CHAPTER 7

MONITORING ACTIVITIES DURING RESTORATION

Following the establishment of practical restoration goals (see Chapter 6), monitoring is needed to determine if goals are being met. The monitoring program must produce data that are accurate enough to measure definitively the responses of target populations. Factors to consider in designing monitoring programs include (1) the restoration goals, (2) defining the target populations (i.e., species and sites) to be monitored, including appropriate "control" or "reference" populations for comparison, (3) selecting appropriate parameters to measure, (4) quantifying objectives for desired minimum detectable differences, and (5) choosing the required sampling intervals and methods. A properly designed monitoring program should test hypotheses about patterns of change over time. For restoration monitoring of seabird populations following oil spills, it is important to monitor not only target populations but also resources that affect their survival and reproductive success. An understanding of ecosystem processes is necessary to try to sort out reasons for changes observed during monitoring (see Chapters 12 and 13).

TARGET POPULATIONS

Species

Injured species are the most obvious targets for restoration monitoring, but it may also be important to monitor other species that indicate important ecosystem processes affecting recovery rates. For example, if restoration goals call for common murre reproductive success to return to a self-sustaining level, it would also be important to monitor the reproductive success of other piscivorous seabirds breeding at the same sites, particularly if they were not injured by the spill, to evaluate whether environmental conditions, including prey availability, are conducive to normal reproductive success.

Sites

Multiple sites need to be monitored both within ("experimental") and outside ("control" or "reference") restoration areas to measure geographic variation. Ideally, comparisons would be made along an injury gradient from "heavily injured" to "not injured." Comparisons among experimental areas and between experimental and reference sites permit a more powerful evaluation of restoration efforts than do single-site comparisons. Selection of experimental and reference sites for which prespill data are available is desirable, because these data will be used to define "normal" or baseline conditions, including how populations were trending at the time of the spill.

Selection of reference sites requires careful evaluation of ecological similarity to experimental sites with respect to important comparative variables. For example, oceanographic conditions at experimental and reference sites should be similar enough so that trends in monitored parameters are similar (in the absence of injury). If possible, reference sites should be selected for which there are available historical data about ongoing trends and normal patterns of variation in parameters of interest. Furthermore, efforts should be made to select reference sites where target populations are not linked to experimental sites through dispersal to or from affected areas. Otherwise, reference sites may not provide independent "controls."

Another important consideration in selecting monitoring sites is the feasibility of collecting data safely and efficiently. For example, many seabird breeding colonies do not lend themselves to the rigorous collection of data on productivity because of difficult access.

PARAMETERS

Hatch *et al.* (1994) list the types of parameters that are normally measured in seabird monitoring programs. Data on the demographic parameters that may have been affected by an oil spill and are being targeted for restoration provide a basis for selecting which parameters to measure in restoration monitoring (see Chapter 3b). Since data on the number of individuals killed and the demographic profile of that population is usually the basis for initiating restoration activities, population trends are clearly important to measure. Nevertheless, population increases do not occur rapidly for long-lived seabirds having relatively low reproductive capacity (Nur and Ainley 1992). Therefore, other parameters frequently provide more sensitive indications of responses to restoration programs. Various components of productivity, survival, timing of nesting events, behavior, diet, and energetics are all potential candidates. Data also need to be gathered on environmental conditions that affect factors like prey availability and are independent of perturbations caused by oil spills.

Populations

Depending on restoration objectives, it may be necessary to estimate total populations of target species, but frequently, abundance indices will be monitored instead. For example, for most seabirds it is very difficult and expensive to derive overall population estimates. For this reason, replicate counts of birds or nests on a series of systematically selected plots provide the basis for estimating trends.

Productivity

One or more from a set of variables could be measured to provide an indication of productivity for target populations. For most seabirds, these would need to be measured at breeding sites (but see specific recommendations for marbled murrelet and pigeon guillemot). The list of potential measures includes laying success (percentage of nests in which eggs are laid), clutch size,

hatching success, and fledging success. Causes of loss of reproductive potential (e.g., predation) should be evaluated to try to separate direct and indirect effects of oil spills from normal mortality.

Survival

Characteristically, annual adult survival tends to be relatively high for most species of seabirds. For at least some species (e.g., murres; Sydeman 1993), this parameter can vary between years in response to changes in food availability. It would also be expected to change following perturbations like oil spills if large numbers of adults were killed. Measures of survival need to be fairly accurate (e.g., within 2-3% for some species), because even small changes can have substantial population effects. Survival monitoring will involve banding adequate numbers of birds with markers that allow individual recognition.

Timing of Nesting Events

For many species of seabirds, egg laying is timed so that the increased energy demands of reproduction coincide with periods of relatively high food availability (Lack 1968). Substantial shifts in timing of laying in response to environmental perturbations such as oil spills or oceanographic events (e.g., El Niño Southern Oscillations) can result in reduced productivity. Restoration monitoring programs in cases where timing was disrupted should include some measure of nesting chronology (e.g., laying, hatching, or fledging dates). Synchrony of egg laying may also be an important variable that is sensitive to perturbations like oil spills.

Behavior

Disruptions in some aspects of breeding behavior may occur following oil spills, and parameters that may be important in restoration monitoring programs include colony attendance patterns, feeding rates, and foraging trip lengths. For many species of seabirds, "normal ranges" in these parameters are available for comparison, but within-season variability needs to be considered in designing monitoring programs.

Diet

Restoration monitoring will frequently need to include some measure of seabird diets, because food availability has a major influence on most of the other parameters monitored. Shifts in the composition of diets may cause fluctuations in reproductive parameters that are independent of oil spill or restoration effects.

Energetics

Several seabird life history or population parameters have been used as indicators of temporal changes in the marine food web (see Boersma 1978, Cairns 1987, Montevecchi 1993, Ainley *et al.* 1995b). These parameters include adult survivorship, breeding success, chick growth rates, colony attendance, and adult activity budgets, and have been reviewed by Cairns (1987). The most appropriate parameter(s) that would indicate temporal changes in the marine food web will depend on species and location. However, in any case, data on diet composition and energy content of major prey must also be available to provide a link between these parameters and an understanding of how ecosystem processes affecting seabird energetics cause both long- and short-term fluctuations in seabird populations. We recommend that aspects of seabird energetics be monitored using the most appropriate set of parameters.

MINIMUM DETECTABLE DIFFERENCES

A major consideration in selecting parameters appropriate for restoration monitoring is defining the level of change that researchers need to be able to detect. The minimum differences that can be detected are based on variability within the target populations, desired confidence levels, and sample sizes. For restoration monitoring programs in field settings, it may be too costly to gather adequate samples for some parameters. Prior to instituting restoration monitoring, minimum detectable differences need to be set for each parameter, and necessary sample sizes need to be determined and evaluated for feasibility.

SAMPLING INTERVALS AND METHODS

The usual objective of restoration monitoring programs is to compare postevent time-series data for selected parameters with restoration target levels. For example, a restoration target may be the return of reproductive success to "normal" (with "normal" being defined as, for instance, between 0.5 and 0.7 fledglings per nest). Furthermore, part of the objective may be to examine correlations between environmental factors and patterns of change in reproductive success. Parameters that are sensitive to environmental change on an annual time scale, such as reproductive success, need to be measured annually to increase the probability of understanding ecosystem processes. Parameters that may not change rapidly for long-lived species with relatively low annual recruitment rates, such as population levels, may not need to be monitored annually. Power analysis (Gerrodette 1987) can help to select the sampling interval needed to meet restoration monitoring objectives.

Recommended monitoring methods have been published for many species of seabirds (e.g., Nettleship 1976, Walsh *et al.* 1995), and it is important to use standard methods in restoration monitoring for selected species. Very specific protocols need to be developed so that results for different sites may be readily compared. Even apparently obvious terms need to be defined so that all observers are recording data in the same way. For example, it is not sufficient to state

that kittiwake nests should be counted; the word "nest" needs to be defined (e.g., a structure to which vegetation has obviously been added during the current year).