CHAPTER 9

RESTORATION TECHNIQUES: DESCRIPTIONS

Part A: Introduction

This section describes a variety of restoration techniques that managers might consider in designing and implementing a seabird restoration program. As discussed elsewhere, each technique must be evaluated in light of the specific conditions at colonies and former colonies near an oil spill. Seabirds are migratory, with many species undertaking extensive migrations and spending much of the year distant from their natal or breeding colony. Thus, individuals impacted by an oil spill (especially one during the nonbreeding season) could come from colonies hundreds or thousands of kilometers distant (see Chapter 2a). Additionally, rates and distance of natal dispersal for seabirds can be high (Halley and Harris 1993, Harris and Wanless 1991), and population growth or recovery can involve immigrants from distant colonies or regions. Some of the techniques described below might be employed to the benefit of the injured population far from the colony.

Part B: Management of Predators, Herbivores, and Vegetation

BIOLOGICAL EFFECTS OF INTRODUCED PREDATORS AND HERBIVORES

Predator, herbivore, and vegetation management can, in many circumstances, be very effective techniques for restoring injured seabird populations. These techniques can enhance recruitment, productivity, and survivorship of seabirds. Management can be directed toward introduced exotic species, indigenous species introduced by humans from other sites in the same region, or species that are indigenous to the colony. The techniques available for managing each category of species are similar, but managers and the public are often more willing to use more severe measures to remove exotic species than to remove indigenous species.

Exotic and indigenous predators throughout the world have had profound adverse effects on seabird populations (Nelson 1979, Burger and Gochfeld 1994), and managing predators can reduce the take of eggs and chicks and mortality of adults. While habitat destruction and human exploitation and disturbance have also been important, the widespread introduction of mammals, both deliberate and accidental, has dramatically reduced the natural biodiversity of island ecosystems (Moors and Atkinson 1984). Predation by alien mammals and other pests is probably the single most significant factor influencing the decline of, or maintaining the small size of, many seabird populations today.

Seabirds are particularly vulnerable to predation by alien predators. Their low annual productivity and their general lack of effective antipredator behavior against mammals makes most seabird populations in previously predator-free environments vulnerable to introduced predators (Moors and Atkinson 1984). In addition, most seabirds are colonial breeders, nesting in large, conspicuous colonies on islands or in islandlike situations. Nests are typically on the ground or in shallow burrows. Some species, such as the small procellariiforms, auklets, and terns, are especially vulnerable because of their small size and the fact that they leave their chicks unattended for extended periods while they make long-range feeding flights. In combination, these features mean that predation by alien predatory mammals frequently results in annual mortality in seabird populations that consistently exceeds annual recruitment. Predation impacts may be masked by the large size of some breeding colonies, the long breeding life of some species, immigration from other breeding colonies, and the characteristics of particular sites. Nevertheless, such predation almost invariably leads to dramatic population declines and, in some cases, extirpation (Moors and Atkinson 1984, Harrison 1990).

Such predators as carnivores and rodents have reduced populations or extirpated colonies of virtually every seabird taxon (Moors and Atkinson 1984). Foxes, mongoose, mink, and cats will eat nesting adults, chicks, or eggs and can eliminate a colony rapidly. Introductions of foxes in Alaska have had a devastating effect on seabird populations, especially burrow-nesting species (Bailey 1993). While foxes were originally absent from most Alaskan islands in the north Pacific, Russians began introducing Arctic and red foxes on Aleutian Islands in the 18th century for fur farming. By the 1930s, more than 450 islands had been stocked, and fox trappers regarded seabirds as free feed (Bailey 1993). At a 600-hectare island off Newfoundland, 12 foxes consumed 31,000 Leach's storm-petrels during a single breeding season (Skepkovych 1986).

Mongoose have severely restricted the range of all ground-nesting birds on four of Hawaii's main islands. For example, wedge-tailed shearwaters are restricted to breeding on mongoose-free bluffs on Maui (Harrison 1990). Mink are currently spreading in western Scotland and ravaging its ground-nesting and cavity-nesting seabirds, such as gulls, terns, cormorants, eiders, and black guillemots (Craik 1993). Ghost seabird colonies are becoming common in Scotland, where a single mink can seize and cache as many as 100 eggs or chicks. Introduced cats and pigs have reduced the grey-faced petrel population to very low numbers at Tuhua, New Zealand (A. Saunders, pers. com.).

Often a predator will not extirpate a colony but will diminish recruitment, productivity, and survivorship. For example, on Terui Island, Japan, predation by feral cats on adults and chicks seems to contribute to a declining population of black-tailed gulls (Watanuki and Terasawa 1995). Other factors, such as vegetation cover, would also be involved, but controlling or eradicating cats at Terui Island probably would increase the gull population.

The introduction of rats and other rodents at colonies has been catastrophic for many seabirds and has caused local extinctions of populations (Atkinson 1985). Rats tend to eat eggs and young instead of adults, although they have attacked adult birds as large as Laysan albatross (Harrison 1990). In Hawaii, black rats introduced during 1943 on the Midway Islands have extirpated storm-petrels and Bulwer's petrels, have depleted Bonin petrel populations, and may even have affected large seabirds such as red-footed boobies (Harrison 1990). Black rats have caused breeding failure of populations of Cory's shearwater in the Corsican Islands, Mediterranean Sea, and introduced Polynesian rats have severely reduced the breeding success of gadfly petrels by eating chicks at Henderson Island, Pitcairn group (Brooke 1995). The U.S. Fish and Wildlife Service in Alaska has implemented a program to prevent the introduction of rats within the Alaska Maritime National Wildlife Refuge and on the Pribilof Islands (A. Sowls, pers. com.). Norway rats and ground squirrels have been introduced at several colonies in Alaska.

Introduced herbivores can also damage seabird colonies. In a classic example of ecological catastrophe, the manager of a guano mine set loose guinea pigs and two types of rabbits on Laysan Island, Hawaii, in 1903. Within six years the rabbits had overrun the island, consumed the vegetation, created desert conditions, caused the extinction of three endemic land birds, and destroyed the habitat for seabirds that nest on or under vegetation (Harrison 1990). Competition for cavities between seabirds and the introduced European rabbit was thought to be responsible, in part, for the decline of tufted puffin and rhinoceros auklet populations on Southeast Farallon Island; puffin and auklet populations increased following the removal of the rabbits in 1974 (Ainley and Boekelheide 1990).

ERADICATION OF INTRODUCED PESTS AND RESTORATION OF SEABIRD COLONIES

Sites where introduced predators have extirpated colonies or depressed populations present a great opportunity for seabird restoration. While frequently the colony was extirpated or greatly reduced by factors unrelated to an oil spill, these sites usually offer suitable nest sites and foraging conditions to allow for re-establishment of the colony once the perturbing factor (e.g., exotic predators) has been eliminated. There is little doubt that removal of alien predators or herbivores from breeding colonies can allow the restoration of the natural biodiversity, including the recovery of depleted seabird populations (Moors and Atkinson 1984). Removal of indigenous predators, however, is controversial in areas where their populations are not increasing.

Seabird managers have developed and employed cost-effective techniques for predator removal in diverse locations around the globe. In many cases the removal of exotic predators has quickly allowed the re-establishment of the former colonies.

Nizki and Alaid Islands in the western Aleutian Islands, with a combined area of 1,200 hectares, are often joined by a sandbar. Arctic foxes were introduced in 1911, and by 1937 nesting birds had been drastically reduced or extirpated (Byrd *et al.* 1994). Managers killed the foxes in the mid-1970s and subsequently made periodic counts. By 1990, the population of breeding birds had tripled to about 14,000 birds. Byrd *et al.* (1994) found particularly impressive increases of the populations of red-throated loons, pelagic cormorants, common eider, glaucous-winged gulls, and tufted puffins. These increases are probably continuing.

Kaligagan Island, in the eastern Aleutians, was stocked with foxes in 1921. In the 1930s, its seabird population plunged so low that the renowned Alaska naturalist Olaus Murie recommended that it continue as a fox farm because it seemed to hold little promise as a seabird colony. In the early 1980s, after foxes had died out without human assistance, Kaligagan had 125,000 burrowing seabirds (Bailey 1993). Bailey (1993) estimates that there are about 46 islands in Alaska where foxes continue to survive by depredating seabird colonies.

There have been similar success stories in many parts of the world. The removal of cats from Jarvis Island, in the central Pacific, enabled blue-gray noddies and Christmas shearwaters to recolonize and populations of other species to increase dramatically (M. Rauzon, pers. com.). When rabbits were eliminated from Laysan Island, native vegetation recovered and seabird populations recovered dramatically (Harrison 1990). The cessation of human predation has enabled Manana Island, Hawaii, to support the largest seabird colony in the main Hawaiian Islands despite being devoid of seabirds at the turn of the 20th century (Harrison 1990).

Because New Zealand's Department of Conservation considers introduced pests to be the most significant remaining threat to New Zealand's biodiversity (Clout and Saunders 1995), it has implemented an extensive program that has eliminated 12 predatory mammals and one predatory bird from 60 islands (Veitch and Bell 1990). The eradication of feral pigs in 1936 from Aorangi Island, New Zealand, increased Buller's shearwaters from about 100 pairs in 1938 to over 200,000 pairs in 1981 (Harper 1986). The survival of grey-faced petrel chicks increased dramatically immediately following the eradication of Norway rats in 1986 at Motuhoura (Harrison 1992). At Marotiri, New Zealand, 85% of the chicks of little shearwaters survived following the eradication of Polynesian rats from one island in 1993, while only 5% of the chicks survived on an adjacent island where rats remained (R. Pierce, pers. com.).

The Canadian Wildlife Service is currently using funds from the *Nestucca* oil spill to remove introduced raccoons, which are colonizing new islands, in the Queen Charlotte Archipelago, British Columbia. This area supports more than 1.5 million breeding seabirds, including about one-half of the world population of ancient murrelets. Raccoons have tremendous destructive potential to burrow-nesting seabirds such as ancient murrelets. The Canadian Wildlife Service is also using oil spill funds to remove rats from Langara Island. While this site is distant from the spill, the removal of the rats is likely to increase seabird populations in the Queen Charlotte Archipelago.

It is not possible to estimate with any precision the increase in seabird populations when constraints on growth from predators or herbivores are reduced or eliminated. Evidently, increases *per island* can be substantial. The seabird population on the Nizki and Alaid Islands has increased by about 10,000, and the Kaligagan Island population seems to have increased by

100,000 or more. It is possible that a few decades following predator removal, a colony of one million or more birds might be re-established.

METHODS

Removal of introduced predators or herbivores can usually be accomplished cost-effectively if managers are allowed to use the most effective tools available. In virtually every situation, eradication of the target species is the preferred option over merely a sustained reduction in numbers (Veitch and Bell 1990). In most situations, obtaining approval to use toxicants (e.g., M-44s or Compound 1080) is necessary, although trapping and shooting programs are feasible on smaller islands. The responsible agency must firmly commit to defending the decision to use toxicants and to countering any adverse publicity that may be generated by opponents of this approach. Veitch and Bell (1990) recommend asking opponents to suggest another viable alternative.

Because there is often opposition to the use of toxicants on nontarget species, any toxicant program must be planned carefully. It is usually possible to choose locations and design a program that reduces or eliminates the risk of affecting nontarget species. In recent years important advances have been made in the development and refinement of techniques to effectively eradicate mammal pests from larger islands. In particular, the aerial application of second-generation anticoagulant rodenticides has allowed for successful rodent eradication operations on islands greater than 200 hectares where ground-based approaches were impractical (Towns *et al.* 1994). In New Zealand, plans are well advanced to use aerial application techniques to eradicate rodents from islands greater than 1,000 hectares in size.

CONTROL OF INDIGENOUS SPECIES

The issue of controlling native species may arise most frequently with avian predation. On Terui Island, Japan, slaty-backed gulls and crows eat eggs and chicks of common murres (Watanuki and Terasawa 1995). In Prince William Sound, Alaska, black-billed magpies and northwestern crows eat the eggs and chicks of pigeon guillemots (L. Hayes, pers. com.), a species that the Trustee Council has determined was injured by EVOS. Northwestern crows and black-billed magpies, foraging opportunistically with bald eagles, have dramatically reduced the reproductive success of black-legged kittiwakes in Prince William Sound (Irons 1992). Bald eagles have also had a drastic effect on the colony attendance, stability, and reproductive success of common murres on Tatoosh Island, Washington, and Triangle Island, British Columbia (Parrish 1995, 1996) and on common murre breeding phenology on Shag Rock, Oregon (R. Lowe, pers. com.) In the Gulf of Maine, a few Atlantic puffins have re-established colonies, assisted in part by the poisoning of more than 3,800 native herring gulls and great black-backed gulls (S. Kress, pers. com.). The circumstances under which it is appropriate to control one native species to increase the population of another native species is a question of overall management philosophy that this report does not address.

CONTROL OF VEGETATION

Control and strategic use of exotic vegetation can be a useful technique for enhancing recruitment and productivity of seabirds. Laysan albatross began nesting on coastal bluffs at Kilauea National Wildlife Refuge, Hawaii, in the 1980s in part because refuge managers removed exotic shrubbery and created an exotic lawn that attracted adult pairs. The success of this project can also be attributed to the fact that the lawn was completely fenced so that feral dogs could not kill albatross. It is recognized that the expansion of the native *Calamagrostis* at Terui Island favors an increase of rhinoceros auklet burrows, while black-tailed gulls appear to avoid dense *Calamagrostis* areas (Watanuki and Terasawa 1995). The question of whether to manipulate vegetation in such a situation is ultimately a question of defining the management goals.

Part C: Management of Human Impacts

Seabirds are long-lived, have low reproductive rates, tend to breed in large numbers on predator-free islands, and feed in relatively small areas of high biological productivity (Duffy and Nettleship 1992). These characteristics make seabirds vulnerable to human activity, especially since activities of humans also are often concentrated in areas of high biological productivity (e.g., fisheries).

Human activities near seabird nesting and foraging areas may negatively or, in some cases, positively affect productivity. Activities that negatively affect seabird reproduction include disturbance or destruction of nesting locations and egg collection, causing decreased productivity; introduction of predators near nesting areas; hunting; pollution; and mortality associated with fisheries bycatch. Future problems may include increased human disturbance and competition with humans for marine resources (Duffy and Nettleship 1992).

Recently, resource agencies have placed much emphasis on multispecies or ecosystem management, but managers often have limited information on how ecosystems function. Lacking sufficient information on ecosystem function it may be simplest to address anthropogenic effects known to be harmful, such as disturbance, feral animals, unsustainable exploitation by humans, and pollution (Duffy 1994).

The workshop divided human disturbances to seabirds into six categories: (1) colony disturbance, (2) at-sea disturbance (primarily at foraging areas), (3) incidental mortality associated with net fisheries, (4) predator introduction at nesting locations, (5) habitat loss, and (6) marine pollution. We discuss managing the effects of human disturbance for seabirds in general, and include a summary of the probability of success if applied to the four species listed as injured by the Trustee Council (common murre, marbled murrelet, pigeon guillemot, harlequin duck).

COLONY DISTURBANCE

Sources of human disturbance at colonies include low-flying aircraft, boats near shore, and people present on colonies. Within the designated EVOS zone, aircraft is a common means of transportation and poses great potential for colony disturbance. Fishing operations and nature tours have the greatest potential for nearshore boat activity causing disturbance to seabird colonies, especially since seabirds, fishery operations, and nature tours all seek areas of marine productivity. Other than anecdotal observations, however, minimal data exist that could help determine the extent of disturbance by humans and its impact on colonies within the designated EVOS zone.

Two primary methods of reducing colony disturbance by humans include posting "no access" signs and public education. Posting signs is feasible for seabird nesting locations that are accessible from shore, where signs can be posted in an obvious location at a safe distance from the colony. This would be a valuable approach to reducing disturbance in an area with many pedestrians (e.g., a site near a town, or a site that is regularly visited by nature viewers). Signs are more difficult to place effectively near colonies accessible by boat, however, and are not practical to place near colonies accessible by aircraft, although signs can be placed at boat ramps, harbors, and local airstrips. As has been done at Farallon Island National Wildlife Refuge, for instance, the Federal Aviation Administration should mark important seabird colonies on aerial maps and state that it is a violation of law or refuge/sanctuary policy to approach below a certain altitude. Obeying restrictions posted on signs requires voluntary compliance because enforcement would likely be a low priority for enforcement officials. Particularly in remote sites in Alaska, educating people who travel near seabird colonies is likely to be the most effective means of long-term management.

For species affected by EVOS, reduction or elimination of disturbance at colonies would have the highest probability of success for common murres, little or no success for pigeon guillemots or marbled murrelets, and uncertain success for harlequin ducks.

AT-SEA DISTURBANCE

At-sea disturbance is more difficult to measure than colony disturbance. Boat traffic at or near foraging areas may disturb birds and interrupt feeding. Disturbance to seabirds at foraging areas primarily results from fishing activities or persistent vessel traffic (near ports and shipping lanes, and in areas of recreational boating). At-sea disturbance will have varying degrees of impact on different species. Gulls and kittiwakes are unlikely to be disturbed by boat traffic (as long as the patch of prey on which they are feeding is not disrupted), but marbled and Kittlitz's murrelets may be susceptible to disturbance by boats. Because boat-traffic restrictions may be difficult to implement or enforce, public education may be the best method of reducing at-sea disturbance.

For species affected by EVOS, reduction or elimination of at-sea disturbance would have a low probability of increasing productivity for common murres, pigeon guillemots, marbled murrelets, and harlequin ducks due to the difficulty of identifying specific foraging areas that need protection, and of implementing and enforcing regulations.

NET FISHERIES

Gillnet and longline fisheries have a great potential for impacting seabirds (e.g., DeGange *et al.* 1993). Seabird bycatch can be monitored by implementing observer programs, but the effect on seabird populations cannot be determined unless it is known what colony, metapopulation, or population the birds belong to. This information is easily obtained if fisheries occur near nesting locations, or if the species has a restricted breeding range. In most cases of at-sea mortality resulting from fishing activities, however, the impact on breeding populations of seabirds is unknown because the source population is unknown (Schneider *et al.* 1992). Jones and DeGange (1988) reported that common murre mortality in gillnets in California was large enough to affect local colonies (see also Takekawa *et al.* 1990).

For species affected by EVOS, reduction or elimination of fisheries bycatch would have a high probability of benefiting populations of common murres and marbled murrelets, but would have uncertain benefits for pigeon guillemots and harlequin ducks.

PREDATOR INTRODUCTION

Among the many environmental challenges faced by conservation scientists and managers in the coming decades, managing the inexorable invasion of alien species from distant lands and waters and between previously isolated regions may be the most difficult (Soulé 1990). The introduction of exotic or indigenous predators or pests on islands where they do not occur naturally has resulted in dramatic decline and local extinction of nesting seabirds (Atkinson 1985, Moors and Atkinson 1984, Bailey 1993, Byrd *et al.* 1994).

It is essential that introductions and reintroductions do not occur on islands without introduced predators or where introduced exotic or indigenous predators have been successfully removed. This can be achieved by (1) public education highlighting the potential threats to the local biological diversity posed by the introduction of predators or pests, (2) limiting access to islands with seabird populations that are vulnerable to introduced predators or pests in an effort to avoid accidental colonization, and (3) on islands with permanent human settlements, encouraging people to manage pets and domestic animals to minimize the risk of invasion of natural habitats (e.g., permit only sterile pets on such islands; limit garbage or sources of food that could maintain or facilitate the establishment of rat and mice populations; use poison to control rodent outbreaks).

At seabird nesting locations with nearby human inhabitants, it is important to avoid enhancing populations of indigenous predators beyond the natural carrying capacity. Human activity may provide alternative or additional food resources for indigenous predators (e.g., garbage or fish processors attracting eagles) and may result in larger populations than the habitat would naturally support. An increase in predation rates may follow from an increase in predator numbers. Controlling indigenous predator populations through nonlethal means is preferred over eradication programs because indigenous predators are part of the natural system.

The deliberate introduction of large animals is now illegal in New Zealand, but the accidental introduction of smaller animals remains a problem (Veitch and Bell 1990). Permanent bait stations and traps can be placed around the shores of islands prone to reinvasion (Veitch and Bell 1990), but this requires a long-term commitment because traps and baits will need to be checked regularly. Alternatives include regular inspections of vessels traveling to islands, but this is very costly and logistically difficult. One method of combating the problem of unintentional introduction or reintroduction is through public education. Veitch and Bell (1990) consider it essential that any eradication program be discussed with the appropriate people and agencies from the beginning of planning in an attempt to reduce misunderstandings and undesirable or ill-informed publicity.

Preventing predator introduction or enhancement to nesting areas within the EVOS zone would have the highest probability of benefiting common murres, pigeon guillemots, and possibly harlequin ducks (although in Alaska most harlequin ducks nest on the mainland or on large islands), but will likely have little effect on the productivity of marbled murrelets (but see Chapter 2c).

HABITAT LOSS

Foraging areas for seabirds are often defined by oceanographic processes, and identifying specific foraging areas is difficult. Foraging areas may consist of a small estuary near a nest site, or locations within large geographic regions that change over time. The scope of management, therefore, is limited to managing human activities that conflict with the foraging of seabirds (primarily fisheries or vessel traffic). Seabird biologists need to work with the people involved in those activities on a regional or international level. On a large scale, the Department of Interior currently does not enforce the U.S. Migratory Bird Treaty Act beyond the 12-mile territorial sea. Seabird biologists could press for national marine reserves or sanctuaries to protect foraging areas for seabirds and other marine animals within the 200-mile Exclusive Economic Zone or international reserves beyond the 200-mile limit. They also could help develop multinational treaties that set common standards of behavior toward seabirds among nations (Duffy and Nettleship 1992).

Breeding habitat can be created by constructing artificial burrows (Byrd 1979, Priddle and Carlile 1995), modifying vegetation, or creating nesting islands and platforms. Seabirds also may be attracted (Kress 1983) or translocated (Kress and Nettleship 1988, Towns *et al.* 1990b) to alternate nesting locations (see Chapters 9e and 9f). However, if a large number of adult birds die as a result of an oil spill, many previously occupied nest sites would become available, and there would be no need to create additional nest sites. Therefore, simply protecting available habitat and potentially enhancing the nesting area through vegetation or predator control or attracting birds back to the site may be all that is needed.

Reduction or elimination of breeding habitat loss within the EVOS zone would be very beneficial for marbled murrelets (old-growth forest) and harlequin ducks (streamside habitat), but would have little benefit for common murres or pigeon guillemots, since there is little threat to their nesting habitat.

SUBSISTENCE HARVEST

In locations where subsistence harvest can significantly affect the local population of seabirds, it is important to have an estimate of annual take and life history models to determine what, if any, management actions are necessary. Life history models provide managers with different management schemes. For example, is it better to exploit eggs or adults, or to harvest one egg of each three-egg clutch throughout the colony, or to harvest all eggs in one-third of the colony (Duffy 1994)?

Enforcement of laws and regulations on private land has been a primary method of protecting seabirds in Northern Hemisphere countries (Doughty 1975). Such methods, however, have not been effective in isolated areas where traditional subsistence hunting occurs (Blanchard 1994). We recommend regulation of subsistence harvest by implementing education programs that emphasize minimum take and self-regulation. In locations where seabirds are an important part of a local culture or where seabirds are linked, directly or indirectly, to the local economic base, it is important that seabird managers work with local cultures and economic goals rather than against them (Blanchard and Nettleship 1992).

Within the EVOS zone, subsistence harvest of common murres, pigeon guillemots, and marbled murrelets likely is minimal and does not affect recovery of populations. Subsistence harvest of harlequin ducks is probably greater than that of alcids, with an unknown effect on recovery of populations.

MANAGEMENT OF MARINE POLLUTION

Pollutants enter the marine environment through point sources (e.g., oil spills and industrial discharges) and non-point sources (e.g., persistent organochlorine, plastic fragments, and small-scale oil discharge from vessels; Fry 1992). Organochlorine pollutants have become globally distributed from direct point-source inputs (Tanabe *et al.* 1984, Brun *et al.* 1991), and, although discharge of organochlorine pesticides has been eliminated or greatly reduced in North America and Europe, it has taken 15 to 20 years for residues to fall below reproductively harmful levels (Fry 1992). Only about 10% of oil pollution, however, is caused by the few massive point-source disasters such as *Torrey Canyon*, *Exxon Valdez*, and the Persian Gulf spills. Small spills occur more frequently and may be much more damaging to seabirds over the longer term (M'Gonigle and Zacher 1979, Fry 1992, Gandini *et al.* 1994, Nur *et al.* 1995). These conclusions emphasize the importance of working not only to prevent tanker spills, but also to reduce the occurrence of chronic oiling from point and non-point sources.

Given the importance of oil transportation at sea, it is necessary to identify important seabird colony sites on land (e.g., Lloyd 1984) and foraging areas at sea (Tasker *et al.* 1990). These colonies and foraging areas should be marked on navigational charts to encourage navigators to avoid such areas altogether or to take increased precautions in their vicinity (Duffy and Nettleship 1992). Although management of tanker traffic is a complex issue, seabird biologists can play an important role in working with oil shipping companies and the U.S. Coast Guard to help provide protective measures through voluntary compliance or regulations (see the discussion of sensitivity maps in Chapter 2a).

Plastic debris is another increasingly common form of pollution in the ocean. More than 80 species of seabirds throughout the world have been reported as ingesting plastic fragments (Day *et al.* 1985, Ryan 1988, Fry 1992). In the subarctic north Pacific, Robards *et al.* (1995) reported that ingestion of plastic particles by seabirds significantly increased between studies collected in 1969-77 and 1988-90. Enforcement of regulations may be an efficient means of treating pollution, but education promoting voluntary compliance may be the most feasible method of dealing with pollution.

There is insufficient information on the extent of marine pollution and its effects on seabirds within the EVOS zone. However, a program to reduce marine pollution would not negatively affect seabirds, and may be a positive influence.

CONCLUSION

To achieve long-term conservation goals, we feel that education is of paramount importance in the management of human activities affecting seabirds. The focus of such education should be to promote the importance of seabirds in maintaining a healthy ecosystem and to let people know that voluntary conservation efforts will make regulation unnecessary. Although imposing regulations may secure the desired results more rapidly in the short term, education promoting voluntary conservation efforts (using an educational approach that instills a vested interest in resource users) will be more effective over the long term and in remote areas where enforcement of regulations is difficult or impossible. Blanchard and Nettleship (1992) point out that where conservation policies remain at unresolved odds with local economic and cultural imperatives, enforcement of those policies may end in failure and backlash from the culture. This has been the case with spring shooting of waterfowl by Alaskan Natives (Raveling 1984, Pamplin 1986, Blanchard 1987) and efforts to manage the hunting of thick-billed murres in Newfoundland and Labrador (Nettleship 1977, Brown and Nettleship 1984, Elliot 1991, Elliot *et al.* 1991).

Conservation efforts can succeed only with the support of the public. Craig and Veitch (1990) found a need for three methods of improving public perception of their seabird conservation work: (1) greater public access to islands, (2) increased protection of island ecosystems, and (3) more information for the public. It is important that scientists, managers, environmental educators, and resource users work together to produce effective conservation programs.

Part D: Management of Seabird Food Resources

The likelihood that seabird populations will recover from losses caused by oil pollution or other factors may depend strongly on the availability of suitable food (e.g., forage fish, euphausids) during the first few years following the initial mortality event. Factors influencing the annual abundance and availability of food include natural changes to the marine environment that may directly affect growth and recruitment of prey species (see Chapter 12); competition; and predation by natural marine predators, including seabirds, marine mammals, and large predatory fishes such as cod, pollock, and salmon. In addition, abundance can be affected by a range of anthropogenic effects, including overfishing (Springer 1992).

OVERVIEW OF RELATIONSHIP BETWEEN FOOD RESOURCES AND SEABIRD POPULATIONS

There is good evidence to suggest that over short time periods, seabird foraging success and population dynamics may be tightly coupled with local food abundance (Ashmole 1963, Birt *et al.* 1987, Uttley *et al.* 1989; see also Chapter 12). Seabird populations in some ecosystems may use a significant fraction of local forage fish stocks (Furness 1990, Duffy and Schneider 1994), and seabird breeding parameters may track long-term changes at lower trophic levels (Aebischer *et al.* 1990). In Alaska, dramatic shifts in forage and predatory fish populations apparently have occurred in the Gulf of Alaska and Bering Sea, which were accompanied by marked changes in diet composition and population declines of several seabird and marine mammal species (Springer 1992, Hatch *et al.* 1993, Piatt and Anderson 1996).

While some seabird and marine mammal populations have shown increasing signs of stress (i.e., decreases) during the past decade in the north Pacific, populations of large predatory fishes, such as pollock and salmon, have increased dramatically (Springer 1992), and herring have decreased (Wespestad and Fried 1983). There is strong evidence that these changes have occurred in response to, or simultaneously with, decadal-scale shifts in the marine ecosystems of the north Pacific (Duffy 1993). Predatory fishes may be directly consuming forage fish used by seabirds and/or outcompeting forage species for shared lower trophic-level food resources during early life stages.

Interspecific competition is suggested by the negative relationship between herring and pollock biomass in the Bering Sea (Wespestad and Fried 1983). Data collected by the Alaska Predator Ecosystem Experiment project in Prince William Sound provide further support for the competition hypothesis: pollock and herring school together during the fall (L. Halderson, University of Alaska Fairbanks, unpubl. data) and their diets overlap (M. Sturdevant, National Marine Fisheries Service, unpubl. data). Furthermore, the Alaska Predator Ecosystem Experiment also determined that piscivorous seabirds select herring and other forage species over pollock (W. Ostrand, USFWS, unpubl. data).

EFFECTS OF MANAGING FOOD RESOURCES

Restoration techniques that increase the abundance of prey available to a seabird population would act primarily to increase productivity and the survivorship of adults and young. However, as stated in Chapter 13, altering the environment for the benefit of seabird populations may, at the same time, negatively affect populations of other species. Before implementing projects that would enhance the productivity of seabird food resources, managers must seriously consider whole ecosystem consequences of such activities.

Manipulating the seabird food environment by augmenting forage fish populations or reducing competition by large predatory fish might be an effective strategy in some circumstances for facilitating the recovery of injured seabird populations. In the following we identify some conditions under which such efforts are most likely to be successful:

1. Smaller-scale interventions are more likely to be effective and have predictable outcomes than are larger-scale, ecosystem-level interventions. For example, the creation or maintenance of local nearshore spawning habitat for forage fish or the management of a specific forage fish hatchery is a small-scale operation that may increase local prey abundance. The deliberate overfishing of a predatory fish competitor of a seabird species is a larger-scale community- or ecosystem-level technique that may result in unpredictable or undetectable results, due to unexpected trophic interactions or time lags (Butterworth *et al.* 1988).
2. The probability of designing effective food-related restoration projects for seabirds is directly related to our knowledge of the trophic structure within the local marine ecosystem. Understanding the causes of the variability in both seabird and forage fish populations, and determining if and how these populations are limited, will determine what types of manipulations might be employed. However, we stress that understanding systems does not necessarily indicate that restoration techniques are readily available, and the use of a known technique can lead to unsatisfactory results if the systems are not well known. For example, trophic-related restoration activities for the Aleutian tern, whose biology is poorly known, may owe any success to luck. Moreover, different species may

respond differently to food manipulation. If factors other than food availability, such as predation on adults or nest contents, are limiting recovery, manipulation of food may be futile.

3. The economic and biological value of intervention is likely to vary with the ecology of the species of birds and prey involved, the scale of the spill, and the rarity of the birds. For example, a small spill at the single colony of a rare species might merit extreme, intensive measures such as feeding young by hand or establishing feeding pools for adults. A larger spill affecting more common species might merit more extensive efforts, such as the establishment of intertidal spawning habitats or commercial fishing restrictions or modifications.

METHODS OF MANAGING FOOD RESOURCES

There are few data on the methods for, or the effectiveness of, managing food to facilitate restoration following oil spills or other perturbations. We offer the following as suggestions and strongly recommend that each of these ideas, as well as any others under consideration, be thoroughly researched before they are implemented.

Increasing Food Availability Through Reduction of Competing Consumers

Ecosystem-level interventions by humans are extremely common in marine systems, but are usually unplanned and have accidental consequences (May 1984). Interventions designed to increase food for seabirds by manipulating their competitors may also have unanticipated outcomes, so they should be used with caution and only where the marine system is reasonably well understood. Where there is competition between forage fish species (e.g., herring and pollock), it may be productive to harvest the species that is less desirable from the birds' point of view (pollock) in order to obtain an increase of the preferred forage species (herring). However, where the renewal rates of the competing forage fishes vary, one possible outcome is the extinction of both species (e.g., Tilman 1982, 1986). Without sufficient information about forage fishes and their competitors to enable us to understand the ecological processes, it is difficult to predict whether this technique would be efficacious or even detrimental.

Nevertheless, directed fisheries or culls of seabird competitors (e.g., pollock) for forage fish may be appropriate in certain conditions. For example, an increased pollock fishery might reduce predation on forage fish or reduce competition of young pollock with such species. Similarly, because hatchery-raised salmon may reduce the seabird prey base through competition (i.e., juvenile salmon) or predation (i.e., adult salmon), it might be appropriate to cut back on salmon hatchery operations or locate hatcheries where the salmon will not conflict with forage fish used by seabirds. Finally, reduction in human fisheries for forage fish such as herring or the exclusion of fisheries from the foraging zones of seabirds may be required in certain circumstances (Duffy and Schneider 1994), although at the current time there are no forage fish species, other than herring, that are commercially exploited in Alaska.

Modeling of the existing system and the effects of intervention on birds, the targeted fish species, and the ecosystem as a whole is a critical step before action is taken. For example, a simple and preliminary carrying-capacity model suggests that *juvenile* salmon are unlikely to compete with other forage fish in Prince William Sound (Cooney 1993), so that managing salmon hatcheries *to reduce competition with herring, capelin, or sand lance* may not be an effective strategy. However, if direct evidence or models indicate that hatchery-raised *adult salmon are competing with seabirds* for forage fish, managing salmon hatcheries may be an effective strategy in restoring certain seabird populations.

Improving Fish Habitat

Several high-latitude forage fish species, such as herring, capelin, and sand lance, spawn in the subtidal and intertidal areas that are highly susceptible to oil spills and their persistent effects (Pinto *et al.* 1984). Thorough cleaning of known or likely spawning sites may be critical, especially in deep, loose sediments, such as gravel or sand, where oil may persist. In addition, new intertidal spawning areas could be created (probably at considerable expense) near seabird colonies or in unoiled areas by placement of appropriate substrates, to increase surviving fish populations. In Alaska the herring roe fishery places tree branches and kelp in the water to facilitate harvest. If such measures increase spawning success, they also might be used as a management tool to increase herring populations. Finally, and most importantly, if existing and productive spawning beaches can be protected from development and the harmful effects of pollution, populations of forage fish may be maintained at levels sufficient for local seabird populations.

Reducing Bycatch of Nontarget Fish

Many commercial fisheries, especially net fisheries, take large quantities of nontarget species that are not marketable or desirable. In most instances, the nontarget species do not survive and are simply dumped overboard. Restoration planners should sponsor research to develop commercial fishing techniques that would decrease the bycatch of prey populations that are important to seabirds. Such techniques might include gear changes or modifications of the time of day that nets or longlines are set.

CONCLUSIONS

The science of managing forage fish resources for seabirds is still in its infancy, but it may prove in time to be an effective approach to restoring injured seabird populations. However, because these techniques are expensive and may produce unexpected results, they should be used with extreme caution. These techniques may be appropriate to use in restoring rare or endangered species or critical colony sites, when "heroic" efforts are warranted.

Directed research could provide the scientific underpinnings for managing food resources to enhance recovery. Experimental interventions in noncrisis situations and models of their effects on seabird populations (Migot 1992, Spendelow *et al.* 1995) could provide objective guidelines on use of such techniques, and we strongly recommend that this research be pursued.

Part E: Management of Seabird Habitats

SOCIAL ATTRACTION

Social attraction as a seabird restoration technique consists of the use of decoys and sound recordings of a particular species to attract recruits to a specific location or habitat. Most seabird species nest colonially, and the majority of recruitment occurs at locations where conspecifics are breeding or at least present. Social attraction lures potential recruits by mimicking a breeding colony or aggregation. It attempts to assist restoration by increasing immigration or directing recruitment to target locations. The technique assumes that an increase in immigration will not be deleterious to a source population or colony and that the probability and rate of natural colony formation are low.

The technique was first described as a management tool by Kress (1978), who used Atlantic puffin decoys in conjunction with translocation of chicks to re-establish puffins to Eastern Egg Rock, an historic nesting island in the Gulf of Maine. Social attraction (without translocation of chicks) was also used to establish a mixed colony of more than 1,000 pairs of common terns, Arctic terns, and roseate terns at Eastern Egg Rock (Kress 1983).

A variation of the technique (sound and artificial burrows) was used to attract Leach's storm-petrels to several historic nesting islands in Maine (Podolsky and Kress 1989b) and to attract endangered dark-rumped petrels to artificial burrows in the Galapagos Islands (Podolsky and Kress 1989a). As a result of these studies, puffins, terns, and storm-petrels successfully re-established breeding colonies that continue to grow or have remained stable more than 10 years after recolonization.

Social attraction offers managers the possibility of reducing risks to seabird populations that are concentrated on one or a few islands. While the technique works by recruiting immigrants, immigrants are typically inexperienced birds or, rarely, experienced birds relocating due to disturbance (Kress and Nettleship 1988, Divoky and Horton 1995). The technique requires a pool of potential recruits that are not philopatric. Seabirds vary in their level of philopatry, and within a species philopatry can be expected to vary with local conditions (Waser 1985). In general, the success of social attraction programs can be expected to be proportional to the species' level of dispersal. Terns, which display high levels of breeding and natal dispersal, have been the subject of several social attraction programs (e.g., Kress 1983, Hall 1995). For example, social attraction, typically employed in conjunction with other restoration techniques, has been used to successfully restore colonies of several species of terns in various locations: (1) common terns in Upper St. Lawrence River, Ontario (H. Blokpoel, pers. com.) and in Duluth-Superior Harbor on Lake Superior (Matteson 1986); (2) roseate terns at Ram Island, Massachusetts (Harlow 1995); and (3) least terns at many sites, including California (Rigney and Emery 1980, Anderson 1981) and New Jersey (Kotliar and Burger 1984).

While decoys and recordings have been used most often to establish waterbird colonies at historic nesting islands, they may also be used to improve productivity through shifting recruitment to potentially higher-quality breeding habitat. This is the rationale behind an effort to encourage the endangered short-tailed albatross to shift nest sites from the side of an active volcano on Torishima Island, Japan, where albatross chicks and eggs are often buried in ash, to level habitats away from the volcano. After decoys and recorded sound had been used for four years, the first pair of short-tailed albatross nested among the decoys on the more secure habitat in 1996 (H. Hasegawa, pers. com.). Presumably, over the long term, pairs that nest away from the loose-ash substrate will have greater productivity than those that nest on the ash.

Social attraction can be facilitated through the concurrent use of other restoration techniques such as predator control, translocation, or reducing human disturbance (Kress 1983, Kress and Nettleship 1988, Hall 1995). The need for social attraction techniques in conjunction with other techniques may depend on specific biological or political circumstances. Habitat or nest-site creation and predator removal in a region where a species is common might result in relatively rapid establishment or growth of a colony without the need for social attraction. This has been the case in Alaska at islands where predators have been removed (Bailey 1993). In areas where densities of prospecting birds are low, social attraction may be needed for a species to find and prospect a given location. In addition, social attraction can be used to help establish a colony within a time period acceptable to project managers. The success of a social attraction program for terns, or the time period before recolonization occurs once a program has been established, may be related to the time interval between the abandonment or extirpation of the colony and the implementation of the program. This relationship may be a function of the presence of individuals that had bred previously at the site.

Social attraction programs generally require recruits from pre-breeding age cohorts. However, populations classified as nonrecovering could *not* be expected to have large pools of recruits resulting from immigration, recent high breeding productivity, or increased postfledging survival. Thus, in nonrecovering populations, social attraction would have to be used only for a specific purpose (such as re-establishing a high-profile colony), not for the goal of increasing numbers of the *total breeding population*.

Social attraction would probably not be appropriate where recruitment and productivity are already sufficient and there is no reason to believe that seabirds would benefit from additional colonies or subcolonies. This appears to be the case with the depleted common murre colonies on islands in the northern Gulf of Alaska, where productivity for surviving birds remains high. In addition, social attraction would not be practical for noncolonial nesting species with dispersed breeding, such as loons, harlequin ducks, and scoters.

The technique may be detrimental if used to establish birds on locations or habitats where recruits would experience increased risk of predation or disturbance. In summary, social attraction offers managers an opportunity to establish or re-establish colonial waterbirds at additional sites. New colonies may benefit the population by spreading the risk of catastrophic events and by expanding ranges back to earlier limits. However, natural colony formation occurs regularly in many seabird species without the need for social attraction (Divoky and Horton 1995).

NEST SITE IMPROVEMENT OR PROVISION

Nest site improvement techniques (e.g., vegetation control, nest box provision) are best used at colonies where nest sites are limited or where the quality of breeding habitat is suboptimal (and thus thought to be reducing recruitment or productivity). These techniques act to increase the recruitment of birds by creating attractive recruitment opportunities and to increase productivity by providing sites and habitats that, due to increased cover for eggs and chicks, support increased breeding success. Because breeding dispersal is low for most seabird species, the majority of individuals occupying new sites would be expected to be first-time breeders.

The utility of nest site improvement and provisioning for nonrecovering populations is unclear. Populations that are not recovering from oil spill mortality would be expected to already have an excess of sites or habitat available to them (the sites and habitat previously occupied by the part of the population removed by the spill). In such situations nesting habitat improvement or creation may serve mainly to increase the breeding productivity of individuals remaining after the mortality.

Vegetation control has been conducted in order to improve breeding habitat of surface nesting species, including common and least terns (S. Schubel, pers. com.), roseate terns (M. Tasker, pers. com.), and burrow-nesting species. Control of dense ground cover that precludes burrowing by ground-nesting species can free additional areas that otherwise would not be used (J. Takekawa, pers. com.). Vegetation control can be conducted using a variety of methods, including mechanical techniques (e.g., handpulling, hand tools), chemical agents, and limited-controlled grazing (if habitat allows).

Nest boxes have been used by a variety of cavity-nesting species (Priddle and Carlile 1995), including rhinoceros auklet (Wilson and Manuwal 1986), Cassin's auklet, tufted puffin, pigeon guillemot, ashy storm-petrel (Ainley and Boekelheide 1990), horned puffin (Divoky 1982), and black guillemot (Divoky *et al.* 1974). Nest boxes can increase productivity by providing protection from native predators (e.g., gulls and crows) or preventing the collapse of burrows due to erosion, marine mammals, or human activity. In addition, nest boxes can provide nesting habitat in areas where nest sites are limited. The provision of nest boxes in Arctic Alaska, where natural sites are extremely limited, resulted in the increase of a black guillemot colony from 15 pairs to 210 pairs in less than a decade (G. Divoky, pers. com.).

The construction and design of nest boxes can be varied to produce attractive and productive sites. The diameter of the entrance can be modified to select for certain species, and baffles and angled entryways can be used to reduce predation. Nest boxes can be designed to allow investigators easy access to nesting cavities for species that typically nest in inaccessible situations. This can provide access to nest contents and breeding adults that would facilitate the assessment of a range of demographic parameters important in postspill monitoring.

The creation of nesting ledges to increase recruitment is less common. The nests of a black-legged kittiwake colony in Great Britain that was the subject of a long-term study (Aebischer and Coulson 1990) were on the window ledges of a dockside warehouse. Recent research on black-legged and red-legged kittiwakes on the Pribilof Islands showed that both species readily occupied manmade wooden ledges attached to rock cliffs (D. Kildaw, pers. com.).

HABITAT CREATION

The creation of nesting platform islands is a technique used when habitat availability is limited or increased recruitment is desired. In general, nesting platform islands are constructed and designed to meet the habitat requirements of individual species. Artificial nesting platforms built on posts made of wood and metal have been used by double-crested cormorants (USFWS 1983). Also, certain seabird species (western gulls, pelagic cormorants, double-crested cormorants, Brandt's cormorants, least terns, and pigeon guillemots) will nest opportunistically on such structures as abandoned lighthouses, navigational lights, bridges, abandoned piers, duck blinds, and electrical transmission towers (Carter *et al.* 1992). Nesting islands created from dredge-spoil deposits have also been used by a number of species including least terns, ring-billed gulls, Forster's terns, and Caspian terns (J. Hainline, pers. com.; J. Albertson, pers. com.).

HABITAT PRESERVES

The designation of an area as a habitat preserve serves to safeguard habitats or areas that are of critical importance to seabirds. For seabirds this almost always involves the preservation of nesting sites, although coastal roosting sites are frequently included in wildlife refuges. While the designation of an area as a preserve does not directly lead to the increase of a nonrecovering population, it does ensure the availability of essential breeding habitat in the future. Most U.S. habitat preserves for seabirds are owned by the federal government and are in the Department of Interior's National Wildlife Refuge system. There are, however, examples of private preserves (e.g., The Nature Conservancy). Aside from ensuring that the habitat protected will be available and undisturbed in the future, the designation of an area as a reserve allows the restriction of human activities that could disturb breeding (e.g., hiking, motor vehicle activity). Habitat preserves also facilitate the management and monitoring of seabird populations.

LAND PURCHASE

The purchase of land from private owners is considered to be a viable restoration option. Land purchased through restoration funds can benefit seabird populations in the same way as designation of habitat preserves can.

Part F: Supplement Wild Populations

CAPTIVE REARING

Captive rearing has proven an effective technique for reintroducing peregrine falcons and other raptors (Cade and Temple 1977) and has been attempted for a variety of other rare birds, such as *Amazona* parrots (Nichols 1977) and whooping cranes (Erickson 1976). It is generally agreed to be a technique of last resort due to high cost, potential genetic problems, and the complicated reintroduction procedures that it may require.

With the exception of the publicly appealing penguins and puffins, seabirds are notably absent from most zoos because of the expense necessary to maintain aquatic exhibits with ample size, water circulation, and temperature controls. Penguins are the best-represented seabird in zoos, but the number of zoos and aquaria with the specialized and expensive habitats necessary for alcids are increasing (e.g., Oregon Coast Aquarium, Newport, Oregon; Hubbs-Sea World, San Diego, California). In a 1991 review of the status of alcids in captivity, Gunther (1991) found that only eight of the world's 22 species of alcids were represented in the collections of the nine largest aquaria in the United States. To date there has been relatively little success at breeding auks in captivity. Tufted puffins are the notable exception and are considered a routine breeder at most aquaria that keep this species.

The release of captive-raised birds may directly increase the pool of potential recruits for a nonrecovering population, but there are a number of drawbacks to raising seabirds in captivity. The cost per released individual is excessive, and, except for a population that has been reduced to a few birds, the release of captive birds is likely to be insignificant compared to local production. Because the captive-raised birds would be released as young, they could be expected to suffer the high first-year mortality characteristic of seabirds and might experience higher than normal mortality.

Captive breeding would be most practical for species having no postfledging parental care; it seems of limited value for species with precocial young or species whose young have extended parental feeding and care. For example, common murre chicks typically leave the colony at 21 days and remain with the male parent for 60 to 85 days. Therefore, murres are an unlikely candidate for captive breeding. However, Fry (1991) and Kress and Carter (1991) have proposed a method of raising and releasing common murre young to the wild. Finally, captive-raised birds may also show philopatry to the breeding facilities. At present, there are no seabird breeding facilities large enough to cost-effectively produce birds for release.

TRANSLOCATION

Translocation (the relocation of nestling seabirds) is similar to captive breeding except that the young released to the wild are the progeny of seabirds breeding in the wild rather than in captivity. Potential limitations of this technique include the need to feed young for extended periods, provide ample food supplements (e.g., vitamins, minerals), transport them from collection to release sites, provide quarantine and rearing facilities, and prevent undue human contact that could lead to young birds imprinting on humans. These same limitations would apply to captive breeding. Compared to most other techniques (except captive breeding) translocation is expensive, frequently involving long-distance transportation of chicks, high labor and logistics costs, and long-term monitoring (10-plus years) to determine the outcome of the project. Because mortality is especially high for the fledging period, survival to breeding is low, with less than 50% of most cohorts reaching breeding age. This high mortality necessitates moving large numbers of young. This is especially important since survival of young to breeding age varies from one year to the next due to marine conditions, such as available food and weather, that are beyond the influence of seabird managers.

There has been few long-term translocation of seabird chicks. Fisher (1971) relocated fledgling Laysan albatross and found that many returned to their original hatching location as they approached reproductive age. Likewise, Serventy (1967) moved fledgling short-tailed shearwaters, but these also eventually returned to their hatching place. In both experiments, chicks moved at earlier ages tended to return to the release site rather than to their hatching locality.

More recent work with translocation demonstrates that young Atlantic puffins, translocated as downy chicks, will eventually return to nest at their release site. In this experiment, chicks were translocated from Great Island, Newfoundland, to Eastern Egg Rock and Seal Island National Wildlife Refuges in Maine (Kress and Nettleship 1988). Returning translocated chicks recolonized both islands eight years after commencement of translocation, and currently both colonies have stable or increasing populations.

In summary, the life histories of many seabirds preclude translocation as a potential restoration option. For those species whose life history allows translocation, the technique is most appropriate where natural recovery is unlikely or where less intense techniques, such as social attraction, are not feasible. Translocation should not be attempted unless a large source population is available that could contribute ample young without impacting the source. This technique requires long-term funding and adequate effort dedicated to monitoring in order to reliably evaluate the outcome of the project.

REHABILITATION

Rehabilitation of seabirds that have been oiled by a spill or by chronic pollution is conducted routinely. With some exceptions, the low success rate of rehabilitation and the low survival rate of released birds make it primarily a humanitarian rather than a restoration technique. Live birds are collected, cleaned, fed, and, when they are healthy (as determined by a veterinarian), released back into the wild. The percentage of individuals that survive to release varies depending upon the species, time of year, and type of oil encountered. Sharp (1996) showed that the survival rate for rehabilitated Northern Hemisphere alcids is low. Most importantly, there is no information indicating that the few birds that do survive are able to enter or return to the breeding populations. A study conducted on postrelease brown pelicans resulted in no individuals returning to the breeding population (Anderson *et al.* 1996). In contrast with the relatively poor success rate for alcids and pelicans, 50% of the rehabilitated African penguins oiled during the *Apollo Sea* spill of June 1994 were found breeding (i.e., adults with eggs or chicks) on Dassen Island, South Africa, in 1995 (T. Williams, pers. com.). Furthermore, some rehabilitated cormorants have successfully bred following the Persian Gulf oil spill (P. Symens, pers. com.). It appears that the success of rehabilitation may be species- and locality-dependent; the technique may be useful in some situations for some birds.

To date, rehabilitation is generally not accepted as a viable restoration technique for alcids because few of the oiled birds brought to rehabilitation centers will ever return to the breeding population, and the rehabilitation technique (collecting, cleaning, feeding, etc.) is expensive (but is usually paid for by the party responsible for the oil spill). Rehabilitation has been proposed as a restoration technique in California (Fry 1991). In extreme cases (e.g., endangered species) this technique may be used as a last resort with rehabilitated animals placed in captive-rearing programs. Additional research on rehabilitation techniques is currently under way and may increase survival rates (and decrease costs), making this a viable restoration alternative in the future.