32	70	82	2.05	2.56
2011	41	12	28	61	81	1.38	2.85
2012	42	17	33	73	87	1.38	2.64
2013	39	19	36	55	64	0.93	1.72
2014	46	10	44	94	94	1.27	2.59
2015	48	11	30	65	69	1.21	2.30
2016	46	15	29	66	70	1.23	2.41
2017	47	16	29	69	71	1.18	2.45
2018	43	17	26	67	74	1.23	2.85
Grand total			**320**	**779**	**693**		
Grand mean						**1.32**	**2.50**

3. SUPPLEMENTARY FEEDING PROTOCOLS

Summary:

- Supplementary feeding of Islay's chough population was carried out from December 2009 to April 2019 (as contracted, Section 1.2).
- Supplementary feeding has occurred at three sites on Islay; Ardnave, Coull and Sanaig.
- Feeding was managed to avoid changes in the choughs' natural behaviours, by being carried out pre- or post-roosting and in locations where choughs have been observed to naturally forage.
- Feeding was managed to avoid parasite transmission by utilising sandy areas (i.e. not areas where key intermediate host species of parasites are likely to be present), by regularly cleaning feeding sites, or by changing location.

3.1 Initiation of supplementary feeding

Supplementary feeding on Islay was primarily intended to increase food availability for sub-adult choughs, and protocols were designed accordingly. On Islay, observations of colour-ringed and thus known-age choughs suggest some degree of social segregation between adults and sub-adults, with sub-adults tending to forage and roost together in flocks that are discrete from the adults (Bignal *et al.,* 1997; Still *et al.,* 1987). Observations also suggested that individuals in the sub-adult flock tend to feed together pre-roosting (about an hour before communal roosting), close to two main communal roosting areas in the north of the Rhinns of Islay (Ardnave and Coull). These observations of the choughs' social behaviour meant that supplementary feeding could be carried out to target the sub-adult choughs soon after fledging, by carrying out supplementary feeding in the vicinity of the two main communal roosting areas during the pre-roosting or post-roosting period.

Supplementary feeding was first trialled in December 2009 using live mealworms (Bignal & Bignal, 2011). During the first attempts, small heaps of mealworms were provided during the pre-roosting period at a range of sites in areas where pre-roost foraging had previously been recorded, and which could be observed from a distance. These first attempts were unsuccessful in attracting the birds to feed; few choughs showed any interest in the mealworms and none attempted to eat them. Further, it was difficult to put down food without scaring the choughs away, often for long distances. Eventually, a site where choughs had been observed feeding on blow-fly larvae from a sheep carcass was trialled. One chough started feeding on the provided mealworms, and over several days others gradually followed.

3.2 Supplementary food provided

The supplementary food consisted of live mealworms, pinhead oats and suet pellets. Up to 150g mealworms and 1.5 kg of pinhead oats were put out on each feeding occasion, with suet pellets only used occasionally when weather conditions are particularly unfavourable for choughs to forage. Use of large quantities of mealworms has required setting up a mealworm 'farm', to generate the required amounts of live mealworms. This has principally been managed by Sue Bignal (SCSG).

3.3 Supplementary feeding sites

Supplementary feeding has been carried out at three sites on Islay; Ardnave, Sanaig and Coull/Kilchoman (Figure 3.1). The results of the supplementary feeding at the three sites are detailed in a series of interim reports to SNH (Annex 1), with the feeding protocol at each site outlined below.

Figure 3.1. Locations of the three supplemenatry feeding sites on the Isle of Islay. A-C corresponds to the Ardnave, Sanaig and Coull areas.

3.3.1 Ardnave feeding area

After the initial trial feeding in December 2009, supplementary feeding was carried out every few days in the Ardnave area (Figure 3.1 & 3.2) through to the start of the 2010 breeding season (i.e. mid-March), when all choughs except the local breeding pairs left the area.

Supplementary feeding was then resumed almost every day after the 2010 breeding season ended (i.e. June), when choughs returned to the area. Supplementary feeding has since continued daily each year through to 2019, with a break during each breeding season (between mid-March and late June, depending on the timing of breeding and fledging each year). Originally the only food provided was live mealworms, but from July 2011 pinhead oatmeal and suet pellets were additionally provided.

3.3.2 Coull feeding area

Observations of colour-ringed choughs suggested that a second sub-adult flock regularly fed in the Coull/Kilchoman area of Islay (Figure 3.1). This second flock was originally intended to be used as an unfed ‘control’ group, so that survival between sub-adults that did and did not receive supplementary food could be compared. However, a stark contrast in survival was observed in the spring of 2011 between the sub-adults receiving supplementary food at Ardnave compared to the unfed sub-adult flock at Coull; 0 out of a flock of 32 sub-adults at Coull survived, while ~74% (14 out of 19) of the sub-adult flock at Ardnave were still alive.

In response to this critically low survival, SCSG decided to initiate emergency supplementary feeding at Coull in addition to Ardnave. As at Ardnave, observations of chough foraging sites at Coull were used to inform the supplementary feeding strategy; in July 2011 two breeding pairs accompanied by their nine fledglings were observed to start feeding on blowfly larvae at the Coull farm animal burial pit. This provided an ideal opportunity to initiate the supplementary feeding at Coull, and this commenced on a daily basis from 6th July 2011. Supplementary feeding at Coull was initially carried out during the pre-roosting foraging period, but subsequently was carried out during the chough's natural post-roosting (i.e. early morning) foraging period to fit better with farm management at Coull.

3.3.3 Sanaig feeding area

In addition to the emergency feeding implemented at Coull, supplementary feeding was also introduced at Sanaig in 2011. Again, observations of chough foraging sites at Sanaig were used to inform the supplementary feeding strategy: in early July 2011 the Sanaig breeding pair and their three fledglings were observed feeding in the Sanaig farm burial area in the Braigo sand dunes. This provided an ideal opportunity to initiate the supplementary feeding at Sanaig, and this commenced on a daily basis from 8th July 2011. In several of the following years, colour-ringed sub-adults that were mostly from the Ardnave flock were also observed to attend the supplementary feeding here.

Figure 3.2. Chough feeding on the live mealworms supplied at the Ardnave feeding site. Colour-ring combinations of the attending individuals are recorded on each feeding occasion at Ardnave, so that detailed data on individual use of the supplementary feed is available.

3.4 Managing the feeding to avoid changes in behaviour

By carrying out the supplementary feeding pre- or post-roosting and in the vicinity of the main communal roost sites, the feeding was designed to interfere as little as possible with the normal daily routine and behaviour of the choughs. Additionally, feeding sites were selected to minimize human disturbance to the birds; all feeding sites were at some distance from places where birdwatchers and tourists frequent and there was no publicity about the feeding. In the few cases where people did come to watch the feeding, because choughs feeding in a flock can be noisy and conspicuous, it was explained to them that being in the area was not appropriate. Most people were happy to move away, or in a few cases when possible, stayed with SCSG to watch the birds.

One unavoidable behavioural change has been the reaction of the choughs attending the supplementary feeding to the vehicle delivering food. At the start of the supplementary feeding the choughs flew away some distance when the vehicle arrived and food was put out, and came back gradually. However, after a while this response decreased and now the choughs come to meet the vehicle arriving to put out the food. However, this response to the vehicle may not be problematic because if visiting the area outside the normal feeding time (in the same vehicle) there are few choughs present in the feeding area, and therefore there is little response to the vehicle. When other vehicles pass the feeding area before or at feeding time, the choughs have been observed to show no response. This therefore suggest that the choughs can recognise the vehicle that delivers the food and the response is specific to that vehicle.

3.5 Managing the feeding sites to minimize the risk of parasite and pathogen transmission

Provisioning of supplementary food can be associated with increased risk of parasite and pathogen (e.g. bacterial, viral, fungal, protozoal) infection and spread in the receiving population, for example through increased contact between hosts and/or promoting parasite and pathogen accumulation at feeding sites (Murray *et al.,* 2016). Several different parasites and pathogens have been shown to affect chough on Islay (Annex 2, Section 4), in particular the bacterial pathogen *Yersinia pseudotuberculosis* and the internal parasites gapeworm (*Syngamus* sp.), hairworm (*Eucoleus* sp., previously *Capillaria*), thorny-headed worm (Genus *Plagiorhynchus*) and gizzard worm (*Streptocara* sp.).

Parasites and pathogens that can be transmitted directly between birds, as opposed to requiring an intermediate host (i.e. a host that is required for a parasite to complete a developmental stage) or commonly using a transport host (i.e. a host that is not required for development, but aids in transmission), may be of particular concern at supplementary feeding sites. *Y. pseudotuberculosis* is likely to be acquired from the main reservoir species such as rodents, lagomorphs and wild birds such as pigeons and doves, but could also be transmitted directly between choughs. Gapeworms can be transmitted directly, through birds accidentally consuming eggs from the faeces of infected birds, but more frequently indirectly through transport hosts such as earthworms and leatherjackets (crane fly larvae, Fernando & Barta, 2008). Some hairworm species can also be transmitted directly but often use earthworms as transport hosts, while other hairworm species can only be transmitted through earthworm intermediate hosts (Yabsley, 2008). Gizzard worms (Genus *Streptocara*) and thorny-headed worms (Genus *Plagiorhynchus*) are both transmitted indirectly through intermediate hosts such as sandhoppers and woodlice (Carreno, 2008; Lisitsyna 2011), and therefore may be less of a concern at the supplementary feeding sites.

As a precaution, supplementary feeding was managed to minimize the risk that it could contribute to parasite or pathogen infection or spread in Islay choughs. As the intermediate or transport host species of the major parasites recorded in Islay chough primarily live in soil or rotting vegetation, all supplementary feeding was carried out in areas of bare sand. To minimize the risk of direct parasite or pathogen transmission through ingestion of infected faeces at the feeding sites, each of the sandy feeding areas has been periodically scraped to remove the top layer and replaced with clean sand (Figure 3.3). Furthermore, at Coull where there are multiple sandy areas, the feeding locations have also been periodically changed.

However, transmission of parasites at the supplementary feeding may be unlikely to be a major source of infections in choughs on Islay because symptoms of parasite infection have been observed in individuals at the nestling stage, and thus before these individuals could have attended the supplementary feed (Section 4). Furthermore, post-mortems after natural mortalities of sub-adults that were never observed attending the supplementary feed have also revealed the presence of pathogens and parasites. Indeed, since the start of the supplementary feeding only one unaffected adult has been observed to subsequently display symptoms of pathogen infection (Section 4), despite many adults having regularly visited the supplementary feeding for the entire period.

Figure 3.3 Photo showing removal of the top layer of sand at the Ardnave supplementary feeding site, to avoid any build-up of parasites and pathogens at the site.

4. PARASITE TREATMENTS

Summary:

- High burdens of respiratory and alimentary tract parasites have been found in sub-adult choughs, potentially acting as an additional source of mortality.
- Trapping and treating of individuals showing signs of parasite infection was undertaken during 2014-2018.
- Subsequent survival of treated sub-adults appears to be high.
- Birds could only be trapped and treated while attending the supplementary feeding, providing a secondary advantage of the feeding intervention.

4.1 Treatment justification and protocol

Recent post-mortem examinations of choughs found dead on Islay have identified several parasites and pathogens (Annex 2). However, of particular concern is the finding of pathologically significant parasite burdens in 14 out of 24 individuals examined from 2004-2018 (Table 4.1). Parasites may therefore represent an additional source of mortality in the Islay chough population (T. Pennycott, *pers. comm.*). The most common pathologically significant parasites were respiratory and alimentary tract parasites, in particular gapeworms (*Syngamus trachea*), hairworms (*Eucoleus* sp.), gizzard worms (Genus *Streptocara*) and thorny-headed worms (Genus *Plagioryhnchus,* Table 4.1). In response, it was decided to begin treating birds showing symptoms of parasite infections with an antihelminthic during 2014-2018.

Table 4.1. Major parasite types detected at post-mortem examination within adult, sub-adult or unknown age choughs diagnosed with pathologically significant helminth burdens, and number found with no or non-significant helminth burdens. Note: some of these parasites co-occurred within individuals and thus column totals do not equal numbers of individuals of each age group examined (N).

Parasite type	**Adults (*N*=8)**	**Subadult (*N*=15)**	**Unknown age (*N*=1)**
Gapeworms	1	7	1
Gizzard worms	1	6	0
Thorny-headed worms	1	8	0
Hairworms	1	1	1
No/non-significant helminth burdens	6	4	0

Signs of respiratory tract parasitism in live birds are breathing difficulties that cause gaping with open bill, head shaking, coughing and “sneezing” (Figure 4.1c&d). Infected nestlings at 2-3 weeks post-hatch were identified and treated during routine nest-site visits to colour-ring and monitor breeding success. Infected sub-adult birds were identified through observations at the supplementary feeding sites, which allow an opportunity for detailed individual observations. These birds were individually trapped using a specially designed cage trap (Figure 4.1a), treated and released by SCSG. This method of individual trapping was extremely time-consuming and became more difficult if the target individual’s symptoms got worse and it fed less vigorously. If possible, sick birds needed to be identified and treated as soon as symptoms were visible.

Infected individuals were given the antihelminthic treatment Ivermectin, available commercially as 0.08% w/v in Noromectin (oral sheep drench). This was administered orally in a solution of propylene glycol (we used Provita Energy Plus – a nutritional supplement for sheep composed of Propylene glycol with added cobalt and vitamin B12). Using a solution of 1ml of Noromectin in 4.5ml of Provita, birds were treated at the rate of 0.14ml per 100g (approximating, allowing for field conditions, to the recommended dose of 200micrograms/kg in the BSAVA Manual of Exotic Pets). This treatment was approved by Beth Newman Veterinarian MVB, MRCVS and is known to be effective in chickens with similar signs of infection. It was carried out under licence issued by SNH (see Figure 4.1b).

Figure 4.1 Photos of (a) the trap used to capture individual choughs showing signs of parasite infection, (b) orally administering antihelminthic treatment to an infected bird, (c) and (d) a sub-adult and nestling choughs respectively, showing characteristic open beak associated with heavy gapeworm infection.

4.2 Summary of treated birds and subsequent survival

During 2014-2018, 62 sub-adults and one adult chough were individually caught at the supplementary feeding sites and treated for parasites (Table 4.2). Captured individuals were often very thin; mean weight was 311g (±5g SE) with the worst affected individuals being only 255g. As a comparison, an adult male chough can weigh 395g, while nestlings at ringing age can weigh 300g (Bignal, unpublished data). Subsequent observations of treated individuals at the supplementary feeding sites showed that all ceased showing symptoms of infection within two or three days after treatment, and none showed signs of re-infection. Catching and treating of infected individuals took place between July and September each year. The mean proportion of treated first-year individuals that survived to age one was 0.45 (i.e. survival from treatment to age 1, Table 4.2). However, it is important to note that this survival cannot be directly compared to first-year survival of non-treated birds as measured from fledging to age one. Mean subsequent survival of treated sub-adults from age 1 to age 2 was relatively high (mean across the 2014-2016 cohorts was 0.83, Table 4.2).

Table 4.2 Numbers of first-year (fledging to age one) choughs from each cohort that were caught and treated for parasites each year. The proportion that survived from date of treatment to age one, and of those surviving (N), the proportion that survived from age one to age two are shown.

Cohort	No. treated	Treatment dates	Survival from treatment to age 1	Survival from age 1 to age 2 (*N*)
2014	20	Aug-Sept	0.60	0.58 (12)
2015	3	Aug-Sept	0.33	1.00 (1)
2016	20*	July-Sept	0.60	0.92 (12)
2017	11	Aug-Sept	0.27	-
2018	8	Sept	-	-

*In 2016, one additional adult chough was also treated for parasites, such that the total treated individuals was 21.

During 2016-2018, 45 nestlings from 14 broods were also treated for parasites during routine nest-site visits (Table 4.3). The mean proportion of treated nestlings that survived to age one was 0.19 (across the 2016 and 2017 cohorts, Table 4.3). This is comparable to the mean first-year survival across all individuals in the 2016 and 2017 cohorts of ~0.18. Of the two treated nestlings that survived to age 1 from 2016, both subsequently survived to age 2. However, the effect of parasite treatment on survival is difficult to determine because only obviously infected individuals were treated, and there is no untreated infected control group for comparison.

Table 4.3 Numbers of nestling choughs that were treated for parasites each year. The proportion that survived to age one, and of those surviving (N), the proportion that survived from age one to age two are shown. – indicates data not yet collected at time of analysis.

Treatment year	No. treated	Prop. surviving to age 1	Prop. surviving to age 2 (*N*)
2016	7	0.29	1.00 (2)
2017	13	0.08	-
2018	25	-	-

4.3 Parasites and chough conservation

Parasites and pathogens have been implicated as a major causal factor in the decline of a variety of threatened populations (e.g. avian malaria in Hawaiian avifauna, Warner, 1968; white-nosed syndrome in bats, Thogmartin *et al*., 2013; chytridiomycosis in amphibians, Hudson *et al*., 2016), and are also likely to be a contributing factor to many other population declines (Preece *et al*., 2017). In particular, threatened populations are often small and isolated, leading to low genetic diversity and high levels of inbreeding (Keller & Waller, 2002). High levels of inbreeding can be associated with decreased immunocompetence (Reid *et al.,* 2003b) and high parasite abundances (Whiteman *et al.,* 2006). Additionally, low genetic diversity can decrease 'herd immunity' and compromise a population's ability to adapt to any emerging infectious diseases (Lyles *et al.,* 1993). Islay's chough population is known have relatively low genetic diversity (Wenzel *et al*., 2012), small 'effective population size' (Trask *et al*., 2017), and is likely to have high levels of inbreeding. These choughs may consequently be more susceptible to parasites than more outbred and genetically diverse populations.

Poor host condition is also known to increase susceptibility to parasites and pathogens (Beldomenico & Begon, 2010). High burdens can then further decrease body condition, leading to a 'vicious circle' of deteriorating body condition and further infections (Beldomenico *et al*., 2008; Beldomenico & Begon, 2010). Islay's chough population is likely to be experiencing environmental stress from low food availability and/ or abundance that could lead to poor average condition of individuals. In turn, this could also contribute to increased parasite susceptibility in the population.

In addition, decreased abundance or availability of the choughs' principle food sources, such as dung invertebrates and leatherjackets, may lead to individuals utilizing alternative food sources that could be the intermediate hosts for new parasites. In particular, alternative prey species could include sandhoppers (Family Talitridae), which are an intermediate host species for gizzard worms and thorny-headed worms, and earthworms, which are an intermediate host species for gapeworms. Both of these have been observed during post-mortems of Islay choughs (Table 4.1, Pennycott, 2016). Indeed, sandhoppers and earthworms were not previously detected in an assessment of chough diet on Islay during 1986-1989 (McCracken *et al.,* 1992), however a recent assessment in 2011-13 did find evidence of both sandhoppers and earthworms (MacGillivray *et al.,* 2018).

On Islay, the presence of gapeworms has previously been recorded in nestling and sub-adult choughs during a study conducted 1979-85 (Bignal *et al.,* 1987). Gapeworms were also recorded in the historical Cornish chough population before its extinction (Haycock, 1975), as well as in choughs that appeared subsequently in Cornwall (Meyer & Simpson, 1988). Gapeworms have also been observed in the recently reintroduced population of choughs on Jersey (L. Corry, *pers. comm.*). In contrast, gizzard worms and thorny-headed worms, first identified in Islay choughs in 2010, have not been previously recorded in choughs in the UK.

5. EXTENT OF SUPPLEMENTARY FEEDING

Summary:

- Intensive effort has gone into providing supplementary food to choughs on Islay on a daily basis from June/July through to the following April every year during 2010-2019.
- Intensive effort has also gone into recording colour-ringed individuals visiting the feed on every feeding occasion at the Ardnave and Sanaig feeding sites, and on some feeding occasions at the Coull feeding site.
- Chough attendance at the supplementary feeding sites has increased across years, with most surviving colour-ringed choughs in the population now having been recorded attending a feeding site at least once in recent years.

5.1 Summary of the supplementary feeding effort

Since the start of the supplementary feeding program, intensive effort has gone into both providing supplementary food and recording identities of individuals that attend the feeding, thereby providing the data required to assess the effectiveness of the feeding in increasing key demographic rates. Supplementary food has been provided at Ardnave on average ~254 days a year, and at Sanaig ~187 days a year when choughs were present at the site (Table 5.1). Supplementary food was also provided at Coull most days throughout the year since 2011, however recording of colour ringed individuals attending the feed was less intensive at this site; recordings of colour ringed choughs attending the feed were carried out on average ~31 days each year (Table 5.1). In total there have been ~87,453 colour-ring resightings collected of individuals attending the supplementary feeding (Table 5.1).

The feeding and observations were carried out by Eric and Sue Bignal at Ardnave and Sanaig, and by Donald Jones at Coull, representing substantial time commitments.

Table 5.1 Number of days that supplementary feeding and recording of attending colour-ringed choughs were carried out at the Ardnave, Sanaig and Coull feeding sites, and total number of re-sightings of attending colour-ringed choughs each year. Similar regimes of feeding and observations were carried out during 2018-2019, but the data are not yet fully computerised or summarised.

Year	Number of days of supplementary feeding and colour-ring resighting			Total no. of colour-ring re-sightings
	Ardnave	*Coull**	*Sanaig*	
2010-11	228	NA	NA	5603
2011-12	244	29	39	8979
2012-13	295	30	233	13,017
2013-14	246	32	200	12,313
2014-15	296	25	0	16,852
2015-16	215	23	274	11,304
2016-17	252	44	0	9878
2017-18	259	44	65	9507

*At Coull, colour-ring resightings were not carried out every day that supplementary food was provided. The total number of days on which food was provided was similar to that at Ardnave.

5.2 Attendance at the supplementary feed

After the first year, when supplementary feeding was only carried out at Ardnave, most colour-ringed choughs known to be alive on Islay were observed at a feeding site at least once (Table

5.2). Although the feeding was designed to primarily target sub-adult choughs, adults also commonly used the supplementary feed. Of the adult choughs (i.e. aged three years or older) alive across the supplementary feeding period (Figure 1.4), 87% (91/105) were observed at the supplementary feed at least once.

However, individuals differed in the regularity of attending the feed; across the supplementary feeding period 69 adults regularly attended the supplementary feeding sites, while 36 only occasionally or never visited the feeding sites. This difference in regularity of attending the feed was used to classify individuals as having been supplementary fed (hereafter 'fed') or not (hereafter 'unfed', Section 6). Adult attendance at the feed increased across years, with the fed proportion of the adult population increasing from 23% in 2010 to 69% in 2017 (Table 5.2).

Table 5.2 Total numbers of colour-ringed choughs (recorded alive just after each cohort of nestlings is colour-ringed each year) and percentage recorded attending the supplementary feeding, and total numbers of colour-ringed adults and percentage that regularly attended the supplementary feeding each year.

Year	**All ages**		**Adults**	
	% of individuals *recorded* at a feeding site *	Total number of colour-ringed individuals	% adults *regularly fed* at a feeding site	Total number of colour-ringed adults
2010-11	48	120	23	39
2011-12	91	110	41	37
2012-13	84	135	45	38
2013-14	87	130	52	44
2014-15	91	182	57	51
2015-16	83	156	71	61
2016-17	86	144	69	64
2017-18	85	150	69	67

*includes all colour-ringed individuals observed attending the supplementary feed regardless of frequency of attendance.

6. PRELIMINARY SUMMARY OF EFFECTS OF SUPPLEMENTARY FEEDING

Summary:

- Preliminary analyses show that supplementary feeding has had clear positive effects in increasing key demographic rates in Islay's choughs.
- Across the years of feeding, first-year survival rates (i.e. fledging to age 1) were consistently higher for fed individuals than unfed individuals.
- Almost all one-year old individuals attended the supplementary feeding and second year survival rates (i.e. age 1 to age 2) across the years of feeding was comparable to the long-term average.
- Adult survival probability (i.e. individuals age 3 or older) increased in fed areas but remained the same in unfed areas compared to years before feeding started.
- Overall breeding success increased in fed areas but remained the same in unfed areas. This was mainly driven by an increase in the proportion of pairs successfully rearing a brood, as opposed to a change in brood size.
- There were differences both within and between cohorts in the regularity and frequency of visits to the supplementary feeding, suggesting individuals do not become 'tied' to the supplementary feeding areas.

6.1 Estimation of the effect of supplementary feeding on sub-adult survival

Full analyses of effects of supplementary feeding on sub-adult survival rates are currently ongoing as part of a *NERC iCASE PhD studentship (2017-2021)* awarded to Sarah Fenn (as detailed in Section 1.2). However, a summary analysis was undertaken to inform the current report and population viability analysis (Section 7), and is presented here.

Individuals attending the supplementary feed that were observed to display signs of parasite infection were also caught and parasite-treated where possible. Any effects of supplementary feeding and parasite treatments on subsequent survival and reproductive rates could therefore not be separated; effects of supplementary feeding presented in this report therefore represent the combined effects of supplementary feeding and parasite treatments.

6.1.1 First-year survival

Due to high annual resighting probabilities of colour-ringed individuals, the impact of supplementary feeding on first-year survival (i.e. fledging to age one) was estimated by direct comparison between the proportion of colour-ringed fledglings that were fed versus unfed that survived to age one. Colour-ringed sub-adults were classed as fed or unfed depending on how often they were observed attending the supplementary feeding; individuals were classed as fed if they were observed at least once at the Coull feeding site or at least five times at the Ardnave feeding site (to account for lower resighting effort at Coull compared to at Ardnave). Thirty-seven fledglings that died before mid-July (i.e. before supplementary feeding was started each year) were removed from the analysis as this could downwardly bias survival rates of the unfed group.

The proportion of fledglings that survived to age one was consistently higher for those that were fed compared to those that were unfed (Figure 6.1a). The mean proportion of fed and unfed fledglings surviving to age one was 0.45 ± 0.07 SE (N=273) and 0.05 ± 0.03 SE (N=175) respectively, across the years of feeding. The survival of fed fledglings to age one is therefore comparable to the long-term pre- population collapse (1983 - 2006) average first-year survival probability of ~0.41 (Reid *et al.*, 2008).

6.1.2 Second-year survival

For estimation of the effect of supplementary feeding on second-year survival (i.e. age one to age two), direct comparison between the proportions of fed and unfed one-year old choughs that survived to age two was not possible because almost all (97%, 107/110) one-year old individuals attended the supplementary feeding. Consequently, second-year survival probability in the feeding period was compared to the mean second-year survival probability before the periods of extremely low sub-adult survival that sparked the implementation of supplementary feeding (i.e. 1983 – 2006, Reid *et al.*, 2011).

The mean proportion of fed one-year olds (*N*=107) that survived to age two was 0.68±0.07 (Figure 6.1b). None of the three unfed one-year olds survived to age two. The survival of fed one-year olds to age two is therefore comparable to the long-term mean second year survival probability of ~0.68±0.03SE (excluding years 2001, 2003 and 2004 where there were very few surviving one year olds with which to estimate second year survival probability, Reid *et al.*, 2008).

Please note that these results for sub-adult survival are preliminary. Full analyses, including investigation of monthly survival rates through the first year, are currently in progress as part of Sarah Fenn's PhD studentship (as detailed in Section 1.2). These analyses are expected to be completed by the end of 2019.

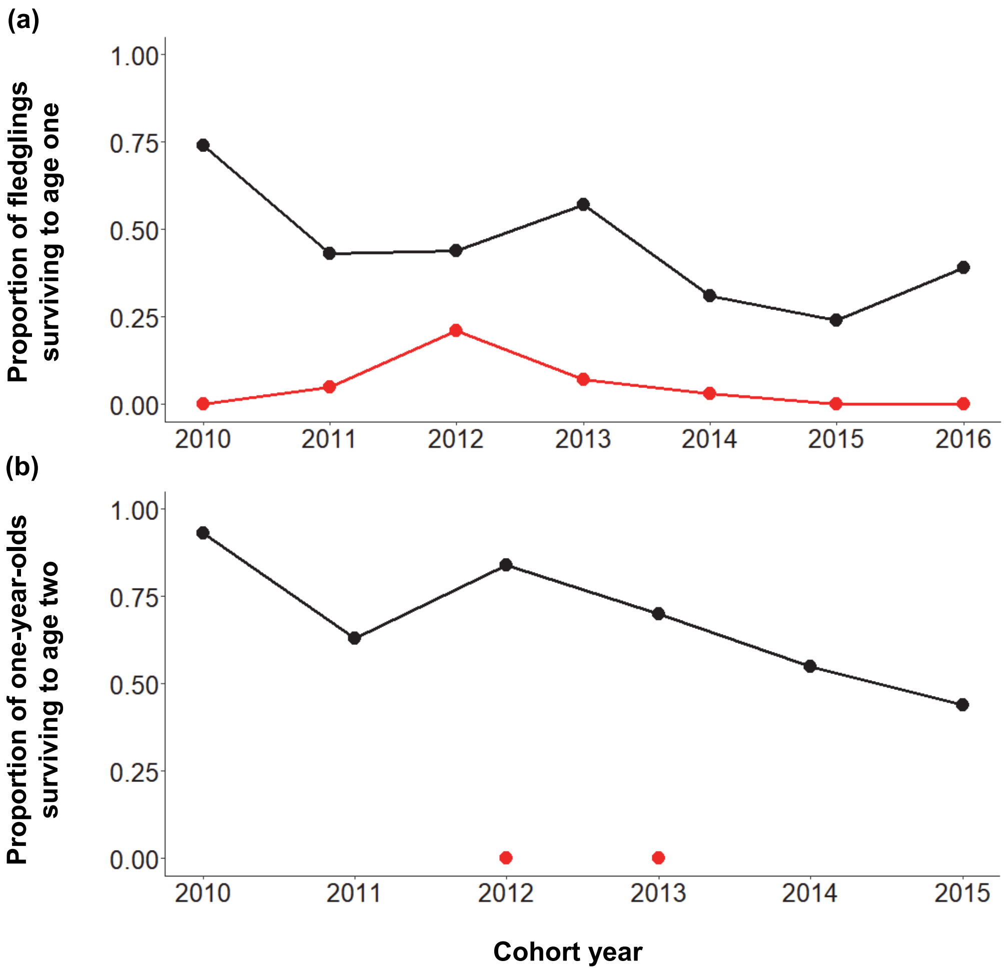

Figure 6.1 Proportion of colour-ringed (a) fledglings that survived to age one and (b) one-year-olds that survived to age two that received supplementary food (black dots and line) or did not receive supplementary food (red dots and line) for each year's cohort.

6.2 Estimation of the effect of supplementary feeding on adult survival and breeding success

6.2.1 Methods

Resightings of adult choughs at supplementary feeding sites during 2010-18 demonstrated that adult use of supplementary food was spatially segregated across Islay. The breeding territories of adults that regularly attending supplementary feeding (i.e. were “fed”) were largely clustered into three areas; in the northern areas of the Rhinns, associated with the feeding site at Ardnave; on the west of the Rhinns, associated with the feeding site at Coull/Kilchoman; and in the Ballygrant Valley, where birds generally fed at the Ardnave feeding site through the late summer, autumn and winter. Conversely, most adults that did not attend the supplementary feeding (i.e. were “unfed”) had a territory outside these three areas. Because of this spatial segregation, effects of supplementary feeding on adult survival and breeding success could not be reliably estimated by direct comparison between ‘fed’ and ‘unfed’ adults. This is because any differences between ‘fed’ and ‘unfed’ adults could be due to environmental factors, such as territory habitat quality, rather than because of supplementary feeding.

Effects of supplementary feeding were therefore estimated using before-after control-impact (BACI) analyses (Figure 6.2). These analyses used observations of colour-ringed adults’ territory locations to compare adults inhabiting areas on Islay with and without supplementary feeding during the designated feeding period (2010-18, Figure 6.2), with individuals inhabiting these same areas in years prior to supplementary feeding (2003-09, Figure 6.2). It was assumed that any changes in environmental conditions across the two periods unrelated to the feeding happened similarly in the different areas, and therefore that differences between areas and time periods represent the effect of the supplementary feeding.

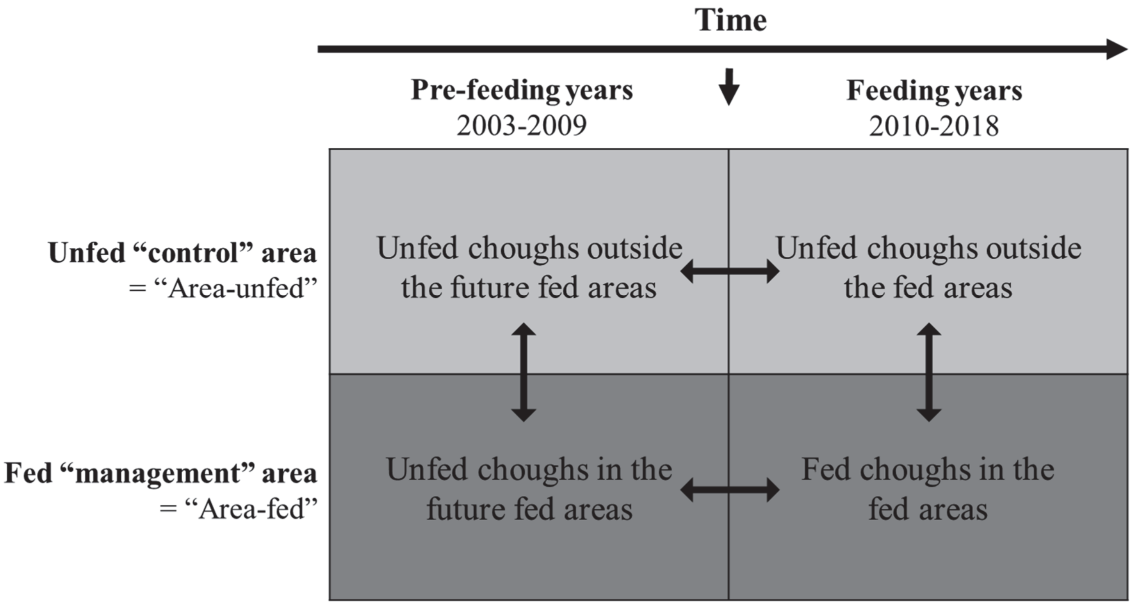

Figure 6.2 Representation of the before-after control-impact (BACI) approach used to estimate the effects of supplementary feeding on adult survival and breeding success. Comparisons can be made both between areas (‘Area-unfed’ vs ‘Area-fed’), and within areas across time (‘Pre-feeding years’ vs ‘Feeding years’), as represented by the arrows.

During the years with supplementary feeding, the frequency of resightings at the supplementary feeding sites was used to assign each colour-ringed adult as either “fed” or “unfed”. While most adults were observed at least once at a feeding site during the supplementary feeding period (91 out of 105), classification as ‘fed’ required an individual to regularly and consistently attend a feeding site across the year. Therefore, unfed individuals were those that fed at supplementary feeding sites rarely, infrequently, or not at all. Most individuals could clearly and confidently be assigned as either fed or unfed, and the few that were less clear to assign had no substantial influence on the final results.

We then used generalised linear mixed models to assess whether the change in survival or breeding success across the pre-feeding and feeding periods differed between the two areas (Area-unfed vs Area-fed). The effect of supplementary feeding on annual breeding success was assessed by directly modelling the number of chicks alive at fledging across all monitored pairs, and by modelling two breeding success components: whether or not an individual successfully produced a brood, and the realised brood size at fledging conditional on success, in relation to whether the individual lived in a fed or unfed area the year immediately prior to each breeding season. As the male and female within a breeding pair would have the same breeding success in a given year, and both individuals within a breeding pair could be colour ringed, reproductive success was analysed for each sex separately to avoid pseudoreplication.

6.2.2 Results

Annual adult survival probability remained relatively stable across the two time periods in areas where most individuals were unfed (Area-unfed). In contrast, the annual survival probability increased substantially in the fed areas (Area-fed) over the two time periods, by approximately 0.1 (Figure 6.3, time period by area interaction was significant: $Z = 2.21$, $p = 0.027$).

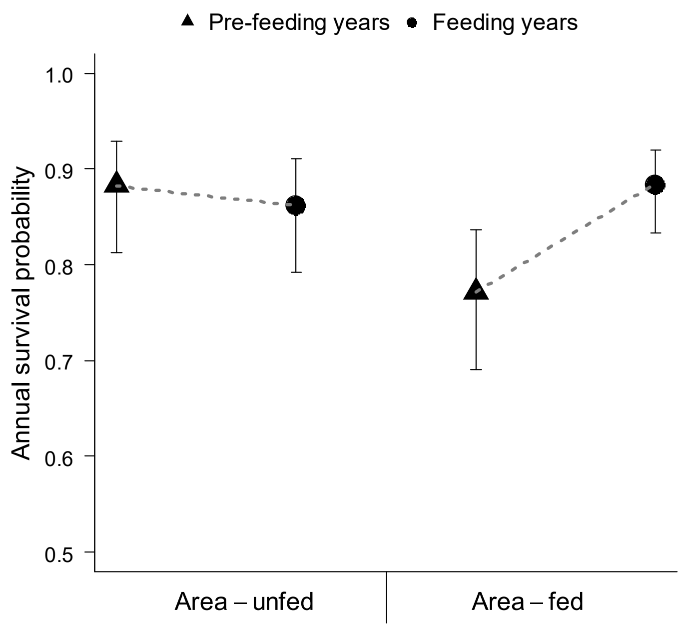

Figure 6.3 Annual survival probability of adult choughs on Islay in relation to area and time period. Time periods comprise the pre-feeding years (i.e. years prior to the introduction of supplementary feeding 2003/04-2009/10, triangles), and the feeding years (i.e. years during the supplementary feeding programme 2010/11-2017/18, circles). Error bars show the 95% confidence intervals. Dotted lines between time period points facilitate visualisation of changes in survival probability between time periods within each area.

Overall breeding success, measured as the number of fledglings produced per breeding attempt per year, decreased in the control unfed areas (Area-unfed), but remained stable in Area-fed for both males and females (Figure 6.4a&b). However, the interaction between period and area was borderline non-significant for males ($Z = 1.80$, $p = 0.07$), and non-significant for females ($Z = 0.85$, $p = 0.40$).

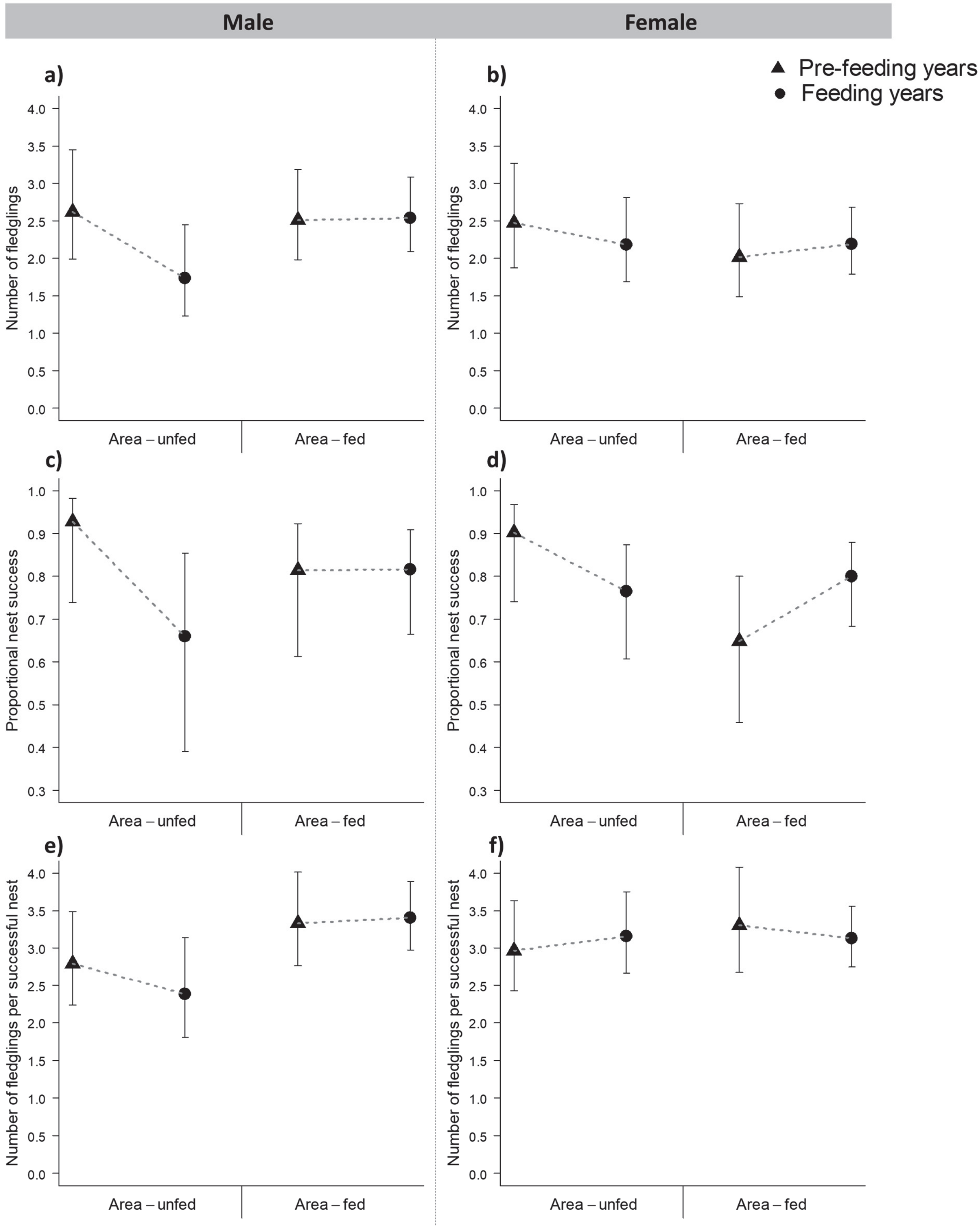

Figure 6.4 Overall breeding success (a & b), proportion of nests successful (c & d) and number of fledglings in successful nests (e & f) of male (a, c & e) and female (b, d & f) adult choughs inhabiting fed and unfed areas on Islay. Time periods comprise the pre-feeding years (i.e. years prior to the introduction of supplementary feeding 2003/04-2009/10, triangles), and the feeding years (i.e. years during the supplementary feeding programme 2010/11-2017/18, circles). Error bars show the 95% confidence intervals. Dotted lines between time period points facilitate visualisation of changes between time periods within each area.

However, closer examination revealed variation in components of breeding success, and particularly in proportional nest success (i.e. the proportion of nests that successfully raised at least one offspring to fledgling). The change in the proportional nest success across time differed between the two areas. For both males and females, the proportion of nest success decreased across time in Area-unfed, while remaining stable (male model) or increasing (female model) over time in Area-fed (Male model: Figure 6.4c, $Z = 1.74$, $p = 0.08$; Female model: Figure 6.4d, $Z = 2.16$, $p = 0.03$). While the male and female models show a slightly different relationship between time period and area, overall, the difference in estimated proportional nest success over time between the two areas was approximately 0.3 for both males and females. However, fledgling brood size from nests that successfully raised at least one offspring did not change significantly over time in either area for either males or females (Figure 6.4e&f, male model: $Z = 0.84$, $p = 0.40$, female model: $Z = -0.63$, $p = 0.53$).

6.3 Behaviours of different sub-adult cohorts

Supplementary feeding as a management strategy could potentially have unintended effects on the population, for example by altering individuals natural foraging behaviour or tying individuals to the location where supplementary food is supplied (e.g. Carrete *et al.*, 2006; Cortés-Avizanda *et al.*, 2016). For Islay's chough population, the exceptionally high resighting rate of colour-ringed individuals means that the movements and foraging behaviours of different sub-adult cohorts (i.e. individuals fledged in the same breeding season) have been closely monitored across the years of supplementary feeding.

6.3.1 Attendance at the supplementary feeding sites and use of alternative food sources

After each breeding season, fledged choughs generally joined either the Ardnave or Coull sub-adult flocks. However, the subsequent attendance of juveniles at the feeding sites at Ardnave, Sanaig and Coull has varied among cohorts. In some years, the sub-adult flocks regularly and consistently attended their local feeding site. However, in other years the sub-adult flocks have been more mobile and moved between the different supplementary feeding sites. At other times, the sub-adult flocks did not attend any supplementary feeding sites for considerable periods. The attendance of juveniles at the supplementary feeding sites has also varied among individuals within a cohort. For example, at Ardnave some individuals frequently visited throughout most of the year. However, some individuals visited less frequently or switched between regular visits for a period, followed by not attending for a period.

For periods when not attending the supplementary feed, the sub-adult flocks have been observed to disperse and use alternative food sources. This has particularly occurred during August and September, but in some years the sub-adults have not returned to the supplementary feeding sites until the following spring. This dispersal has been associated with the appearance and use of transiently abundant food sources. Examples of this include in 2013, when juveniles from the sub-adult flock that had been visiting the Ardnave feeding site dispersed to the Traigh Bhan area and were observed to forage on the beach. In 2016, juveniles from the Coull sub-adult flock were observed to forage principally across hill ground on cow dung, with very few visits to the Coull feeding site. Additionally in 2016, the sub-adult flock that had been regularly visiting the Ardnave feeding site dispersed to a re-seeded grass field at Kilchoman house and were observed to forage there on leatherjackets almost every day through November and December.

These observations of the opportunistic use of transiently abundant food sources across different cohorts suggests the sub-adult choughs are not tied to the supplementary feeding areas. Additionally, the variation in frequency and regularity of attendance at the supplementary feed across and within cohorts suggest that the supplementary feeding has not impacted the choughs natural foraging behaviours; individuals are still able to find and utilise natural food sources.

More detailed descriptions of individual cohort behaviours can be found in Annex 3.

7. EVALUATING ECOLOGICAL AND GENETIC THREATS TO POPULATION VIABILITY

Summary:

- We used population viability analysis (PVA) to evaluate the effects of different potential management strategies on the persistence of Islay's chough population.
- We considered four scenarios: (i) no management (i.e. cease supplementary feeding and associated parasite treatments); (ii) genetic management only (i.e. translocations to reduced inbreeding, cease supplementary feeding); (iii) ecological management only (i.e. continued supplementary feeding); (iv) simultaneous genetic and ecological management (i.e. translocations and supplementary feeding).
- Our models showed that:
  - With no management (i.e. cease supplementary feeding and associated parasite treatment), Islay's chough population is likely to decline to extinction in a relatively short time-frame (within 50 years).
  - On their own, translocations are unlikely to prevent this decline.
  - Current supplementary feeding is slowing the rate of decline but may not be enough on its own to maintain a stable population size.
  - Simultaneous translocations alongside continued supplementary feeding may result in a stable population size.
  - There is inevitably considerable uncertainty around exact outcomes, yet the overall qualitative conclusions across the considered scenarios are reasonably clear.
  - Our results suggest that both ecological management, ideally through habitat management, and genetic improvements through population reinforcements, may be required to ensure the viability of Islay's chough population.

7.1 Summary of population viability analysis for Islay's chough population

Islay's chough population is known to be facing ecological threats from low food abundance and/or availability (Reid *et al*., 2011, 2008), and is likely also facing genetic threats from inbreeding, leading to inbreeding depression (Trask *et al*., 2016, 2017). Management of ecological threats would require either continued supplementary feeding or equivalent habitat management that successfully increased natural food abundance and/or availability. Management of genetic threats would require translocating new choughs from populations outside of Scotland into the Scottish chough population to alleviate inbreeding (i.e. population reinforcements). However, the success of ecological management strategies may be constrained by failure to address the genetic threats, and vice-versa (Figure 1.3). Carrying out either management strategy independently may then fail to achieve management goals of increasing population viability and could instead waste conservation resources. In order to design an effective and efficient future management plan for Scottish choughs, we therefore need to evaluate the efficacy of ecological and genetic management strategies implemented independently versus simultaneously. To do this we built a stochastic individual-based, genetically-explicit population model and used this to carry out population viability analysis (PVA).

First, we created a baseline model, reflecting Islay's chough population before supplementary feeding started (i.e. using data from 2003-2009, Figure 1.4). We then created a set of scenario models of different potential management strategies (Table 7.1). Genetic management scenarios were designed to evaluate the potential for population reinforcements to result in a viable population given current environmental conditions, as opposed to designing optimal translocation strategies. Likewise, ecological management scenarios were designed to reflect current supplementary feeding and parasite treatments, to evaluate whether current environmental conditions could result in a viable population. We started each simulation from a population of 118 individuals, to reflect the population size in 2017.

The model was built using the program VORTEX v10.2.17.0 (Lacy & Pollak, 2017). The model includes a lot of variability, including among-year variation in reproduction and survival (i.e. 'environmental stochasticity'), and also chance effects on individual success (i.e. 'demographic stochasticity'). Consequently, two runs of the same model will never give exactly the same answer. Furthermore, the model includes substantial uncertainty because the exact effect of supplementary feeding on the population is uncertain as feeding was carried out as an emergency intervention as opposed to a replicated, controlled experiment (we therefore used a range of values from preliminary estimates, Section 6). The magnitude of inbreeding depression is also uncertain for this population, so we used a range of plausible values, based on data from other systems. We therefore ran each model scenario many times (5000 replicates). To interpret model outcomes, we compared the mean answer and the variation around the mean between scenarios to identify which modelled management strategy is likely to result in the greatest improvements in population viability.

Here, we provide a summary of the population viability analysis and the key results. For further details of the model and analysis, see our full manuscript and supporting information (Trask *et al.*, 2019), which is provided as Annex 4.

Within Annex 4 and throughout this section modelled effects of supplementary feeding implicitly include effects of parasite treatments as all treated individuals also received supplementary food, so these effects could not be separated.

Table 7.1. Descriptions of the different scenarios simulated in the population viability analysis.

Scenario	Description
1. What is likely to happen to Islay's chough population without any management (i.e. no supplementary feeding or population reinforcements)?	We parameterized the model with pre-supplementary feeding demographic rates (from 2003-2009), to create a 'baseline' model (Scenario 1) of what may happen to the population if supplementary feeding ceased and no population reinforcements were undertaken. As the magnitude of inbreeding depression in this population is unknown, we used a range of potential values from published studies on wild populations.
2. What is likely to happen to Islay's chough population if population reinforcements are carried out (without supplementary feeding)?	We modelled two scenarios of moderate-sized population reinforcements consisting of one or two translocations of 24 unrelated choughs, added into the Scenario 1 model, without any supplementary feeding. We also modelled an additional scenario of two larger translocations of 48 unrelated individuals into the Scenario 1 model, to ensure that some translocated individuals would survive to breed in the modelled population.
3. What is likely to happen to Islay's chough population if supplementary feeding is continued (or equivalent habitat management)?	We used estimates of the effects of supplementary feeding on first year, second year and adult survival probabilities and breeding success (see Section 6) and added these estimated effects into the Scenario 1 model. To incorporate uncertainty around these estimated effect sizes into our model, we used a range of values of 10-100% of the potential effect sizes and ran multiple replicates of the model, with each replicate drawing from the range of effect sizes. This conservative range was

	chosen because supplementary feeding was not carried out as a controlled experiment, meaning that differences between fed and unfed individuals might partly reflect differences in local habitat quality.
4. What is likely to happen to Islay's chough population if both supplementary feeding and population reinforcements are carried out?	We used the supplementary feeding model (i.e. Scenario 3) and added population reinforcements as in Scenario 2 (i.e. one and two moderate-sized translocations of 24 individuals and two larger translocations of 48 individuals). We additionally modelled a scenario of three moderate-sized translocations of 24 individuals, with the third translocation in year 25.

7.2 Key results of the population viability analysis

Scenario 1. What is likely to happen to Islay's chough population without any management (i.e. no supplementary feeding or translocations)?

When using the pre- supplementary feeding demographic rates, all simulated populations declined to extinction relatively rapidly, with a mean population growth rate (λ) of 0.86 (95% CI: 0.81 – 0.91, i.e. population size could decline by about 14% per year, Figure 7.1) and a probability of extinction within 50 years (P_E) of 1 (i.e. all simulated populations went extinct).

This projected population decline is in concordance with previous population projections of λ= 0.87, estimated for the population before supplementary feeding started (Reid *et al.*, 2011).

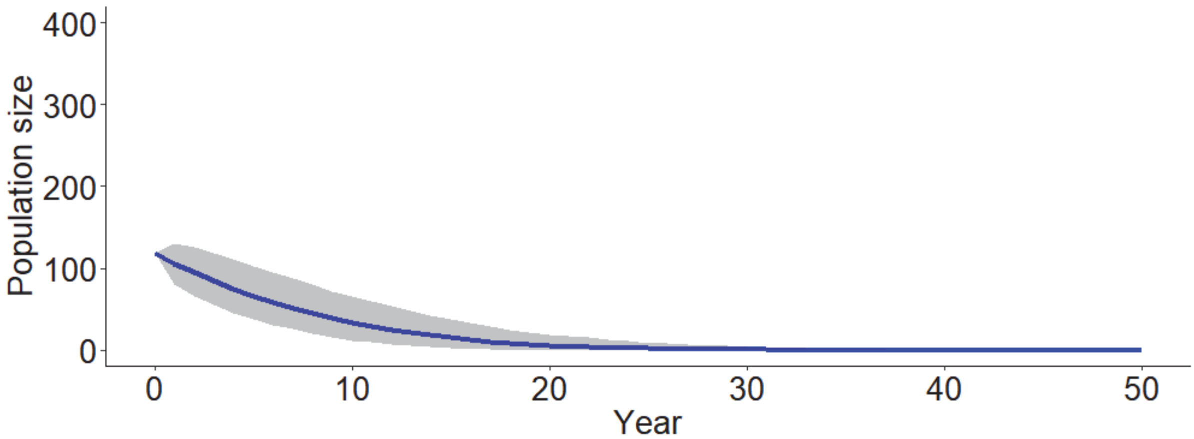

Figure 7.1. Projected size of Islay's chough population 50 years into the future with no supplementary feeding or population reinforcements (i.e. 'baseline' model). The mean projected population size across replicate simulations (blue line) is shown, with the 95% confidence interval (grey shaded area).

Scenario 2. What is likely to happen to Islay's chough population if population reinforcements are carried out (without supplementary feeding)?

When we modelled the effects of carrying out population reinforcements without supplementary feeding, all simulated populations continued to show relatively rapid declines after the initial translocations (Figure 7.2, Annex 4).

When a single translocation of 24 individuals was added to the baseline model, mean $\lambda = 0.89$ (95%CI: 0.84 – 0.93, Figure 7.2a). When two translocations were added, mean $\lambda = 0.90$ (95%CI: 0.86 – 0.94, Figure 7.2b). When two larger translocations of 48 individuals each were added to the baseline model, mean $\lambda = 0.92$ (95%CI: 0.88 – 0.96, Figure 7.2c). The probability of extinction within 50 years for all three of these scenarios of population reinforcements was high ($P_E \geq 0.94$).

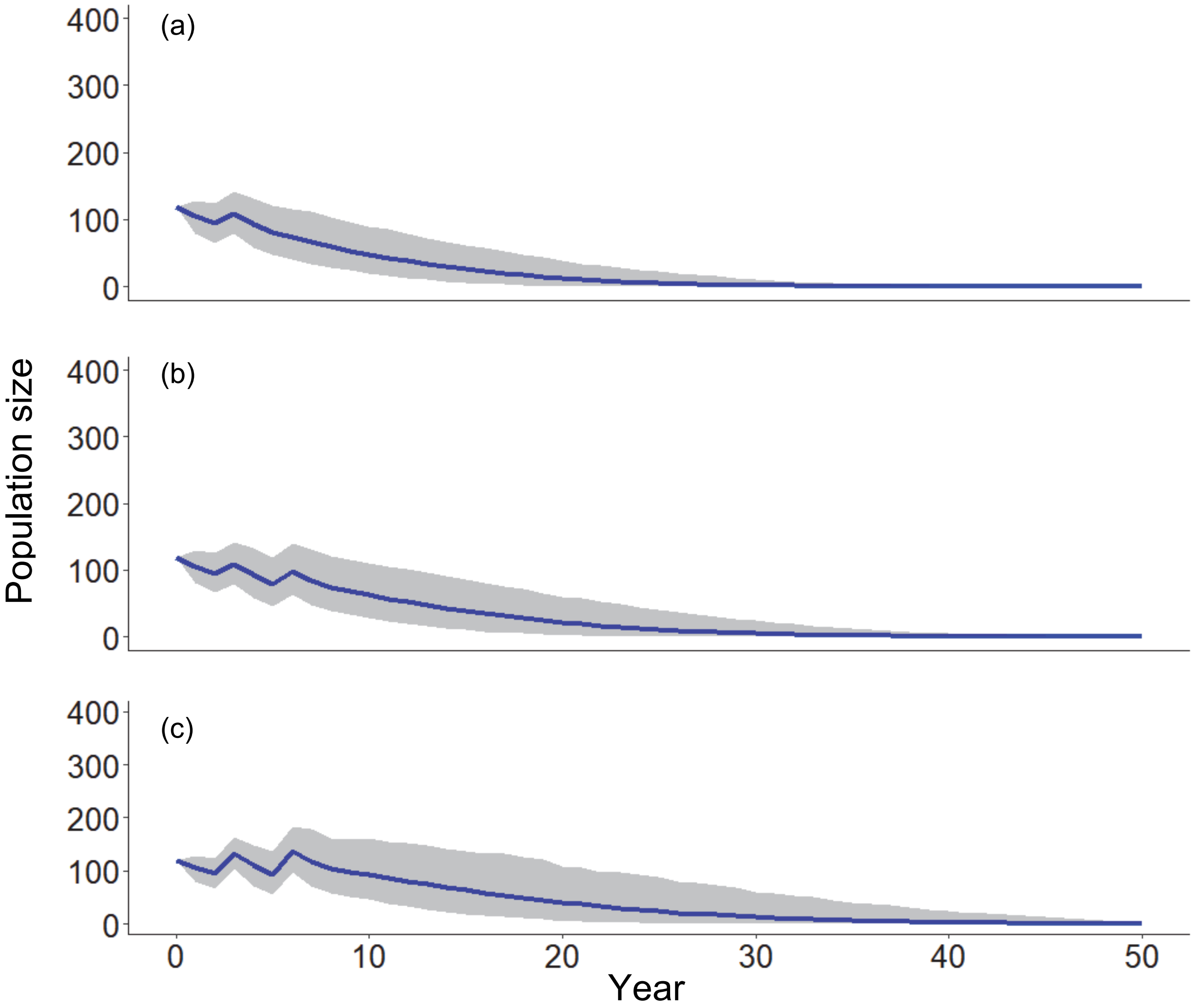

Figure 7.2. Projected size of the Islay chough population 50 years into the future with genetic management only, consisting of translocations of (a) one or (b) two translocations of 24 individuals each, or (c) two translocations of 48 individuals. The mean projected population sizes across replicate simulations (blue lines), with 95% confidence intervals (grey shaded areas) are shown.

Scenario 3. What is likely to happen to Islay's chough population if supplementary feeding is continued?

When the effects of supplementary feeding were added to the baseline model mean λ= 0.93 (95% CI: 0.86 – 1.02, Figure 7.3), suggesting that supplementary feeding is likely to slow the rate of population decline compared to scenarios of no management or population reinforcements alone. However, this scenario still resulted in a high probability of extinction within 50 years (P_E = 0.66), suggesting supplementary feeding may not be enough on its own to maintain a viable population.

To provide some validation, we compared the projected population size from this model to the observed change in the Islay chough population size through the supplementary feeding period (2010-2017). The Islay chough population size was estimated from the observed numbers of breeding pairs plus the estimated numbers of sub-adults from survival and reproductive rates for each year. The observed change in the Islay chough population size falls within the 95%CI of the projected population sizes (Figure 7.3), implying that the model captures the dynamics of the Islay chough population and the effects of supplementary feeding reasonably well.

Note – this estimation of population size allows comparison of overall population trends as opposed to absolute population sizes, because the pre-supplementary feeding period covers the period from the start of supplementary feeding up to 2017, while the model projects forward from 2017.

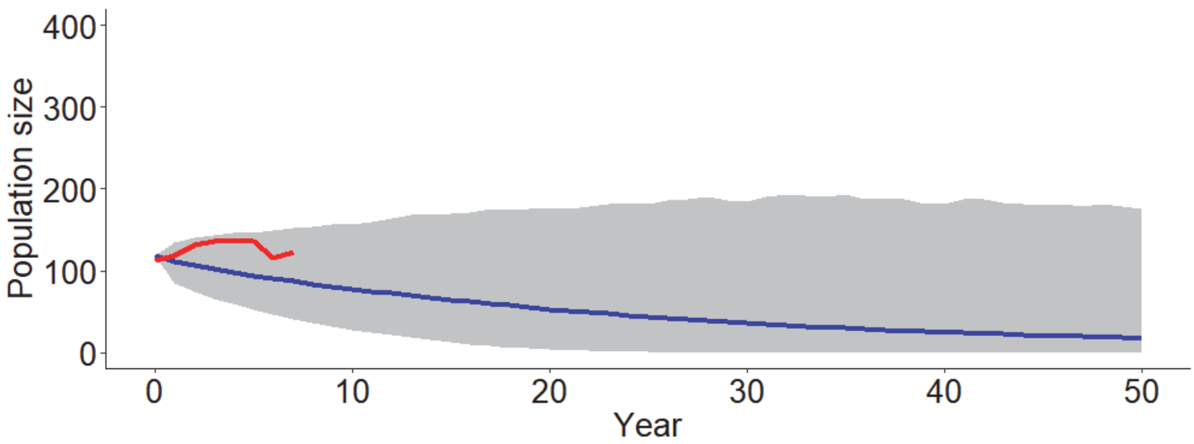

Figure 7.3 Projected size of the Islay chough population 50 years into the future with ecological management only. The mean projected population size across replicate simulations (blue line) is shown, with the 95% confidence interval (grey shaded area). The red line shows the estimated size of the real Islay chough population after the start of supplementary feeding.

Scenario 4. What is likely to happen to Islay's chough population if supplementary feeding and population reinforcements are carried out simultaneously?

When both the effects of supplementary feeding and population reinforcements were added to the model simultaneously, a higher mean λ and lower P_E was predicted than when either supplementary feeding or population reinforcements alone were modelled.

When supplementary feeding and one moderate-sized translocation of 24 individuals was modelled, mean λ = 0.97 (95%CI: 0.89 – 1.05, Figure 7.4a), thus suggesting a slow population decline. Supplementary feeding and two translocations of 24 individuals each resulted in an initial stable population growth rate on average (across years 8 - 25 λ = 1.00, 95%CI: 0.89 – 1.08, Figure 7.4b), but a renewed slow population decline after year 25 (across years 26 - 50 λ = 0.97, 95%CI: 0.82 – 1.06). This is because after the initial translocations, the population then remains isolated and thus inbreeding re-accumulates in the population. These two scenarios resulted in a moderate probability of extinction (supplementary feeding with one moderate-sized translocation: P_E =0.38; with two moderate-sized translocations: P_E =0.22).

However, additional model simulations suggest that this can be resolved with either two larger translocations each of 48 individuals (Figure 7.4c) or a third translocation at year 25 (Figure 7.4d) alongside supplementary feeding. Both of these scenarios suggest a stable population size on average over the full 50-year time-frame and only a small probability of extinction within 50 years (two larger translocations: mean λ = 1.01 (95% CI: 0.93–1.08) and P_E =0.09; three moderate-sized translocations: mean λ = 1.00 (95% CI: 0.94–1.07) and P_E =0.10).

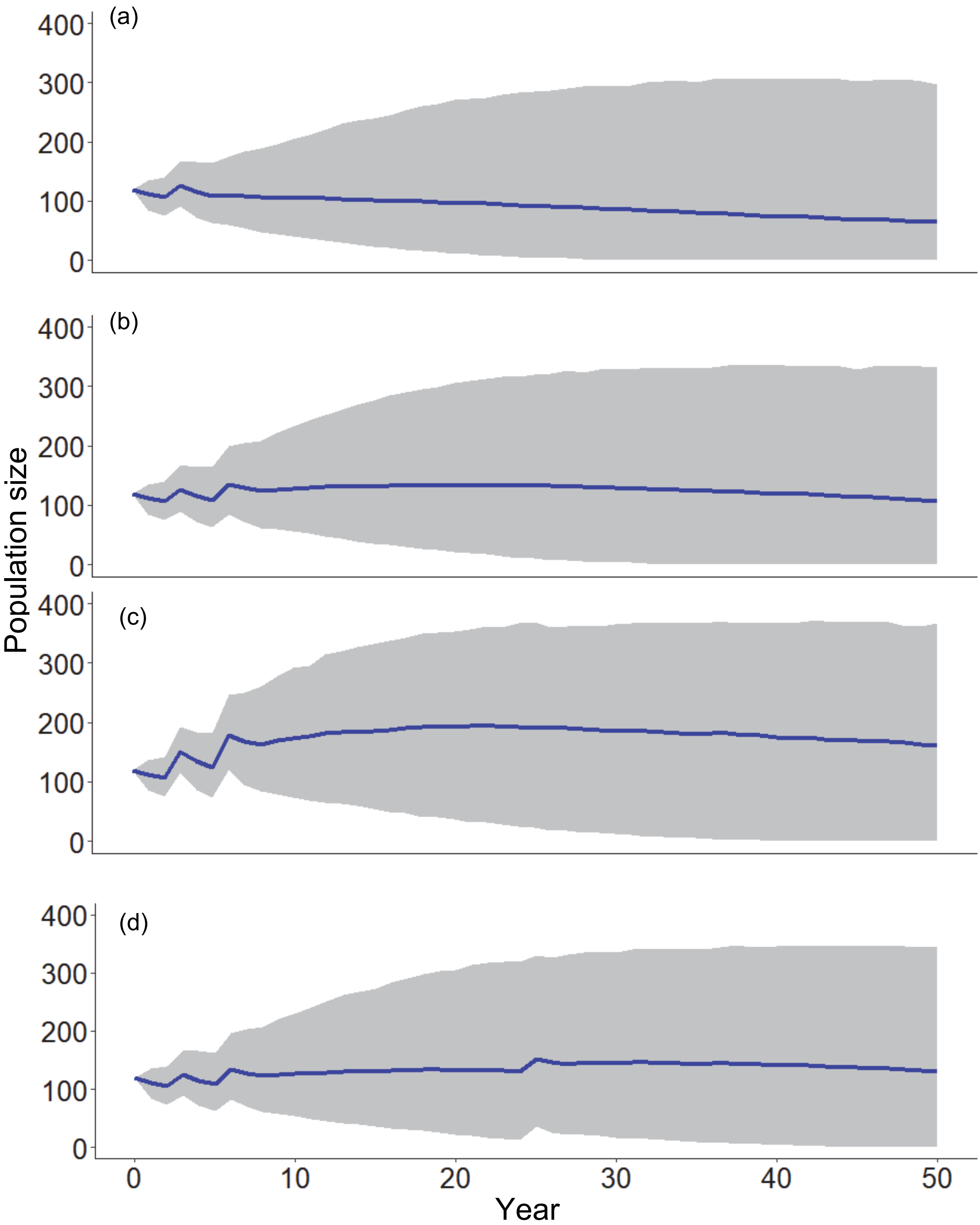

Figure 7.4. Projected size of the Islay chough population 50 years into the future with simultaneous ecological and genetic management comprising (a) one and (b) two moderate-sized translocations of 24 individuals each, (c) two larger translocations of 48 individuals each, or (d) three moderate-sized translocations of 24 individuals each at years 3, 6 and 25. The mean projected population sizes across replicate simulations (blue line), with 95% confidence intervals (grey shaded area) are shown.

7.3 Key conclusions of the population viability analyses

Our modelled scenarios without supplementary feeding, with and without population reinforcements, resulted in rapid projected population declines. This implies that ceasing supplementary feeding, in the absence of recovery of natural food resources, could result in extinction of choughs in Scotland.

Our modelled scenario of continued supplementary feeding showed that this intervention slowed the projected population decline, but did not result in a stable population size in the medium-term. Continuation of current supplementary feeding may therefore facilitate the persistence of choughs in Scotland for notably longer than if supplementary feeding was ceased, but is unlikely to result in a viable population in the longer term.

The only modelled scenario that resulted in a stable population size, and thus a viable chough population, was simultaneous ecological and genetic management (i.e. both supplementary feeding and population reinforcements). This suggests that management of both ecological and genetic threats is required to maintain choughs in Scotland. We modelled ecological management based on the estimated increases in key demographic rates due to supplementary feeding, however a more sustainable long-term management strategy would be to achieve these increases through improvements in habitat management. This would require improvements in current agri-environment schemes, so that grassland habitat on Islay provides increased chough prey equivalent to what is provided currently through supplementary feeding. Indeed, our simulations assume that baseline environmental quality, and hence key demographic rates, do not deteriorate further.

Alongside supplementary feeding or equivalent habitat management, our simulations suggest population reinforcements would also be required. However, simulations of one or two translocations resulted in an initial stable population size, followed by subsequent slow decline. Our simulations of larger initial translocations or additional translocations in the future was required to ensure viability over the full projected time-frame. This suggests that a one-off translocation, followed by continued isolation of the Scottish chough population from the other UK populations, may not result in a viable population in the longer term. Alongside effective habitat management, a long-term management strategy could be to either carry out occasional population reinforcements into the future. Alternatively, restoration of connectivity between British Isles chough populations, for example through re-establishment of stepping-stone populations along the west coast of the UK, would facilitate natural gene-flow.

8. NEXT STEPS IN SCOTTISH CHOUGH CONSERVATION

8.1 Planning population reinforcements

Our population viability analyses paint a bleak picture of the current status of Islay's, and hence Scotland's, chough population; a combination of ecological and genetic threats require rapid interventions without which there is a high probability that the population will go extinct.

Following presentation and discussion of these results with SCSG, SNH and RSPB in September 2018, it was agreed to progress to the next stage of considering the case for population reinforcements for the Scottish chough population, and thereby objectively consider the arguments for and against such action.

The next step in considering the case for population reinforcements (through translocation) is to work through the requirements set out in the *Scottish Code for Conservation Translocations* and the *Best Practice Guidelines for Conservation Translocations in Scotland* (National Species Reintroduction Forum, 2014a & b). These frameworks include objectives of:

- Assessing the potential risks and benefits of any translocations, including biological and socio-economic factors.
- Assessing the feasibility of any translocations in terms of potential donor populations.
- Gauging the views of different stakeholder groups, including relevant farmers and landowners, the wider public and other key stakeholders (including RSPB, since choughs are a focal species on their Islay reserves).

Any reinforcement/translocation plan should then be developed in consultation with these key stakeholders and reviewed by the National Species Reintroduction Forum.

Here, we summarise progress towards these objectives that has been achieved to date.

8.2 Priorities for a future conservation strategy – supplementary feeding and habitat management

The first key point emerging from the supplementary feeding (Section 6) and our PVA (Section 7) is that ecological threats, comprising food shortage and potential parasite burdens, are currently the major limitation on the persistence of Islay's chough population. These threats pose a major biological risk to the success of any potential population reinforcements.

These ecological threats have, during 2010-2019, been successfully ameliorated by the SNH-funded programme of supplementary feeding and associated parasite treatment. The first priority for a future conservation strategy must consequently be to decide how to move forward given that the funding for supplementary feeding has now ended (Section 1.2), and the PVA suggests that a rapid population decline is likely to ensue.

In the very short term, SCSG are planning to continue supplementary feeding and parasite treatment (currently unfunded) for the expected 2019 cohort of fledgling choughs through the known critical period for first-year mortality (i.e. July-October 2019).

SNH will need to urgently consider whether the current supplementary feeding program should be continued beyond that timeframe. The longer-term value of this activity will depend on the likelihood that appropriate habitat management can be rapidly enacted to increase natural food resources (section 8.2).

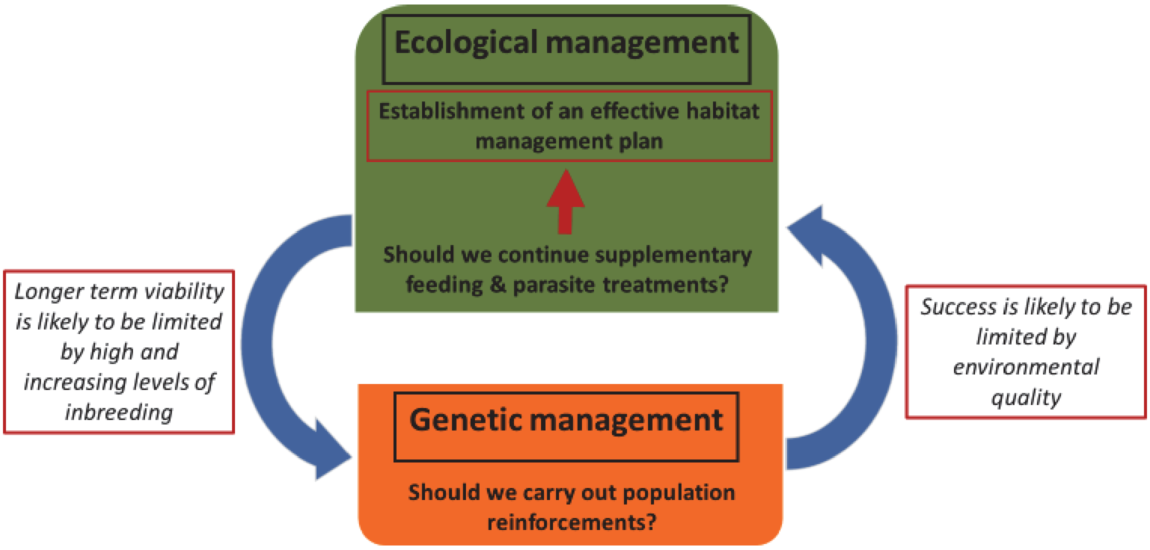

Figure 8.1. The success of any population reinforcement is likely to be dependent on environmental quality. Environmental quality from 2010-2019 was improved through supplementary feeding, for which funding has now ceased. A sustainable long-term strategy to improve environmental quality for choughs is to establish an effective habitat management plan.

Given that it may not be feasible or desirable to maintain a long-term supplementary feeding programme, renewed attention (following on from a previous Research and Policy Report for Scottish choughs, Reid *et al*., 2009) must be placed on the need to improve habitat quality and hence the abundance and/or availability of key invertebrate prey for choughs (Figure 8.1).

Some insights can be gained by qualitatively comparing environmental conditions on Islay and Colonsay now with the situation in the 1980s when chough numbers were higher. We can thereby highlight multiple factors that, in various combinations, are likely to be causing the lack of potential food and/or adequate foraging conditions during the period of greatest juvenile mortality (i.e. late summer and early autumn, Reid *et al*., 2011). Some or all of these changes will need to be reversed, so that improving the overall environmental conditions for choughs happens through a series of "marginal gains" which in combination have the required larger positive effect.

This could be achieved through assessing each farm or group of farms with choughs present against a list of limiting factors, and recommendations then made to introduce remedial action.

Key management requirements at the critical time (June – September):

1. A) **Grassland management.** Over the years, grassland management on Islay has become more intensive, and there is less spatio-temporal diversity because of agri-environmental schemes that stipulate dates for management actions (e.g. mowing, or not grazing). There need to be cut silage aftermaths available in June and July in the places where chough pairs with newly fledged families forage. There need to be grazed, unfertilized grass fields available to breeding pairs from March to the end of June, thereby maximising the potential availability of soil invertebrates (in particular leatherjackets, Tipulid larvae, Figure 8.2a).

   B) **Semi-natural grassland management.** There are problems associated with supplementary feeding livestock (e.g. with draff or silage) on the ground. This destroys the natural vegetation and attracts other bird species (e.g. rooks, crows, jackdaws, gulls and pheasants) onto grass pastures that they would not otherwise use. This may be a contributing factor in the increase in parasitic infections in young choughs (Section 4) that subsequently forage over these grasslands. There are also problems associated with mechanical topping of vegetation, which destroys dung pats. Simultaneously, there are issues arising from destocking or reduced stocking densities in key areas. In part, this reflects changes in farming subsidy payments from headage payments to area-based payments, which tend to encourage destocking when livestock production without subsidy is not profitable. However, as farming becomes more intensive and mechanised, there is also an increasing trend for livestock production to concentrate on better land and abandon poorer natural pastures.

2. **Management to promote dung invertebrates.** Dung is well known to provide a critical substrate for key invertebrates (Figure 8.2b). Cattle grazing from March to November (and year-round in some key sand-dune systems) is very important in providing cow pats, which can provide easily available abundant food for sub-adult choughs. However, some livestock treatments may negatively impact dung fauna (Gilbert *et al.,* 2019). The use of antihelminthic treatments which reduce the abundance of dung invertebrates should therefore be minimised and only used during periods when it will not affect the availability of dung invertebrates to choughs.

3. **Management to promote blowfly larvae and other maggots**. Blowfly larvae are an important additional food for choughs, but this resource is likely to have decreased in recent years following increasingly strict adherence to requirements to rapidly bury animal carcasses. Ideally, there needs to be some arrangement to manage this process in key chough areas on Islay and Colonsay. Most livestock farms have a burial pit of some description which could be modified to meet this requirement without compromising animal or public health.

4. **Management to promote bee and fly larvae.** Areas with solitary and colonial mining bees should be identified and protected from physical damage (Figure 8.2c). Similarly, foreshore accumulations of seaweed (wrack) should not be disturbed as these can be rich in fly larvae at critical times (Figure 8.2d).

5. **Management to minimise human disturbance.** Disturbance of foraging choughs by humans may be an increasing issue, resulting from increasing tourism to Islay. Some crucial chough foraging areas are also potentially attractive to tourists at the very time of year when they are particularly important for choughs. Wherever possible management should aim to avoid actively attracting people to these areas at this time, and potentially provide information about the need to minimise disturbance.

Currently there are two management options within the Scottish Rural Development Programme (SRDP) that aim to improve habitat quality for choughs through management of pastoral grassland systems: ‘Mown Grassland for Corncrake and Chough’ and ‘Grazed Grassland for Chough’. There has been a reasonable up-take of these options in key areas on Islay. However, survival of sub-adult choughs remains low and there is little evidence that the existing options (and associated expenditure) have been successful in improving chough foraging conditions and hence population viability. In some cases, the resulting management may even have had a negative effect (e.g. recommendations within ‘Grazed Grassland for Chough’ to manage sward height to 13cms). Moreover, there is no compulsion for farms in key chough areas to enter the schemes. Particularly striking examples of this include Kilchoman dunes in the Rhinns Site of Special Scientific Interest (SSSI), which was considered the most important site in Scotland for choughs, but is now in unfavourable status for choughs. Here, the current owner is not interested in entering the SRDP scheme, and the unfavourable status seems unlikely to change.

The current SRDP management options were constrained from the outset, partly because they aimed to provide suitable conditions for chough and corncrake (*Crex crex*) at the same time. This has posed challenges which have not subsequently been successfully addressed. Managing grassland for corncrakes (i.e. grazing cessation in spring and late summer mowing) was paid at a higher rate than for choughs, and these rates increase with later mowing dates. The effect has been to homogenise grassland management over large areas and reduce the availability of short grass swards during key chough foraging periods. In most important chough areas a temporal and spatial patchwork of grassland management integrating pasture and meadow has been replaced by a monoculture of intensively managed grassland mown late in the summer. More generally the SRDP options, which have to provide an "off the shelf" list of management activities to fit all farms, fail to address the (often unique) requirements needed in specific places and at particular times.

In our view, the only realistic way to make the huge improvements in habitat quality that are required (rather than at best keeping the current status quo that is failing to maintain the chough population) is to initiate a scheme of individual farm management agreements that can target the most important places and activities to provide the micro-habitats that address the limiting factors and provide the best foraging places for choughs. There will also need to be a new more effective way to ensure, within the Special Protection Area (SPA) and SSSI, that landowners and managers do enter into such agreements.

It should be noted that habitat management for choughs would also support traditional pastoral farming systems and high biodiversity-value grasslands, and hence likely benefit the biodiversity landscape more generally. Indeed, a move away from single-species management prescriptions will be a necessity if Islay and Colonsay are to be successfully managed for the suites of species that should occur alongside chough; corncrake, sea eagles, wintering geese and the other species for which the Rhinns and Oa SSSI and SPAs are designated to protect.

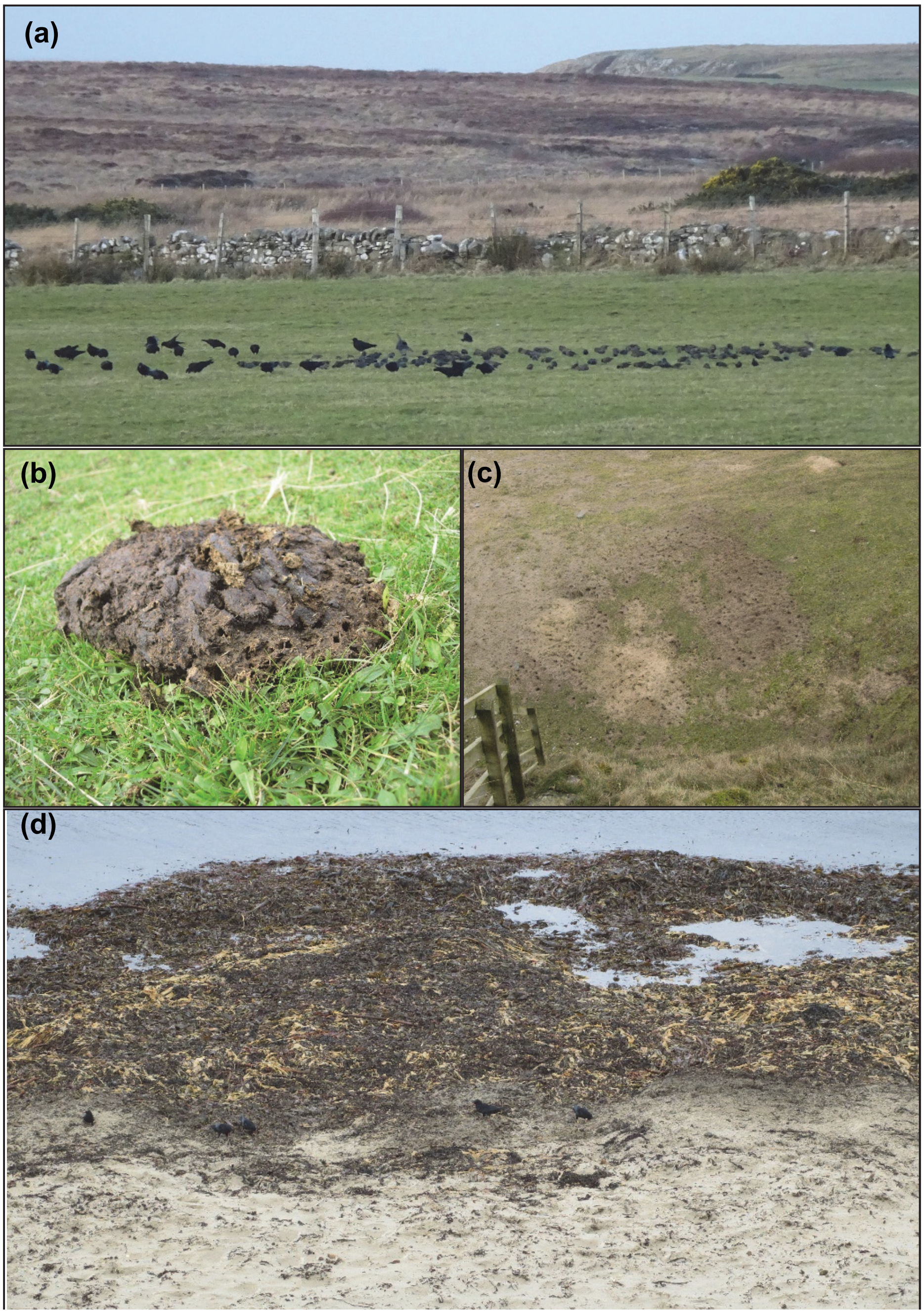

Figure 8.2 Photos of the critical substrates for key chough invertebrate prey species, including (a) grassland for soil invertebrates such as Tipulid larvae, (b) dung for a variety of dung invertebrates, (c) sandy banks for miner bee larvae, and (d) wrack seaweed for fly larvae.

8.3 Further funding for supplementary feeding

Improvements in habitat management will be a more sustainable long-term conservation strategy for choughs than indefinite supplementary feeding. However, if there is an ambition to implement such management, and for rapid action, then it would be prudent to continue the programme of supplementary feeding until expected benefits of new management become a reality. In this case, the current supplementary feeding protocols could potentially be expanded.

8.3.1 Future supplementary feeding program: feeding sites in other areas

The supplementary feeding program of 2010-2019 was carried out in three areas across Islay (Figure 3.1). However, choughs inhabiting areas outside of these three areas did not receive supplementary food. Conditional on further funding, a future supplementary feeding program could consider extending supplementary feeding into additional areas. For example, additional supplementary sites could be set up on the Oa, including the RSPB reserve, and/or in the south of the Rhinns, if there are sub-adult choughs using these areas.

Supplementary feeding is also not currently carried out on Colonsay, despite observed similar population declines there. The feasibility of expanding the supplementary feeding to Colonsay should be assessed.

However, the time and logistical requirements to undertake an effective programme of supplementary feeding should not be underestimated, including time taken to ‘farm’ the required mealworms, to set up feeding sites, to distribute food on a daily basis, and to monitor its use.

8.3.2 Future supplementary feeding program: type of food provided

Supplementary food provided during the 2010-2019 program consisted principally of live mealworms and pinhead oats. Conditional on further funding, a future supplementary feeding program could consider trialling different food types. In particular, commercial pellet foods that have been specifically developed for wild birds may provide a more nutritionally balanced and higher calorie content food for choughs.

Durrell Wildlife Conservation Trust are currently involved with supplementary feeding a recently reintroduced chough population in Jersey and have trialled a variety of different diets for nutritional content and palatability to choughs. The Jersey chough population is currently supplementary fed with a mix of commercial pellet (Orlux remiline granules) and mealworms. This, or a similar diet, could be trialled for Islay’s chough population. However, use of pelleted food could attract other birds to the feeding sites, which the current feeding system on Islay has managed to avoid for the most part. Sharing of expertise, and potential collaboration to develop an appropriate supplementary feed and feeding method for choughs, could be mutually beneficial and should continue with Durrell Wildlife Conservation Trust.

8.4 Feasibility of population reinforcements

The second strand of any plan for population reinforcements is to consider the availability of, and impacts on, potential source populations of choughs for translocations to Islay.

Potential source populations should be of the same *P. p. pyrrhocorax* subspecies as the Scottish chough population, to minimize the risk of outbreeding depression (i.e. reductions in survival or reproductive success of the recipient population following translocations, due to genetic differentiation of the recipient and source populations, Frankham *et al*., 2011). Potential source populations include larger wild populations of *P. p. pyrrhocorax*, for example in the Republic of Ireland. Alternatively, captive populations of choughs at Paradise Park

Wildlife Sanctuary, Cornwall (Burgess *et al*., 2012), and at Durrell Wildlife Conservation Trust, Jersey could also be potential source populations. Molecular genetic analyses showed that these captive birds in Cornwall and Jersey originated in Wales (Wenzel *et al*., 2012). Durrell Wildlife Conservation Trust also have expertise in translocating choughs from their recent reintroductions of choughs to Jersey.

Amanda Trask and Pat Monaghan visited Durrell Wildlife Conservation Trust to learn more about the methodology and logistics of planning conservation translocations of choughs and to assess the suitability and feasibility of their captive population as a source population of choughs. Full details of the visit are in Annex 5.

Briefly, Durrell Wildlife Conservation Trust, and in particular Elizabeth Corry who manages their chough project, are keen to share expertise and help in developing a plan for carrying out population reinforcements for Islay chough. However, while they have established 12 breeding pairs in the wild and a non-breeding flock, their captive chough population currently only consists of a single breeding pair due to space constraints. This captive population could contribute as a source population but is not large enough to be the sole source of choughs for translocations to Islay. Alternative source populations, such as Paradise Park or a wild population, would therefore need to be considered. The Royal Zoological Society of Scotland have expressed a wish to help with any population reinforcement project for choughs in Scotland, including establishing a captive breeding population at the RZSS Highland Wildlife Park.

This situation means that sourcing sufficient choughs for a major translocation into Scotland is likely to be feasible but not a trivial task, likely requiring ongoing activity across several years.

8.5 Gauging public opinion of chough conservation in Scotland

The third strand of any plan for population reinforcements, and associated expenditure, is to gauge the opinion of key stakeholder groups. These include key farmers and landowners and the wider public on Islay, conservation practitioners, the interested birdwatching and naturalist public who are likely to visit Islay to see choughs alongside other wildlife, and the wider general public.

As a first step, we took advantage of an opportunity afforded by the British Trust for Ornithology/Scottish Ornithologists' Club annual Scottish Birdwatchers' Conference, held in Oban in March 2019, to gauge the opinion of two of these stakeholder groups: the interested birdwatching public and conservation practitioners.

Jane Reid gave a 30-minute talk that summarised the current state of Islay's chough population, and the supplementary feeding. Conference delegates were then encouraged to answer a short questionnaire. The questionnaire asked delegates to self-identify as a 'professional ornithologist, ecologist or conservation practitioner' or as an 'enthusiast birdwatcher'. It then presented either a 'positive normative' or a 'negative normative' statement regarding the future of chough conservation (see below). These statements were designed to elicit non-neutral responses, asked both positively and negatively in case directionality altered the response. Potential responses to each statement were 'Strongly disagree', 'Disagree', 'Neither agree nor disagree', 'Agree', 'Strongly agree', 'Prefer not to answer'. The two statements were randomly allocated among conference attendees.

Positive normative statement: "*Population models suggest that supplementary feeding, habitat management and translocations will be necessary to maintain choughs in Scotland. We should endeavour to implement these interventions and thereby increase the chance that we can keep choughs in Scotland for the foreseeable future.*"

Negative normative statement: "*Population models suggest that supplementary feeding, habitat management and translocations will be necessary to maintain choughs in Scotland. These interventions are costly and artificial. We should cease such activities and accept that choughs might go extinct in Scotland.*"

We obtained a total of 210 responses, out of a total of ~220 people estimated to have attended the conference (i.e. 95%). Only one respondent selected 'Prefer not to answer'. This indicates a very high level of interest in chough conservation among the conference attendees.

Answers to the positive normative statement were overwhelmingly positive: 91 out of 106 (86%) respondents either agreed or strongly agreed with the statement "*We should endeavour to implement these interventions and thereby increase the chance that we can keep choughs in Scotland for the foreseeable future.*", while only 9 respondents disagreed or strongly disagreed (8%, Figure 8.2a). Interestingly, there was a tendency for self-identified 'conservation professionals' to be more strongly positive than 'enthusiasts' (Figure 8.2a). Indeed all 28 'professionals' who answered the positive normative question either agreed or strongly agreed, with zero disagreement.

Correspondingly, answers to the negative normative statement were substantially negative: 73 out of 104 (70%) respondents either disagreed or strongly disagreed with the statement "*We should cease such activities and accept that choughs might go extinct in Scotland.*" (Figure 8.2b). However, there was also a notable minority of respondents that agreed or strongly agreed with the negative statement, including some 'professionals' (total 25 respondents, 24%, Figure 8.2b), perhaps recognising the resources involved in the required conservation activities.

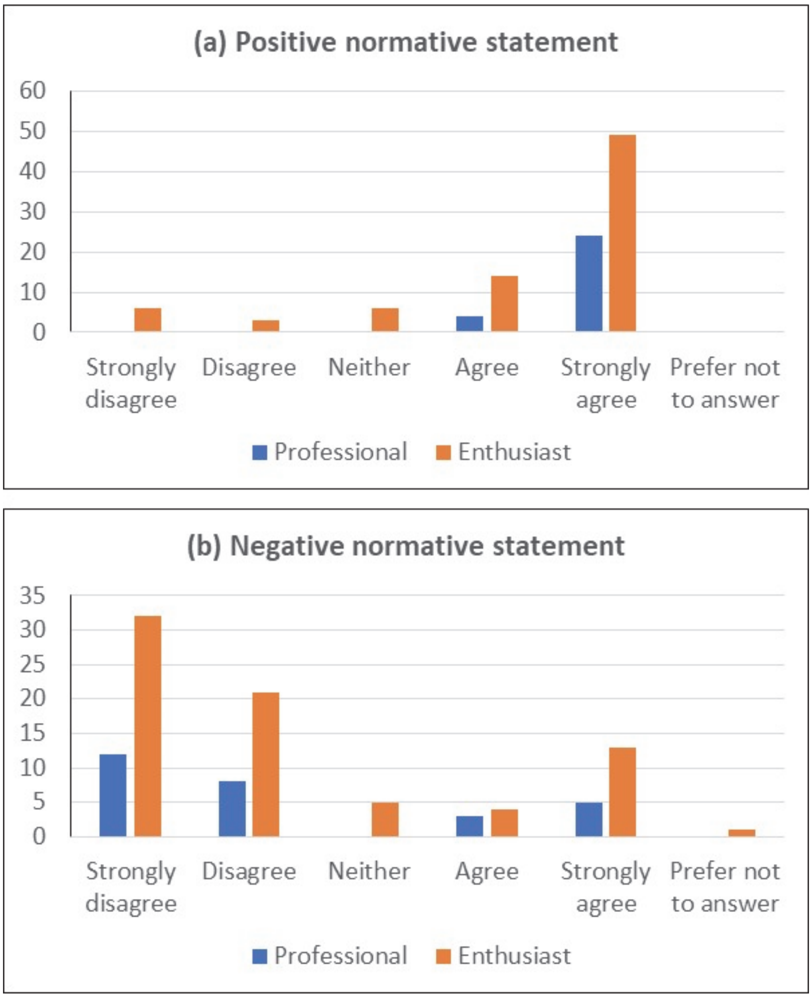

Figure 8.2. Summary results of responses to (a) positive normative and (b) negative normative statements designed to gauge opinion regarding chough conservation from two key stakeholder groups: self-declared 'professionals' (blue) and 'enthusiasts' (orange).

If there are any prospects for future pro-active chough conservation in Scotland then a key next step will be to engage farmers and landowners in the key areas for choughs on Islay and Colonsay. It seems unlikely that conservation efforts, involving habitat management and population reinforcements, could be successful without the support of this community.

8.6 Conclusions

Red-billed choughs are not currently listed as 'conservation action needed' in the Scottish Biodiversity List, despite their precarious status. Our work suggests that this should be changed. Choughs clearly meet the criteria of 'in significant decline in Scotland, often linked to land-use change', and 'rare or restricted distribution and/or under threat'. The ecological and genetic threats to the population are unusually well understood, not least due to the high-quality demographic data and analyses that are available for the population. Potential routes to chough conservation have been identified and, since choughs are closely tied to pastoral agricultural environments, are largely under human control. What is now required is a clear decision as to whether chough conservation in Scotland is of sufficient priority to warrant investment in effective land management and translocations. If yes, these activities should be enacted in ways that truly deliver the desired biological outcomes.

9. IMPLICATIONS FOR SCOTLAND'S BIODIVERSITY

The Scottish Government is committed to conserving Scotland's rich biodiversity in line with the Convention on Biological Diversity's (CBD) Aichi targets, to be met by 2020. Key species and habitats that are considered to be of principal importance for biodiversity conservation in Scotland are those under protection in the Wildlife & Countryside Act (1981) and included on the Scottish Biodiversity List (2004). The chough is included on both and thus is considered to be of principal conservation importance. Scotland is currently failing to meet 13/20 of the Aichi targets (Interim Progress Report 2017). Prevention of loss of an important native species, underpinned by high quality and detailed scientific evidence as is the case for choughs, should be an essential part of Scotland's conservation strategy. Management to conserve the Scottish chough population falls within at least two of the Aichi targets that are not on track:

- Target C12: Extinction prevention – PVA results indicate that without urgent management action chough will likely become extinct in Scotland over a relatively short time-frame.
- Target C13: Genetic diversity maintained – implementation of population reinforcements will increase the genetic diversity of the Scottish chough population and alleviate high levels of inbreeding.

Furthermore, choughs rely on low-intensity pastoral grassland habitats which are themselves of high biodiversity value. Successful long-term management strategies for choughs are therefore linked to the conservation and restoration of such habitats.

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ANNEX 1: ISLAY CHOUGH INTERIM REPORTS

We are committed to making the findings of our research publicly available whenever possible. However, some species are threatened by or vulnerable to human activities and therefore require protection. Making some of our research confidential is a way of protecting these species and may help their survival; this applies to Annex 1 of this report. All other sections of the report are published in full.

If you would like to request access to a copy of the full report please email research@nature.scot

ANNEX 2: TABLE OF RESULTS FROM POSTMORTEM EXAMINATIONS OF CHOUGHS FOUND DEAD ON ISLAY 2004-2018

Postmortem examinations were carried out by Dr Tom Pennycott.

Diagnosis	Number of individuals affected	Age of birds
Eye problems	15	N/F x15
Significant worm burdens	14	A x2; J x11; UC x1
Trauma	10	A x3; J x1; N/F x6
Oesophageal necrosis	5	N/F x5
Yersinia pseudotuberculosis	4	J x2; N/F x2
Adverse environment	2	N/F x2
Staphylococcus aureus	1	N/F x1
Erysipelothrix rhusiopathiae	1	N/F x1
Meningo-encephalitis	1	N/F x1
Reproductive tract disorder	1	A x1
Significant external parasites	1	A x1
Isolation of *Mycoplasma gallisepticum*	2	N/F x2
No diagnosis	10	A x3; J x2; N/F x5

Number of diagnoses exceed number of individuals because some had more than one diagnosis. A=adult, J=juvenile, N/F=nestling/fledgling, UC= uncertain if adult or juvenile.

ANNEX 3: BEHAVIOURS OF DIFFERENT SUBADULT COHORTS

Background

Prior to starting the supplementary feeding there was little detailed information on the behaviour of sub-adult chough on Islay. The first colour ringing of nestlings started here in 1982, and subsequent observations from a number of studies observed that prior to pairing and breeding, juvenile, sub-adult and pre-breeding choughs foraged together in more or less discrete flocks and that these roosted communally. Bignal *et al.* (1997) described roosting behaviour and suggested main roosts and sub-roosts, and that these reflected some social segregation between breeders and non-breeders.

Observations during the 9 years of this study have recorded more detail and inevitably discovered a more complicated and less predictable situation than was previously thought. The details for each annual cohort are given in a series of interim reports to SNH (Annex 1) which also includes confidential information about breeding and roosting locations. The section below is a summary of these reports focussing on behaviour during the periods of highest mortality.

Behaviour of the 10 cohorts (2009 – 2018)

Prior to the supplementary feeding, post-fledging survival of the 2007 – 2009 cohorts had been extremely poor – in fact only 8 birds born in these years ever became adults – so there were virtually no sub-adults or a sub-adult flock to make observations on for those years.

In 2009 the feeding did not begin until late December and there had been significant post fledging mortality before this, leaving only 9 young at Ardnave which were fed through to the following May. In mid-July 2010 feeding resumed and by mid-November that year there were twenty 2010 birds and six 2009 birds in the flock of 34 at the Ardnave. There is no information on the movements of these birds prior to this nor the reasons for mortality – but these 26 birds were the only young of the 143 nestlings ringed in these two years still surviving at the end of November 2010. By the spring of 2011 none of the 32 young that had been at Kilchoman ("unfed") had survived whilst 14 of the 19 recorded at Ardnave ("fed") were still alive.

Because of the striking contrast in survivorship between Ardnave ("fed") and Kilchoman ("unfed"), from 2011 the feeding strategy was modified, abandoning the Kilchoman "unfed control" and introducing feeding there (Coull) and also trial feeding of a breeding pair at Sanaig. These changes, and the observations they necessitated at the three sites, have provided new, more detailed, information of the behaviour of the subsequent ringed cohorts.

The expectation was that most or all newly independent birds of each annual cohort would join the respective flocks at either Ardnave or Coull, and remain in these flocks through to the following spring; this is thought to be what had happened to the 2009 and 2010 cohorts. However, a different, more complicated and less predictable picture was seen in the subsequent cohorts.

In 2011 the new chough families were in two main groups, one at Ardnave in the sand grasslands and the other centred on Kilchoman where they foraged in silage aftermaths at Kilchiaran from mid June to mid July. The 2011 cohort (78 fledglings of which 61 were colour ringed) eventually comprised 18 birds (seven at Ardnave and 11 at Kilchoman) by March 2012. However, during the previous months (particularly during September and October) there had been many movements by young birds between the two areas e.g. one bird (from Coull) was recorded at Kilchiaran, Coull, Saligo, Sanaig and Ardnave – the latter on the same day. Clearly there had also been many losses either before or during this time. This was the first indication that, for at least part of their first year, the juveniles might not remain part of the flock which was composed mostly of both failed and successful breeders; also that this was the period of greatest mortality.

At Ardnave in late June of 2012, there were 74 choughs at the feeding made up of 16 pairs and 36 young (there was also six 2011 birds); by mid-July there were at least 90 birds foraging at Ardnave. At Coull in the flock of up to 25 birds there were never more than eight juveniles at the feeding area. At Sanaig in July just the family (pair and four young) were at the feeding, but during August several young that were in the Ardnave group also spent some time at Sanaig. However, when the Sanaig young moved to Ardnave in late August, thereafter only the Sanaig pair were present.

In 2013 this dispersal from Ardnave by the juveniles was more pronounced, and in mid-August a group of up to 20 juveniles established themselves at Traigh Bhan (at the west end of the Sanaig cliffs) roosting on nearby rock outcrops. This group would spend much time foraging on the beach at Traigh Bhan. From early September these birds began coming to the feeding site at Sanaig. By 12 September, for the first time, there were no young at Ardnave but the flock there did for the first time include a number of yearling choughs (20 of the 2011 cohort). All the surviving fledglings were now feeding at Sanaig (sometimes returning briefly to Ardnave) and this persisted through to the following April and into the summer when a very mobile group of (up to 30) 2012 and 2013 born birds foraged from Smaull, Eilean mor, Sanaig and to Ardnave.

At Coull, few 2013 fledglings in the Kilchoman flock (maximum of 8) ever made it to the feeding. As in previous years, immediate post-fledging mortality seemed much higher there than at Ardnave resulting in the flock being mostly composed of pairs and sub-adults.

In late June and July 2014, the Kilchoman flock of 50 birds (comprised mostly of families) foraged in the silage aftermaths at Kilchiaran particularly in one field (the Bradge), roosting at Creag Mhor, but few families and young were ever part of the flock (32 mostly 2012 and 2013 birds) visiting the feeding area despite feeding on the Coull hill during the day. At Ardnave there was a similar pattern to 2013 with the newly independent fledglings moving in August to the Sanaig – Eilean mor area, joining the previous year's sub adults and sometimes retuning to Ardnave to roost and visit the supplementary feeding there. At the end of August 35 choughs, all 2013 and 2014 birds, were at Sanaig.

The fledglings were clearly very mobile as the composition of the flocks changed from day to day, and the Sanaig group even included some 2014 young from the Kilchoman flock. It was not until October that most fledglings returned to Ardnave (24) or Coull (five). By the end of the year the Coull flock comprised many sub-adults (e.g. in a flock of 33 there were seven 2013, eight 2012, four 2011, three 2014) and the Ardnave flock comprised 20 breeding pairs, twelve 2013 birds and twenty 2014 fledglings.

The 2015 breeding season followed an exceptionally wet winter and post fledging survival was poor with only 17 fledglings surviving into October (10 at Sanaig, five at Coull and two at the Oa). As expected, the juveniles spent July at either Coull or Ardnave; but from August the picture was again one of dispersal from Ardnave with the juveniles now joining the 2013 and 2014 cohorts and moving between Ardnave, Sanaig, Sanaigmhor and Braigo and roosting at Eilean mor. However when the 2013 and 2014 cohorts returned to Ardnave in October, none of the 2015 juveniles returned with them. The few birds surviving were either at Coull (six) or Sanaig (six). However for the first time since the project began there was a group of at least 40 sub-adults in the Islay chough flock.

In 2016 immediate post-fledging mortality was again high with 18 of the 66 fledged chicks dead and never seen more than once. By the end of October, the 25 fledglings known to be surviving were at Ardnave (20), Sanaig (one) and Coull (four).

Although there was dispersal behaviour similar to previous years, the pattern in 2016 was quite different. At Coull, few young visited the feeding area until the turn of the year, instead foraging (often in cow dung) across the hill ground of Coull, Saligo and Braigo. The young from the Ardnave feeding area moved not to Eilean mor but to a reseeded grass field at Kilchoman House (a field not ploughed for over 30 years) where they foraged virtually every day during November and December, feeding on leatherjackets and sometimes visiting the Coull feeding.

In 2017, again immediate post-fledging mortality was high – by the end of July only 35 of the 60 fledged were surviving and several “sick” fledglings were seen at both Ardnave and Kilchoman. Up to 29 fledglings visited the feeding area at Ardnave in July but few visited Coull. During August there was the now predictable movement of the new cohort from Ardnave to Sanaig / Eilean mor (19 there from 12 natal sites on 27th) but with some birds returning to Ardnave to roost (and to the supplementary feeding). By December there were only 11 fledglings known to be surviving (from eight natal sites)

Of the 65 colour ringed fledglings in 2018, 55 were seen at least once after fledging but there were 10 fledged young that were never seen. By the end of September there were only 19 known to be surviving (15 Ardnave, one Oa, three Kilchoman [but of which two were definitely sick]). Of these 19, five had been sick, had been treated (3-9 Sept) and had recovered. Of the other 36, two were found dead, 15 were missing assumed dead and there were 19 birds that had been seen only once (at fledging) but never again.
In 2018 breeding was about 10 days later than in previous years. The first families only started to arrive at Coull and Ardnave from 21 June, but by early July there we at least 12 families at Ardnave (with 23 young). During July the flock at Ardnave comprised about 50 birds. At Coull at this time there was a flock of 55, although the latter included few young. However, the Coull flock did include at least 15 of the 2016 and 2017 cohorts.
2018 was unusual, compared to previous years, in that many of the pairs that arrived with their young to join the flock at Ardnave lost many (and in some cases all) of these within the first week or two, or in some cases the first few days. Even by early August at Coull the flock (about 40) included no 2018 birds (but at least 15 “sub-adults” from the 2016 and 2017 cohorts). At the end of October at Ardnave there were 55 birds including 14 young but by mid-January the number of young here had fallen to nine.

Eric Bignal, SCSG

ANNEX 4: JOURNAL PUBLICATION PROVIDING FULL TECHNICAL DETAILS AND RESULTS OF POPULATION VIABILITY ANALYSIS

This annex is an article published in the Journal of Ecology and can be accessed on their website.

https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.13464

ANNEX 5: REPORT FROM VISIT TO JERSEY CHOUGH REINTRODUCTION PROJECT

Visit to the Jersey red-billed chough reintroduction project with Elizabeth Corry, Durrell Wildlife Conservation Trust.

Amanda Trask & Pat Monaghan, 26th April 2019

Liz Corry spent the day with us, taking us to the various breeding and foraging areas, and to the release site and supplementary feeding area. Liz provided us with lots of information and was extremely helpful. Below we briefly summarise the information we obtained.

Background to the project:

- Chough extinct in Jersey by ~1910; known to be present on Guernsey in 1902, but extinct soon after (from records from egg collectors in 'Birds of the Channel Islands', Derickson)
- Not known what the original cause of the extinction was, but likely a combination of habitat degradation/loss, especially in the south of Jersey where there was a lot of development and persecution.

Current status of the project:

Wild population:

- 48 individuals in the wild in December 2018
- Possibly now 37 (but this may be an underestimate due to colour ring loss)
- Breeding pairs: 10 pairs in Ronez Quarry, 1 in a sea cliff site at Plemont, 1 in a sand quarry site (Simon Sand & Gravel)
- Supplementary food is provided daily at a feeding station near the original release site.

Captive population:

- 1 breeding pair (currently on 4 eggs) – both previously have bred, but first year this male and female have been paired together (after previous mate loss). Note that no mate choice opportunities, but this could improve performance in captivity if there were sufficient birds.
- 1 foster female (from Italy, habituated to humans not used in breeding but used as a foster parent)
- There is pressure from Durrell Wildlife Trust to keep this captive population small, as captive breeding programs of other species are now given priority.

Habitat management:

- Carried out by National Trust for Jersey
- Introduction of Manx Loaghtan sheep to coastal grassland areas (thought to be similar to the original Jersey sheep)
- Idea of chough reintroduction driving habitat restoration work
- We visited various areas used by choughs for foraging – rough pasture grazed by sheep and horses, the racecourse, coastal grassland areas. The suitable foraging habitat is somewhat limited – there is a lot of heather and long grass. However, the areas currently used by the choughs appeared good.
- Human population density is high (>100000 people on an island around 120Km^2 and there is a lot of disturbance from human recreational activities. Nonetheless, the choughs appear to be doing well.

Methodology of the releases:

Note: The Jersey chough conservation translocations were designed as part of a reintroduction as opposed to a population reinforcement, as would be the case for Islay chough. No local birds were therefore present on Jersey and thus the released birds had no access to any local knowledge.

Overall strategy: Aimed for 30-50 birds released over a 5-7 year period, through annual releases of 6-10 birds per release. Release group size was based on the idea of this reflecting the size of a social group consisting of two parents and four offspring.

2010/11 - birds first brought over from Paradise park to start a captive breeding program on Jersey, with the intention of using these for releases to the wild. There were some initial teething problems with this, so the first releases were done with birds straight from Paradise Park, not breed in the Jersey captive population.

Later released birds have been reared in captivity in Jersey either by their parents or foster parents, or hand reared.

2012/13 – first releases of choughs to the wild:

- March – eight 1 and 2yr old (parent-reared birds) brought over from Paradise park for the first release to the wild. Initially kept in a specially-made aviary at Sorel (north Jersey coast) until August (see Fig 1 a-d). This included the following: a 30 day quarantine (as Jersey is outside the UK), to give them time for social bonds to form; training them to come to the supplementary feeding; fitting radio-transmitters; avoiding release them during moult.
- Before release, birds were trained to associate a whistle and target boards (wooden boards with a conspicuous symbol painted on them, Fig. d) with the supplementary food. Such boards are still used in the feeding station on rodent proof poles. These are regularly cleaned.

August 2013 – first 'soft releases':

- Food was reduced just before the release (to help ensure that the birds are highly motivated to come back to the supplementary feeding stations) and first release carried out just before roosting time, to increase the probability that the birds return to the aviary to roost.
- Day 1 – hatches in aviary opened for 30 mins for 'exploratory release', then birds brought back into the aviary. Only 3 birds actually left the aviary on this first day, with two staying on the outer shelves of the aviary and 1 making a short flight.
- Day 2 – 1 pair left and flew to the nearby Ronez Quarry (encountering a peregrine on the way), where they stayed for 3 nights. The male appeared to have sustained an injury. Not much food was available at the quarry, so Liz had to make repeated visits to try to get them to take supplementary food there, before finally managing to get them to return to the aviary.
- Other birds then also went to Ronez Quarry in later releases, with two other birds staying in the quarry.
- October – two birds died; all remaining birds were then returned to the aviary over winter.

2nd releases - April 2014:

- Original birds in re-released
- 4 hand-reared birds from Jersey captive population and 6 from Paradise park added (birds put into aviary for integration before release)

2015:

- 6 birds in the wild
- 10 parent-reared birds from Paradise park released
- First wild-hatched chick

2016:

- 4 foster-reared birds from Jersey captive population and 6 from Paradise park released

2017:

- No releases
- 2 wild birds lost to Syngamus

2018:

- 3 parent-reared birds released: one 1st-year bird from Jersey captive population and 2 from paradise park
- 1st-year bird from Jersey captive population subsequently died, possibly due to lack of foraging experience (the Paradise park birds get some foraging experience prior to release as they are kept in large poly-tunnels with more natural foraging opportunities)
- Pressure to release these birds, despite the sub-optimal small release group size, as not much room in captivity
- Preferentially would create flocks for release, so they have more opportunity for mate choice

Costs:
Although they did not have to pay for the birds (there is a surplus at Paradise Park), there were costs of the transport crates and transport costs (this was relatively low cost for Jersey as the Paradise park owners drove the first choughs for release to Jersey themselves, and later choughs were flown in on a private aircraft by Lee Durrell).

Current breeding sites:
The 10 pairs breeding at Ronez quarry, which is close to the release site, are breeding in noisy, dusty buildings. The quarry staff monitor the birds. Nest boxes have also been provided in some cliff/cave areas.

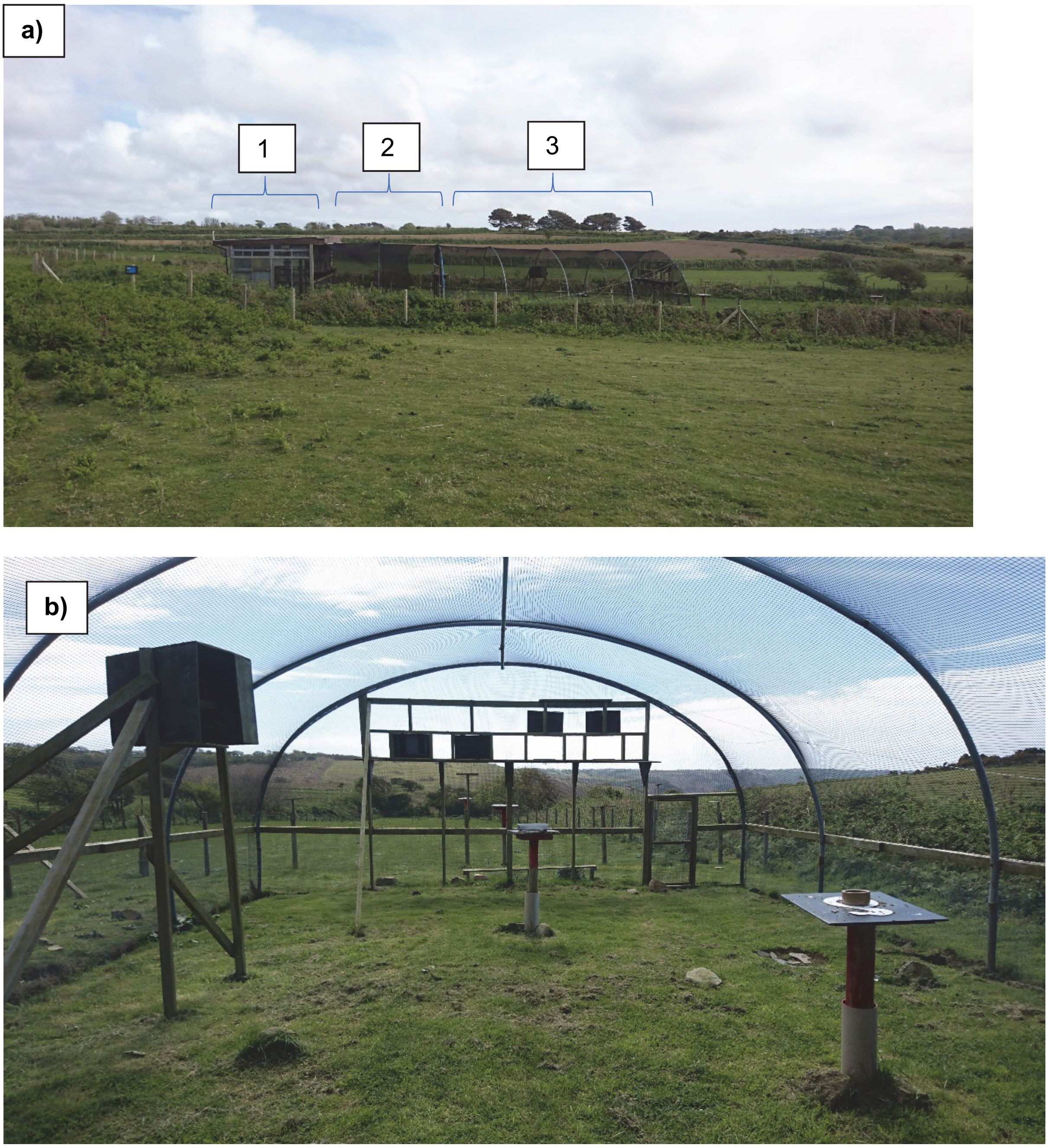
Predators on Jersey:
Cats, feral ferrets, peregrines, black-backed gulls – possible reduced anti-predator behaviours displayed as there have been a number of observations of choughs interacting with gulls.

Human disturbance issue:
As mentioned above, Jersey is about 1/5th of Islay size, but population size of ~100,000 residents plus tourists. Also, dog-walking, motor-cross, quarry works and go-karting near some of the chough habitats.

Supplementary feeding:
Variety of different food types tried, but currently use a mix of commercial pellet (Orlux remiline granules) and mealworms for the wild population, or waxwing moth larvae for the captive population (can't use these for the wild population as pest species).

Liz has tried a variety of food types and has put together a table of different food types with some information on palatability and nutritional content – she has offered to send this to us. She is very keen to collaborate in developing a suitable pellet mix for choughs.

Other:
While there, we met Dr Charlotte Macdonald, Director of Conservation and living collections at Edinburgh zoo who was taking part in a conference. She expressed a keen interest in helping with any translocations, for example by establishing a captive chough population at the Highland Wildlife Park, to aid with population reinforcements in Scotland.


a)
1
2
3
b)

c)

Fig. a-c: The chough aviary at Sorel. This is the aviary they use to keep birds before releases to the wild, as well as for keeping any wild birds in that become sick and are under treatment. (a) The aviary is made of three compartments with (1) being the innermost compartment, and (3) being the outermost compartment. (b) inside the outmost compartment of the aviary. (c) in the middle compartment, looking towards the innermost compartment. All the compartments are linked through closable hatches. This area is also used as a feeding station for the free-flying birds. These are now generally fed once per day around 4pm; 22 birds turned up for the feeding when we were present.

Fig. d: One of the ‘target boards’ (symbol currently covered) on which they supplementary feed the choughs. These boards can be kept clean, and also aid in training the birds to come to the supplementary food. These boards are placed both inside and outside the aviary. Feeding was initially 3 times per day, now scaled back to once per day.

Availability of birds:
Jersey could provide us with the young birds that their breeding pair produce this year, since they do not have space to keep these birds. Other captive birds would most probably have to come from Paradise Park, who appear to have surplus birds. However, it is worth noting that there are discussions to reintroduce choughs to Kent, with these birds also potentially being sourced from Paradise Park.

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ISBN: 978-1-78391-797-6

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