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Review

A Review of the World's Active Seabird Restoration Projects

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ABSTRACT Within the past several decades, seabird populations have been actively restored in locales where they were reduced or extirpated. Chick translocation, acoustic vocalization playbacks, and decoys are now used widely to lure breeding seabirds to restoration sites. In this first worldwide review of seabird restoration projects we evaluate the factors affecting project success or failure and recommend future directions for management. We identified 128 active restoration projects that were implemented to protect 47 seabird species in 100 locales spanning 14 countries since active restoration methods were pioneered in 1973. Active seabird restoration can achieve conservation goals for threatened and endangered species, and for species affected by anthropogenic impacts (e.g., oil spills, invasive species, fisheries). It also can be used to relocate populations from undesired breeding locales to more favorable locations, and to establish multiple breeding locations to reduce risks posed by catastrophic events. Active restoration can help to restore ecological processes, as large seabird colonies function to cycle marine nutrients to terrestrial ecosystems and create habitats for commensal species. Active restoration is especially appropriate where the original causes of decline are no longer working to suppress colony establishment and growth. Successful restoration efforts require careful planning and long-term commitments. We introduce the different forms of active seabird restoration techniques, review their utility for different seabird species, and use case studies to suggest how to optimize this technique to restore seabird species globally. Wildlife managers can use this review to guide their seabird restoration projects in the planning, implementation, and monitoring stages; tailor their restoration to seabird-specific life histories; and identify areas for further research to improve restoration utility in the future.

KEY WORDS coloniality, philopatry, seabird reintroduction, seabird restoration, social attraction, social facilitation.

Nearly one-third of seabird species are threatened with extinction due to entanglement with fishing gear, reduction in marine food supplies, environmental contaminants, oil spills, overharvest (mostly of eggs and chicks), and introduction of invasive species that prey on seabirds or destroy their nesting habitat (International Union for Conservation of Nature [IUCN] 2009). Even species with large populations are at risk, especially where few colonies exist and ranges have contracted due to the effects of global climate change and ocean acidification (Croxall et al. 2002, Frederiksen et al. 2004). Active seabird restoration (hereafter, seabird restoration) programs expand existing colonies, restore historical populations, and help protect seabirds from further threats. Seabird restoration denotes efforts to actively restore seabirds through direct management interventions rather than allowing seabirds to passively recover following the removal of disturbance factors such as invasive mammals (Jones et al. 2011).

Seabird restoration efforts began in the 1970s with efforts to reestablish populations of Atlantic puffins (*Fratercula arctica*) that were eliminated from islands in the Gulf of Maine (Kress 1998). Since then, new restoration techniques have been implemented worldwide to encourage recolonization of seabird nesting colonies to their historical ranges, and to augment or translocate current breeding populations. Seabird restoration methods typically supplement the more conventional methods of eliminating invasive predators and managing habitat, because these activities alone may prove inadequate to reestablish colonies. Seabird restoration was primarily developed to restore populations where they were lost due to human exploitation or invasive species predation (Kress 1998). Restoration has since been applied to relocate seabird colonies when populations conflict with fisheries (Roby et al. 2002), or when they are vulnerable to effects of climate change (J. Madeiros, Bermuda Department of Conservation Services, personal communication), environmental dangers such as volcanism (Hasegawa and Watkinson 1982) and marine pollution (Parker et al. 2007). In this review, we consider 2 methods of restoration: chick translocation and social attraction.

Chick translocation refers to active movement of chicks to a new location, and is preferred for species that exhibit high natal site philopatry, do not exhibit post colony-departure care, or for those restoration projects without a nearby source colony. Most seabirds exhibit some degree of natal philopatry (Greenwood and Harvey 1982, Warham 1990), which

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makes them excellent candidates for translocation (Kress 1998). Although it is not fully understood when and how birds acquire their homing information, it is likely that seabird chicks imprint on their natal colony before becoming fledglings (Fisher 1971, Serventy et al. 1989). Therefore, most chick translocation projects translocate downy chicks to release sites and hand-rear them to fledging age. Hand-rearing methods are now well established for many seabird species, especially burrow nesters, leading to 100% fledging success in many cases (Miskelly et al. 2009). The translocated chicks return as adults to breed and often lure immigrant conspecifics to the restoration site, thereby increasing colony numbers (Kress 1978, Miskelly et al. 2009).

Chick translocation is labor intensive, expensive because of the need for either resident chick tending stewards or frequent visits to the translocated chicks, and is successful only for species with particular life history traits. Because adults are not moved with chicks (adults would readily abandon the restoration site), chicks must be fed with dietary supplements until they fledge. Therefore, chick translocation is limited to species that feed their chicks whole fish or those that depend on regurgitated meals (e.g., albatross and petrels). Species that feed their young after colony departure (e.g., terns, murres, razorbills, and precocial murrelets) are poor candidates for chick translocations.

Accordingly, a second method, social attraction, is often employed for species that are poor candidates for chick translocation. Social attraction aims to lure adult birds to restoration sites with the goal of establishing breeding colonies. More than 95% of seabirds are colonial, meaning they are attracted to breeding sites by the presence of conspecifics and other seabirds (Rolland et al. 1998). Coloniality makes seabirds excellent candidates for restoration because they can be lured using decoys (models of adults, chicks, and eggs), sound recordings, mirrors, scent, and artificial burrows, all of which replicate features of an established colony. These attractants are placed in suitable habitat usually within a few miles of an existing source colony. Social attraction can be used with chick translocations to increase the likelihood of success. Typically, acoustic playback of non-aggressive vocalizations, decoys, and other enticements that simulate the colony from a distance lure prospecting seabirds to new nesting habitat (Parker et al. 2007). Acoustic attraction can be used for both diurnal and nocturnal species, but decoys have been used only for diurnal species. Decoys sometimes are supplemented with mirrors to give the appearance of a larger colony and movement in the colony (Parker et al. 2007). As such, prospecting birds become living decoys that help to attract conspecifics. Acoustic playback has been used alone, or in combination with decoys and chick translocation to attract new breeders.

Despite the widespread implementation of seabird restoration techniques, the circumstances under which they are or are not successful have not been identified. We therefore conducted a search of the literature on seabird restoration to assess the success of projects with differing methodologies. Our goal was to collate information on seabird restoration projects globally, provide guiding principles for future seabird restoration projects, and identify case studies useful to demonstrate the advantages, challenges, and potential utility for seabird restoration.

APPROACH

We compiled data from peer-reviewed and unpublished literature about seabird restoration projects. We also searched Web of Science with the concatenated string of the following words: seabird AND social attraction AND facilitation AND decoy AND chick translocation AND restoration AND new colony. We then searched the cited literature in each of the manuscripts located for further applicable manuscripts. We relied on the authors' interpretations to judge whether or not a project was successful. If no author opinion was available, we considered a project successful if it attracted breeding seabirds and maintained or added to the number of breeding seabirds for at least 2 years.

To date, at least 128 seabird restoration projects have been implemented to protect 47 seabird species in 100 locales in 14 countries (Fig. 1; Supporting Information Appendix). Thirty-four percent (16 of 47) of the seabird species that have been targeted for restoration are near threatened if not critically endangered (Supporting Information Appendix). Of the projects where methodology was clearly described, 10 used only chick translocation, 8 used only decoys, and 14 used only acoustic playback to attract breeding seabirds. Nine projects used a combination of chick translocation and acoustic playback, 59 used a combination of decoys and acoustic playback, and 3 used a combination of chick translocation and decoys. Many projects were begun too recently to ascertain success or had incomplete information. We thus have incomplete success or failure data for 40 of the restoration projects.

Of the 88 projects where measures of success were available, 55 were deemed successful by the authors or by our criteria. Success rates varied among methodologies, with projects using only acoustic attraction, chick translocation, or decoys having 50% ($n = 7$ of 14), 100% ($n = 5$ of 5), and 29% ($n = 2$ of 7) success rates, respectively. Projects using some combination of all 3 methods had a 70% success rate (Fig. 2; $n = 41$ of 59). Although our results appear to show that adding decoys to translocation projects reduces success rate (Fig. 2), we believe that is an artifact of small sample size in the translocation-decoy category ($n = 3$), rather than a reflection of reality. Seabird families had differing success rates, with the highest success seen for procellarids (83% of projects successful), terns (67% of projects successful), and alcids (60% of projects successful) and the lowest success rate for Phalacrocoracidae (29% of projects successful; Table 1; Fig. 3). We chose some of the most consequential studies to demonstrate key considerations for designing effective seabird restoration programs.

CASE STUDIES

Pioneering Projects

The pioneering seabird restoration project began in 1973 and brought 954 Atlantic puffins over 12 years from

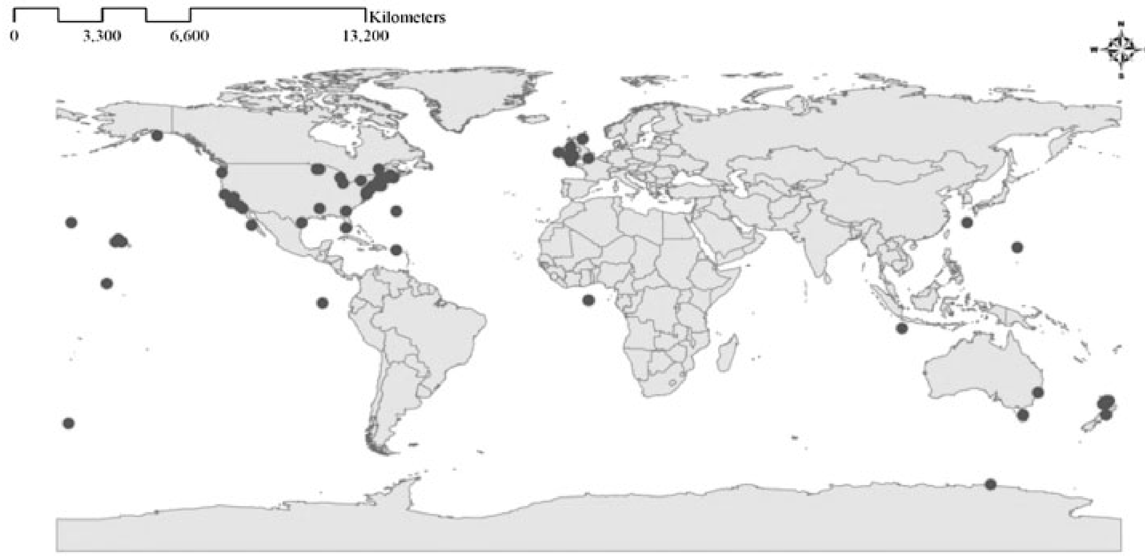

Figure 1. Worldwide locations (circles) of seabird restoration projects. Adapted from Jones et al. (2011).

Newfoundland to their historical nesting site on Eastern Egg Rock Island in Maine (Kress 1997). This project was the first to use decoys for attracting seabirds back to a historical nesting site. Nine hundred forty puffin chicks fledged and adult puffins began nesting on Eastern Egg Rock 8 years after translocation began. In 1981, 5 pairs nested, the first puffins to breed at Eastern Egg Rock in nearly 100 years (Kress and Nettleship 1988). The Eastern Egg Rock puffin colony has now reached 123 nesting pairs (Kress et al. 2009).

This project demonstrates the need for a program that includes 5 or more years of translocation cohorts and spans at least a decade to monitor the results. This project took 4 years for the first translocated puffin to return, 8 years for the first nesting attempt, and 35 years for the colony to reach 100 pairs. Returns from the transplant cohorts prior to 1977 were too small to form a colony. Consequently, if translocations had ended prior to the 1977 transplant cohort (in which 52 puffins returned and many eventually nested), it is unlikely

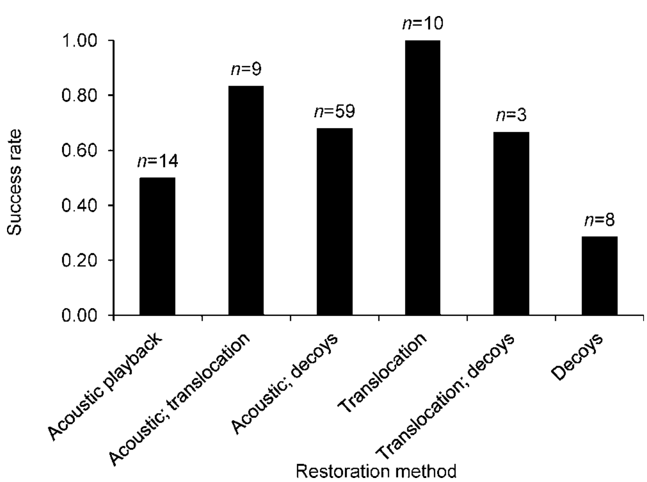

Figure 2. Success rate of seabird restoration projects as a function of methodology. Numbers above bars indicate the total number of projects used to calculate success rates.

that the project would have proved a success, as these colonists no doubt helped to attract additional breeders in subsequent years. Return rates varied widely among puffin cohorts (Fig. 4). Some of this variability may have resulted from advances in chick-rearing methodology during the project (e.g., designing burrows with suitable drainage), but it also may reflect variation in environmental factors affecting puffin survival. Both advances in chick rearing methods and variability in marine conditions during the project argue for multiple years of translocations to increase odds for success.

Puffins were not the only species that was lost from the Gulf of Maine in the 20th century. Tern (*Sterna* spp.) colonies used to be abundant around Maine, but hunting and gull predation drove terns to near extirpation by 1914 (Kress 1997). Terns have life histories that precluded the use of chick translocation so new restoration techniques had to be developed to restore them in the Gulf of Maine. In contrast to puffins, adult terns are not highly philopatric, feed their chicks at sea after fledging, and typically accompany their chicks to their wintering area. Therefore, the focal life stage for tern restoration is adults instead of chicks. To restore terns, their predators (nesting gulls [*Larus argentatus and L. marinus*]) were eliminated from Eastern Egg Rock in 1980 (Kress 1983). Managers then played acoustic non-aggressive tern vocalizations and deployed tern decoys to encourage adults to colonize and breed in high-quality habitat. Both arctic (*S. paradisaea*) and common (*S. hirundo*) terns were immediately observed landing in and around the decoys (Kress 1998). Common and arctic terns nested in 1980 and roseate terns (*S. dougallii*) joined the colony in 1981. By 2010, there were 714 pairs of common terns, 83 pairs of arctic terns, and 82 pairs of roseate terns breeding on the island (Kress et al. 2009). Twelve similar projects throughout the Gulf of Maine have restored nesting colonies with consistently high reproductive success (Kress et al. 2009; Supporting Information Appendix). All of these

Table 1. The number of seabird restoration projects characterized by both seabird family and method. Success rates for each combination are in parentheses. NA indicates insufficient data to calculate success rates.

	Acoustic	Acoustic and chick translocation	Acoustic and decoy	Chick translocation	Chick translocation and decoy	Decoy
Alcidae	2 (50)		4 (75)		3 (67)	2 (0)
Diomedeidae	2 (NA)	1 (NA)	1 (100)			
Hydrobatidae	7 (43)					
Laridae			1 (100)			
Pelecanoididae		2 (100)				
Phalacrocoracidae			7 (29)			
Procellariidae	3 (67)	6 (75)	2 (NA)	9 (100)		
Spheniscidae			1 (NA)			1 (100)
Sternidae	1 (100)		36 (76)			3 (33)
Sulidae			3 (NA)	1 (NA)	1 (NA)	1 (NA)

projects require ongoing management of tern predators and competitors and vegetation to ensure the terns' continued nesting success.

Other Seabird Restoration Projects

Many of the world's island ecosystems are dominated by seabirds. On such islands, large nesting colonies of seabirds provide an allochthonous nutrient subsidy through input of marine resource-based guano that enhances primary and secondary production in island food webs (Bancroft et al. 2005, Croll et al. 2005, Fukami et al. 2006, Jones 2010). Island managers now recognize the importance of seabird restoration not only for species preservation but also for restoring ecosystem functions (Miskelly 1999).

Mana Island, New Zealand, provides a case study where managers restored seabird populations specifically to promote ecosystem recovery through seabird-derived nutrients. Invasive species and agriculture led to the demise of seabird colonies on this island. Beginning in 1993, managers played common diving petrel (*Pelecanoides urinatrix*) calls continuously on Mana and transferred 239 chicks from a nearby source colony from between 1997 and 1999 (Miskelly and Taylor 2004). By 2004, 20 of these translocated petrel chicks had returned to Mana as well as 57 new immigrants. In 2008, at least 10 pairs were known to be nesting, and as many as 18 pairs have nested in recent years (Miskelly et al. 2009).

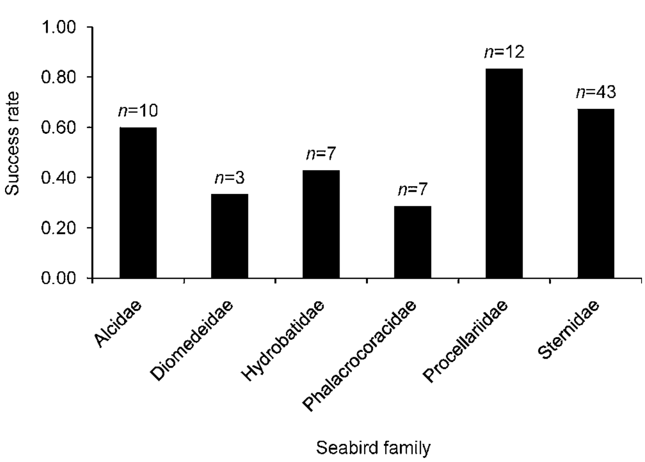

Figure 3. Success rate of seabird restoration projects as a function of seabird family. Numbers above bars indicate the total number of projects used to calculate success rates.

Similar chick translocations were undertaken to establish fairy prions (*Pachyptila turtur*) and fluttering shearwaters (*Puffinus gavia*) from 2002 to 2008. Both species have returned and bred in small numbers (C. Miskelly, Museum of New Zealand Te Papa Tongarewa, personal communication), and many more shearwater returns are expected as it takes from 5 to 10 years for individuals to reach reproductive maturity (Bell et al. 2005).

Many social attraction projects (usually combining acoustic playback with display of decoys) have added to the pioneering projects described above (Supporting Information Appendix). One of the biggest successes was the relocation of an entire colony of about 9,000 breeding pairs of Caspian terns (*Hydroprogne caspia*) to East Sand Island in the Columbia River estuary. Previously, there were around 4 smaller colonies along the Washington coast. However, in 1997, biologists discovered that over 7,000 pairs of Caspian terns had abandoned their previous nesting sites to nest on Rice Island, where terns were first noted nesting in 1986. This presented 2 problems: 1) A catastrophic event could wipe out two-thirds of the North American west coast population of Caspian terns; and 2) the terns were feeding on threatened or endangered populations of salmon and steelhead smolts as well as large numbers of hatchery-reared smolts (Collis et al. 2002, Roby et al. 2002).

Federal resource managers began a program in 1999 to prepare an alternative historical nesting site 21 km west of Rice Island on East Sand Island. It was hoped the terns could

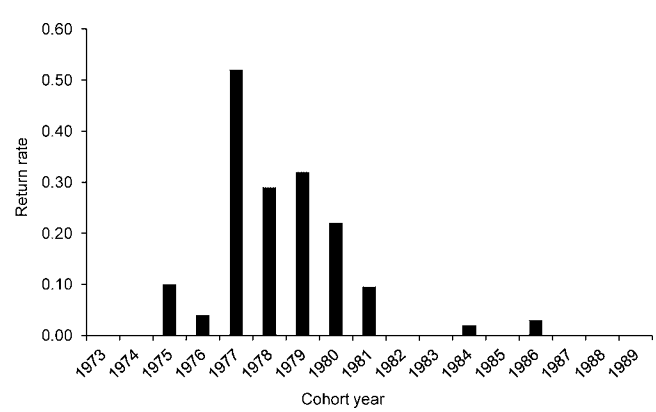

Figure 4. Return rate versus cohort year for Atlantic puffins translocated to Eastern Egg Rock, Maine from 1973 to 1985.

find a greater variety of prey species, and specialize less on fish species of conservation concern on East Sand Island. To encourage colonization, managers removed vegetation to expose underlying sand (bare sand is the preferred nesting habitat for Caspian terns) and then installed an acoustic sound system surrounded by 380 Caspian tern decoys. Within 2 years, the entire colony moved to East Sand Island, where their diets were composed of only 33% salmon and steelhead versus 74–90% in previous years when the colony was on Rice Island (Roby et al. 2002, D. Roby, Oregon State University, personal communication). Because this still left the single large colony vulnerable to a catastrophic event, the Army Corps of Engineers built artificial islands for the terns to nest on throughout Washington, which ultimately increased the number of Caspian tern breeding colonies (D. Roby, personal communication).

Managers often conduct pilot studies to address particular issues with the focal seabird species. For example, a study on the feeding frequency, meal size, and chick growth of Pycroft's petrel (*Pterodroma pycrofti*) ensured petrel chicks were fed an adequate diet upon translocation (Gangloff and Wilson 2004). Likewise, a study of prospecting Laysan albatross (*Phoebastria immutabilus*) at Kilauea Point, Hawaii tested the effects of decoys in different postures and dimensions with and without acoustic playback of vocalizations on prospecting bird behavior. The study showed that decoys and vocalizations used together were most effective at attracting prospecting birds and that 3-dimensional decoys in sky-pointing postures were the most effective decoys (Podolsky 1990). Pilot studies such as these illustrate an important first step to any seabird restoration project because they ensure restoration efforts are tailored to the focal species and restoration location.

DISCUSSION

Many seabird species are threatened with extinction (IUCN 2009). Life histories of delayed age to maturity, low reproductive rates, Allee effects, high natal philopatry, and high colony fidelity make establishing new seabird colonies challenging. Despite these odds, many successful projects demonstrate that it is possible to restore seabird populations using chick translocation and social attraction. Given the need to expand ranges and establish multiple breeding sites for threatened seabirds, these restoration techniques offer an encouraging future for rare species whose populations have declined, whose ranges have contracted, or who have lost important nesting sites. It is especially encouraging that 2 of the 4 most threatened seabird families (alcids and procellarids, based on number of species threatened per family, IUCN 2009) show the highest seabird restoration success rates.

Unfortunately, much of the information on seabird restorations remains unpublished or difficult to access (only 13 papers cited out of 29 in the Supporting Information Appendix were in peer-reviewed journals or books). This resulted in substantial data gaps in some cases (Supporting Information Appendix). Despite this general lack of data, several factors affecting the success or failure of seabird restoration projects can be identified. Kress (1997, 1998) reviewed many of these, but the most important issues seem to be: 1) the original cause of decline or extirpation is abated, 2) funding is guaranteed for many years, 3) adequate life history research is conducted to understand the habitat requirements and breeding ecology of focal species, and 4) pilot studies are conducted to determine which restoration methods are most effective for the focal species. In particular, chick translocation can only be used for species that are highly philopatric, have diets that are easy to replicate, and do not feed their young after leaving the nesting colony (e.g., many procellarids, some alcids, and albatross). Social attraction decoys can only be used for diurnal species that use visual cues for breeding (e.g., terns, albatross, and boobies) whereas acoustic attraction can be effective for both diurnal and nocturnal species.

Failures are often more instructive than successes for developing restoration techniques, yet very few examples of failures are published in the literature. For example, attempts to start colonies of Australasian gannet (*Morus serrator*) in New Zealand (Mana Island) and northern gannet (*Morus bassanus*) in Maine, Nova Scotia, and Quebec failed, but a restoration project using decoys and sound playback for Australasian gannets at Young Nick's Head, New Zealand achieved colonization (S. Sawyer, Ecoworks New Zealand, personal communication). In this case, the proximity of a nearby large, expanding colony apparently provided enough potential colonists. In contrast, the failed gannet restoration projects for both northern and Australasian gannet attempted to start colonies far from source colonies, underscoring the importance of distance to source colonies in restoration projects.

Some seabird taxa (Sulidae, Pelecanidae, Phaethontidae, Fregatidae) are either rarely targeted or have not yet been targeted for seabird restoration. This is likely an artifact of there being relatively few species in these families ($n = 11, 7, 3, 5$ species, respectively) compared to more commonly targeted families (e.g., Alcidae, Procellariidae, Sternidae; $n = 24, 82, 45$ species, respectively) rather than seabird restoration being ineffective or more difficult for these species. In contrast, some other taxa are well represented in seabird restoration efforts. Terns in particular are often actively restored for several reasons. First, they show relatively little natal philopatry and often feed their young after they leave the colony. This makes social attraction the only option for restoring them. Social attraction is less expensive than translocations, and may result in signs of success more quickly because it focuses on adults rather than waiting years for chicks to reach breeding age. Second, terns are very responsive to decoys and playbacks so tern restoration projects nearly always lead quickly to success, a delight to managers and funders. Third, the same agencies conduct many tern projects, and local success encourages other agencies to carry out similar projects. Lastly, terns are umbrella species, which means that when they are restored, other species often follow, in part because tern restoration typically means setting up resident camps that can deter avian and mammalian predators, and other seabird species benefit from this protection.

Alcids, procellarids, and terns have relatively high restoration success rates whereas projects targeting gannets, storm-petrels, and cormorants are less often successful. Such failures may in part be related to local factors such as long distances to source populations and the small number of projects. Some successful projects with these latter groups suggest that local conditions and methodology are especially important (Table 1; Fig. 3). New methods may help to increase success rates. For example, luring storm-petrels (and other tube-nosed seabirds) with scent could increase colonization since they use olfactory senses to forage, navigate, and locate their nests (Minguez 1997, Nevitt 2000). More research on this attraction method would be valuable for future attempts to restore storm-petrels and other Procellariiformes populations.

The Importance of Habitat Suitable for Nesting

Habitat has been shown to be a key factor in establishing new seabird colonies (Kildaw et al. 2005). Different seabird species have different nesting habitats including burrows, crevices, ground-surface, vegetation, and trees. So, depending on the focal seabird species, artificial or enhanced habitat may be needed to establish a colony. Some ground-nesting species, such as terns, require active intervention to produce their preferred low-growing vegetation for nesting (Dunlop et al. 1991, Kress et al. 2008).

Artificial burrows are some of the most common modifications to nesting habitat and are typically used in chick translocations. Usually, artificial burrows are hand excavated into soil or consist of artificial wooden or plastic burrows placed in suitable habitat. Such burrows typically have a door on their top so that researchers can readily check the burrow for productivity and growth studies.

Predator and Competitor Control

Islands are generally devoid of land-based predators in their natural states, and most seabirds have therefore evolved in the absence of land-based predators and lack the defense mechanisms required to avoid predation (Igual et al. 2007). Predator-naivety makes seabirds particularly vulnerable to predation so seabird restoration projects should ensure restoration sites are free from invasive predators. If predators cannot be removed, predator-proof nesting structures or areas may be required to protect breeding seabirds (e.g., Chatham petrels [*Pterodroma axillaris*] in New Zealand; Miskelly et al. 2009).

Although over 300 predator eradications have been conducted, often costing millions of dollars (Nogales et al. 2004, Donlan and Wilcox 2007, Howald et al. 2007), relatively few of these projects have been followed with seabird restoration (Jones et al. 2011). Seabirds fail to return to breed on many islands because of natal philopatry or a continued perceived predation risk (Gaze 2000). In the absence of these nutrient vectors, managers may not be meeting their goal of island restoration to pre-invasion states (Mulder et al. 2009, Jones 2010). Seabird restoration can thus be a catalyst for recovery of entire ecosystems because seabirds play integral roles in maintaining trophic interactions and nutrient cycling on breeding islands (Croll et al. 2005, Fukami et al. 2006, Kurle et al. 2008). Seabird restoration could be efficiently implemented in conjunction with predator eradications because both require similar infrastructure, logistics, and staff coordination. Moreover, if the goal of eradicating predators is ecosystem recovery, restoring seabirds will be a critical step to reaching that goal and could be considered as part of eradication project budgets. This would be an important step forward for both eradication and seabird restoration projects and could bring new funding sources to both efforts.

Native avian predators such as gulls and owls may also need to be actively removed or relocated far from the capture site if they aggressively hunt restoration species (Kress et al. 2008). For example, even a single great horned owl (*Bubo virginianus*) or black-crowned night-heron (*Nycticorax nycticorax*) can cause common and roseate tern colonies to abandon their eggs and chicks at night, exposing them to extreme climates and increased risk of predation (Shealer and Kress 1991). Newly restored colonies are especially vulnerable to predators as they are typically small, such that even minimal predation can prevent colonies from being established.

Gull populations have been steadily increasing due to anthropogenic food sources (Weiser and Powell 2010) and their expansion often hinders restoration of other seabird species (Jones et al. 2011). Gulls compete for nesting habitat and also prey on some seabird species' eggs, chicks, and adults, and are thus a principal threat to colony establishment where they are abundant (Kress 1983, Anderson and Devlin 1999). For these reasons, where large gulls are abundant, gull control is usually the first step to seabird restoration (Blokpoel et al. 1997, Kress 1998). Even after successful restoration projects, ongoing gull control may be necessary to maintain restored populations (Blokpoel et al. 1997). Gull control may be the only action necessary to reestablish populations that have been eliminated by gull predation or competition (Anderson and Devlin 1999). Management to reduce the effects of growth of invasive vegetation, levels of chronic human disturbance, and effects of climate change such as ocean level rise may be required in other cases.

Defining Success

Definitions of seabird restoration success vary between specific projects, stages of projects, and methodology. For example, chick translocations may be considered successful if most chicks fledge at the restoration site. However, the program would only be successful if translocated birds returned to breed. For social attraction with decoys and acoustics, projects may be considered successful at early stages when adults begin prospecting among decoys, eggs are laid, and chicks fledge successfully. Early indicators of success (especially during the prospecting stage) are difficult to measure without resident observers. Success indicators are especially difficult to measure for nocturnal species, but they are important early predictors of the outcome of a program.

Realistic timelines should be used to calculate budgets and predict the time needed for employing personnel. Projects are often time and staff-intensive in the beginning (e.g., when translocating and feeding chicks, setting up decoys, and setting up speakers), and require less time and effort later on (e.g., the time between when chicks fledge and return to breed for chick translocation projects or non-breeding time for social facilitation projects). In this review, we used nesting for at least 2 years as a minimum criterion for a successful restoration project, but emphasize the need to have ongoing measurements of success that ideally should span decades rather than years.

We suggest that the ultimate measure of success for any seabird restoration program is when a restored population reaches a self-sustaining population. Only a demographic study can evaluate whether success has been achieved, and the data for such studies are often lacking. The Mana Island diving petrel population is a successfully growing colony (Miskelly et al. 2009) and many of the projects we reviewed (Supporting Information Appendix) continue to grow without further intervention. For other projects, ongoing habitat and predator management may be necessary to manage invasive vegetation, human disturbance or human-subsidized predator populations. These programs should be considered successful in terms of consistent nesting success. Many projects we reviewed meet this criterion and can be considered successful, although some are in such early stages that it is too soon to tell. The projects that have had the longest to unfold, such as those in the Gulf of Maine, are good examples of restoration success with ongoing management.

Although self-sustaining populations are the ultimate goals for most seabird restoration projects, some projects have additional or different goals and thus have different criteria for success. Our definition of success may be too narrow for such projects, which should develop criteria for evaluating success that are appropriate to the intricacies of their seabird species and project goals. For example, the goals of the Caspian tern case study mentioned above were to move the terns to reduce predation on threatened salmonid populations and to establish multiple breeding sites to reduce vulnerability of the population to catastrophic events impacting any individual site, with a tangential goal of a self-sustaining population. Therefore, the project was considered successful when the terns reduced predation pressure on salmonids and when they established multiple breeding locales. Although success definitions may vary according to the project, the key common themes for defining success are identifying specific, attainable, and measurable goals so that success or lack thereof is immediately obvious.

The opportunities for future research in seabird restoration are tremendous. As the number of projects increases, more quantitative meta-analyses will be possible. Such analyses could investigate the roles played by distance to source colony, funding amount and duration, location and deployment duration of vocalization playbacks and decoys, the number of chicks translocated, and many of the other factors listed above in influencing restoration success. Research on the potential role of scent in attracting Procellariiformes seabirds would be useful as would research on methods for families underrepresented in this review (Spheniscidae, Phaethontidae, Fregatidae, Sulidae, Pelecanidae).

Financing Seabird Restoration

Financing seabird restoration projects is typically the greatest obstacle to success. Seabirds are long-lived and have deferred breeding, which often requires restoration plans to span a decade or more. For example, the Eastern Egg Rock Project took 35 years to establish 100 pairs of Atlantic puffins (Kress et al. 2009). Species that respond to social attraction (e.g., decoys and recorded sound) may respond more quickly to colony restoration than species that do not, but ongoing stewardship may still be necessary to sustain the restored colonies.

Long-term projects are difficult to sustain financially, especially in the early years when there are few signs of success. Annual budgets for programs such as these should allocate money to maintain the necessary fundraising efforts. Although the costs to restore seabirds will vary from country to country, they are substantial and ongoing. For example, maintenance of the 7 islands maintained by National Audubon Society's Seabird Restoration Program in the Gulf of Maine costs about $800,000 annually. Where ongoing management is necessary, public education can help build community support and interest in sustained protection, but this component can add another $100,000 annually. Projects are most likely to succeed where partnerships exist between government agencies and non-profit organizations.

MANAGEMENT IMPLICATIONS

Before initiating a seabird restoration project, we recommend managers consider a few key factors. First, there must be a thorough site selection process that assesses both biological constraints to breeding success (e.g., risks from predators, food limitation, and human disturbance) and logistic constraints (e.g., costs and practicality of establishing a field camp for managers and a business plan for long-term stewardship). Second, seabird restoration should only commence when the principal cause(s) for extirpation or depletion are known and corrective actions are in place to reduce threats. Third, a long-term plan for funding, monitoring, and management should be in place and specific measurable goals should be defined. If managers follow these general rules, they can improve survival prospects for threatened seabirds by encouraging colonization at locations where seabirds are safe from biological and environmental stressors.

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