ENGLISH NATURE

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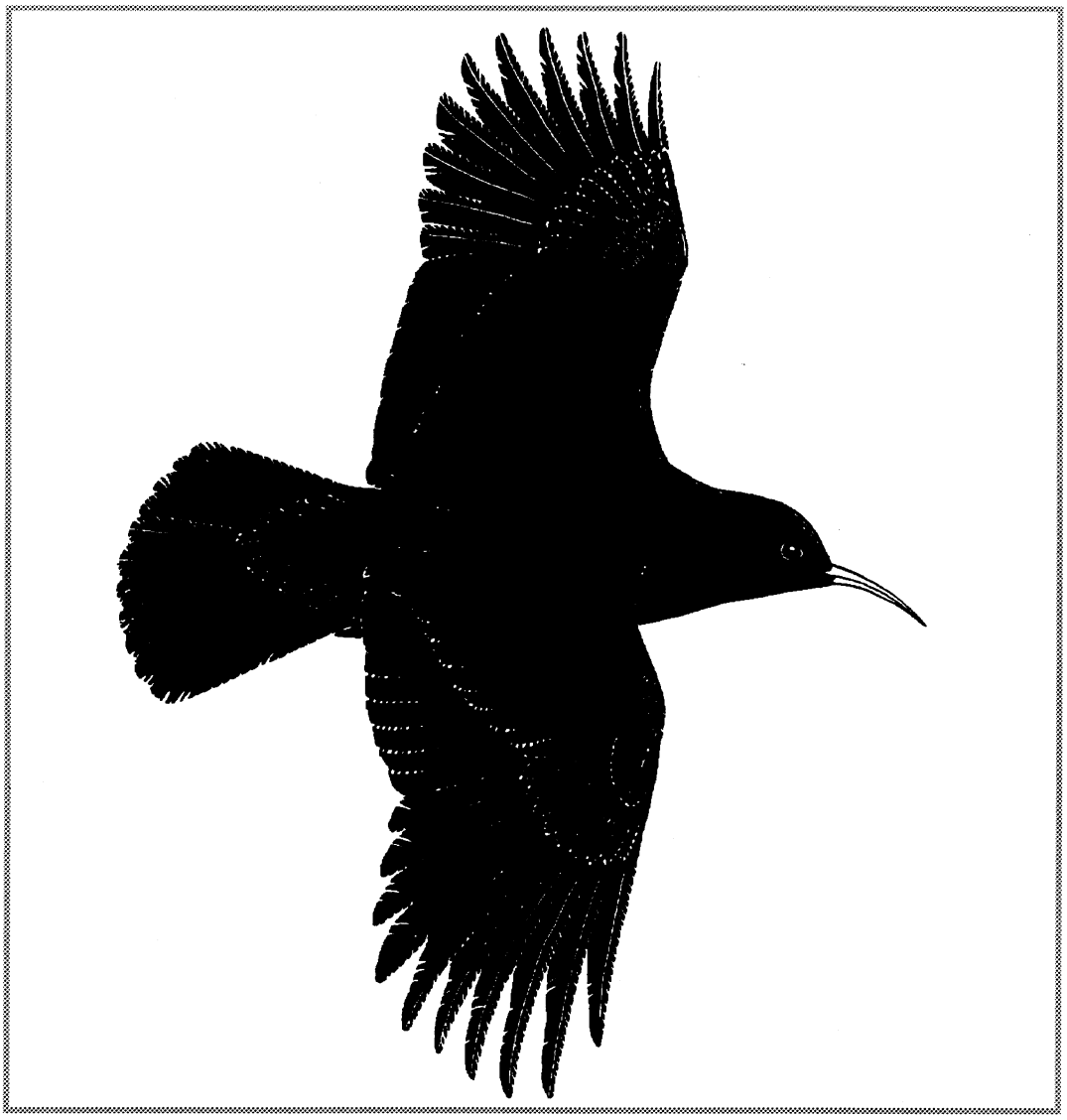
A discussion document

No. 456 - English Nature Research Reports



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English Nature Research Reports

No. 456

The restoration of the chough in south-west England: A discussion document

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ISSN 0967-876X

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SUMMARY AND CONCLUSIONS

1. The chough was once widespread along the coasts of southern and western England, but declined mainly as a result of changes in the management of their preferred habitats. Chough bred in Devon until about 1910 and in Cornwall until 1952, the last confirmed breeding record in England.

2. South-west England has been a major focus for those interested in restoring the chough to England during recent years due to the former prevalence of the species in the region, its popularity with local people and the large areas of potentially suitable habitat remaining.

3. Reintroduction is one option for restoring the chough to south-west England and there have been calls from a variety of individuals and organisations for such a project to take place. In order to help consider the merits of such a proposal this report includes a formal assessment of a chough reintroduction project against the internationally agreed IUCN guidelines. The aims and objectives of the RSPB/Statutory Conservation Agencies' Action Plan for the chough are also discussed.

4. In the spring of 2001, a small influx of 4-7 chough occurred along the south coast with birds recorded from the Isles of Scilly to Portland, Dorset. Three birds arrived in the same area of southern Cornwall, including a pair that remained in the area until spring 2002 when they attempted to breed. In the light of this influx and a consideration of the IUCN guidelines it is suggested that proceeding with a costly, time consuming and unpredictable reintroduction project would be inappropriate in the short term. Efforts to restore chough to south-west England should instead focus on increasing the area of semi-natural coastal habitat that is managed appropriately.

5. Any chough present in south-west England during the next few years will be closely monitored so as to inform future conservation action. It is hoped that a breeding population may become established naturally and that habitat restoration work will allow the population to increase and spread during the coming years. If this does not happen within the next few years then a well-organised reintroduction project may provide the best way forward.

6. In order to coordinate work to restore the chough in south-west England a Recovery Programme will be established to be managed jointly by English Nature, the National Trust and RSPB. Funding will be provided for monitoring work, publicity material and, where not available from other schemes, for habitat management work. A project officer will be employed to coordinate the programme.

1. INTRODUCTION

The chough *Pyrrhocorax pyrrhocorax* is on the amber list of Birds of Conservation Concern and is considered a high conservation priority in both a European and a UK context (Tucker & Heath 1994). The bird is listed on Annex 1 of the EU Birds Directive and on Appendix II of the Bern Convention. In the UK it is protected under Schedule 1 of the Wildlife and Countryside Act (1981) and the Wildlife (Northern Ireland) Order (1985), and in the Isle of Man by the Wildlife Act (1990).

The chough breeds patchily from Ireland south to the Atlas Mountains of Morocco and the Canary Islands, and from the Bale Mountains of Ethiopia across the Palearctic to China. The European population of some 12,000 to 17,000 pairs (Hagemeijer & Blair 1997) has declined greatly in recent decades and the bulk of the population is now found in Spain, France and Greece (though there are a further 5,000-50,000 pairs in Turkey). Many populations are now small, isolated and of doubtful viability (Tucker & Heath 1994). The chough is a local breeding species in the UK with an estimated 315 breeding pairs found mainly in Wales, the Isle of Man and on the islands of Islay, Colonsay and Jura in Scotland. There are about 830 pairs in Ireland (Gibbons *et al* 1993). The chough was once widespread along the south and south-western coasts of England, and although details of the bird's former numbers are scant, we have excellent information concerning its distribution, especially in the period immediately prior to extinction (Brown & Grice in prep).

Considerable research has been carried out into the chough's basic ecology and its habitat requirements are reasonably well understood (e.g. Bignal & Curtis 1988). National surveys were conducted in 1963, 1982 and 1992 and changes in distribution over time are readily apparent. Populations on Islay and in Wales have been well studied (including at least three unpublished PhD/MSc theses by Warnes (1982), Meyer (1991) and Owen (1985), and detailed research on feeding site selection continues in Wales. Four separate colour-ringing studies are ongoing and may further improve our knowledge of post-fledging dispersal behaviour and survival rates. The feeding habits of choughs in England were sketched by Ryves (1949) and the details of the foraging habits of two choughs, thought by some to have escaped from captivity, which were at large in Cornwall in winter 1986/87 were described in detail by Meyer (1990). The decline of this species has been well documented and the reasons for the bird's extirpation from England relate mainly to changes in the management of its preferred habitats.

The chough is a high profile and popular species and several well-intentioned groups would like to see it reintroduced into south-west England as soon as possible. There have been a number of attempts at captive breeding (there are an estimated 60-70 captive individuals in the UK) and several large areas are now managed specifically to provide suitable habitat. The National Trust have a special interest in this species as they are the major landholder in the coastal areas which were once frequented by chough and manage all four of the sites where chough last bred in the late 1940s and early 50s.

This document discusses the potential for restoration of the chough in south-west England against the background of the aims and objectives of the UK Action Plan for the species, and the internationally agreed IUCN guidelines for reintroduction projects.

2. THE UK ACTION PLAN

The following section is based on the RSPB/Statutory Conservation Agencies' action plan for chough, updated where necessary. The action plan has the following targets:

- in the short term, ensure that the breeding populations in Wales, Scotland, Northern Ireland and the Isle of Man, at the time of the next annual survey, in 2002, are no lower than 1992 levels (c.342 pairs)

- in the short term, maintain the current range of the chough in the UK and the Isle of Man

- in the medium term, increase the breeding population to at least 375 pairs by the time of the 2012 national survey

- in the medium term, increase the breeding range of the chough, particularly into sites recently vacated and sites adjacent to existing breeding pairs

The broad policies of the plan are to:

- ensure the maintenance and restoration of suitable land management and farming systems in their current range in order to provide feeding opportunities in proximity to breeding sites

- identify unoccupied but potentially suitable breeding areas away from those in current use, followed by the promotion of changes in habitat management to encourage chough to colonise them. Target areas will be in Northern Ireland, south-west Scotland and south-west England

- discourage the use of stock treatment chemicals with an insecticidal effect in dung

- continue to provide artificial nest sites in appropriate areas where these are currently limited

- liase with land managers and statutory agencies to ensure the protection of choughs from disturbance and other threats

The main factors affecting chough appear to be:

- the extent and quality of available short-sward, cattle grazed, invertebrate-rich, coastal grassland (much grassland is now too tall and overgrown after abandonment of grazing and much has been ploughed and re-seeded). The cattle in many well-grazed areas are treated with chemicals which retain an insecticidal effect in dung and so reduce invertebrate availability - crucial importance

- nest site availability (caves, sea cliffs and many man-made structures continue to be available in much of the bird's English range) - crucial importance

- climatic factors - chough are likely to find feeding difficult when the ground is frozen. There is a clear correspondence of their distribution with the mild west coast maritime climate in the UK - moderate importance

- predation - peregrines may take some birds - importance unknown but probably small

- human disturbance - much of the bird's current and former range is subject to a high level of recreational usage, principally by ramblers and rock-climbers - importance may be high in some areas but many areas used currently are covered by voluntary agreements with climbing organisations

- human persecution - once widely and intensely persecuted; may still continue at a very low level - importance low

- disease - gapeworm infestations are known in captive and wild birds but the importance of this is unknown. It has been suggested that this is only a problem when birds are feeding on earthworms, which may be given to birds in captivity or taken regularly by wild birds where habitat availability is sub-optimal (Ian Johnstone pers comm.)

- competition - jackdaws and peregrines may occupy nest sites but those selected by jackdaws are usually significantly different from those used by choughs, and peregrines are insufficiently numerous to give major cause for concern - importance unknown

Despite sensitive management, the short-term objectives of the action plan have not been met. Whilst there has been a welcome expansion of range eastwards along the south Wales coast and in the Isle of Man, the chough has declined on Islay, the bird's Scottish stronghold, and is close to extinction in inland mid-Wales. Despite a recent influx of three new birds, the chough has been virtually lost as a breeding species from Northern Ireland.

The action plan urges the identification of unoccupied but potentially suitable breeding areas away from the bird's current range and the promotion of habitat management changes that might encourage their colonisation by choughs. South-west England is identified as one target area. This area was the English locality most recently occupied by breeding chough and it still retains an abundance of nesting areas. There is considerable local support for the return of the chough to Cornwall and the bird is to be found on many emblems and coats of arms around the county. 'Operation Chough' was established in 1987 with the expressed aim of working towards the reintroduction of the chough to Cornwall. Much once-suitable habitat is now under the ownership of the National Trust an organisation firmly committed to the cause of the chough in south-west England.

As outlined in the action plan, an ideal breeding area for chough would comprise the following:

- a historical breeding location with suitable cliff structures for nest sites and communal roosts

- an area of unimproved maritime grassland or coastal heath, maintained as a short-sward by year-round grazing by cattle (horses and sheep may provide supplementary grazing) adjacent to suitable breeding cliffs

- grassland or coastal heath should contain a sufficient area of exposed soil or rocks, and, if possible, an abundance of anthills (some of these features may be provided by cliff face habitats)

- restrictions on the use of chemicals with insecticidal properties in dung
- close proximity to winter arable stubbles or fixed dunes/dune slacks with unimproved grassland maintained by year-round grazing, in order to provide year-round foraging habitats
- land in the ownership of organisations or individuals likely to retain conservation uppermost amongst their land-management concerns
- an area with only low levels of disturbance, particularly during the breeding season

A considerable amount of habitat management has been undertaken in Cornwall to encourage wandering chough to remain. This has been conducted by the National Trust and a small number of individuals within the farming community, with advice from a range of grassland and chough specialists and from those with an interest in re-introducing the Large Blue Butterfly, whose requirement for a tightly-grazed unimproved sward coincides with that of the chough. An expert group made an evaluation of a series of potentially suitable sites in Cornwall and Devon in 2000 and Gowenlock (2001) summarised current knowledge of potentially suitable sites in north Cornwall.

Despite considerable habitat management work, until recently there seemed little prospect of chough naturally re-colonising south-west England within the foreseeable future. This is because chough of breeding age (usually in their third year) are very site faithful and although juveniles disperse widely, they usually show strong natal philopatry, returning to breed close to their own place of birth. However, the Welsh population has recently expanded eastwards along the south Wales coast. Breeding birds have been found on the Gower, some 30-40km from the nearest breeding areas at Castlemartin and have now expanded a further 40km eastwards from Gower. On a clear day, Lundy and the north Devon coast are clearly visible from the Welsh coast. This may account for the recent increase in records in these areas and offers some hope for natural recolonisation in the future.

Spring 2001 saw an unexpected influx of chough into south-west England (see Appendix 1), with records spread along the southern coast from the Isles of Scilly to Portland, Dorset. It is difficult to be certain about the total numbers involved, as individuals may have been seen at more than one location. A conservative estimate suggests a minimum of four different birds were seen during the spring and the true number may be a high as seven. As records in the south-west are normally along the northern coast there is speculation that the birds may have originated from the Brittany population. However, this population is small (around 30-40 pairs) and declining and it is perhaps equally likely that the birds came from Ireland or Wales. The influx included at least three (possibly five) birds at the same site in southern Cornwall. Courtship feeding was observed between two of these birds in 2001 and nest building was observed in the same area in March 2002.

Due to chance variations in breeding success and first-year survival of progeny, it remains unlikely that a single breeding attempt would lead to the establishment of a self-sustaining population unless additional recruits were attracted into the area. Nevertheless, in the light of the 2001 influx and the breeding attempt in 2002, it would seem sensible to concentrate short-term efforts on habitat management and re-assess the situation in a few years time. If the prospects for natural recolonisation remain poor then there is the option of a translocation project in order to ensure that at least one self-sustaining population of chough is re-

established in the UK during the next ten years. This option is assessed below against the internationally agreed IUCN guidelines.

3. AN ASSESSMENT OF A CHOUGH REINTRODUCTION PROJECT AGAINST CURRENT IUCN GUIDELINES

In the sections below, italics indicate direct quotations from the IUCN guidelines and the numbering of paragraphs follows the published guidelines.

1. Definition of terms

The term *reintroduction* would apply to an attempt to bring about the return of breeding chough to England: it would be *an attempt to establish a species in an area which was once part of its historical range, but from which it has been extirpated or become extinct.*

2. Aims and objectives of reintroduction

The principle aim of a chough reintroduction project, as with any reintroduction, would be *to establish a viable, free-ranging population in the wild, of a species, subspecies or race which has become globally or locally extinct, or extirpated, in the wild. It should be reintroduced within the species' former natural habitat and range and should require minimal long-term management.*

The objectives of a reintroduction project may include:

to enhance the long-term survival of a species
to re-establish a keystone species (in the ecological or cultural sense) in an ecosystem
to maintain and/or restore natural biodiversity
to provide long-term economic benefits to the local and/or national economy
to promote conservation awareness; or a combination of these

The objectives of a chough reintroduction project would encompass all of the above.

3. Multidisciplinary approach

A reintroduction requires a multidisciplinary approach involving a team of persons drawn from a variety of backgrounds. As well as Government personnel, they may include persons from governmental natural resource management agencies; non-governmental organisations; funding bodies; universities; veterinary institutions; zoos (and private animal breeders) and/or botanic gardens, with a full range of suitable expertise. Team leaders should be responsible for co-ordination between the various bodies and provision should be made for publicity and public education about the project.

A chough reintroduction project would almost certainly involve both government-funded and voluntary organisations, providing the full range of expertise required to carry out a project of this nature. The work would be overseen by a project steering group made up of representatives from all the organisations involved.

4. Pre-project activities

4a) Biological

(i) Feasibility study and background research

1. *An assessment should be made of the taxonomic status of individuals to be reintroduced. They should preferably be of the same subspecies or race as those which were extirpated, unless adequate numbers are not available. An investigation of historical information about the loss and fate of individuals from the reintroduction area, as well as molecular genetic studies, should be undertaken in case of doubt as to individuals' taxonomic status. A study of genetic variation within and between populations of this and related taxa can also be helpful. Special care is needed when the population has long been extinct.*

There is considerable morphological variation across the chough's extensive world range including a number of different races. The *pyrrhocorax* race occurs in Britain and Ireland. A recent genetic study (Bruford & Tomaskovic unpubl.), including samples taken from historical Cornish specimens showed that there was little, if any, phylogenetic variation between different UK chough populations. Birds from anywhere within the range of the *pyrrhocorax* subspecies in Britain and Ireland would therefore provide suitable donor stock for a reintroduction in England. If captive birds of unknown origin were considered for release then genetic work would be required to demonstrate that they are from the *pyrrhocorax* sub-species.

2. *Detailed studies should be made of the status and biology of wild populations (if they exist) to determine the species' critical needs. For animals, this would include descriptions of habitat preferences, intraspecific variation and adaptations to local ecological conditions, social behaviour, group composition, home range size, shelter and food requirements, foraging and feeding behaviour, predators and diseases. For migratory species, studies should include the potential migratory areas. Overall, a firm knowledge of the natural history of the species in question is crucial to the entire reintroduction scheme.*

The status and biology of the chough in the British Isles is well-known (see, for example, Bignal & Curtis 1988; Bignal, Bignal & McCracken 1997). The chough has particularly specialised habitat requirements. It nests in crevices or on sheltered ledges of sea cliffs, in caverns, quarries, mineshafts and on abandoned buildings. In Britain, most nest sites are coastal, but elsewhere, large numbers breed in inland mountains. Three to five eggs are laid between April and early June in a nest usually made of dead heather or gorse sticks and lined with dry grass and wool. Incubation lasts 20-22 days and birds fledge after some 40-50 days in the nest, usually by mid-July. Outside the breeding season, chough are highly gregarious and will often roost communally in sea caves and cliff ledges. They forage in parties or larger flocks on rough, heavily grazed, short-sward grasslands and heaths, also using well-grazed improved pasture and cereal stubbles at times. The diet is made up of soil and dung-dwelling invertebrates, principally beetle and crane-fly larvae and adults, ants and spiders. Worms, molluscs, caterpillars and grain occasionally feature in the diet.

Two birds observed at Rame, Cornwall between November 1986 and January 1987 associated strongly with scattered, scrub-free open areas of coastal cliff and also used a dung-rich field of stubble turnips from which cattle had recently been removed (Meyer 1990). The habitat preferences of three birds from the recent influx into south-west

England were studied in southern Cornwall in summer 2001 (Wotton, Coath & Campbell 2001 – see Appendix 2).

3. *The species, if any, that has filled the void created by the loss of the species concerned, should be determined; an understanding of the effect the reintroduced species will have on the ecosystem is important for ascertaining the success of the reintroduced population.*

No species has been identified as having filled the void left by the loss of choughs from England. Peregrine, raven and jackdaw breed along rocky coasts and their presence may limit nest site availability for choughs. However, as all three species historically nested within the same range in England and do so today in parts of the chough's British range, we would expect any impacts to be small. If competition for nest sites is perceived as a problem then it would be possible to provide artificial nest sites for chough as been done, successfully, in other parts of the range.

4. *The build-up of the released population should be modelled under various sets of conditions, in order to specify the optimal number and composition of individuals to be released per year and the numbers of years necessary to promote establishment of a viable population.*

5. *A Population and Habitat Viability Analysis will aid in identifying significant environmental and population variables and assessing their potential interactions, which would guide long-term population management.*

Based on historical records and the present availability of habitat, the north Cornish coast is thought to be the most suitable area for chough in England. A full assessment of coastal habitats in north Cornwall has now been carried out (Gowenlock 2001). This study was based on a literature review, contact with landmanagers and site visits. It concluded that approximately 5km of suitable cliff-top habitat already exists, 8.5km supports patches of suitable habitat with the potential for rapid improvement once appropriate management was in place, and a further 11km, although currently unsuitable, could provide suitable habitat within five years given appropriate management. All the areas of habitat in the three categories above were mapped and their management requirements summarised.

From studies of colour-ringed birds in Wales it is known that young choughs breed up to 40km away from their natal site (Cross & Stratford unpubl. data). As all the potentially suitable breeding areas in north Cornwall are well within this distance of the next-nearest area, it is expected that if a population becomes established, there would be exchange of individuals between sites, rather than a series of small, isolated and therefore vulnerable populations.

A population viability analysis has been carried out by Ian Johnstone based on various different release scenarios and a model using demographic data from studies of chough carried out in Britain and Ireland. The analysis and conclusions are provided in full in Appendix 3 and summarised below:

- A suggested minimum viable population (MVP) of 10 breeding pairs is given based on the existence of an isolated, stable population of roughly this level in Brittany, France.

- It is suggested that in the region of 50 first-year birds or 24 adult birds would need to be released over three years to achieve the MVP although there is a high level of uncertainty in these estimates.

- The outcome of various release options varies hugely depending on whether 'best-case' or 'worst-case' scenario demographic data are used in the model.

- Stochastic factors are not taken into account in the model. The lack of variance estimates for most of the population data available means that the outcome of each release scenario cannot be predicted with any certainty. Using the worst-case scenario data in the model resulted in rapid population extinction, whereas using best-case scenario data resulted in an expanding population of between 23 and 55 breeding pairs after 10 years, depending on release strategy.

(ii) Previous reintroductions

1. *Thorough research into previous reintroductions of the same or similar species and wide-ranging contacts with persons having relevant expertise should be conducted prior to and while developing reintroduction protocol.*

We know of no attempt to re-establish a population of chough.

(iii) Choice of release site and type

1. *The site should be within the historic range of the species. For an initial re-enforcement there should be a few remnant wild individuals. For a reintroduction, there should be no remnant population to prevent disease spread, social disruption and introduction of alien genes. In some circumstances, a reintroduction or re-enforcement may have to be made into an area which is fenced or otherwise delimited, but it should be within the species' former natural habitat and range.*

The chough was once widespread along south and south-western coasts. Although details of former numbers are scant, there is good information concerning the bird's distribution, especially in the period immediately prior to its extinction. The species was formerly widespread along the coasts of Devon and Cornwall. In Devon birds bred on the north coast at Lynton until at least 1910, but the last reported pair on the south coast was at Berry Head in 1880 and the bird was clearly already exceedingly scarce along the south coast by the second half of the nineteenth century. On Lundy it was 'numerous' in the 1860s but had declined to just one or two pairs by 1888, with 'odd ones' remaining until 1895 (Brown & Grice in prep).

Cornwall probably supported the highest numbers of any county. Penhallurick (1978) has drawn together a considerable amount of information on the bird's former status in that county. In 1856 it bred 'in tolerable abundance' at Bude Haven, Tintagel Head, Port Isaac, Pentire Head, Newquay, Perranporth, Portreath, Cape Cornwall, Land's End, St. Levan, Mullion, Predannack Head, around Kynance and from Lizard Point to Manacle Point. Further east, it was said to be exceedingly scarce. Numbers declined rapidly and surveys conducted in 1901, 1904 and 1905 revealed just seven, ten and twelve nests respectively, all between Hennacliff and Mawgan Porth on the north coast. After 1930 practically all known nesting sites were between Watergate Bay and Tintagel and, even though probably no more than three or four were occupied in any

given year, young continued to fledge almost annually until 1947. Young were reared at four of five occupied sites in that year but only one further nesting attempt appears to have been made, unsuccessfully, in 1952. Just one pair remained from about 1960 until 1967 when one bird died in March of that year. The sole survivor was last seen on 11th February 1973.

No remnant population remains, although wandering birds from other populations do appear infrequently in England. From 1980 to 2000, for example, there were three records in Cornwall (where several other records probably refer to escaped birds or birds deliberately released), six (one of two birds together) in Cumbria and an increasing number of reports from Lundy and the north Devon coast. A series of records in spring 2001, unprecedented in recent times, involved an estimated 4-7 birds in Devon, Cornwall and the Isles of Scilly. This influx offers increased hope for natural recolonisation and the situation will be closely monitored during the next 1-2 years.

North Cornwall is thought to provide the best area of south-west England for a chough restoration project due to the abundance of historical records, the potential availability of suitable habitat and the cultural importance of the chough in Cornwall. Adjacent areas on the south Cornish coast and north Devon are also thought to provide potentially suitable habitat.

2. *A conservation/benign introduction should be undertaken only as a last resort when no opportunities for reintroduction into the original site or range exist and only when a significant contribution to the conservation of the species will result.*

Not applicable: England is within the former range of the chough.

3. *The reintroduction area should have assured, long-term protection (whether formal or otherwise).*

Almost all of the suitable, or potentially suitable, habitat on the north Cornish coast is either owned by the National Trust, who are firmly committed to restoring the species, or is designated as SSSI providing a mechanism for influencing future management.

(iv) Evaluation of reintroduction site

1. *Availability of suitable habitat: reintroductions should only take place where the habitat and landscape requirements of the species are satisfied, and likely to be sustained for the foreseeable future. The possibility of natural habitat change since extirpation must be considered. Likewise, a change in the legal/political or cultural environment since species extirpation needs to be ascertained and evaluated as a possible constraint. The area should have sufficient carrying capacity to sustain growth of the reintroduced population and support a viable (self-sustaining) population in the long run.*

It is notable that in the British Isles, choughs have persisted in those few areas where extensive, tightly-grazed, undisturbed rough pastures are found adjacent to suitable sea cliff nest sites. In most parts of the bird's former range in England, such pastures have either been ploughed and set to arable, highly improved by the addition of inorganic fertilisers or re-seeded to support exceptionally high densities of cattle which are routinely treated with anti-parasitic drugs. Other coastal grasslands are no longer grazed and sward heights are far too tall to attract foraging chough. The development

of scrub and bracken after stock removal has further reduced the area available for foraging birds.

Many potentially suitable breeding areas continue to be available along the north Cornish coast and adjacent areas up to at least Morte Point, Devon and from Lands End to the Lizard on the south Cornish coast. The expert group which visited the area in summer 2000 concluded that suitable sites were those with cattle-grazed, herb-rich pastures along coastal cliff-tops, where areas of exposed substrate such as bare earth, rock and scree were present. Other areas such as grazed sand-dunes and arable stubbles would provide additional habitats for wintering and non-breeding birds. Details of the current condition of key sites on the north Cornish coast, with outline management prescriptions for restoring suitable habitat where appropriate, are provided by Gowenlock (2001).

Almost all the key sites are either owned by the National Trust or entered into MAFF's Countryside Stewardship scheme where funds are provided to manage land in an environmentally friendly manner. Some sites are designated as SSSIs providing an additional framework for securing long-term management agreements through English Nature's Wildlife Enhancement Scheme. The commitment of English Nature, RSPB and the National Trust, together with the increasing diversion of funds from mainstream agriculture into the maintenance of wildlife habitat should ensure the long-term future of sites important for chough. Agri-environment schemes in Wales include specific prescriptions for chough and these will help to guide the setting up of similar prescriptions for chough in south-west England.

2. *Identification and elimination, or reduction to a sufficient level, of previous causes of decline: could include disease; over-hunting; over-collection; pollution; poisoning; competition with or predation by introduced species; habitat loss; adverse effects of earlier research or management programmes; competition with domestic livestock, which may be seasonal. Where the release site has undergone substantial degradation caused by human activity, a habitat restoration programme should be initiated before the reintroduction is carried out.*

The chough last bred in England in 1952 in Cornwall. The main causes of the chough's decline are thought to be a combination of habitat loss and human persecution.

Many of the older county avifaunas attest to the relentless persecution suffered by the chough (Brown & Grice in prep). Due to changes in public attitudes and the introduction of legislation since the chough last bred in Cornwall, such threats are now highly unlikely to threaten a re-establishing chough population.

(v) Availability of suitable release stock

1. *It is desirable that source animals come from wild populations. If there is a choice of wild populations to supply founder stock for translocation, the source population should ideally be closely related genetically to the original native stock and show similar ecological characteristics (morphology, physiology, behaviour, habitat preference) to the original sub-population.*

A recent genetic study has shown that there is very little variation between choughs currently breeding in Ireland, Wales and Scotland, and museum specimens of birds

from the former range in England. A total of four specimens from Cornwall were included in the study, dating from 1869 to 1941. Any birds from the British and Irish race *Pyrrhocorax pyrrhocorax* would therefore provide suitable donor stock for a reintroduction in England.

2. *Removal of individuals for reintroduction must not endanger the captive stock population or the wild source population. Stock must be guaranteed available on a regular and predictable basis, meeting specifications of the project protocol.*

Breeding populations in Wales, Scotland and the Isle of Man are small and vulnerable. Larger populations exist in Ireland. Large numbers of birds would be required for release, particularly if juveniles were used, as survival rates to adulthood can be low. The release of established breeding pairs would probably reduce mortality levels and so fewer birds would need to be taken. Adults may also be less prone to wander away from the release site as, in the wild, they tend to remain faithful to their breeding sites. However, it is possible that adults taken from the wild might try to return to their home area on release and thus be lost to the project.

It is estimated that, in total, 60-70 choughs are currently held in captivity at Paradise Park in Cornwall and at various other sites across the UK. Some birds are paired up and have bred in captivity although breeding success has been low with few young reared to fledging. If the decision is taken that collecting birds from the wild is impracticable or undesirable then this captive population may provide a source of birds for release. It will, however, be necessary to improve the current levels of breeding success in order to achieve the numbers of birds required for a release project.

Individuals should only be removed from a wild population after the effects of translocation on the donor population have been assessed, and after it is guaranteed that these effects will not be negative.

Use of wild birds would not be considered before a thorough assessment of the impact on the donor population had been undertaken. The necessary permissions and licences from authorities in the donor country would also be required.

3. *If captive or artificially propagated stock is to be used, it must be from a population which has been soundly managed both demographically and genetically, according to the principles of contemporary conservation biology.*

The genetic background of the stock held by Paradise Park and its prospective partners is unknown, but could be easily established by a genetic study based on blood samples. There is a likelihood of recruitment by wild birds into a re-established population in Cornwall within the medium-term, which would increase levels of genetic variation.

4. *Reintroductions should not be carried out merely because captive stocks exist, nor solely as a means of disposing of surplus stock.*

The most appropriate source of birds will be determined from the options available based on scientific evidence rather than a desire to make use of surplus captive stock.

5. *Prospective release stock, including stock that is a gift between governments, must be subjected to a thorough veterinary screening process before shipment from original source.*

Any animals found to be infected or which test positive for non-endemic or contagious pathogens with a potential impact on population levels, must be removed from the consignment, and the uninfected, negative remainder must be placed in strict quarantine for a suitable period before retest. If clear after re-testing, the animals may be placed for shipment.

Since infection with serious disease can be acquired during shipment, especially if this is intercontinental, great care must be taken to minimize this risk.

Stock must meet all health regulations prescribed by the veterinary authorities of the recipient country and adequate provisions must be made for quarantine if necessary.

All birds would be subject to veterinary checks before release into the wild. These would most likely be carried out by the Zoological Society of London under a contract set up as part of English Nature's Species Recovery Programme.

(vi) Release of captive stock

1. *Most species of mammal and birds rely heavily on individual experience and learning as juveniles for their survival; they should be given the opportunity to acquire the necessary information to enable survival in the wild, through training in their captive environment; a captive bred individual's probability of survival should approximate that of a wild counterpart.*

The release technique would be designed to allow for a gradual adaptation to life in the wild, including the opportunity for young to learn foraging behaviours from adults, before they have to fend for themselves totally. As this would be the first reintroduction project involving the species, an element of experimental work may be required in order to assess the ability of captive-reared birds to adapt to conditions in the wild. Radio-tracking would be carried out in order to check for any unforeseen problems.

2. *Care should be taken to ensure that potentially dangerous captive bred animals (such as large carnivores or primates) are not so confident in the presence of humans that they might be a danger to local inhabitants and/or their livestock.*

Not applicable - choughs pose no threat to man or livestock

4b) <u>Socio-economic and legal requirements</u>

1. *Reintroductions are generally long-term projects that require the commitment of long-term financial and political support.*

English Nature, RSPB and The National Trust are committed to expanding the chough's range as described in the UK action plan for the species.

2. *Socio-economic studies should be made to assess impacts, costs and benefits of the reintroduction programme to local human populations.*

It is likely that, in the longer term, a reintroduction project would benefit the local economy by providing an added attraction to encourage people to visit the area. Visitor pressure is currently highest in mid-late summer, after the chough breeding season

when the species is most vulnerable to disturbance. Funds for habitat management work would be provided by landowners of key sites (mainly the National Trust), through Countryside Stewardship agreements and possibly also through English Nature/RSPB management agreements.

3. *A thorough assessment of attitudes of local people to the proposed project is necessary to ensure long term protection of the reintroduced population, especially if the cause of species' decline was due to human factors (e.g. over-hunting, over-collection, loss or alteration of habitat). The programme should be fully understood, accepted and supported by local communities.*

The chough is a highly popular bird in Cornwall where it is even referred to as the Cornish chough. Local landowners in key areas would be consulted but most have already expressed overwhelming support for a chough restoration project. There has been considerable media coverage of 'Operation Chough' and the latest recovery proposals and all feedback received so far indicates that a reintroduction project would have almost unanimous local support. Before any releases take place, all organisations with a vested interest (e.g. rock climbing groups) would be officially consulted about the proposals.

4. *Where the security of the reintroduced population is at risk from human activities, measures should be taken to minimise these in the reintroduction area. If these measures are inadequate, the reintroduction should be abandoned or alternative release areas sought.*

Deliberate human persecution is no longer a significant threat to the chough due to changes in legislation and human attitudes since the time when the species last bred in the area. There are potential problems with unwitting disturbance of breeding birds by visitors to the area. However, these problems are likely to be of minor importance as nest sites and many of the feeding areas tend to be on inaccessible cliff slopes. In the early stages of a reintroduction project local problems may need to be managed. It is expected that this would be done by site managers in conjunction with a project officer responsible for monitoring released and breeding birds. There is a small risk that nest sites would be disturbed by rock climbers and local agreements with rock climbing groups might be necessary, as is currently the case with nesting peregrines.

5. The policy of the country to reintroductions and to the species concerned should be assessed. This might include checking existing provincial, national and international legislation and regulations, and provision of new measures and required permits as necessary.

Reintroduction must take place with the full permission and involvement of all relevant government agencies of the recipient or host country. This is particularly important in reintroductions in border areas, or involving more than one state or when a reintroduced population can expand into other states, provinces or territories.

There is no licensing system as such for the release of native species, but a licence would be required to remove birds from the wild. The chough is listed on Schedule 4 of the 1981 Wildlife and Countryside Act, so captive birds must be ringed and registered with DEFRA. If birds are collected from the wild outside Britain then the necessary import/export licences would need to be secured in consultation with DEFRA and the government of the donor country.

Legislation under the Abandonment of Animals Act (1960) would prevent the legal release of birds into an area where, due to a lack of suitable habitat, they stood little chance of long-term survival.

6. *If the species poses potential risk to life or property, these risks should be minimised and adequate provision made for compensation where necessary; where all other solutions fail, removal or destruction of the released individual should be considered. In the case of migratory/mobile species, provisions should be made for crossing of international/state boundaries.*

Not applicable. Chough pose no known risk to life or property in the UK or elsewhere.

5. Planning, preparation and release stages

1. *Approval of relevant government agencies and land owners, and co-ordination with national and international conservation organizations.*

A series of international workshops have been held concerning chough. Links are thus well-established with European workers interested in chough conservation.

2. *Construction of a multidisciplinary team with access to expert technical advice for all phases of the programme.*

The RSPB and English Nature have access to all necessary expert technical advice for all phases of a reintroduction programme. Representatives from all appropriate organisations involved would form a steering group to oversee the smooth running of a project.

3. *Identification of short- and long-term success indicators and prediction of programme duration, in the context of agreed aims and objectives.*

Modelling work carried out by Ian Johnstone was based on a release phase lasting three years (see Appendix 3). This would be the minimum duration of releases required in order to have a good chance of establishing a self-sustaining population of ten breeding pairs and associated non-breeders. In the medium to long term a project would be regarded as successful if a breeding population in excess of 25 pairs was established in south-west England. Results based on the deterministic model are highly uncertain due to a lack of information for some parameters. Intensive monitoring, carried out by a project officer would therefore be essential in the early years of a project in order to help refine the release programme if necessary. A longer-term programme of monitoring would be put in place to assess the status of a breeding population once established.

4. *Securing adequate funding for all programme phases.*

Opportunities for commercial sponsorship may be sought to provide funding but the project partners would ensure that sufficient resources were available should external funding not meet the costs of the project in full.

5. *Design of pre- and post- release monitoring programme so that each reintroduction is a carefully designed experiment, with the capability to test methodology with scientifically collected data. Monitoring the health of individuals, as well as the survival, is important; intervention may be necessary if the situation proves unforeseeably favourable.*

Radio-tagging of released birds would be carried out to check that the release method does not result in high mortality because of inexperience in finding food in the wild or predation. Radio-tracking would also allow movements of released birds to be followed and provide valuable information on habitat use and foraging behaviour. Sampling of body feathers from all the founders of a reintroduced population, and from birds present in subsequent years, would allow the degree of interbreeding with wild birds from other areas to be estimated by DNA studies.

6. *Appropriate health and genetic screening of release stock, including stock that is a gift between governments. Health screening of closely related species in the reintroduction area. If the release stock is wild-caught, care must be taken to ensure that: a) the stock is free from infectious or contagious pathogens and parasites before shipment and b) the stock will not be exposed to vectors of disease agents which may be present at the release site (and absent at the source site) and to which it may have no acquired immunity.*

If vaccination prior to release, against local endemic or epidemic diseases of wild stock or domestic livestock at the release site, is deemed appropriate, this must be carried out during the 'Preparation Stage' so as to allow sufficient time for the development of the required immunity.

Appropriate veterinary or horticultural measures as required to ensure health of released stock throughout the programme. This is to include adequate quarantine arrangements, especially where founder stock travels far or crosses international boundaries to the release site.

Development of transport plans for delivery of stock to the country and site of reintroduction, with special emphasis on ways to minimize stress on the individuals during transport.

The appropriate level of screening would be carried out as required, and veterinary services brought in to ensure these requirements are met (this work would most likely be carried out by the Zoological Society of London's, Institute of Zoology under a contract with English Nature for all veterinary work undertaken as part of its Species Recovery Programme). Advice on transport methods would be sought from animal welfare experts.

7. *Determination of release strategy (acclimatization of release stock to release area; behavioural training - including hunting and feeding; group composition, number, release patterns and techniques; timing).*

There are two main options for sourcing birds for a release project, (i) using birds bred from captive stock currently held at various centres in Britain or (ii) collecting birds from wild populations in Britain, Ireland or elsewhere. Decisions would also need to be taken on the age and group size of birds to be released.

The chough has a complicated social organisation and experts believe that the chances of birds remaining in the release area would be improved if adults or mixed-aged

groups were released. Further work is required to assess the natural foraging ability and survival prospects of birds that have been held in long-term captivity.

Before making a final decision on a release strategy there would need to be full consultation with chough experts, including individuals with experience of wild populations and those with expertise in captive rearing. As suggested above, an experimental approach may be required in order to establish an appropriate release technique.

8. *Establishment of policies on interventions (see below).*

Intervention would be difficult once birds have been released into the wild but radio-tracking may allow weakened birds that have struggled to find food to be found and taken back into captivity. Policy on such interventions would need to be decided by the project steering group.

9. *Development of conservation education for long-term support; professional training of individuals involved in the long-term programme; public relations through the mass media and in local community; involvement where possible of local people in the programme.*

It is envisaged that a chough reintroduction project would be high profile, offering plenty of opportunity for local and national publicity, as long as the need for site confidentiality in the early stages was not compromised. A reintroduction project would provide an opportunity to raise awareness of the importance of semi-natural coastal habitats and their appropriate management, as well as the range of species that would benefit from habitat management carried out for choughs.

10. *The welfare of animals for release is of paramount concern through all these stages.*

Veterinary expertise would, most likely, be provided through English Nature's contract with the Institute of Zoology.

6. Post-release activities

1. *Post release monitoring is required of all (or sample of) individuals. This most vital aspect may be by direct (e.g. tagging, telemetry) or indirect (e.g. spoor, informants) methods as suitable.*

Demographic, ecological and behavioural studies of released stock must be undertaken.
Study of processes of long-term adaptation by individuals and the population.
Collection and investigation of mortalities.
Interventions (e.g. supplemental feeding; veterinary aid; horticultural aid) when necessary.

A project officer would be employed to oversee the release project, carry out post-release monitoring and other studies, and to support RSPB/EN staff in implementing management work for chough at the release site. Any corpses would be collected and sent to the Institute of Zoology for post-mortem.

2. *Decisions for revision, rescheduling, or discontinuation of programme where necessary.*

   A project steering group would oversee all work and make decisions on revisions as and when necessary.

3. *Habitat protection or restoration to continue where necessary.*

   The appropriate management of key habitats would be put in place before the first birds were released, as discussed earlier. If, as hoped, a breeding programme became established, then opportunities to extend the chough's range through additional habitat restoration in south-west England would be explored.

4. *Continuing public relations activities, including education and mass media coverage.*

   RSPB and English Nature public affairs staff would ensure that a project continued to receive an appropriate level of publicity beyond the initial release phase.

5. *Evaluation of cost-effectiveness and success of reintroduction techniques.*

   Progress reports would be produced regularly giving full details of the releases carried out and post-release monitoring. These would be valuable in guiding further releases and any future reintroduction projects involving this, or similar, species.

6. *Regular publications in scientific and popular literature.*

   It is expected that scientific papers would be produced once a project was sufficiently advanced for its likely success to be determined. More popular articles would be produced at suitable times during the course of a project.

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Appendix 1: The distribution of chough records in south-west England in 2001

Records compiled by Alistair Cameron & Leigh Lock

Cornwall

27th January to 5th February at least: A single bird observed near Falmouth.

1st March to 5th March: A single bird was first seen on St Agnes (Isles of Scilly) on 1/3, and was seen around Wingletang Down until 5/3. Presumably the same bird was also seen on Tresco on 4/3.

27th March: A single bird was seen around Land's End, Nanjizal and Porthgwarra from 27/3. This bird may have been the one seen on the Isles of Scilly earlier in the month.

7th April to early May: Two birds together, first observed in the Kynance area on the Lizard on the first date. They were also seen at Lizard Point on the same day. Three birds were seen together on 8th April. There have been no records from the Kynance area since early May.

28th April to 29th April: A single bird was reported from a back garden in Redruth.

3rd May onwards: A single chough was observed in the Bass Point area, the day the coastal path was reopened here. All three birds were seen together here on 4th May.

Dorset

21st March to 22nd March: A single adult was observed feeding along the cliff edge near the observatory on Portland.

3rd April to 8th April: A duller individual than the above bird was also seen in fields near the observatory, feeding with other corvids. In all probability, the same bird was also seen on 8th April in the same area.

5th May to 6th May: A chough was observed flying on to Portland from the south on 5th May, and was seen in a field on 6th May. It was last seen heading north along the West Cliffs.

Devon

1st April to 6th May: On the first date a single chough was observed flying along the coast from Slapton to Start Point where it landed with other corvids in a field. It was seen again on 11th April flying over East Prawle village, Beesands and Slapton, and also reported on 5th May and the morning of 6th May.

Appendix 2: Monitoring choughs in southern Cornwall in 2001

Simon Wotton, Dominic Coath and Lennox Campbell, preliminary report, August 2001

Introduction

In spring 2001 there were several records of chough at various locations in southwest England along the south coast from Portland, Dorset to the Isles of Scilly. These records have been compiled by the RSPB South West Regional Office in Exeter and are shown at the end of this report (Leigh Lock, pers comm).

Chough were first reported on the Lizard at Kynance Cove on 7th April when two were seen there and later at Lizard Point. There were three birds at Kynance Cove the following day. Because of the Foot and Mouth outbreak, the area around Kynance Cove was not re-opened to visitors until 23rd March, but as the National Trust car park did not re-open until 6th April, few visitors were present until the later date (Alistair Cameron, pers comm). It is therefore possible that the chough had been present well before the first recorded sighting in April. The chough were seen regularly in the same area throughout April and when parts of the coastal footpath were reopened on 3rd May, a single chough was located near Bass Point on the same day. All three birds were seen at Bass Point on 4th May, and these have been seen regularly in this area throughout May, June and July. None were seen at Kynance after early May. The coastguard lookout at Bass Point had been open all the time, but no choughs were seen here before 3rd May.

Once it became clear that the chough had settled on the Lizard, RSPB, English Nature and the National Trust decided to set up a monitoring programme to determine the exact numbers of chough present and to gather information on habitat usage and behaviour. The first phase of this programme was completed in mid-July.

Monitoring

Systematic monitoring was carried out by two RSPB fieldworkers – Simon Wotton (6th June to 15th June) and Dominic Coath (24th June to 12th July). For the first two weeks some time was also spent searching the western side of the Lizard peninsula, to try to establish whether there were two birds in the Kynance area in addition to the three at Bass Point.

The main aims of the monitoring were to describe chough behaviour, record and quantify what habitats they were using, particularly for feeding, and to identify whether there were any potential causes of disturbance that could lead them to abandon the area. The method used to quantify the birds' habitat selection and foraging behaviour was based on work carried out on choughs in Wales by the RSPB (Ian Johnstone pers comm; Roberts (1983); Whitehead *et al* unpublished). When monitoring the choughs, a distinction was made as to whether the observations were of all three birds, the pair or the separate individual. The arrival and departure time within each broad habitat type was recorded, as was the reason for leaving and the behaviour whilst there. The broad habitat types used were: rock, cliff and stone walls; improved and semi-improved agricultural grassland (grazed or ungrazed); coastal

heath (grazed or ungrazed); coastal grassland (grazed or ungrazed); dry heathland (grazed or ungrazed); wet heath (grazed or ungrazed); paths (bare ground and worn swards associated with public rights of way); burned areas; bracken; Cornish hedges (i.e. stone-faced earth banks) (Whitehead *et al* unpublished). Additional information on habitat use at a finer spatial scale was also recorded.

A total of 8595 minutes were spent in the Bass Point area between 6th June and 12th July. Choughs were observed for 1657 minutes, 19% of the total search time. The amount of time spent by the birds in each broad habitat type is summarised in Table 1. The raw data have been assembled in an Excel spreadsheet and will be fully analysed when the monitoring work is complete.

Table 1: The habitats used by the choughs on the Lizard. The amount of time in each habitat type is given in minutes but is also shown as a percentage of the total amount of observation time (in brackets).

	Observation time, minutes		
Broad habitat type	*3 together*	*pair only*	*individual only*
Rock and cliff	232 (14)	93 (6)	155 (9)
Semi-imp. grassland (grazed)	194 (12)	187 (11)	213 (13)
Coastal grassland (ungrazed)	214 (13)	212 (13)	126 (8)
Paths	5 (<1)	0	0
Bracken	0	2 (<1)	0
Cornish Hedges	0	3 (<1)	15 (1)

A co-ordinated survey of the coast between Cadgwith Cove and Kynance Cove was carried out with staff from English Nature and the National Trust on 3rd July. Only a single bird was seen, at Housel Bay.

On completing this initial period of more intensive observation, steps were taken to ensure that the main areas used in June and July continued to be regularly visited by local staff or volunteers. A transect route enabling effective coverage of the cliff-top and adjacent fields used by chough was defined and a set of survey instructions and recording form produced.

Conclusions

It would seem likely that the three choughs first seen in the Kynance Cove area relocated to Bass Point in early May, possibly due to increased disturbance in the Kynance Cove area following the reopening of the National Trust land here. There have been no confirmed sightings of any choughs at Kynance Cove since early May, although there have been several more recent sightings of the pair, and of all three birds, flying from south of the Kynance area (at Caerthillian Cove) to the Bass Point area. Although there have been reports of five birds on the Lizard (i.e. two in the Kynance Cove area and three in the Bass Point area), there have not, to our knowledge, been any sightings of five birds together. The tendency for the pair to be separated from the lone bird for much of the time would support the idea that there have been only the three birds present. One of the three birds appears to be slightly smaller than the other two. This would suggest that the lone bird is another male.

The three birds appear to have settled in the Bass Point area, despite all the public rights of way now being open. It would appear that the choughs are probably roosting on the cliffs (or in caves) below the coastguard lookout at Bass Point. All three have regularly been seen flying to and from this particular section of cliff. Almost all of the observed foraging has either been on the Churchtown Farm fields or on patches of cliff-top coastal grassland between Pen Olver and Hot Point. Some later observations in the Housel Bay area suggested that they might be foraging in fields here as well.

The proximity of the Churchtown Farm fields to Bass Point may be an important factor in the choughs continued presence at Bass Point, as these fields have been shown to be a prime foraging site. Churchtown Farm appears to be an ideal food source for the choughs as the fields have a short grass sward with plenty of bare patches, due to year-round cattle grazing.

Plans for the future

Assuming that the chough remain in this area, it is hoped that, using local staff, volunteers, or paid contractors an overview of their distribution and activity week by week will be maintained. It is intended to carry out further periods of more intensive observation of feeding behaviour during the course of the autumn and winter to continue to describe preferred foraging habitats and in particular to detect any changes as the season progresses. The next such period of observation is likely to be in September or October, unless there are major changes in chough distribution or activity in the meantime. If the pair make a breeding attempt in 2002 then monitoring will continue into the breeding season.

Acknowledgements

We are grateful to Ray Lawman (EN), Alistair Cameron (National Trust), Dave Chown and Kevin Rylands (RSPB). Thanks also go to Mike and Alex Lord for providing extra information and helping to continue the monitoring and to Headley Stephens for allowing access to Churchtown Farm.

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Appendix 3: Chough releases: how many and will they increase?

Ian Johnstone, RSPB Cymru, April 2002

Summary

1. A minimum viable population (MVP) size of 10 pairs is suggested, but has weak justification.
2. A deterministic single population model is developed for choughs, but cannot be adequately tested.
3. The MVP will be achieved more quickly by releasing more birds each year and by releasing adults rather than first year birds.
4. The number of birds to release to achieve an MVP of 10 pairs is in the region of 50 first year birds or 24 adult birds staggered over three years, but this depends on their survival rates.
5. The founder population may increase or become extinct depending on productivity and survival rates.
6. A better understanding of demographic rates and their variance in chough populations adjacent to Cornwall is required before a more informative population viability analysis can be carried out.

Introduction

For the likelihood of success of a species reintroduction to be fully assessed, the following information is required:

1. The size of the minimum viable population (MVP). That is, a population that can maintain itself without excessive human intervention (Soule 1987), despite unpredictable events such as severe weather.
2. The number and age of birds that will be released over a specified time-period.
3. A projection of the likely trend of the population after the release phase is complete (the objective here is a population that will increase from the MVP and begin reoccupying its former range within the intermediate time-scale of 10 yrs).

This information can be obtained in two ways. Firstly, using anecdotal evidence from the literature, and secondly and more preferably, from simulations based on parameters measured from real populations. These are normally the population density, the breeding and mortality rates and the number of individuals moving in or out of the population (Clobert & Lebreton 1991), and are known as demographic parameters.

Methods

Modelling population trends

Demographic models are often used to inform decisions about species of conservation concern. These are often referred to as population viability analyses (Caughley 1994). Population models can range in complexity from deterministic single-population models which require a minimum of parameters, to stochastic metapopulation models

which require considerable information on demographic rates, their variance and dispersal between sup-populations (Bessinger & Westphal 1998). The type of approach used depends on what demographic parameters are available. For the chough, these are limited at present. Therefore, a deterministic single-population model of the number of breeding and non-breeding females at the start of each breeding season was developed. The assumptions made in the model are shown in table 1.

Two release scenarios are considered. First, releasing equal numbers of male and female one year old birds in each of three successive years, and second, releasing pairs of adult choughs in each of three successive years. A staggered release is logistically more practical and introduces an age structure into the released population. In both cases, birds were "released" at the start of the breeding season. For each scenario, two sets of projections were made. First, the number of breeding females surviving to the end of the release phase after releasing different numbers in each year, using median values for the demographic parameters. Second, the population trend of breeding females and flock-living females was calculated over a 10 year period from the start of the release phase, using best and worst-case demographic parameters and a standard number of released birds. The calculations of population size were carried out in an excel spreadsheet using the formulas given in table 2.

The available parameters

A number of estimates of the demographic parameters are available from the literature and ongoing studies for choughs in the UK (table 3), although these seldom have associated measures of variance (standard errors or confidence limits).

The minimum viable population

The lack of variance estimates for the demographic parameters means that it was not possible to introduce natural annual variation into the parameters used by the population model (i.e. a stochastic population model; Beissinger & Westphal 1998). Therefore the MPV: a population size that has an extinction chance of less than 5% over a given time period, say 10 years (Bessinger & Westphal 1998), could not formally be identified. However, this may be possible in the future, if better estimates of the demographic parameters become available from the four chough colour-ringing projects that are ongoing.

Nevertheless, some evidence for the persistence of very small chough populations over a number of generations can be found in the literature. The country and regional chough populations in the UK are all currently greater than 40 pairs (Newbery 1998). Within these populations, young birds form large social flocks at traditional autumn and winter-feeding sites (Bignal & Bignal 1997), moving up to 50km from isolated nest sites as family groups to reach these (Cross & Stratford *pers comm*[1]). Consequently, there are no small but stable or increasing populations in the UK that are truly isolated, and which could be viewed as analogous to a reintroduced Cornish population. However, the chough population in Brittany is relatively small (27-39 pairs Kerbiriou 2001) and highly fragmented. Of most interest is the population on

[1] The Cross & Stratford Chough Colour-ringing Project in an independent research project being carried out in mid and north Wales. It has received some funding from the RSPB in recent years

Belle Isle, an island approximately 5x10 km in length and 130km from the next chough-breeding site at Cap Sizun. This distance is similar to that between potential release sites in Cornwall and the nearest current chough breeding sites in Pembrokeshire. The habitat between Belle Isle and Cap Sizun is unsuitable for choughs, and there is no evidence of birds moving between these sites. The Belle Isle population has declined from about 40 pairs and a flock of 50 birds in the 1950s to 8-10 pairs in the 1980s. The population has remained stable since then, with 7-10 pairs and a flock of about 12 birds recorded in the late 1990s (Kirbiriou 2001). This suggests that the population has been able to maintain its self over a period of several generations at this small size. Therefore, for the purpose of this paper, the value of 10 pairs will be adopted as a MVP.

Results

Model tests

The predictions of the deterministic single population model are only of value if they are accurate. The accuracy of the model was tested using sets of demographic parameters that are available for Wales and Islay, and the population estimates from recent chough surveys in these regions. The model was seeded with the population estimate from an early survey and the predicted population at the time of the later survey was compared with the survey estimate (table 4). For Wales, the predicted and observed population trends were in the same direction, although the predicted population size was 15% lower than the survey estimate over a 10 year period. For Islay, the predicted and observed population trends were also in the same direction, although the predicted population size was 34% higher than the survey estimate over a six-year period.

The number of birds to release

The number of female chough of breeding age was calculated over the release phase of a reintroduction for both release scenarios (first year birds and adults). The release phase was defined as the period until all released birds were old enough to breed, since the success of the releases cannot be assessed until all birds reach this age. Predictions were made for releases of different numbers of birds each year (fig 1). The assumed MVP was achieved more quickly by releasing more birds each year, and by releasing adult rather then first year birds.

Population trends over 10 years

The demographic parameters used in the simulations were from table 3 and are shown in table 5. The values were selected so that they reflected best-case and worst -case chough populations (i.e. good and poor productivity and survival). Two intermediate cases are also shown. The results show that the introduced population will either increase above or decline below the MVP (eventually to extinction), depending on the parameters used by the model (table 5). The population trends for breeding females are shown in figure 2, and these are mirrored by the trends in the number of females in flocks and not yet old enough to breed.

Sensitivity analysis

To assess the sensitivity of the model's predictions to the values of the demographic rates, simulations were carried out in which each parameter was decreased by 10% in turn. The resulting percentage change in the population size was calculated (table 4).

The model was most sensitive to changes in the adult survival rate, and least sensitive to changes in productivity. Sensitivity to changes in first year survival rate was intermediate, but close to that of productivity.

Discussion

How useful is the model?

The population model correctly predicted the direction of the population trends for Wales and Islay. However, there were discrepancies between the predicted and observed population sizes. Because the model is deterministic, the predictions lack confidence limits and it is not possible to say whether the magnitude of these differences was significant. One possible reason for the difference for Wales is the improved survey methods in 1992. The 1982 figure would therefore have been an underestimate. On Islay, the population has been undergoing a decline following an increase. It is possible that the large discrepancy is due to variation in the demographic rates over the time-period. These were estimated at the end of the six-year period, and any earlier differences are not taken into account by the model. A simple sensitivity analysis suggested change in adult survival had most impact on the population trend. Although this is better assessed by the elasticity of lamda (eg Caswell 1978), this requires more complex matrix population models. It should be stressed that these tests are weak, and it is possible that the model is not sufficiently sophisticated to predict chough population trends with any confidence. Furthermore, the assumptions made by the model have not been tested and in some cases are likely to be wrong (particularly assumptions 1-3). Nevertheless, limiting predictions to short time periods should minimise errors and inform objectives for reintroductions to some extent.

The minimum viable population

These simulations do not take into account any stochastic effects, such as chance variation in sex ratios of broods and the effects of severe weather on productivity and survival, since the parameters required to do this are not available. Therefore, the MVP could not be objectively identified based on extinction rates. Instead, a value from the literature is used, and there are reasons why this may be misleading. For example, because Brittany is 300km further south than Cornwall, it may receive less variable and extreme weather. If chough productivity and survival is significantly influenced by weather, then a larger MVP may be appropriate to ensure a released Cornish population achieves an extinction probability of less than 0.05. In addition, young birds in the small Belle Isle population may benefit from contact with experienced older birds, which will be lacking in a Cornish founder population.

A fundamental of population genetics is that in small and closed populations, the genetic variation will decline over several generations (Lande & Barrowclough 1987). The Belle Isle choughs are currently going through a population bottleneck. There is currently no information on the implications of this for their genetic diversity (and fitness). However, if introduced birds are of known origin (wild birds) or have a known origin and breeding history (captive bred birds), then the founder stock could be selected to maximise genetic diversity from the outset. Given the history of chough records in south-west England, natural recruitment would be expected to add to genetic diversity in the long term.

How many to release and will the population increase?

Assuming 10 pairs is an adequate estimate of the MVP; then it will be achieved more quickly by releasing more birds each year, and by releasing adult rather then first year birds (fig 1.). The number of birds to release to achieve an MVP of 10 pairs within a five-year release phase is in the region of 50 first year birds or 25 adult birds staggered over three years, but this depends on their survival rates. A release of birds of mixed age classes would result in intermediate population trends. It is important to note that the number of birds to release and the outcome of any releases will depend on the demographic parameters of the founder population. It is impossible to predict what these might be given the absence of data from the extinct Cornish population, although they might be expected to be most similar to those in Pembrokeshire and Brittany because of their geographic proximity. However, it may be significant that the only demographic data available for Brittany (Isle Ouessant) gives productivity as 0.5-1.8 fledged per nest (mean for yrs 95-99), lower than any values in table 3. Except for these, parameters estimates specific to these regions are not available in the literature.

The population projections based on best and worst-case demographic parameters from the literature indicate that a released population will either increase above the MVP, or decline below it and approach extinction over a 10 year period (fig 2). The outcome of a real release will fall somewhere between these extremes. The wide range of values in table 3 could be real population differences, differences between years, or a combination of both. There are a number of reasons why a population composed of recently released and early Cornish-bred birds might tend towards the lower of these trends. Firstly, the absence of established autumn flocks that juveniles can join may result in lower survival rates. Secondly, the survival rates of captive-bred birds of both age classes is likely to be lower than those of wild-bred birds. This is because captive bred birds will have little experience of how to survive in the wild and have no older birds to learn from. They may also be immunologically inferior and more prone to diseases such as gapeworm, to which choughs are susceptible. These factors will be less relevant to choughs translocated from other populations. It is difficult to identify any practical conservation measures to maximise productivity and survival beyond appropriate habitat management at a suitable geographic scale.

For many bird populations there are relationships between productivity and mortality rates, and population density. Usually, birds produce fewer young and survive less well at high population densities. At present, there is no evidence for density-dependent effects in the chough. However, it is possible that the demographic rates measured for existing populations are heavily influenced by the effects of population density, and these effects might be much lower in a small released population.

No attempt is made here to assess the best way any releases would be spatially arranged (all at the same sites or a number of different sites). However, the assumption is made that groups of released birds would not be isolated from each other, and would function as a single population. There is no point in releasing birds if their potential for establishment and range expansion is limited by habitat availability. Whilst habitat preferences are well understood, there is currently no objective way of identifying what area of suitable habitat might be required to support a) the MVP and b) subsequent increases in population size and range above this.

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Table 1. The assumptions made in the deterministic single population model developed for choughs.

1. Released birds have the same fitness as wild birds
2. No differences in productivity between ages within the adult age class
3. No differences in survival rate between ages within the adult age class, or between sexes
4. Equal sex ratios in broods
5. Birds live in a flock until they breed at three years of age
6. First year birds have a lower annual survival rate than older birds
7. Productivity and survival is not density dependent
8. No emigration

Table 2. Formulae used to calculate the number of breeding females and flock females alive in successive years. S_j = proportion of young birds surviving their first year, S_a = proportion of adults surviving each year, P = productivity (chicks fledged per breeding female). The terms in the formulae sum the number of older females surviving to year t, the number of young produced and surviving to first breeding age in year t and the number of released birds surviving to attain breeding age in year t. The 0.5 multiplication term converts the number of young fledged into the number of females fledged, assuming an equal sex ratio.

	Release of one year old birds	Release of adults
No. of breeding females in yr t	females yr t–1 x S_a + females yr t-3 x P x 0.5 x S_j x S_a x S_a + released cohort in yr t-2 x S_a x S_a	females yr t-1 x S_a + females yr t-3x P x 0.5 x S_j x S_a x S_a + released cohort in yr t
No. of flock females in yr t	females yr t-2 x P x 0.5 x S_j x S_a + females yr t-1 x P x 0.5 x S_j + released cohort in yr t–1 x S_a + released cohort yr t	females yr t-2 x P x 0.5 x S_j x S_a + females yr t-1 x P x 0.5 x S_j

Table 3. Estimates of a) productivity (defined as mean number of young successfully fledged per nest) and b) survival rates for choughs in the UK taken from the literature. Measures of variation are given where available.

a)

Productivity Mean	*n*	Site	Source
2.85	67	Ireland	Bullock et al (1983)
2.78	9	Colonsay	Cook et al (1999)
2.68	160	Coastal Wales	Bullock et al (1983)
2.67	43	Coastal Wales	Green & Williams (1993)
2.63	16	Inland Wales	Green & Williams (1993)
2.35	65	Ireland	Berrow et al (1992)
2.07	43	Islay	Cook et al (1999)
2.05	79	Inland Wales	Bullock et al (1983)
1.88	67	Isle of Man	Bullock et al (1983)
1.82	34	Islay	Bullock et al (1983)

b)

Annual survival rates	Source
First year	
71%	Bignal *et al* (1987)
40%	Cook *et al* (1999)
21% (95% CL 18-24, range over 9yrs 8-50)	Cross & Stratford provisional estimates
Adult	
74% second year	Bignal *et al* (1987)
Assume 74% for all adults	Cook *et al* (1999)
82% (95% CL 77-87) second yr and older	Cross & Stratford provisional estimates

Table 4. Tests of the deterministic single population model for choughs using demographic parameters and population estimates for regions with different population trends.

Region	Demographic rates			Population size			
Wales	*P*	S_j	S_a	1982	1992	Predicted 1992	% Difference
	2.68	0.21	0.82	140	177	150	-15
Islay	*P*	S_j	S_a	1992	1998	Predicted 1998	
	2.07	0.40	0.74	69	44	59	+34

Table 5. Simulated population trends for breeding and flock females over a 10 year period after a release of a) 15 male and 15 female 1yr old choughs staggered over three years and b) 15 adult pairs of choughs staggered over three years. Simulations are presented for best case, worst case and intermediate demographic parameters.

a)

Year	Released cohort	Number of Breeding females				Number of Flock females	
	Parameter	*Best case*			*Worst case*	*Best case*	*Worst case*
	P	2.85	1.82	2.85	1.82	2.85	1.82
	S_j	0.71	0.71	0.21	0.21	0.71	0.21
	S_a	0.82	0.82	0.74	0.74	0.82	0.74
1	5	0	0	0	0	5	5
2	5	0	0	0	0	9	6
3	5	3	3	3	3	9	6
4		6	6	5	5	8	2
5		8	8	6	6	9	1
6		9	8	5	5	14	2
7		12	9	5	4	16	2
8		15	11	4	4	19	1
9		19	13	4	3	25	1
10		23	15	4	3	32	1

b)

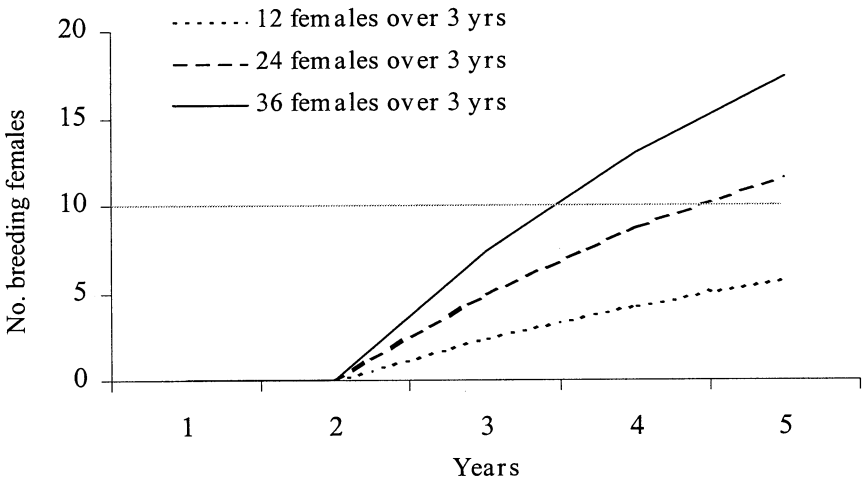
Year	Released cohort	Number of Breeding females				Number of Flock females	
	Parameter	*Best case*			*Worst case*	*Best case*	*Worst case*
	P	2.85	1.82	2.85	1.82	2.85	1.82
	S_j	0.71	0.71	0.21	0.21	0.71	0.21
	S_a	0.82	0.82	0.74	0.74	0.82	0.74
1	5	5	5	5	5	0	0
2	5	9	9	9	9	5	1
3	5	12	12	11	11	13	2
4		14	12	9	9	20	3
5		17	14	8	8	24	3
6		23	17	8	7	29	3
7		28	19	7	6	37	2
8		35	22	7	5	47	2
9		44	25	6	5	58	2
10		55	29	6	4	73	2

Table 6. A sensitivity analysis of the deterministic single population model for choughs. The model was seeded with 100 birds and run over ten years. S_a = adult survival, S_j = first year survival and P = productivity.

Category	Standard model	10% decrease in each parameter					
		S_a	%change	S_j	% change	P	% change
Breeding females	280	85	-69	213	-24	218	-22
Flock females	257	84	-67	179	-30	184	-28

Fig.1. The effect of introducing different numbers of a) one year old birds, and b) adults, on the number of breeding female choughs at the end of the release phase. The median values from table 2 were used to predict population size (P = 2.49, S_j = 0.46, S_a = 0.78). The reference line indicates the assumed MVP.

a)



b)

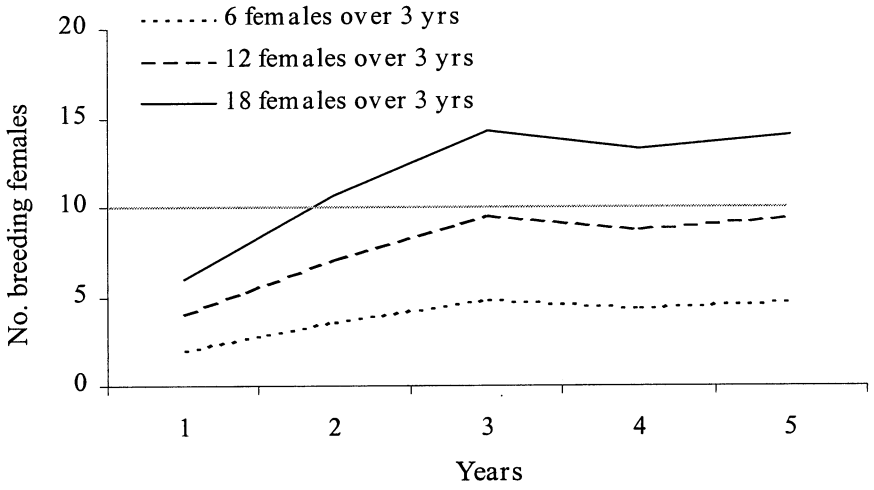


Fig 2. Population trends of a) 30 released 1yr old choughs and b) 15 pairs of released adult choughs, predicted using a deterministic single population model. Trends are shown for best case, worst case and intermediate demographic parameters. The horizontal line indicates the assumed MVP, above which the population must remain to survive unpredictable natural events, such as severe weather