CHAPTER 6

RESTORATION GOALS

Distinct populations, species, communities, or ecosystems may differ in their undisturbed states and in their responses to human perturbations. Consequently, it is inappropriate to use the same restoration goals or the same criteria to evaluate if these goals have been met for each seabird population or species that may be restored. However, it is possible to define a single *conceptual goal*: to achieve a healthy and normally structured ecosystem, operating within the bounds of normal functions and processes, such as might have existed before the perturbation. Implicit in this conceptual goal is an understanding of (1) constraints to natural or human-assisted recovery of ecosystems and their constituent populations and (2) processes that may lead to extinction or extirpation of populations. (See Chapter 12 for a discussion of potential difficulties in achieving any of the following goals.)

DEMOGRAPHIC PARAMETERS

Unfortunately this conceptual goal requires a deeper understanding of the normal structure and function of perturbed ecosystems than is typically available. Within populations, we seldom have robust data on the three key demographic parameters—reproduction, survival, and migration (see Chapter 3b). Even less frequently can we quantify how these parameters vary in relation to natural abiotic and biotic changes in the environment. Operational goals in seabird restoration tend to focus on individual populations and measure numbers of birds or reproductive attributes. Interpreting censuses or information on reproduction can be problematic.

Numbers of individuals counted in an area in a particular year (i.e., attendance), such as a set of study plots within a colony, typically represent a variable and unknown proportion of the seabirds using the area. Delayed maturity typifies all seabird species. Subadults often travel widely and may briefly visit a colony or regularly visit particular areas within a colony for much of the breeding season (Halley *et al.* 1995). Adults whose reproductive attempts fail may attend a colony sporadically. Generally, breeding pairs alternate attending the nest, with off-duty mates spending little time on the colony. Thus, a survey will include all on-duty mates of breeding pairs, but only variable numbers of subadults, failed breeders, and off-duty mates. Because reproductive activities may vary markedly from year to year, annual counts may be highly variable even in the absence of perturbation. Thus, if researchers use only single counts at colonies, it may be difficult to quantify with any accuracy or precision the impact of a perturbation or the progress of recovery following a perturbation. Moreover, at some colonies it is difficult to select plots to study that are representative of the colony.

Setting restoration goals in relation to reproductive performance is also problematic. All phases of Alaskan seabird reproduction may change greatly from year to year. The number of adult pairs that attempt to breed, number of females producing clutches, number of eggs laid, hatching success, and fledging success may all vary substantially in the absence of human perturbation. As with colony attendance data, reproductive variability obscures both effects of and recovery from perturbations.

Many demographic measures of seabird populations, such as survival of juveniles, subadults, or adults and age at first breeding, have rarely been quantified. The factors affecting the variability of immigration and emigration are poorly understood for most seabirds and may contribute greatly to local changes in numbers.

Given this daunting background in relation to the conceptual goal, it is nonetheless necessary to establish *operational goals* to measure progress toward and achievement of restoration of injured seabird populations. Each operational goal outlined below focuses at the population level of individual species. Choice of a particular operational goal will be dictated by knowledge about the population before the perturbation and the degree to which both the effect of the perturbation on the population and recovery of the population can be quantified. In many restoration programs it may be appropriate to include more than one operational goal or to combine elements from several goals to evaluate recovery.

OPERATIONAL GOALS

1. Population Returns to Pre-Oil Spill Level

Although we can quantitatively evaluate whether the population has returned to prespill levels (i.e., attendance), this goal will be unsuitable in situations where populations have large natural fluctuations, or when prespill data are insufficient to provide needed information. Where a population had been increasing or decreasing before the perturbation, it may be impossible to evaluate whether this goal has been attained. This constraint can be overcome if there are sufficient preperturbation data to establish the *trend of the baseline population* and thus predict changes that would have occurred in the absence of a perturbation. However, predictive models can result in highly variable outcomes even when there are satisfactory explanations to account for baseline variability and trends. Only a few years of baseline data would be needed if the population has been stable, but many years of population data would be necessary if variability is high. Unfortunately, in order to determine if the population is stable, data must be collected for many years to fully appreciate baseline variability.

Any of three quantitative criteria can satisfy this goal. First, mean attendance at the recovering colony, calculated from censuses taken during the entire breeding season, must exceed, for three consecutive years, that colony's prespill mean attendance minus one standard deviation. Second, attendance must exceed, for five consecutive years, the prespill mean minus two standard deviations. Third, a similar criterion, defined at the time of the perturbation, can be identified; it should be selected so that it will be difficult to meet if the population remains depressed after the perturbation, but relatively easy to meet if the population has recovered. For example, for either unaffected or fully recovered populations, the probability that annual counts would exceed the mean of previous annual counts for three consecutive years would be 0.125 (i.e., 0.5^3), assuming that the frequency distribution of counts is symmetric. If the frequency distribution of annual counts is normal, 84% of the values will exceed the mean minus one standard deviation. That is, there would be an 84% chance that the mean count in a particular year would exceed the mean minus one standard deviation. Thus, for either unaffected or fully recovered populations, annual counts could be expected to exceed the mean minus one standard deviation for three consecutive years with a probability of 0.59 (i.e., 0.84^3). Clearly, if the population has not recovered, the probability of exceeding the mean minus one standard deviation would be lower, and a population that is far from recovery would be highly unlikely to satisfy this criterion.

2. Population Functions Normally

If baseline data on reproductive success and survival are available, they may serve as criteria to determine if the population is functioning normally. A population would be considered to be functioning normally if reproductive success or survival were fluctuating within bounds predicted by baseline values. Alternatively, the parameter could be compared to trends at nearby reference sites. The goal would be achieved if the parameter exceeded a particular threshold value for a specified period.

This operational goal is useful if baseline attendance data for the injured population are not available or are highly variable, thus precluding comparisons of current populations to prespill levels. Data can be compared to concurrent values at nearby reference sites or to baseline values at the affected site. This approach assumes that conditions are identical, except for the effect of the spill, across both space and time.

3. Population Fluctuates in Parallel with Environmental Change or with Reference Populations

If the injured population fluctuates in tandem with environmental changes or with reference populations, we can conclude that it is no longer constrained by the effects of the spill. Evaluating the achievement of this goal requires not only extensive (probably decadal) baseline data but also long-term monitoring of the population after the event. There are now several Alaskan colonies where the population status of one or more species of seabirds has been monitored for a decade or more, and where fluctuations in numbers and breeding performance have been associated strongly with fluctuations in environmental conditions. Even at colonies where reproduction has varied markedly among years, long-term data provide a suitable baseline and the foundation for an effective analytical approach to evaluate postevent counts and other parameters.

The influence of immigration/emigration among sites and the possible lack of concordance even among nearby sites must be considered in establishing this operational criterion. For example, population numbers may decline more at one colony during a regional population decline or increase more slowly during a regional expansion (see Chapter 3). Given local site differences, changes in numbers may not always occur in parallel, and reference sites to evaluate recovery must be chosen carefully.

4. Population Ceases to Perform Better Than Before the Spill or Than Reference Populations

This goal assumes that restoration activities in some way augment the population so that it is "artificially" enhanced beyond "normal" until it reaches density-dependence. The goal is reached when the affected population ceases to perform better for some specified period (i.e., density-dependent adjustment is complete). We did not consider this an appropriate goal because we know little about the role of density-dependence for most populations (e.g., population numbers at a particular colony could be kept in a nonequilibrium state by repeated natural disturbances). Furthermore, restoration activities may increase the carrying capacity for this colony, whereby density-dependent effects would occur at a population size greater than "control" populations. In either case, it would be extremely difficult to measure density-dependence both before and after an oil spill.

5. Population Achieves a Level Predicted by Prespill Trend

To implement this operational goal, it must be possible to predict population trends following the spill based either on long-term documentation of trends and environmental fluctuations before the spill or on models using demographic data collected before the spill. Although the demographic approach uses well-established modeling protocols, it may be limited by the quality of the data used for input.

To model the recovery, values of demographic variables that would have occurred in the absence of the spill must be estimated and compared to actual postspill values. Recovery can be defined as either (1) that point at which the actual trajectory based on postspill conditions intersects the predicted trajectory based on prespill conditions or (2) the point at which the trajectories are parallel. Parallel trajectories, with postspill populations at lower levels than prespill populations, imply that the postspill population is functioning "normally," but at a lower level. This lower value can be the result of many different factors, including the fact that the spill has altered the ecosystem such that it has lowered the overall carrying capacity.

This goal is preferable to Operational Goal 1 if the population is cycling or changing monotonically up or down, but requires more data and a modeling approach, which may in turn require the incorporation of untestable assumptions.

6. Population Achieves Relative Former Size Compared with Control Colonies (i.e., it reaches its prespill percentage of a regional or global population)

This may be a good operational goal for common murres and can be applied not only to population numbers but also to areas or habitats that are occupied. It would not be a useful criterion for colonies at the edge of a species' geographical range or near other ecologically set limits, where environmental factors may naturally alter relative percentages. As with Operational Goal 3, this criterion should be used with caution because populations of adjacent or nearby colonies often do not change in parallel.

7. Replacement Birds are Demonstrated

The goal of this approach would be to replace, for example, 500 seabirds killed by a spill with 500 birds either at the colony from which the birds were killed or at another site, perhaps away from the spill zone. This strategy was used in British Columbia following the *Nestucca* oil spill. It would likely be effective in the Aleutian Islands if exotic Arctic foxes were removed from islands that once had much more numerous populations of murres or other affected species. This goal may be easy to achieve and evaluate if introduced predators or other habitat alterations can be manipulated.

8. Restoration Is Evaluated Using At-Sea Populations

There are circumstances where restoration must be evaluated at sea instead of at colonies. Species such as *Brachyramphus* murrelets and *Cepphus* guillemots, and probably all petrel species, cannot be monitored readily on land because they nest in cavities, singly or in small, scattered colonies, or are nocturnal (e.g., Piatt and Ford 1993, Spear *et al.* 1995b). In addition, spills that occur between late summer and the following spring will injure birds in wintering assemblages, not necessarily near breeding colonies. The seabirds in these assemblages may include birds from several breeding populations over a wide area as well as species that nest inland and cannot easily be monitored there, such as grebes, loons, and ducks.

Operational Goals 1, 3, 5, 6, and possibly 7 are suitable for evaluating at-sea populations. Methods of monitoring birds on the water have been well developed, but surveys are labor-intensive. Because variability is high, large areas must be sampled within a short period, and sampling must be designed rigorously so that results can be extrapolated to the entire water body.

CONCLUSIONS

The ability of seabird populations to recover from catastrophic mortality and our ability to recognize recovery is both species- and locality-specific. It depends on the demographic characteristics of the population and the environmental context or ecosystem stability.

Because seabirds are part of ecosystems that vary both spatially and temporally, an evaluation of the success of restoration efforts must incorporate consideration of this variability. Variability on short time scales can be quantified by multi-year monitoring. Likewise, spatial variability can be quantified by the study of multiple affected sites (if more than one site is affected) and multiple reference sites. Selection of colonies or sites with a similar level of injury or colonies with a gradient of injury provides a far more effective framework for evaluating recovery than does selection of a single affected colony or site. Single affected sites and single control or reference sites should be avoided if possible, because it is difficult to distinguish the effects of restoration programs from intrinsic differences between the two locations. Several reference sites that were unaffected by the event within the same biogeographical region in which the event occurred should be established. Replication is critical both within affected areas and in control sites. Affected and reference populations may be linked by immigration, thus forming subpopulations within a larger population rather than a series of distinct and demographically independent populations. In many seabirds, dispersal of subadults before first breeding may occur, blurring distinctions between affected and control populations even when there is a lingering effect of the spill. In general we lack critical information on movement among colonies, but genetic variance can be partitioned within and among colonies to estimate movement rates, and such a study should be incorporated in evaluating the recovery of affected populations.